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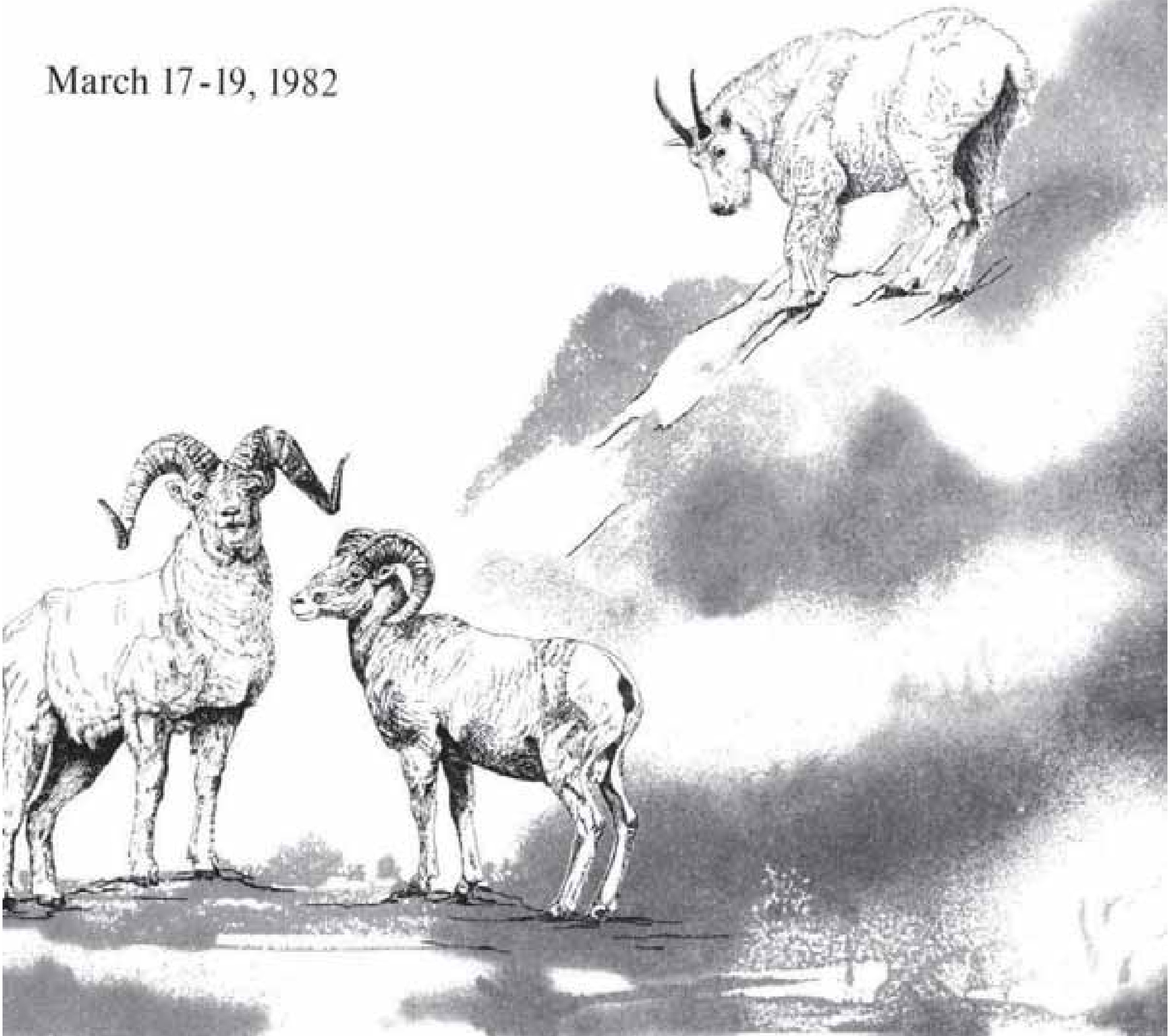

NORTHERN WILD SHEEP AND GOAT COUNCIL

Proceedings
of the Third Biennial Symposium

March 17-19, 1982
Fort Collins, Colorado

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FOREWARD

Papers included within these proceedings were presented during the Third Biennial Symposium of the Northern Wild Sheep and Goat Council held March 17-19, 1982 in Fort Collins, Colorado. Papers were reviewed by session chairman and also by other members of the Council. However, final versions of all papers were totally at the discretion of the authors and were not refereed.

A few papers are presented in abstract form only. While information presented by these authors is necessarily brief it was felt that including these abstracts in the published proceedings supports the Council's objective of disseminating information in a timely manner which may be useful to others in managing wild sheep and Rocky Mountain goat resources.

We attempted to record conference discussions following each presentation for inclusion in these proceedings. However, due to recording difficulties, etc., several papers are presented without this discussion although there was considerable interest expressed in these presentations during the conference.

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DALL SHEEP MANAGEMENT IN ALASKA FOLLOWING CONGRESSIONAL SETTLEMENT OF THE ALASKA LANDS ISSUE

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ABSTRACT

Marketing of Alaskan oil required construction of a pipeline from the oil fields on the North Slope to an ice-free port. Construction of the Alaskan pipeline could not begin until the Native land claims were settled. This settlement also involved conservationists who objected to the pipeline. The resulting compromises settled the Native claims, provided for construction of the oil pipeline, and assured conservation interests that at least 80 million acres would be added to the four Federal conservation systems. This final action required further Congressional action, and a bitter struggle developed between the State of Alaska and the Federal Government over which lands and how much of them would go into national parks and other conservation systems. During this battle, vast national monuments were administratively created to pressure Alaska into acceptance of the Federal package. These monuments were created with extremely restrictive hunting regulations and had dramatic impacts on Dall sheep (Ovis dalli) management. Subsequent resolution of the issue by Congress relaxed these restrictions to the point that Alaska can now manage about 75 percent of the Dall sheep in the State. Problems with continued sport hunting on park/preserve lands and decreased hunting opportunity lie ahead. The subsistence use of Dall sheep may have particularly far-reaching impacts under new State and Federal laws.

INTRODUCTION

Development of the substantial oil fields in Alaska and increasing uncertainty about foreign oil availability to the United States have caused a dramatic change in the opportunity to hunt Dall sheep in Alaska. Environmentalists and conservation groups generated considerable resistance to construction of the oil pipeline which bisects Alaska, running south from Prudhoe Bay to Valdez. Ironically, the concerns of these environmentally oriented groups have placed Dall sheep in a more precarious position throughout Alaska than they occupied before the battle to protect wildlife and wildlife habitat began.

In order to understand this odd turn of events and clear away the confusion surrounding sheep hunting in Alaska today, we must review some history. Before the pipeline could be built, the unresolved land claims of Alaska Natives had to be settled. Once the importance of Alaskan oil to the United States was recognized, these Native claims were quickly resolved by Congress. Part of this settlement was a compromise in which environmental protection interests accepted the pipeline in exchange for a guarantee that an additional 80 million acres of Alaskan land would be included in Federal park, refuge, wild and scenic river, or forest conservation systems. The first deadline for congressional action on these additions to the Federal conservation systems was the close of the 1978 congressional session. As adjournment drew near, the Alaska National Interest Lands Conservation Act passed the House and went to the Senate. When passage by the Senate appeared to be jeopardized by resistance of the Alaskan senatorial delegation, Secretary of the Interior, Cecil Andrus, attempted to force the Alaskan delegation to abandon its resistance to the bill by threatening administrative withdrawals under the Bureau of Land Management's Organic Act and National Antiquities Act. These classifications, he threatened, would be far more restrictive then the proposed congressional actions. The Secretary's tactic was not successful and the Alaska lands bill failed to pass the Senate. This prompted the Secretary to make good his threat, and in December 1978 President Carter, acting on the advice of Interior Secretary Andrus, administratively created 56 million acres of new national monuments in Alaska and classified 49 million acres as wildlife refuges under terms of the BLM Organic Act. As of that date, hunting became illegal on all National Park Service-administered national monuments, and a significant portion (nearly half) of Alaska's Dall sheep resource was off limits to hunters.

These administrative closures of Dall sheep hunting were not well enforced during the hunting season of 1979. During that hunting season, numbers of irate Alaskans and some nonresidents reported hunting and taking at least 150 sheep in the newly designated national park monuments. In December 1980, both houses of Congress passed the Alaska National Interest Lands Conservation Act, relaxing some of the stringent restrictions on hunting Dall sheep. Subsequently, regulations were developed which related to subsistence taking of Dall sheep in the national parks as well as regulations for sport hunting in the national park preserves. Park preserves are areas adjacent to parks which have the habitat protection afforded to parks, but allow recreation hunting. The results of these actions have been confusing to Dall sheep managers and hunters alike.

The purpose of this article is to make the present status of sheep hunting in Alaska as clear as possible and assess the future of sheep hunting.

METHODS

Obviously, a subject such as the one I am discussing here involves methods which beg scientific description. Suffice it to say, power politics was the method of choice, and strange bedfellows were made by the methods of Shakespeare (1864) and Warner (1870). Population estimates were made from aerial surveys. Harvest data were gathered using mandatory hunter reports.

RESULTS

Important changes which resulted from oil development and all it has occasioned in its wake are discussed below as they relate to Dall sheep management.

Horn Size

The minimum requirement for legal rams was increased from 3/4 curl (27-degrees of a circle) to 7/8 curl (315 degrees of a circle) described by the outside surface of the horn. This effectively raised by 2 years the average age at which rams become legally available for harvest. The Alaska Board of Game adopted this more conservative approach to regulating harvest in response to the distinct possibility that where hunting continued pressure would increase and harvest would quickly remove all larger sheep, an undesirable situation for both sheep populations and hunters.

The decrease in number of sheep harvested under the 7/8-curl regulation was less than anticipated in 1979. The mean harvest of rams in the 2 years preceding the reductions in sport hunting was 1,250. In 1979 the reported harvest was abut 1,000 sheep including known subsistence harvests (a decrease of 20%). In 1980, this number declined to about 850, but the 1981 harvest rose again to about 1,000. Average horn size increased somewhat because the 7/8-curl regulation caused a decrease in the number of very small rams harvested. It is still too soon to know with certainty whether this level of harvest is sustainable or whether the relatively high harvest will result in a depletion of ram stocks. Future surveys and horn size trends will answer this question. I suspect the harvest will stabilize between 700 and 1,000 rams per year as horn size approaches the legal minimum. This means eventually most large, trophy sheep will come from special management areas where harvest is held below recruitment levels or regulations mandate trophy horn size.

Permit Restrictions

The Arctic National Wildlife Range (now a wildlife refuge) was placed on restrictive lottery permit status (with 25% of the permits offered to nonresident hunters). This was largely at the insistence of the U.S. Fish and Wildlife Service who perceived an apparent mandate from nonhunting recreationists to reduce hunter use on the Refuge. In the 3 years this permit system has been operational, the total number of permits offered has never been used by the public. This regulation was a conservative reaction to the threat of increased crowding in an area where Alaskans had approved the Alaska Department of Fish and Game management goal of aesthetically pleasing sheep hunting. Current regulatory changes before the Alaska Board of Game are expected to return to previous sport hunting seasons and bag limits.

Subsistence Hunting

Cooperative alliances between seemingly diverse groups such as anti-hunting preservationists and Native groups (pro-subsistence hunting) resulted in a subsistence hunting title in the Alaska National Interest Lands Conservation Act. Previously, a very similar piece of legislation was passed by the bush-dominated Alaska legislature. The effect of these acts was to define the higest priority use of fish and game resources as subsistence use. At the time the legislation was drafted, there was no generally accepted definition of subsistence, and such a definition is still lacking. The current trend is toward definition by regional proximity to the resource involved. Once implementation of the State subsistence law began and urban resource users realized the potential impact the law had on their activities, a citizens' initiative to repeal the State subsistence law was quickly organized. Enough signatures have been gathered that the issue will be resolved on the November 1982 general election ballot. Recently, the State Attorney General's office informed the Alaska Board of Game that continued procrastination in addressing the subsistence issue, either positively or negatively, will mean that season closures in Alaska will be virtually unenforceable. This would occur because State subsistence legislation prohibits establishment of sport hunting regulations without first assuring that local, subsistence needs have been satisfied. Only if a harvestable surplus exists after these priority demands have been met, can sport hunting be allowed.

This decision has resulted in proposals for consideration by the Alaska Board of Game which may have the following effects on Dall sheep hunting in Alaska. The proposed regulations also establish a lengthy (August 1 to April 30) season with a bag limit of one to three sheep (of either sex) for local residents in much of the Brooks Range. The established 40-day ram season for Alaska residents who live in other parts of the State would continue. Local (subsistence) hunters would also be exemot from most restrictions on methods and means under proposed regulations. That is, subsistence users could take sheep the same day airborne (landing to shoot) and with the aid of snares, artificial salt licks, and radio communications among other things. In the remainder of the Brooks Range, the only area in Alaska where special subsistence regulations for sheep have been proposed sport hunting would continue as it is, but subsistence hunters would have the same long seasons, a bag limit of three sheep, and freedom from costraints on methods and means of taking.

Federal regulations (generally) allow subsistence taking within the new national park "core" areas. Harvest in park preserves is considered sport-taking.

A subsistence sheep hunt was establshed in the Arctic National Wildlife Refuge in 1979. There, hunters may take three sheep after obtaining a registration permit. A quota of 50 sheep per year governs harvest. Preliminary indications are that this management practice is having a detrimental effect on the local sheep populations. Hunter effort has been localized, and the affected populations appear to be declining. Further survey work must establish this as a definite trend before any restrictive actions may be taken. Apparently, the Game Division of Alaska Department of Fish and Game will have to fund, perform, and apply these survey results.

It should be noted that Dall sheep populations in intact ecosystems (those with a natural complement of predators) may lack the inherent ability to produce a harvestable surplus. As a result, sheep populations sustaining subsistence hunting must be monitored to determine if subsistence hunting practices result in population declines. Furthermore, the future may require restrictions on taking sheep because of the subsistence priority law. Should this be necessary, the first step would be an end to sport huntng for rams by non-Alaskans, followed by prohibition of sport hunting for rams by Alaska residents who don't live near the exploited populations. If further restrictions are necessary, local subsistence hunters would probably be restricted to rams only and eventually no hunting would be allowed (even by local residents) until the populations had been reestablished for former abundance.

Sport Hunting

The total number of sheep available for sport hunting in Alaska is about 25 percent less than before the new national parks were created. The degree to which this impacts sport hunting varies with location as the following summaries illustrate.

Brooks Range

The Brooks Range was the most affected of Alaska's mountain ranges. An estimated 8,000 sheep in Gates of the Arctic National Park are now unavailable to sport hunters. With the permit system in the Arctic National Wildlife Refuge, only about 11,000 of the estimated 25,000 total sheep in the Brooks Range are available to sport hunters without special permits. Anticipated removal of the permit requirement from the eastern section of the Arctic Wildlife Range will add another 6,000 sheep to this total. About 500 of these sheep are found west of the new national park in a park preserve on the lower reaches of the Noatak River, its tributaries, and the DeLong Mountains. Sheep resource inventory in the western Brooks Range has been fragmentary, and population estimates for this area will probably change with further survey efforts. It should be noted that the Alaska Department of Fish and Game has always attempted to make conservative estimtes of sheep populations; consequently, it appears likely that further knowledge will increase population estimates.

Tanana Hills-White Mountains

Sheep in the Yukon-Charley National Park Preserve will continue, for the present, to be available to sport hunters. This area is considered to have a high probability of sport hunting restriction in the future because of the relatively high human population and the small, almost relict, sheep populations there. It seems unlikely that local subsistence demand, if satisfied, will leave any sheep for sport hunters. The remainder of sheep in this area are mainly distributed in the Yukon Flats Wildlife Refuge. There is no present indication these sheep will become less available to sport hunters.

Alaska Range

A small number (probably near 200) of sheep in the Mt. McKinley (now called Denali) National Park extension will be lost to sport hunters. From National Park Service surveys in the newly created Lake Clark National Park, I estimate 1,000 sheep formerly available to sport hunters will now be off limits. Historically, harvest in the Lake Clark area has been light, so this loss is really a loss of opportunity to hunt more than a restriction of sheep hunted.

Wrangell Mountains

Intense pressure for continued Dall sheep hunting in the Wrangell Mountains was successfully maintained throughout the legislative process. As a result, up to 85 percent of the Wrangell Mountains sheep are available for sport hunting in the park preserve, and subsistence take (of legal rams) is allowed in the core parks. In this mountain range, the great loss to sheep and sheep hunters is the area near the Canadian border on the upper Chitina River in the southeast corner of the mountain range. The number of sheep lost to hunting in this area is not large, but their importance must not be overlooked. This area, kept in the park rather than shifted to park preserve status, is known to produce the largest Dall rams in Alaska--and perhaps the world. It remains in the park as a result of preservationist influences to keep a portion of unhunted Dall sheep habitat in Alaska adjacent to Kluane Park on the Canadian side of the border.

In addition to this loss of sheep hunting opportunity in Alaska, there is also the potential loss of hunter interest and, ironically, subsequent loss of the protective mantle such interest places over favored species like Dall sheep. There has been a decrease in the number of sheep hunters reporting since the initial creation of the national monuments in 1978. In the 3 years prior to the monument designations, the number of sheep hunters reporting averaged 3,032. For the 3 years since monuments (and eventually new parks) were created, the number of sheep hunter reporting has been 2,284. Other factors, notably economic recession, may be responsible for this decrease. Still, these losses produce a regretable--and unnecessary-displacement of one segment of the sheep-interested public. Interest in public hunting must be kept at a high level if sheep are to fare well in Alaska amid potentially conflicting activites such as mineral extraction and agricultural development. Sport hunters are the only reliable source of revenue and support for continued land use practices which ensure the integrity of mountain sheep habitat.

The future character of recreational sheep hunting in Alaska is still uncertain. Considerable negotiations will be required to assure that sport hunting continues in park preserves. The impact of subsistence regulations both in parks and other Federal lands will be uncertain particularly if the citizens' initiative to repeal the State subsistence law succeeds. Fortunately, sheep hunters, hunting organizations, and associations of biologists (such as the Northern Wild Sheep and Goat Council) are advocating biologically sound management of hunting in northern parks.

Sheep hunters and hunting-oriented conservation groups such as the National Rifle Association, Safari Club International, and the Foundation for North American Wild Sheep were indispensable stalwarts in the fight to save sport hunting of sheep in Alaska. Although the battle was not a total success, there is still hope that a substantial interest in Dall sheep by the hunting public can be maintained and even increased by those willing to put energy and money into holding the line and expanding the opportunity for future hunters to seek Dall sheep in Alaska.

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CONFERENCE DISCUSSION

Q. How many people qualify for subsistence hunting?

Ans. The way it is currently defined, only those people living in direct contact with the resource they choose to utilize. Federal law also has criteria in which "customary and traditional dependence" are considered. Rulings on what is customary and traditional will be made in court if it should ever come to that. An additional criterion, should there ever be a sufficient scarcity of any given subsistence resource, is one of scarcity of alternate resources.

Q. Wayne, you have a Division of Subsistence in the Alaska Department of Fish and Game. Does subsistence hunting contribute any economic support for activities of this division?

Ans. No, the Subsistence Division is completely funded by appropriations from the general fund by the legislature. Currently, the "bush" dominates the legislature because of the apportioning of seats in the legislature. The Subsistence Division has had no money problems so far.

Q. Have you considered alternatives to subsistence hunting? Can you buy meat for the Natives? Is it possible to supplement their diet with beef?

Ans. The Natives are not interested in this approach. Some have said they cannot live if they don't have wild game to eat. Also, one component of the subsistence lifestyle, as it has come to be defined, demands continuance of historic or customary and traditional things. Sociologists tell us that disruption of these things in a cultural transition period leads to alcoholism and other forms of socially deviant behavior. Alaska Native culture is clearly in transition, and we are all "walking on eggs" in an effort to keep social problems to a minimum. (Of course, the legal complications surrounding subsistence have clearly disrupted my lifestyle relevant to sheep research and management, so you may anticipate socially deviant behavior on my part at any time.)

Q. You said that Eskimos, Indians and Aleuts qualify as Natives in Alaska? What percentage of the population is Native?

Ans. About 15 percent, but the Native population is growing rapidly. Improvements in nutrition and health care have probably contributed somewhat to cultural disruption, but they have also resulted in a rapidly increasing population which seems certain to result in increased subsistence demand.

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ECOLOGICAL RELATIONSHIPS
OF MOUNTAIN GOATS AND ROCKY MOUNTAIN BIGHORN SHEEP

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ABSTRACT

Introduction of mountain goats (Oreamnos americanus) into Colorado has created concern over their potential to compete with bighorn sheep (Ovis canadensis). Ecological relationships of goats and sheep are compared based on habitat selection, food habits, and behavioral and structural adaptations. Bighorn sheep are adapted to exploit a wide range of terrain types, provided their areas are near escape terrain, and offer abundant, continuous forage and unobstructed visibility, and are relatively snow-free. Mountain goats are adapted for rugged, steep terrain and can exploit these areas even if visibility is limited or snow is deep. Because of their limited habitat selection, goats must accept a wide range of forages. The potential for goats and sheep to compete is increased in Colorado because: (1) the recently introduced mountain goats exhibit unusual patterns of habitat selection and grouping behavior which expand use onto bighorn habitats; and (2) man's activities have restricted bighorn access to habitat resources. However, potential competition from mountain goats should not divert attention from other severe problems of bighorn sheep in Colorado.

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INTRODUCTION

Introduction of Rocky Mountain goats in alpine habitats within existing and historic ranges of bighorn sheep in Colorado has drawn attention to the potential for these species to compete. Exploitative competition results from mutual use of limiting resources by 2 species (Park 1954). However, evolutionary theory suggests that species being sympatric during their evolution should accumulate adaptations allowing exploitation of separate niches and avoidance of competition. Considering the similarities and differences in the niches of mountain sheep and goats is therefore 1 basis for assessing the probability of competition between these species. Other bases include interference competition and disease relationships, but we do not consider these factors here. We present our views knowing that some aspects of bighorn and mountain goat biology are inadequately understood, in hopes that this will stimulate further discussion of this important subject which has sometimes been treated too simply.

Odum (1971) describes the ecological niche as ". . . not only the physical space occupied by an organism, but also its functional role in the community and its position in environmental gradients of . . . conditions of existence." Odum illustrates 2 common approaches to defining ecological niche. One is the functional niche - the role, especially trophic relations, of a species in a biotic community. This role is determined by the species' anatomical, behavioral, and physiological adaptations. Odum also illustrates the resource niche - the set of habitat resources (space, food, other conditions of existence) used by a species. In this paper, we consider both types of niches for bighorns and mountain goats, as well as behavioral and anatomical adaptations that determine the niches of the species. Characteristics that may be unique to introduced mountain goat herds, such as those in Colorado, and recent constraints on Colorado's bighorns are also discussed. Finally, management options are considered.

ADAPTATIONS OF BIGHORN SHEEP

The predator-evasion strategy dominates the adaptive syndrome of bighorn sheep. This strategy (Risenhoover and Bailey 1980) dictates that sheep forage within a large, dispersed group near steep, rugged terrain. Predator detection and communication among sheep are accomplished visually. Large groups exhibit more total alertness than do small groups while individuals within large groups can be less alert and can spend more time in foraging and social activities (Risenhoover 1981). Also, a more dispersed group should be aware of a greater proportion of its surroundings while minimizing agonistic encounters or competition between individuals.

When predators are detected, bighorns generally assemble and run to escape terrain on which they can outmaneuver predators. Morphologically, bighorn sheep are well suited for running rapidly for short distances and jumping through broken terrain (Geist 1971:257).

As a consequence of this predator-evasion strategy, secure habitat for bighorns includes escape terrain and areas near escape terrain that support low-growing vegetation, allowing unobstructed visibility. Rams often use less secure habitats than do ewes, while ewes with young lambs seldom leave secure habitats. Furthermore, large groups will forage farther from escape terrain than will small groups (Risenhoover 1981).

Since the bighorn predator-evasion strategy is enhanced by large group size, optimum bighorn habitat provides abundant and continuous, rather than patchy, forage. Abundant forage is necessary to support large numbers of sheep, and continuous forage allows dispersion of group members, enhancing their awareness of surroundings while minimizing intraspecific competition.

The major components of bighorn habitats - rugged escape terrain, unrestricted visibility, and dense, continuous forage - are often juxtaposed in isolated patches of the environment. Also, some habitat patches provide resources for bighorns during only part of the year. Consequently, the year-round home range of a typical Rocky Mountain bighorn herd consists of a set of seasonally used ranges: one or more winter ranges, summer ranges, lambing areas, salt lick ranges, and perhaps rutting ranges (Geist 1971:75). These ranges are connected by traditional migration routes which may traverse areas that are relatively insecure because of restricted visibility and/or limited availability of escape terrain.

In winter, bighorn sheep tend to avoid areas of deep or crusted snow (Geist 1971). They may migrate long distances to lower elevation and/or to areas where wind or aspect limits snow accumulation.

Food habits of Rocky Mountain and California bighorns emphasize grasses and sedges (Blood 1967, Demarchi 1968, Todd 1972, Stewart 1975, Harrington 1978, Pitt and Wikeem 1978). Indeed, bighorns seem morphologically adapted for grazing in that they have massive jaws and large teeth (Geist 1971). Furthermore, stands of grasses and sedges are often the epitome of abundant, continuous forage allowing good visibility. However, some bighorn populations, particularly desert bighorns, use browse abundantly during portions of the year (Russo 1956, Wilson 1968, Cooperrider et al. 1980, Rominger 1983).

ADAPTATIONS OF MOUNTAIN GOATS

Compared to bighorn sheep, the adaptive strategies of mountain goats have been less studied and less discussed in the literature. Of the 2 species, mountain goats are more adapted for life on steep, rugged terrain. Goats live primarily in habitats providing security from most predators. Therefore, they rely less on conspecifics for predator detection and evasion than do bighorn sheep. Goats cannot be reached by, or can outmaneuver, most predators on steep terrain. Particularly with medium-sized predators, goats can defend themselves with their potentially lethal horns. Since unobstructed visibility is not an essential habitat requirement, secure habitats may be heavily forested (Hebert and Turnbull 1977, Smith 1982).

To exploit cliff terrain where forage is often patchy and/or sparse, goats must forage alone or in small groups. Benefits of large group size, described previously, are not realized since predator detection is less important and since costs associated with large groups on cliffs are prohibitive. Small patches of forage and usable space are better exploited by small groups. This reduces intragroup competition for limited resources and minimizes agonistic encounters which could lead to hazardous falls (Chadwick 1977).

Mountain goats are structurally adapted for living on precipitous terrain. Goats have compact bodies with short, heavily muscled limbs and broad hooves with sensitive cushion-like pads, well-adapted for climbing (Geist 1971, Rideout 1978). Goats are not well built for running and seldom run far when startled or in danger.

Because of these adaptations, mountain goats tend to exist in small, isolated populations that remain in the same area throughout the year without migrating between distant seasonal ranges (Smith 1976, Adams et al. 1982). In winter, goats may merely concentrate on areas within or adjacent to their summer range. These areas tend to be cliffs interspersed with sufficient, though often small, foraging areas that lack persistent or crusted snow (Adams and Bailey 1980). Suitable areas may be (1) at lower elevations where snow is less abundant and less persistent (Rideout 1974 Smith 1976), (2) open steep or south-facing slopes where snow sheds rapidly (Brandborg 1955, Chadwick 1973, Kuck 1977), or (3) on high wind-swept ridges (Brandborg 1955, Hjeljord 1973). Goats can forage in relatively deep snow however, providing it is not heavily crusted (Geist 1971, Adams 1981). On the Kenai Peninsula, Alaska, Nichols (Unpubl. Rep. Alaska Fed. Aid Proj. W-17-9 and 10, Jobs 12.2R and 12.3R, 1978) found significantly more snow cover on areas inhabited by goats alone than on areas used by goats and Dall sheep (*Ovis dalli*) or by Dall sheep alone and speculated that this may be an important factor in separating the 2 species.

Food habits of mountain goats are highly variable, indicating a wide range of acceptable forage. Goats have been reported to be primarily grazers (Anderson 1940, Klein 1953, Saunders 1955, Hibbs 1967, Hjeljord 1973, Rideout 1974, Smith 1976, Johnson et al. 1978), primarily browsers (Hanson 1950, Kuck, Unpubl. Rep. Idaho Fed. Aid Proj. W-144-R-04, 1973), or either, depending on season (Cowan 1944, Holroyd 1967, Peck 1972), location (Chadwick 1976), or both (Casebeer 1948, Brandborg 1955, Adams and Bailey 1983). Even cryptogams have been considered the most important forage of goats (Harmon 1944). Use of conifers by goats is also reported (Cowan 1944, Saunders 1955, Smith 1976). Brandborg (1955) indicated that conifers were an emergency forage whereas, other authors (Geist 1971, Adams and Bailey 1983) indicated some preference for conifers.

The ability of mountain goats to exploit a wide variety of forages may be an adaptation compensating for their narrow habitat preferences (Geist 1971, Gossow and Hjeljord 1978). Preferred habitats of mountain goats generally have a low abundance of forage, requiring them to use a greater diversity of species to meet intake requirements (Schoener 1971). By utilizing all available vegetation, goats are able to exist on small isolated areas of optimally structured habitat that would not support a species with more limited forage utilization capabilities.

ECOLOGICAL RELATIONSHIPS

The previous discussion suggests that bighorn sheep and mountain goats occupy different, though overlapping, positions along several habitat-related niche dimensions or Odum's (1971) "environmental gradients" (Fig. 1). Bighorn sheep are capable of exploiting a wider range of terrain types, particularly flat or rolling topography, as long as these areas are near escape terrain, provide abundant and continuous forage, offer sufficiently unobstructed visibility, and are relatively snow-free. Goats on the other hand, are able to remain year-round on small tracts of steep or rugged terrain and can exploit these areas even if visibility is limited or deep snow is seasonally present. However, goats compensate for their strong preference for optimally structured habitat by accepting a wider range of forages than do bighorn sheep.

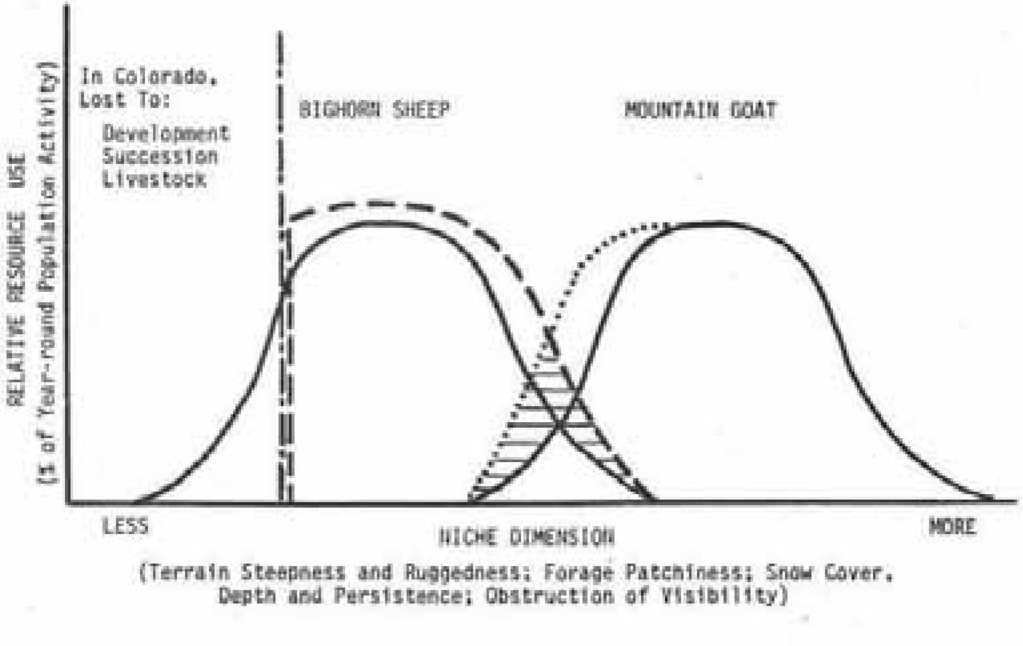

Fig. 1. Conceptual model of ecological relationships of bighorn sheep and mountain goats along some habitat-related niche dimensions. Solid lines represent niche breadths on native sympatric ranges. Dashed line represents observed altered pattern of habitat use by Colorado bighorns, due to habitat losses. Dotted line represents expansion of niche by "young" introduced mountain goat populations. Cross-hatched area represents increase in niche overlap that may be unique to sheep and goat herds in Colorado.

If this analysis is correct, then sheep and goats existing on native sympatric ranges should limit competitive overlap by partitioning their use of habitats as described. This appears to be the case in Glacier National Park, Montana, in the Canadian Rocky Mountain National Parks and on the Kenai Peninsula, Alaska. Studies of the ecological relationships of sheep and goats on such areas would be of great interest.

SHEEP AND GOATS IN COLORADO

In Colorado, mountain goats and bighorn sheep live under constraints and conditions that may not be present where these species naturally occur sympatrically. Mountain goats are recent introductions to the mountains of Colorado and they appear to exhibit characteristics that differ from goats on native ranges. In addition, bighorn sheep in Colorado face many constraints imposed upon them by man and his developments. These factors may greatly affect the potential for these species to compete (Fig. 1).

Mountain goats were first introduced into Colorado in 1948 (Rutherford 1972). By 1975, they had been transplanted into 5 areas of the state and may have expanded into 2 others (Denny 1977). The total population of goats in the state may be approaching 1000 animals.

Study of the Sheep Mountain-Gladstone Ridge herd in the Sawatch Range (Adams 1981) indicates these goats exhibit characteristics that may be unique to introduced populations. Although established mountain goat herds generally exhibit characteristics of "K-selected" or "energy conserver" species (Geist 1975), Colorado goat herds have been exhibiting population trends and habitat relations characteristic of newly introduced rapidly growing, ungulate populations (Klein 1968, Caughley 1970, McCullough 1979). Bailey and Johnson (1977) showed that recently introduced mountain goat herds, 15 years or less after release, averaged twice as many kids per 100 older animals as did native or older introduced populations. The Sheep Mountain-Gladstone Ridge herd, introduced in 1950 and 1 of the oldest transplants in Colorado, first showed evidence of a density-related decrease in reproduction in 1975, 25 years after release (Adams and Bailey 1982).

Compared to native populations, Colorado's mountain goats show different habitat use and grouping behavior which may result from their low ecological density and/or from the lack of capable predators, primarily wolves (Canis lupus), to reinforce traditional habitat selection strategies. Mountain goats on Sheep Mountain-Gladstone Ridge were often observed away from escape terrain in large groups, up to 83 and 37 goats in summer and winter, respectively (Adams 1981:106). Adams also reported that mean group sizes for goats in Colorado tended to be greater than were those of native herds. This difference in grouping behavior may allow Colorado goats to leave escape terrain, enabling them to exploit habitats they would not otherwise use. This behavior represents an expansion of the mountain goat niche and will increase the potential for goats to compete with bighorn sheep (Fig. 1). If this niche expansion arises primarily from the current low ecological density of Colorado mountain goats, any resulting increase in competition with bighorns will be temporary.

At the same time, Colorado's bighorn population suffers from impacts of man's activities. Many bighorn herds do not migrate between seasonal ranges because traditions, normally passed between generations (Geist 1967), were lost with herd reductions early in the century. Transplanted herds have not established such migratory traditions. Fire suppression has reduced the abundance of open habitats between alpine summer ranges and lower elevation winter ranges, further discouraging natural migration regimes and allowing encroachment of trees and shrubs onto important seasonal ranges. Livestock grazing on bighorn ranges may have reduced quality and quantity of available forage and possibly introduced diseases into bighorn populations. Urban, industrial, and recreational development on or near low elevation winter ranges has also restricted use of these ranges by bighorns (Wishart 1978). The range of resources available to Colorado bighorns has contracted, especially in areas used by bighorns and not by mountain goats (Fig. 1). Consequently, bighorns have fewer options for responding to challenges that may include competition from mountain goats.

Bighorn populations may respond to this habitat loss in 2 ways. First, animals may shift use to marginally suitable habitats. Thus, in areas where habitats have been altered, bighorns may seasonally use habitats at slightly greater elevation with somewhat less forage and visibility and greater snow and steepness than optimum. Secondly, bighorn populations may decline in response to habitat loss. If, despite population decline, the absolute level of resource use in some dimensions of the resource niche (on some parts of the year-round range) remains constant, the relative level of resource use in these niche dimensions will increase. For instance, if sheep persist at high elevations while sheep at low elevations decline, the proportion of the total population using high elevations will increase. Consequently, observations of relative habitat use by animals in altered habitats may provide an incorrect view of optimum habitat. Such observations should be supplemented by studies of animal behavior and analyses of adaptive strategies.

For Colorado bighorn sheep, alteration of the pattern of resource use (Fig. 1) probably causes increased relative use of areas somewhat suitable for mountain goats. The result is greater observed overlap of the 2 niches.

COLORADO MANAGEMENT CONSIDERATIONS

The potential for Colorado's bighorn sheep and mountain goats to compete deserves management concern and attention. Exploitative competition requires the mutual use of limiting resources and in this case winter forages are most apt to be limiting. Because of their apparently wider acceptance of forages, mountain goats may have a competitive advantage when and where forage is limited.

It is also important to note the potential for introduced mountain goats to exploit habitats that native goat herds would not. This niche expansion may be temporary, as discussed earlier, and goats may be less inclined to use non-traditional mountain goat habitats once some balance between population size and habitat condition is reached or if these areas must be shared with bighorn sheep.

If native bighorn sheep are to be given priority over introduced mountain goats, which appears to be the policy of the Colorado Division of Wildlife (1977), mountain goats must be managed wisely and cautiously. However, we believe it is possible to maintain viable populations of both species as long as risks to bighorns are considered objectively in each case where the 2 species may come in contact.

Some areas in Colorado are better goat habitat than sheep habitat. Cliff areas that may be partly forested, surrounded by mostly forested habitats, are likely candidates. Such areas would support small, but productive populations of goats but unthrifty bighorn populations, at best. Possible dispersal and colonization by goats from these areas may require future management actions including liberal harvest.

Some areas of Colorado do or, with habitat manipulation, could provide a diversity of habitat that will allow bighorns and goats to partition resources as they do on native ranges where the species are sympatric. In such areas a greater biomass of ungulates can be supported if both species are present since all terrain and vegetation types will be used more fully. Theoretically, the ability of the habitat to support each species, however, will be somewhat reduced by the presence of the other species because some limiting habitats and/or forages will be used in common. Presumably, under these conditions each species would optimize its foraging effort by favoring habitat resources not acceptable to the other, resulting in ecological separation. Currently, the Mount Evans area supports sympatric herds of bighorns (Denney 1976) and mountain goat (Denny 1977), but winter food habits and habitat selection of these herds have not been reported.

Both bighorns and mountain goats can also be supported in areas where sheep migrate to low elevation winter ranges. Migration will allow sheep to avoid competition from goats for limiting forage resources. This occurs on Mount Princeton, in the Sawatch Range, Colorado, where bighorns migrate down to Chalk Creek while goats winter higher.

Many Colorado bighorn herds are small and/or have declined or disappeared in recent decades (Bear and Jones 1973). When herds have diminished coincident with increases in numbers of goats on or near the sheep ranges, it has been tempting and convenient to conclude that goats have been responsible. The evidence is circumstantial, at best. Some Colorado bighorns have diminished without contact from goats during this period and Colorado bighorn herds have been impacted by many negative inflences, as described previously. Blaming mountain goats may divert attenton from the real problems of the state's bighorns.

New and increased contact between sheep and goats in Colorado is occurring with numerical and geographic expansion of goat herds. Further, new transplants of goats are sometimes proposed. It is imprudent, and risky for bighorns, to allow further expansion of goats onto bighorn ranges without analyzing each threatened bighorn herd and its habitat. Unthrifty bighorn herds having lost seasonal ranges, migration corridors, and movement traditions already have bleak futures. The added impact of competition from goats could only exacerbate these problems, but eliminating goat expansion will not solve the problems either.

With or without mountain goats, information on seasonal habitats, migration corridors, habitat conditions, and opportunities for habitat improvement is needed to secure the future of Colorado's bighorn sheep. Once this information is obtained, threats to sheep from expanding goat herds can be realistically evaluated as can opportunities for managing habitats to support sympatric populations of both species.

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CONFERENCE DISCUSSION

Comment:

I'm working an area on the Kenai Peninsula where we have Dall sheep and mountain goats overlapping. Primarily, to the west is sheep range and to the east is goat range. Your model fits our reasoning on why sheep don't get into goat range. The goat range is more coastal with heavier snow. I think it's the snow that limits the sheep primarily. What I can't figure out is why it doesn't work the other way. What keeps goats from encroaching on the sheep more? In the past, before 1920, there were no goats west of the Alaska Railroad on the Kenai, so that was all sheep country. Goats pioneered into it and built to a fairly substantial population in sheep country, while sheep were at a low level. Then the goats decreased in this area, partly due to hunting but also naturally as the sheep herd built up so it appeared that the sheep were outcompeting the goats for food even though the goats could tolerate country that the sheep couldn't. This is just a pure guess. I really don't know what happened, but it would be nice to know why goats don't go into sheep country and take it over.

Q. Up in Montana, the sheep herds that I am familiar with were mostly migratory. In other words they moved down to lower elevations and more open country for the winter. In Colorado, where these sheep and goats exist in the same area, the sheep may not be migratory and may remain in the alpine zone. You have a completely different behavioral situation, so when you put goats on top of sheep, you were actually putting them into the sheep niche; whereas in Montana, goats still winter at the higher elevations but sheep move down.

Ans. A point we are trying to make, is that in many cases, sheep don't migrate in Colorado due to man's involvement with fire suppression and his usurpation of lower-elevation winter ranges for industrial, urban, and recreational uses, transportation facilities, and reservoirs.

Q. What makes you think that sheep did not evolve to utilize alpine ranges in winter, since there were no goats in Colorado to compete with?

Ans. I really don't have an answer for that. I'm not familiar with the situation in Rocky Mountain National Park. Didn't sheep migrate down into the area around Estes Park?

Comment. Yes, but that doesn't mean they did not also winter in the alpine zone.

Q. I was surprised you didn't mention parasite relationships as a possible competitive factor.

Ans. We feel that parasite and disease problems are mostly a symptom of a bigger problem. They aren't the ultimate problem in themselves. In cases involving healthy unconstrained sheep herds, the fact that goats carry certain parasites that can be passed on to sheep may not be a problem. However, if the sheep are already constrained by other factors and already have health problems, such as lungworm, and then goats are introduced on top of the sheep, you are making the situation just that much worse.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:23-24

ON "POPULATION CONTROL" WITH REFERENCE TO MOUNTAIN SHEEP AND GOATS

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ABSTRACT ONLY

Before explaining the demography of American mountain sheep and goats, some aspects of conventional population ecology are examined and found wanting. In this discipline basic semantic problems lead to ambiguous, meaningless hypotheses; ambiguous hypotheses cannot be disproven in principle. The inherent logic of language is confused with reality; the term "regulation" is used in 2 unrelated meanings; the term "population" is reified and treated as substantive reality, not as a convenience of language or convenient fiction which it is. Moreover, it is assumed wrongly that the "population" denotes a teleonomic, that is, goal-directed, system. The question "How do populations control themselves?" is not amenable to scientific investigations and cannot be answered in that semantic formulation. Demography can be explained by asking how an <u>individual</u> maximized reproductive fitness in response to varying environments. It is proposed that individuals are to vary number and phenotype of offspring to maximize fitness, taking as their cue the surplus of resources spared from maintenance. The extremes in phenotype development are labelled maintenance and dispersal phenotypes. Attributes of these phenotypes fit respectively with life under resource scarcity and resource abundance, the latter linked usually to colonizing vacant habitat. The amount of resources spared from maintenance toward reproduction is a consequence of the individual's adaptations as exercised against the resistance of the environment. Therefore, a multi-factorial model of 3 basic components is used to explain demography; the mechanism of the individual controlling phenotype strategy; the individual's adaptations; and the environmental factors. What is referred to as "population control" is the statistical consequence of phenotypic reproductive strategies (long-term) plus the resultant of individual (short-term) actions maximizing reproductive fitness versus the resistance of the environment. Species adaptations can be conceived as consisting of 4 layers of constraints: those typical of all individuals, of the sex-age class, of the phenotype, and the day-to-day decision process of the individual. These can be shown to be a variation in resource acquisition or expenditure, and therefore in demography. The only resources consistently available for reproduction are those freed by death of adults. These resources could be used to maintain 2 extremes in population, 1 consisting of maintenance phenotypes, the other of dispersal phenotypes. Such populations would vary only a little in biomass or size, but would vary greatly in demographic characteristics and in their responses to crises. Populations of dispersal phenotypes cannot exist for

long and will gravitate towards maintenance phenotypes. The extreme is a population of unhealthy, incompetent individuals, highly susceptible to environmental vagaries. To predict demographic changes one must go beyond a model that deals only with the properties of numbers as conventional models do. Some populations are able to clearly exhibit mechanisms that stabilize population densities (show "population regulation") namely those consisting of individuals of maintenance phenotypes. Identification of phenotypes permits conclusions about the extent and timing of resource abundance, as well as about environmental stresses, and offers insights into patterns of colonization and extinction. It is concluded that mountain sheep, by adjusting their phenotypic reproductive strategies to available resources, can vary reproduction above and below that needed for maintaining population size. A long history of stability with concommitant shift to extreme maintenance phenotype characteristics, predisposes a population to a sudden decline from any number of causes. Sheep are seen as recent colonizors of North America, best adapted where ever they have access to ancestral alpine landscapes and poorest adapted where they exist on native American flora. Sheep have apparently radiated in response to megafaunal extinction, and their existence in deserts of the American Southwest is precarious due to inadequacies in their adaptations to that environment. One such inadequacy may be their lack of adaptations to defensive plant toxins that co-evolved with the extinct megafauna. The impact of human activities is detrimental, in particular the introduction of desert-adapted exotics as well as "old Americans" such as the genus Equus. Desert sheep characteristics are linked to a new contingency, namely the availability of water in small, discrete, defendable amounts. American sheep are a rare example of an arctic species colonizing southern latitudes. Whereas sheep do not readily respond demographically to weather changes, except by varying reproductive output and phenotype of the young, American mountain goats respond sharply. This is due to adult females defending limited areas of steep cliffs on which they winter. Under conditions of deep snow the aggression of females escalates, subordinate females are evicted by dominant ones, as are yearlings and males, forcing these to move out in search of adequate habitat. In hard winters these sex-age classes suffer heavy mortality; so do kids despite the protection afforded on a secure territory by their dominant mothers. In addition, the reproductive performance of even dominant females declines. Under favorable weather conditions the adult females are quite tolerant, which leads to high survival of subordinates and a high reproduction by all. This makes goat demography highly sensitive to weather, in particular to snowfalls in winter. Since goats can be readily alienated from their home ranges, and since hunting mortality appears to be additive, and since no compensatory reproduction follows the death of adults; a series of hard winters, plus increased human encroachment and hunting, can rapidly depress goat populations. Sheep populations of high density, living in open landscapes are quite resistant to hunting and may show compensatory reproducton in response to decimation. Sheep living as maintenance phenotypes widely dispersed on small patches of habitat within timbered areas are highly susceptible to decimation and will recover only slowly if at all. Their former distribution can only be achieved artificially by reintroductions and various artificial means to extend home ranges of existing populations.

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and Goat Counc. 3: 25-33

POTENTIAL GENETIC EFFECTS OF SMALL POPULATION SIZE IN WILDLIFE

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ABSTRACT

To be most effective, a program of game management must recognize that a wildlife species is not genetically uniform. Moreover, the genetic quality of a population is subject to degradation if care is not taken to assure its quality. This paper discusses some sources of genetic quality and steps which may be taken to assist in its preservation.

INTRODUCTION

Wildlife managers are paying increasing attention to the genetic quality of the populations they manage. Yet current practices fall far short of producing the advantages that would result from optimal genetic management. There are several bona fide reasons for this lag. First, an appreciation of the genetic diversity present in natural populations has only recently been developed. Second is the difficulty in resolving the biological significance of this diversity. Third, the curricula of wildlife management trainees has not emphasized genetics.

Wildlife management has rightly emphasized habitat improvement as a means for improving the quality of the species in question. The value of this approach, when properly applied, is incontrovertible. However, another important component of the species-habitat system is the genetic quality of the population. An understanding of the nature of this component of the system together with the ability to manipulate it, could pay great dividends. The manager's work could be made more productive and, perhaps, at less expense. The genetic lessons learned by breeders of domestic livestock are readily applicable to many problems with wildlife. Failure to exploit the potential values of genetic management would be unjustified.

GENETIC DIVERSITY

In working out practical procedures for genetic management, the first problem is to determine the kinds and extent of genetic diversity present in the species. Some differences may be relatively simple, e.g., those between snow geese and blue geese. These are referred to as qualitative traits. At the phenotypic level they are usually so rare, or of such small biological significance, that they are of little value as tools in wildlife management. However, at the biochemical level discrete differences such as those seen in different forms of enzymes or other proteins may be valuable in evaluatiing the genetic structure of populations.

In contrast to simple qualitative variation, quantitative differences are of much more interest to the game manager because such traits as reproductive performance, growth rates, and stature fall within this category. Unfortunately, the genetic basis of these traits is not as clear-cut as with qualitative traits. Moreover, in general, environmental effects appear to be more important in the determination of the definitive phenotypes in these cases. Nonetheless, they are of such importance that the extra effort required to tease out the role of the genes in the quantitative traits is well repaid. For example, feed efficiency, rate of gain and egg production in chickens have all been vastly improved through the application of the proper techniques of genetic management.

Genetic diversity is maintained by the action of four factors; mutation, gene flow, normalizing selection and large, stable population size. Mutation typically results in the introduction of a small, steady flow of new genetic material into the gene pool. Admittedly most of these newly arisen variants are soon lost from the population simply due to chance even if they do not convey a disadvantage on the carrier. However, some few, usually those convering some slight advantage or with effects nearly neutral as compared to the pre-existing alleles, will be retained or even increase in the gene pool. Hence they contribute to the maintenance of genetic diversity.

Gene flow was long considered to be a major source of genetic diversity. It has its basis in migration, i.e., animals migrating from one population and being incorporated into the breeding stock of another population would introduce "foreign" genetic materials. The extent of gene flow in natural population was examined by Raven and Ehrlich (1970) and they concluded that it was far less significant force in maintaining diversity than has been previously assumed (Mayr 1963). Fortunately, for the game manager, the ability to transplant stocks permits him to use artificial gene flow much more effectively than might occur in natural populations.

Normalizing selection describes the situation in which those individuals lying near the mean of the population distribution leave relatively more offspring in the next generation than those lying near either extreme. The effect of such selection is to maintain the structure of the population in its present state. Since individuals lying near the mean are usually heterozygous at more loci than those at the extreme, then normalizing selection acts to maintain genetic diversity by tending to keep contrasting alleles in the gene pool. Without doubt, this is the most important mechanicsm responsible for maintaining diversity.

The reason large, stable population size tends to maintain diversity is that under these circumstances genetic drift cannot be very effective. Genetic drift is an outcome of small population effects. Imagine flipping a penny ten times. A result of 7 heads and 3 tails would be no great surprise, but it would be a 20 percent deviation from the expected 5:5 ratio. Next, imagine a trial of 100 flips. A result of the same percent deviation, i.e., 70 heads and 30 tails would lead you to suspect something was wrong with the coin. In just the same way, variation in genetic structure of populations can be affected by the number of trials. A large stable population of 1000 individuals would have 2000 gametes drawn every generation to form the next generation. A population of 10 would result from only 20 gametes. Other factors being ignored, the expected proportion of the gametes drawn in each case would be predicted by the proportions of the various alleles present in the preceeding generation. However, in small populations, the potentiality for deviations from expectations are greater than in large populations. Consequently, changes in allelic frequencies simply due to the accidents of gametic sampling are expected to occur more often in smaller than in larger populations. This phenomenon, called genetic drift, has potentially dangerous consequences in wildlife management. It is one mechanism by which the genetic diversity of a population may be degraded.

So far we have discussed the nature and maintenance of genetic diversity, but have not specifically addressed the issue of its biological significance. It might initially appear that a genetically homogeneous, phenotypically uniform stock might be more easily managed than one with greater diversity. But let us examine the consequences of reducing diversity by considering inbreeding. Inbreeding of close relatives is a very effective way to reduce the range of genetic heterogeneity in a population since it tends to eliminate certain alleles and increase the proportions of their alternates. One of the most often cited cases of reduction of fitness is seen in corn (Zea mays) (Neal 1935).

Figure 1 shows the effects of inbreeding on yield. Not only plants, but animals also show these effects as shown by the work of Albplanalp (1974). Some of his data are presented in Table 1.

The data in Table 1 were derived from lines which were only 25 percent inbred. Yet, the reduction of quality in important traits is obvious. Note also the rather striking differences when comparing chickens and turkeys with quail and chukars. The two former species have been under domestication for a long period and have undergone extensive inbreeding during this period. This would have exhausted part of their genetic diversity and consequently reduced the potential for further inbreeding depression. The quail and partridge are nearer the natural condition and the drastic effects on these species should be noted by those who would attempt genetic management of wild species. They are much more subject to the degradative effects of inbreeding than species which have a long history of domestication.

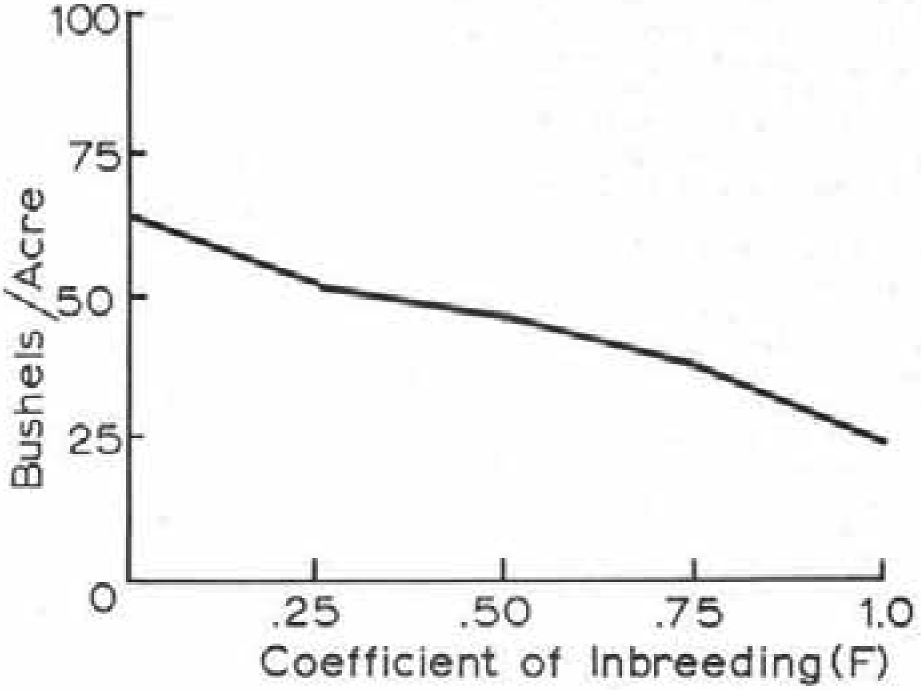

Figure 1. Relationship between inbreeding coefficient and yield in corn (Data from Neal, 1935).

Table 1. Effects of inbreeding on four species of galliform birds. (Outbreds = 100)

Trait	Chicken	Turkey	Japanese Quail	Chukar Partridge
Hatchability	90.0	83.4	72.2	71.3
Fertility	99.1	98.9	79.2	71.1
Female viability	94.3	90.7	81.5	92.1
Egg production	90.4	89.5	83.9	84.1
Total reproduction	74.4	61.6	35.9	34.1
Mean inbreeding depression	1.183	1.938	4.098	4.303

The reciprocal effect of inbreeding depression is called heterosis, or hybrid vigor. Although a number of matings between species do produce highly vigorous offsprings, e.g., the mule, this type of hybrid (interspecies) is of little relevance to game managers. The hybrid vigor we refer to is that resulting from crossing different strains of one species. The literature of plant and animal breeding is replete with examples. Everyone is now familiar with the great impact the use of hybrid corn has made on American agriculture. Although records of natural hybrids are abundant, data on the relative vigor of these organisms is seldom gathered. Yet, laboratory experiments comparing heterozygotes and homozygotes in fruit flies (Wallace 1981) suggest that the phenomenon of heterosis is generally applicable in most animals. Two field studies are relevant to this problem. Singh and Zouros (1978) determined that higher levels of heterozygosity were associated with greater growth rates in oysters (<u>Crassostrea</u>). Batttaglia (1958) crossed two forms of the copepod crustacean, <u>Tisbe reticulata</u>, and showed that the heterozygotes have higher survival than either of the homozygotes. The gains from cross-breeding beef cattle suggest that ungulates are no exception to the increase of vigor resulting from outbreeding.

POPULATION SIZE AND INBREEDING

Effective breeding population (N_e) is a term used by Wright (1948) to denote a statistic useful in predicting the potential effects of population size and structure upon the variance in gene frequencies in succeeding generations. Its significance can be understood by considering a few examples. First, if the numbers of the two sexes contributing gametes to the next generation are unequal, say as in harem formers, the contribution of the breeding males will be disproportionately greater than each of the females, i.e., the males will be more "important" genetically. The N_e in this instance can be calculated by the following equation:

$$Ne = \frac{4N_m \times 4N_f}{N_m + N_f} \qquad (1)$$

Where N_m and N_f are the numbers of males and females, respectively. For example, a band of sheep which has 20 ewes and two rams would have an effective breeding size of only 7.27 instead of 22.

Another situation causing N_e to be misleadingly small is when population numbers vary during different generations. This would exist not only with cycles of abundance, but during periods of population growth. For example if a population of 10 parents were to triple in numbers of reproductives, in four succeeding generations, the value of N_e would be calculated from the equation:

$$\frac{1}{Ne} = \frac{1}{t} \frac{1}{N_1} + \frac{1}{N_2} + \frac{1}{N_3} \cdots\cdot \frac{1}{N_t} \qquad (2)$$

Where t represents the number of generations and N_1, N_2 etc. represent the numbers in each generation. In the example cited, the effective breeding population over this interval turns out to be approximately 33.5. It is far less than one might have assumed since the final population was 810. The reason again is the disproportionate representation of the genes of certain individuals. In this case they are the original generation.

One measure of inbreeding is the probability that the two alleles an individual receives at a given locus are identical by descent. That is, that they are both copies of a specific, single gene present in some individual ancestor. It should be noted that an organism could be homozygous, i.e., having both alleles at a locus identical, but if they were derived from unrelated ancestors this does not represent inbreeding as used here. The degree of inbreeding in a population is denoted by F, the coefficient of inbreeding. This value can be calculated in a number of different ways and techniques for doing so are shown in a number of tests on population genetics (for example, Falconer 1960; Spiess 1977). For our present purpose, suffice it to say that values of F could range from zero in a totally outbred situation to 1 in the case of complete, total inbreeding, e.g., the offspring resulting from monoploids.

Now let us turn to an examination of the relationship between effective breeding population and inbreeding. Frankel and Soule (1981) following Wright (1931), showed the loss of heterozygosity in a population as a change in the inbreeding coefficient of the population. This amounts to the equivalent of an increase in inbreeding. Hetrozygosity is lost at a rate given by the expression:

$$\Delta F = \frac{1}{2N_c} = \frac{1}{8N_m} + \frac{1}{8N_f} \qquad (3)$$

Where F is the change of inbreeding coefficient and the other notations is as in (1).

One of the rules of good genetic management employed by the breeders of domestic animals is to permit no more than 1 percent increase in inbreeding per generation. This substituting into equation 3:

$$2\ N_e = \frac{1}{.01}$$

$$N_e = 50$$

Thus if the number in each sex reproducing were 25 of the F would not exceed the 1 percent per generation ceiling. However, with unequal sex ratio, as is typical in many ungulate species, the situation is a bit more complex. If the sex ratio of reproductive adults were, say 5:1, then, for example a population of 15 males would require 75 females for F to be no more than 1 percent. Moreover, some quick calculations would show that 15 would be approximately the minimal number of males in a population wherein the 1 percent limit per generation would not be exceeded. At numbers lower than this, the number of females required begin to skyrocket toward biologically unrealistic levels.

DISCUSSION

In view of the foregoing, several questions concerning the genetic management of wildlife stocks spring immediately to mind. Among them are:

1. If inbreeding is so deleterious and such a likely outcome of small population effects, how is it that any of the small bands of wildlife have survived?
2. What can be done to counter the potential deleterious effects of inbreeding?
3. Would not outbreeding, by introducing new individuals from other populations, tend to reduce the fitness local populations had achieved through a history of natural selection?
4. In establishing a new population in a previously unoccupied area, how many individuals should be moved?

Considering these questions _en seriatim_, first, why have any small bands survived? The answer must naturally be equivocal because the effects of drift are not uniformly predictable. The very name suggests that there is no systematic effect from this factor. However, it may be that some of these organisms, e.g., small bands of sheep or goats have undergone a prior history of inbreeding, like the chickens and turkeys alluded to earlier and consequently do not suffer as much inbreeding depression as they might otherwise. In view of the social structure of the species, they would be expected to have lower N_e than species which are monogamous. If the assumption that they are already rather highly inbred is true, this does not invalidate the proposition that they would benefit from outbreeding. Reference to Figure 2 shows the relationship of inbreeding and continued consanguineous matings.

Note how the increment in F diminishes as the generations proceed. If a population is already at, say generation 15, continued inbreeding for an additional 15 generations will have a relatvely small effect on F as compared to the foregoing 15 generations. Conversely, outbreeding after the 15th generation of inbreeding would be expected to produce a dramatic reversal of inbreeding depression. In fact, the resulting hybrid vigor should be relatively greater in the first generation of outbreeding than in the ensuing generations. So, despite the fact that some organisms might survive in the face of high levels of inbreeding, these are the populations which may respond most favorably to outbreeding. This possibility should be considered for exploitation.

The answer to the first question immediately suggests an answer to the second, i.e., what can be done to counter inbreeding depression? The answer is to outbreed by introducing unrelated animals into the small isolated stocks. The number required to offset the effects of drift is surprisingly small. Wright (1931) proposed that the introduction of one outside individual into a population every generation is adequate to offset the effects of drift.

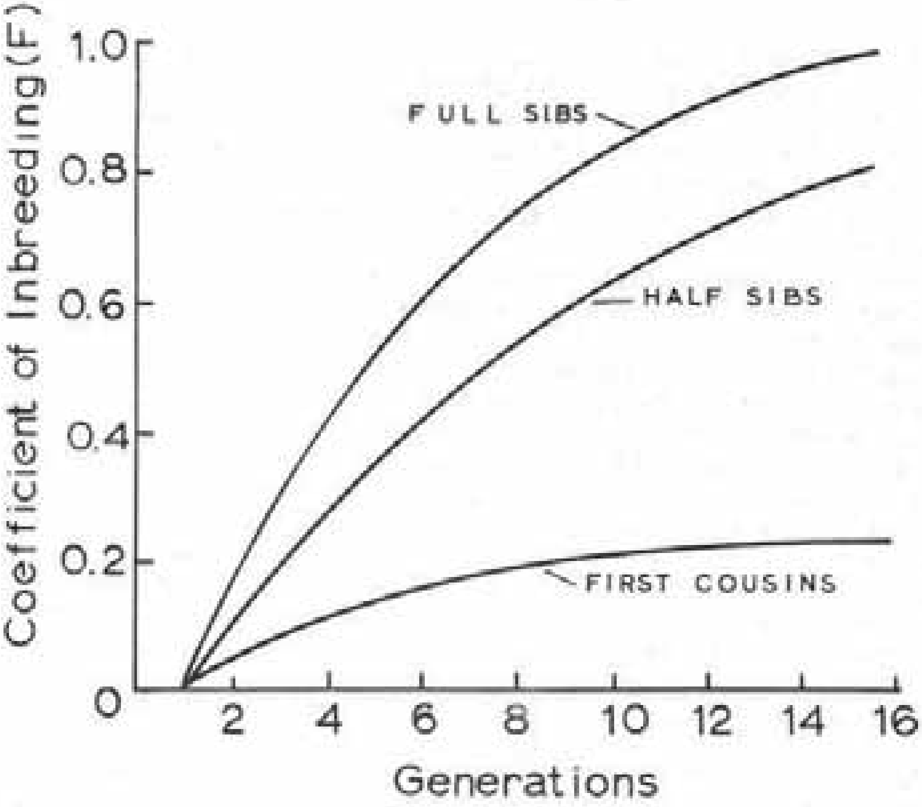

Figure 2. Effect of difference breeding systems on inbreeding coefficient.

The third question concerns the disruption of an adapted population by introducing individuals from other stocks. The question is valid, but when all factors are considered the problem is, on balance, a relatively small one. Most large mammals are more closely adapted to the general niche than they are to the specific set of physical and biotic parameters in their immediate environmemt. Such factors as general vigor, fecundity and disease resistance are general adaptations, not adaptations to a particular geographic area. Consequently, the special (local) adaptedness is not nearly so important in these socially and physiologically well buffered animals. Any slight diminution in special adaptedness caused by the introduction of new indivduals is likely to be more than offset by the increase in the fitness of general adapted traits. Moreover, selection should continue to act to eliminate the undesirable alleles which reduced special adaptedness. So, unless the depression caused by introduction was truly extreme, the population's genetic quality would be improved at little net cost.

In introducing new individuals, the problem of disease control should be given a great deal more attention than the attenuation of fitness.

In answering the last question (size of a new colony?) several constraints must be considered. Naturally, available fiscal and biologic resources are primary concerns. With respect to genetic quality, the number to be transplanted is not quite so important as the genetic structure of the transplanted animals and the prospects for their numerical expansion. If they have come from an inbred stock, they would be less likely to be successful than those derived from a genetically heterogeneous population. If they are from a population of the latter type, and have the prospect for rapid numerical increase, large numbers are not so important. There is no absolute threshold value for adequate and unadequate numbers, but a group of 15-20 which actually participate in breeding can transmit a healthy fraction of the genetic diversity of the parent population to the newly established colony. If there were inequality in the sex ratio the N_e would be reduced according to the equation given previously. But if the population expanded quickly enough even this problem would become inconsequential. The point to be made here is that we should not attempt to establish colonies in habitats extensve enough to contain relatively large populations. Otherwise, we must expect to play genetic nursemaids every generation or so.

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Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:34-42

SMALL POPULATIONS:

OBSERVED GENETIC EFFECTS

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ABSTRACT

It has been demonstrated theoretically that small populations should suffer a reduction in genetic variation. This paper will review studies of the effects of small population size on genetic variation utilizing examples from both laboratory and natural populations. Although many studies have shown that there is a decrease in genetic variation in small populations, other studies have indicated that there may not be a direct relationship between population size and the amount of genetic variation. Implications of these findings for wildlife management will be made.

INTRODUCTION

We have just heard about some of the factors that can lead to changes in gene frequency. Such factors as drift, founder effect, and inbreeding can result in shifts in gene frequency with a resultant lowering of the mean heterozygosity in the population. In my talk I would like to discuss what is known concerning the actual genetic effects of small population size and inbreeding in natural populations of animals.

Before addressing these questions, it would be well to examine briefly how one determines something about the genetic composition of a population. How is it possible for example, to characterize the genetic variation in elk, deer, mountain goats, bighorn sheep, etc. Without a doubt the major breakthrough in this area has been the application of eletrophoresis to detect allelic and non-allelic forms of proteins in individuals. The use of electrophoresis has made it possible to identify precisely the number of indivuduals with different genotypes since it is possible usually to differentiate betwren homozygotes and heterozygotes. This allows one to monitor the amount and distribution of genetic variation in natural populations and to determine the genetic structure of different populations. Most of the studies which have utilized electrophoresis to characterize natural populations have examined twelve or more different genetic loci. In some cases the specific function of the enzyme may not even be known. However, the enzymes are under genetic control and they provide the investigator with a means of determining the genetic variations within and among different populations. It is of interest to determine how many loci are polymorphic in the population and how much heterozygosity is shown by individuals in the population. A review of the mean heterozygosity and the proportion of polymorphic loci (Table 1) indicates that the mean heterozygosity tends to be small, usually 1 to 2 percent.

A study of nearly 300 elephants in the Kruger National Park in Africa (Osterhoff and Schoeman 1974) found genetic differentiation in the serum transferrings, albumins, and esterases, but did not find any differences in the hemoglobins and a number of enyzmes indicating that these groups of elephants seemed to be relatively homogeneous genetically. Since, in general, the loss of genetic variation may make a population or species less able to adapt to sudden environmental changes, the small amount of genetic variation in this herd of elephants may have profound implications for the proper management of the herd.

An additional example of the types of information which come out of electrophoretic studies is seen in the data on deer in South Carolina (Ramsey et al. 1979). Two adjacent populations of white-tailed deer in South Carolina were found to differ widely in a number of demographic features. The two herds, designated "swamp" and "upland", were found to have different age structures, sex ratios, and reproductive rates. The swamp herd had changing demographic patterns whereas the demographic features of the upland herd tended to remain stable over time. Ramsey and his co-workers also studied the elctrophoretic variations of 21 proteins encoded by 22 structural genetic loci. Differences in genotypic frequencies between herds, sexes and age classes were found for the esterase and hemoglobin loci. Correlations between demographic and genetic dfferences may be useful in identifying populations and in defining management units and practices.

We have seen that inbreeding or consanguinity increases the likelihood of homozygosity among the offspring. This will be true whether inbreeding is a result of some irregular system of mating (within some human cultures it was the preferred social custom) or a result of some irregular system or happening. In breeding, per se, is not necessarily good or bad. Its outcome will depend on whether or not the increase homozygosity is good or bad. Studies of laboratory animals, farm animals, zoo animals, and man have shown clearly that inbreeding brings about a decline in characters which are concerned with fitness and survival. Cattle show a 3.2 percent decline in milk yield with a 10 percent increase in inbreeding (Robertson 1954). Sheep show a 5 percent decline in fleece weight (Morley 1954) and poultry show a 6.2 percent decrease in egg production (Shoffner 1948) with a 10 percent increase in inbreeding. Juvenile mortality was higher in inbred animals than in noninbred mammals in several species of small ungulates and other small mammals maintained in zoos (Ralls et al. 1979; Ralls and Ballou 1982).

Perhaps the most extensive and systematic study of inbreeding has been that of populations in Japan (Schull and Neel 1965). Some representative data are given in Table 2. These results, as well as other effects on mortality including stillbirths, all point in the expected direction from the genetic point of view. The children of first cousins, who are the most inbred compared to the children of second cousins and unrelated parents, show the most detrimental effects on child mortality. Second cousins are less related than first cousins and show less effects of inbreeding or inbreeding depression.

Why should an increase in homozygosity be detrimental or lead to inbreeding depression? First of all, increased homozygosity will increase the chance of detrimental recessive genes, which in effect were hidden or masked in the heterozygote, being expressed (Table 3). As the frequency of the recessive gene, q, goes down, the impact of mating a relative goes up. If a gene has a frequency of 1 in a 1000, for example, the chance of getting a homozygous recessive child is $(1/1000)^2$ or 1 in a million. In matings of second cousins there will be 16.6 times as many affected children compared to 63.4 times as many for first cousin matings and 250.8 times as any for matings between full sibs.

What is actually known concerning inbreeding and its effects in natural populations? VERY LITTLE!!! Even the most basic question of knowing if inbreeding has taken place or is taking place is a most difficult one. One might attempt direct field observations to identify all breeding pairs. As you might well imagine behavioral observations of this sort are difficult at best, and for practical reasons, may be impossible for many species. Nevertheless, this approach has been used with good results for some species incuding Greenwood et al. (1978) for Great Tits and Packer (1979) for anubis baboons.

Actually, one might be more concerned with determining the genetic results of inbreeding - increased homozygosity or low heterozygosity or loss of genetic variance. Here is where the use of electrophoresis has assumed such a major role.

Theoretical considerations have led us to think automatically that populations with small effective population sizes have low levels of genetic variation when compared to populations with large numbers. However, the relationship between population size and the amount of genetic variation may not necessarily be a simple or direct one.

An interesting paper was published late last year by Parker and associates dealing with genetic variation in mallared ducks. Although there was a large and nearly panmictic population with high dispersal abilities, there was little genetic variation. The ducks showed low variability both in individual heterozygosity and in the proportion of polymorphic loci. The authors examined 20 loci and found only 4 (20%) to be polymorphic. Heterozygosity was only 2.7 percent in the population.

There are few studies on the effects of inbreeding in natural populations. Perhaps the first detailed evidence of inbreeding depression in a natural population is provided in the study by Greenwood et al. (1978) on great tits near Oxford, England. During the period from 1964-1975 a total of 1,000 matings were observed of which 16 (1.6%) were examples of inbreeding. The 16 matings included 7 mother-son, 9 brother-sister, and 1 aunt-nephew. Laboratory studies have indicated that the timing of reproduction, litter size, infant or fledging mortality, and offspring viability or fertility may all be affected adversely by inbreeding. In the population of great tits there was no evidence that inbreeding pairs produced smaller clutches but nestling mortality was higher for the inbreeders than for the outbreeders, 27.7 percent versus 16.2 percent. The effect of 30 percent is quite similar to that obtained in similar laboratory studies on birds and other organisms.

For mammals there are only limited observations on the effects of inbreeding. These are usually anecdotal in nature as in the study by Packer on anubis baboons (Packer 1979). In these baboons, typically, the males transfer out of one troop into another troop and such behavior is regarded as an example of animals avoiding inbreeding by not staying in their natal troop. It still remains to be determined if the baboons are actually avoiding inbreeding. Nevertheless, Packer did have observations on one male who had bred related females. There seemed to be an effect on infant mortality as only four out of eight inbred progency survived more than one month compared to 32 out of 38 offspring from matings of transferred males who had mated females from another troop. Packer's behavioral observations indicated that females seemed to prefer "transferred" males and, thus, there appeared to be a genuine tendency for the females to avoid mating related males.

With the current emphasis on Sociobiology one sees a lot of recent papers dealing with inbreeding avoidance being exhibited by many species. Zoologists tend to look for behavioral mechanisms of outbreeding. Are there conditions under which inbreeding might actually increase fitness? Smith (1979) has examined this question in an interesting paper entitled "On selection for inbreeding in polygynous animals". If inbreeding is selected against because it leads to increased homozygosity, then so should small population size, but the range of effective population size for many mammals is 10-100. If inbreeding increases inclusive fitness, it should be selected for. If the costs of inbreeding depression are less than the costs of dispersing, etc., then it should occur. Inbreeding or incest is well documented in some cooperative hunters such as the wolf and coyote. This, cooperation among kin in an inbred unit may outweigh the cost of inbreeding depression. All of this is further complicated by the fact that inbreeding depression is not a fixed amount but may vary depending on the reproductive history of the population and the nature of the selective forces acting upon it.

In closing, I would like to call your attention to a recemt paper by Ryman et al. (1981) which appeared late last year in OIKOS. The paper examined the genetic implications of various wildlife management programs. Using stochastic computer simulations, the study estimated the effects of various hunting policies for moose and white-tailed deer on effective population size and generation interval. Time does not permit me to go into much detail, but for the moose the different hunting regimes caused the generation intervals to range from 4.2 to 9.9 years and ratio of effective population size to actual population size to vary from 0.2 to 0.4. What does it mean? The amount of genetic variation in a population can be influenced considerably in relatively short periods of time by the type of management.

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Table 1. Heterozygosity and Polymorphic Loci in Mammals

Species	Number of loci	Mean Heterozygosity	Proportion of Polymorphic Loci	References
Man	74	0.009	0.31	Nei & Roychoudhury (1974)
Northern Elephant Seal	24	0.000	0.00	Bonnell & Selander (1974)
White-tailed Deer	28	0.10	0.32	Manlove et al. (1976)
Moose	23	0.0006	0.04	Ryman et al. (1977)
Pika	26	0.011	0.15	Glover et al. (1977)
Elk	24	0.012	0.04	Cameron & Vyse (1978)
Raccoon	12	0.014	0.42	Beck & Kennedy (1980)
Sika Deer	19	0.000	0.00	Feldhamer et al. (1982)

Table 2. Effects of Inbreeding in a Japanese Population from Hiroshima (data from Schull and Neel, 1965).

	Relationship of Parents		
	Unrelated	Second Cousins	First Cousins
Number of Livebirths	4089	722	1,651
Number of Infant Deaths (prior to on year of age)	145	32	101
Per Cent of Infant Deaths	3.6	4.4	6.1

Table 3. The Factor Increase in the Frequency of Homozygous Recessives with Matings of Related Parents Relative to Unrelated Parents

	Relationship of Parents		
Frequency of Recessive Gene, q	Second Cousins	First Cousins	Full Sibs
0.1	1.1	1.6	3.2
0.01	2.5	7.2	25.8
0.001	16.6	63.4	250.8

Factor increase values (F.I.) are obtained from the expression:

$$\text{F.I.} = \frac{fq + (1-f)\,q^2}{q^2}$$

where f is the coefficient of inbreeding of the children (second cousins, f = 1/64; first cousins, f = 1/16; full sibs, f = 1/4). and q is the frequency of the recessive gene.

CONFERENCE DISCUSSION

Q. Could we get information from the animal husbandry people on inbreeding of domestic sheep herds and how could we get information for wild sheep on inbreeding coefficients?

Ans. A couple of good references for domestic sheep are Morley (1954) and Lamberson et al. (1982). There are no data on inbreeding coefficients for wild sheep. If one had accurate estimates of the effective population size in a herd over a number of years and a good knowledge of the behavior of the species, one might be able to come up with a reasonable estimate.

Commentary. In the late 60's and the early 70's, we had a situation in sheep population in Canada and the question arose - how many? How many should we include in a herd? The number of animals never exceeded 80. 1. The degree of heterozygosity was related to heterosis, and the degree of heterosis was related to dominant individuals in that group. All the formulas you have showed assume random mating, a classical assumption. Under natural conditions, if there is a relationship between heterosis and dominance, the largest animals breed. 2. The population that is preyed upon showed a higher degree of fitness due to heterosis alone, you will then have a very heavy selection against heterozygotes which means even in a tiny population, you maintain a high degree of heterozygosity and therefore genetic variants. Obviously, other mechanisms are working; there is improvement of genetic stocks.

Comment: If the population effective size appears to be really small or the population appears to be isolated, it doesn't take much in the way of immigration, one animal coming into that population, to keep genetic variation reasonably high.

Q. Occasional immigration in a population will make a difference. Are we talking about 1 in a generation or 1 in 10 generation or 1 per 100 generation?

Ans. Normally used is 1 in a generation.

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INBREEDING IN BIGHORN SHEEP: A CASE STUDY

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ABSTRACT

The results of a study of bighorn sheep (Ovis canadensis canadensis) in Dinosaur National Monument are reviewed with emphasis on inbreeding theory. Genetic considerations are related to breeding and dispersal behavior in bighorns. The present management practice of transplanting relatively small numbers of animals is discussed.

INTRODUCTION

Inbreeding has long been suspected as a contributing factor in unsuccessful reintroductions and poor performance of small remnant populations of bighorn sheep. Berwick (1968) believed that inbreeding was partly to blame for poor performance and decreased body size in the Rock Creek, Montana herd. The value of obtaining information on the genetic composition of wildlife has been pointed out by Smith et al. (1976), and Wilson (1974) expressed the need for such information specifically in bighorns. Roberts (1979) found that 4 populations of bighorns in Colorado were genetically distinct, the importance of which has not been fully addressed. The objective of this paper is to bring together some inbreeding theory with data collected during an evaluation of a herd of bighorns in Dinosaur National Monument, and to relate this theory to some aspects of bighorn sheep biology.

Dinosaur National Monument is located in northwestern Colorado and northeastern Utah. Plant communities within the canyon habitat of the bighorns range from a riparian zone dominated by boxelder (Acer negundo) and phragmites (Phragmites communis), through sagebrush (Artemisia spp.) and pinyon-juniper (Pinus edulis and Juniperus spp.) to ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) on the canyon rims. Thirty-two bighorns from central Colorado were transplanted into Lodore Canyon, the northernmost portion of the Monument, in the winter of 1952. The National Park Service authorized a study of the herd in 1958 and 1959. The herd had increased to approximately 130 animals and occupied the length of Lodore Canyon and small contiguous portions of the Yampa Canyon and Whirlpool Canyon within the Monument (Barmore 1962). The herd was expected to occupy all of the canyons in the Monument, because all were historic sheep range. By the mid-1970's, no range expansion outside of Lodore Canyon had occurred, and the National Park Service funded a second study of the sheep. The results of this study (Skiba 1981) will be used as an example of some of the possible effects of inbreeding in bighorn sheep.

MATERIALS AND METHODS

Access to Lodore Canyon was by raft via the Green River and on foot. Rafting provided access to portions of the canyon difficult to reach by foot and made transportation of equipment more efficient. Animals were observed with the unaided eye, binoculars and spotting scope, and placed in 8 sex-age categories (Geist 1971). Individuals were immobilized with M-99 (etorphine) for marking with collars. Collars were used to analyze movement of individuals and to estimate population size with a Peterson-Lincoln index (Ricker 1975). Some animals were equipped with radio-transmitter collars to aid in relocation. An inbreeding coefficient (Falconer 1960) for the herd was calculated based on known population data since the transplant.

RESULTS

Lamb:ewe and yearling:ewe ratios obtained in 1978 and 1979 are presented in Table 1.

Table 1. Lamb:ewe and yearling:ewe ratios of the Dinosaur National Monument bighorn herd, 1978 and 1979.

	Lamb:ewe	Yearling:ewe
1978	0.66	0.32
1979	0.82	0.43

Survival of 1978 lambs to the 1979 yearling class was calculated at 65%. Both ratios were consistent through the main field seasons of both years. Six animals were immobilized with M-99. One animal died, 4 were outfitted with radio collars, and 1 with a numbered vinyl collar. A helicopter census flight in December of 1979 resulted in a population estimate of 38. Two collared individuals had apparently died between collaring in November of 1978 and the census flight. A total of 18 animals were sighted during the flight; 1 was collared. The coefficient of inbreeding was calculated at 24%. Equations used and assumptions made about herd size and structure are presented in Appendix A.

Distribution of the herd was similar to that found by Barmore (1962). The expected range expansion had not occurred to any extent, with very few sightings of animals outside of Lodore Canyon. One ewe, recognizable due to a horn deformity was seen with a lamb in Whirlpool Canyon in August 1978 and in the same area in July 1979. She was also sighted in Lodore Canyon in November 1979. All other reports outside of Lodore Canyon were from Dinosaur National Monument visitors and were of questionable validity.

DISCUSSION

INBREEDING

The primary effect of inbreeding is to increase homozygosity, which causes a decrease in fitness (Soule 1980). The first characters to be depressed are those related to reproduction and viability of offspring (Farnsworth 1978). A generalization used is that a 10% increase in inbreeding coefficient produces a 5% depression in a trait (Soule 1980). Inbreeding has not been addressed in wild populations due to the difficulty of obtaining necessary information on breeding patterns and viability of successive generations. Ralls et al. (1979) found that inbred young were significantly less likely to survive than non-inbred young in 15 of 16 species of captive wild ungulates. Much more data are avaiable on the effects of inbreeding in domestic animals. Effects include decreased survival of young animals to weaning in swine (McPhee et al. 1931), decreases in adult weight, litter size, and litter weight in swine (Mikami et al. 1977), decreased milk yield in cattle (Pearson et al. 1977) and decreased body size and weight in cattle (Miller et al. 1977). The salient point is that inbreeding can cause reduction in fitness of inbred individuals.

With the large number of small herds of bighorn sheep throughout the West, the potential effects of inbreeding become more important to address. In terms of introductions of animals into unoccupied habitats, the current practice (admittedly the only practical method) of transplanting small groups of bighorns only exacerbates the problem. Senner (1980) showed that a population founded with 20 individuals and maintained at 50 individuals would reach a 60% level of inbreeding (i.e., would have lost 60% of its heterozygosity) in about 90 generations. These population figures, however, are for effective population size. Effective size can be calcuated with the following equation (Falconer 1960):

$$\frac{1}{N_e} = \frac{1}{4\,M} + \frac{1}{4\,F}$$

where N_e is effective population size, M is the effective number (number actually breeding) of males in the population, and F the effective number of females. Franklin (1980) suggests that to prevent short-term inbreeding problems, the effective size of a population should be greater than 50. Assuming a population structure of 60 lambs:100 ewes:40 yearlings:75 rams (composition based on data from Bear and Jones 1973), and breeding by 50% of the rams, a population of 50 bighorns would have an effective size of about 20. The actual proportion of rams actually breeding is probably below 50%, which would further decrease the effective size. To obtain an effective size of 50 with the above demographics, the total population size would be 100. The Dinosaur herd currently consists of approximately 15 ewes, 7 lambs, 6 yearlings, and 10 rams (fall population). The effective size (assuming 50% of the rams breed) is 15. The current rate of inbreeding is approximately 1.3% per year (see Appendix A). In Colorado, population sizes range from 15 to 425. The effective population sizes probably range from 10 to 170. A total of 59 populations now exists in the state; 30 of these are currently smaller than 50 individuals. An additional 13 have between 50 and 100 individuals. While the absolute effects of inbreeding are not fully known, there is ample evidence to suggest that the continued maitenance of populations at such low levels can only be detrimental.

POPULATION RATIOS

Lab:ewe ratios in the Dinosuar herd are generally considered to be good. Ratios of 1.00 have been found in bighorns on Wildhorse Island (Woodgerd 1964). The usual situation is for lamb crop to be less than 100 lambs per 100 ewes. The number of nonbreeding ewes is probably minimal in most populations and would have little effect on lamb:ewe ratios. The failure of most herds to reach the ideal lamb:ewe ratio has been attributed to severe weather (Smith 1954), poor forage, high density (Geist 1971), or harrassment of ewes by rams (Pulling 1945). While there is no doubt these factors can and do influence the lamb crop, the effects of inbreeding can be just as important. In fact, environmental factors may increase the detrimental effects of inbreeding (or vice versa). Keller and Brinks (1978) found that different production levels had a greater than expected effect on inbred cattle. It may be wise to consider genetic causes as well as more traditional explanations when bighorn herds do not attain high lamb:ewe ratios. This is particularly true in small remnant herds which exist on areas which should have a good forage supply. In Dinosaur, assuming that all ewes were bred, prenatal and early postnatal mortality was 38% in 1978 and 18% in 1979. Inbreeding of 25% could have had an effect on the survival of embryos and lambs. While other factors could have influenced the lamb crop, inbreeding should not be overlooked.

DISTRIBUTION

Competition with domestic livestock, for both space and forage, is the most probable cause for the limited distribution of the Dinosaur National Monument bighorn sheep herd (Skiba 1981). Until 1976, cattle and domestic sheep grazed the southern end of Lodore Canyon and the western end of the Yampa Canyon. In addition, all of the suitable uplands within and surrounding the Monument were grazed (grazing in the Monument is currently being phased out). Competition with livestock may have limited the movements of the bighorn at the critical stage of range establishment.

The maintenance of this limited distribution, especially in light of the removal of livestock from the area, may be due to the pattern of dispersal in bighorns. Howard (1960) theorized that dispersal is genetically controlled. Subsequent studies have shown that there are genetic differences between dispersing and non-dispersing individuals. Dispersing types have been found in voles (*Microtus ochrogaster*) (Pickering et al. 1974) and in blue grouse (*Dendorgapus obscurus*) (Redfield 1973). Both Redfield (1973) and Myers and Krebs (1971) found that the dispersing individuals were more likely to be homozygous. If a similar genetic control of dispersal occurs in bighorn sheep, inbreeding may influence dispersal. If the dispersal genotype was homozygous, it would be expected to be more common in an inbred population. Dispersal of individuals from an already small poulation would only add to the problem of potential inbreeding, if no outside individuals moved into the population. The pattern of dispersal in some animals is nonrandom, with a larger than expected number remaining close to their natal area, a smaller than expected number moving an intermediate distance, and a larger than expected number moving long distances (Howard 1960). Such dispersal would be invaluable in preventing inbreeding in bighorns if all herds could receive outside individuals. This was probablay the case before populations were separated to the extent they are today. Even under primeval conditions, the distribution of bighorn herds was probably discontinuous. Dispersal betwee groups would aid in dispersing genes and reducing inbreeding. Under present conditions, dispersal may not bring an individual in contact with another herd of sheep. Geist (1971) believed that sheep would not remain in an unfamiliar area if there were no other sheep present. In the case of a dispersing bighorn today, especially in relatively isolated herds, the animal would have the alteratives of returning to its natal area or continuing to explore. In either case, the urge to disperse exposes the animal to hazards that it would not encounter if it did not disperse, and may remove a potential breeding animal from the population. In small herds, the loss of individuals, most commonly young males in bighorn sheep (Geist 1971) would only increase the likelihood of inbreeding. Whether or not dispersal contributed to the present distribution of the Dinosaur herd is unknown. It is very unlikely that a dispersing animal from Dinosaur would find another herd or that individuals are dispersing into the population, since there are no large established herds within 100 km (there is a small recently transplated herd, perhaps of 40 individuals, within 30 km of the range of the Dinosaur herd). While prevention of inbreeding may not be the only reason, or even a major reason for dispersal in mammals (Greenwood 1980), it is a beneficial effect. Under conditions as exist today, dispersal would be detrimental in all but the largest herds or those which are receiving outside immigrants. The primary effect would be to reduce population size and especially to reduce the size of the male segment of the population.

EFFORTS TO PREVENT INBREEDING

There are at least 3 commonly considered techniques for reducing or preventing inbreeding in transplanted bighorn sheep. The first is to increase the size of the original transplant. There is no doubt that this would reduce the rate of inbreeding. The original size of the transplant, however, is not as important as the size at which the population is maintained over time (Senner 1980). With the cost and difficulty of trapping and transplanting large numbers of animals, follow-up management is more promising than increasing numbers of animals.

A second suggestion is to increase the proportion of males in the transplant. This is based on the fact that the numbers of the less numerous sex have a greater influence on the rate of inbreeding (see Appendix A). Since the maintenance size of the population is more important than initial transplant size, rapid population increase and maintenance of large population size are desirable. Having a large number of lambs, yearlings, and pregnant ewes would be a sounder approach than increasing the number of males.

A third technique is to transplant additional animals into the population after it has established itself. In bighorns, the effort would be most productive if males were transplanted. If the males come from a different population than the original transplant stock, more genetic variability would be added. If the additional animals come from a different population, an attempt should be made to use animals from similar habitat. Even if the males came from the same herd as the original animals, it would aid in decreasing the chances of inbreeding. From a practical standpoint, this technique is becoming more viable, at least in Colorado. All available unoccupied transplant sites are expected to be utilized within the next 5 to 10 years (W. B. Rutherford, pers. commun.). If animals are still available for transplants in the future, moving males between populations could take the place of natural dispersal. These relocations might best be accomplished by transplanting small groups of ewes and male yearlings. These yearlings might be more likely to remain in the area with the ewes than yearlings that were removed from familiar social groups. Ewes from a different stock would also contribute to genetic diversity, but a breeding male would more quickly add his genome to the population, and would likely produce more offspring than a ewe.

There are several objections to the third technique. One is the possibility of introducing disease into an established herd. Of particular concern would be viral and bacterial diseases. While this possibility does exist, the benefits of potential genetic variability probably outweigh the possible occurrence of disease. A second objection is that the imposition of males on a herd could upset the established dominance hierarchy in ram groups. This problem could be avoided by transplanting only young males. A third (and probably most valid) objection is that some herds are now genetically distinct and should be maintained in such condition. Risenhoover (1981), for example, makes a case for the existence of specialization in low-elevation herds. There is no queston that distinct herds do exist today. The question is how much of the differences are naturally occurring, and how much is due to the distruptive influence of man. There is obviously a middle ground between indiscriminate mixing of animals from differing habitats and maintaining each bighorn herd as a genetically separate entity. Approximation of natural emigration and immigration can and should be a realistic management goal. Intelligent management of bighorn sheep requires that we find and exploit that middle ground.

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APPENDIX A

CALCULATION OF COEFFICIENT OF INBREEDING

The coefficient of inbreeding for the Dinosaur National Monument bighorn sheep herd was calculated by use of 2 equations derived from Falconer (1960). These equations are:

(1) $$\Delta F = \frac{1}{8\,M} + \frac{1}{8\,F}$$, and

(2) $$F_t = \frac{1}{8\,M} + \frac{1}{8\,F} + (1 - \frac{1}{8\,M} + \frac{1}{8\,F})\,F_{t-1}$$

where F is the change in the coefficient of inbreeding per generation, M is the number of males breeding, F is the number of females breeding, F_t is the coefficient of inbreeding of generation t, and F_{t-1} is the coefficient of inbreeding of the generation preceeding generation t.

Assumptions were made concerning the numbers of breeding animals at various points since the introduction in 1952 (Table 2). The derivation of these numbers can be found in Skiba (1981). These numbers were used in equations 1 and 2 to determine the current coefficient in inbreeding in the Dinosaur National Monument bighorn herd.

Table 2. Assumed numbers of breeding individuals in the Dinosaur National Monument bighorn herd, 1952-1982.

Time period	Number breeding males	Number breeding females
1952-1957	4	18
1958-1962	25	49
1963-1967	25	49
1968-1972	10	22
1973-1977	10	22
1978-1982	5	15

The generation length for bighorn in Dinosaur National Monument was fixed at 5 years based on the age of the oldest rams observed (8 years) and the assumption that males began breeding at 3 years of age. The original transplant was regarded as noninbred, so equation (1) was used for the period of 1952-1957.

$$F = \frac{1}{8(4)} + \frac{1}{8(18)} = .0382/\text{generation, or}$$

.0076/year, or .046 in 6 years.

Subsequent calculations used equation (2). For the period of 1958-1962,

$$F_t = \frac{1}{200} + \frac{1}{392} + (1 - \frac{1}{200} + \frac{1}{392})\ .046 = .0532$$

Continuing the calculations for the remaining time periods, the coefficient of inbreeding at the end of the period of 1963-1967 is .0604; at the end of 1968-1972, .1595; at the end of 1973-1977, .1872; and at the end of 1978-1982, .2137, or 21% inbreeding.

CONFERENCE DISCUSSION

Q. I read a review of supplemental transplants in Colorado by Ruetherford and he concluded that they had been very unsuccessful. I can't remember exactly how many examples he had, at least 5 or 6, and the typical result of supplementing a herd that wasn't doing well was that you got a short-term increase in population and then a decline to the same level as before the supplemental transplant. I think we need to look at what data are available, where some of these things that you suggested have been tried. At least in some cases, it suggests that inbreeding may have not been the problem.

Ans. I think that is one thing we have to keep in mind. In those cases it's probably just as likely that sheep were transplanted into poor habitat in the first place. We can't expect that inbreeding is always the only problem.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:54-67

GROUP SIZE AND MOVEMENTS OF A DISPERSED, LOW DENSITY GOAT POPULATION WITH COMMENTS ON INBREEDING AND HUMAN IMPACT

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ABSTRACT

The population of mountain goats (Oreamnos americanus) on the Cleveland Peninsula in south coastal Alaska consists of some 50 to 70 animals living in groups with a mean size of 6.4 goats. Sub-populations occupy relatively small patches of habitat consisting of slides, rock outcrops or forested areas exceeding 40 degrees mean slope on discrete ridge complexes separated by forested valleys ranging from 0.8 to 2.4 km wide.

Radio-telemetry studies revealed that females were sedentary and exploited small home ranges. Conversely, most males made extensive movements associated with the rut, crossed low elevation valleys, and interacted with several groups.

The small size and patchy distribution of groups creates high potential for inbreeding or periodic local extinction. Exchange of genetic material between groups and optimum productivity occur only because of the inter-ridge movements of males during the rut. Despite the atypical nature of the goat habitat in this area, no unnatural barriers to such movement currently exist.

Within the next 5 years, timber harvest activity will begin on the Cleveland Peninsula. Due to the distribution of commercial timber, virtually every valley eventually will be roaded and/or logged. Habitat alteration, human activity and illegal hunting are expected to reduce inter-ridge movement by males and increase mortality. This could lead to reproductive isolation and instability of groups. The combined effects of genetic isolation and human harassment/mortality may lead to extirpation of many, if not all, sub-populations in the area.

INTRODUCTION

With the settlement of native land claims in 1971[1] and the national interest lands issue in 1980[2], many legal obstacles delaying resource

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[1] Alaska Native Claims Settlement Act of 1971. United States Congress.
[2] Alaska National Interest Lands Conservation Act of 1980. United States Congress.

development in Alaska have been removed. In the southeast Panhandle, these acts have resulted in accelerated mineral and timber extraction on lands not designated as wilderness. Accordingly, wildlife biologists are under increasing pressure to gather data necessary to minimize and mitigate habitat losses resulting from human activities.

In anticipation of impending logging activity on the lower Cleveland Peninsula, the Alaska Department of Fish and Game, the U.S.D.A. Forest Service and the University of Washington have undertaken a 3-year cooperative study of mountain goat (Oreamnos americanus) ecology and habitat use in this area. The primary objectives of this work are to determine distribution and abundance of goats, identify their movement patterns and critical habitats and to evaluate their food habits. The information gathered is to be used in timber sale and road layout planning to minimize impact of timber harvest activities on goats.

Fox and Raedeke (1982) have analyzed the distribution of vegetation and terrain types on a portion of the area and using telemetry data reported by Smith (1982) have made preliminary estimates of important goat habitat. This work revealed that distance to cliffs (i.e. broken terrain with slopes greater than 50°) was the most important factor in determining goat use of the area. Fox (1981) and Schoen and Kirchoff (1982) identified the same relationship in the Juneau vicinity and determined that goats make little use of forested areas over 500 m from cliffs.

The distribution of goats on the lower Cleveland Peninsula is closely tied to specific, isolated patches of escape terrain within the forest. This has significant consequences with respect to breeding in this population. The purpose of this report is to evaluate distribution and movements of goats in this area with reference to reproductive biology.

P. Harrington (USFS) and R. Wood (ADF&G) were instrumental in organizing agency funding of this study and collected some of the initial data. H. Hase, B. Marr and M. Tehan assisted in the 1980 field surveys and J. Schoen, S. Brainerd and L. Smith assisted with the capture of goats.

STUDY AREA

The lower Cleveland Peninsula (Figure 1) is located approximately 40 km northwest of Ketchikan, Alaska within the Tongass National Forest. The climate is influenced by maritime weather which produces relatively cool summers and mild winters for this latitude, as well as an average of 380 cm of precipitation per year. Although warm temperatures occasionally eliminate snow cover below 100 m elevation during winter, snowpack above 600 m often exceeds 2 m from December through March.

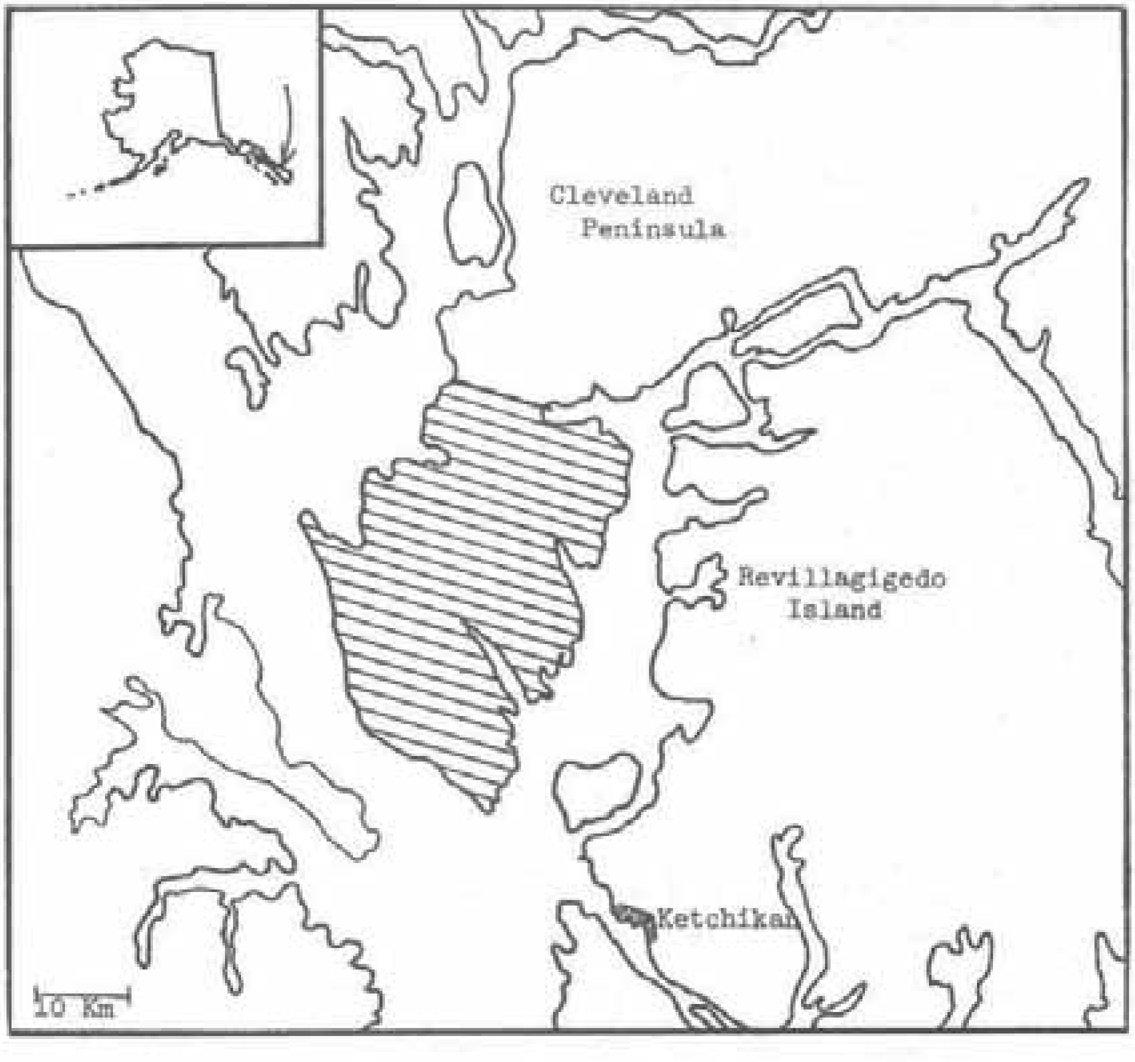

Figure 1. Location of the lower Cleveland Peninsula study area (shaded portion) in southeastern Alaska.

The topography is characterized by rolling ridges with scattered steep slopes and elevations ranging to 960 m. The predominant vegetation is western hemlock - Sitka spruce (*Tsuga heterophylla* - *Picea sitchensis*) forest (Harris and Farr 1974), which completely covers most ridges. Breaks in the forest cover are provided by rock outcrops, slide zones, poorly drained muskegs and limited alpine meadows near some ridge tops. Fox and Raedeke (1982) provide a quantitative analysis of vegetation types.

METHODS

Distribution, size and composition of groups were determined by on-ground observations and aerial surveys during summer 1980 and through observations incidental to telemetry flights from 1980 to 1982. Data presented represent maximum number of goats observed at one time on each ridge complex over the course of the study, exclusive of known mortality, emigration or duplications of radio collared males. Local residents were also interviewed regarding historic goat numbers and distribution.

Goats were captured using standard helicopter darting techniques (Schoen and Kirchoff 1982) with "Cap-Chur" (Palmer Chem. Co., Douglasville, Ga.) equipment and M99, etorphine, (D-M Pharmaceuticals, Rockville, Md.) between 9 and 24 August 1980 and 28 July and 13 September 1981. Captured animals were sexed, aged, measured and fitted with radio-transmitter collars (Telonics, Mesa, Az) in the 150.000 - 151.000 MHZ. range.

Telemetry flights were made in a PA-18-150 Super-cub equipped with dual, twin element yagi antennae. Regular tracking began in November 1980 and is continuing as of this writing. Flights were made once weekly or as often as weather permitted. Relocations were recorded using an x-y coordinate grid system with grid interval equal to 0.16 km (0.1 mile).

The rutting season in goats is generally believed to occur between late October and early December, with a peak in late November (Brandborg 1955, Geist 1964 Chadwick 1973). For purposes of this report, movements made between 20 October and 15 December were considered to be associated with the rut.

RESULTS

GROUP SIZE AND DISTRIBUTION

The lower Cleveland Peninsula supports 8 groups of goats, having a mean size of 6.4 (Table 1). Figure 2 illustrates their midsummer distribution.

Table 1. Minimum group sizes and compositions for mountain goats on the lower Cleveland Peninsula, summer 1980 and 1981.

Ridge Complex	Adult Male	Adult Female	Adult Unknown	Kids	Total	Year
Port Stewart Ridge	1	2	1	1	5	1981
Mt. Burnett/South Ridge	3	1	3	1	8	1980
Helm Bay North Ridge	2	-	-	-	2	1981
Bear Lake West Ridge	4	6	2	5	17	1980
Bugge Ridge	3	-	3	-	6	1981
Niblack Peak	1	-	4	-	5	1981
Bald Ridge	-	3	1	2	6	1981
Caamano Ridge	2	-	-	-	2	1981
Total	16	12	14	9	51	
$\bar{x}$	2.00	1.50	1.75	1.13	6.38	

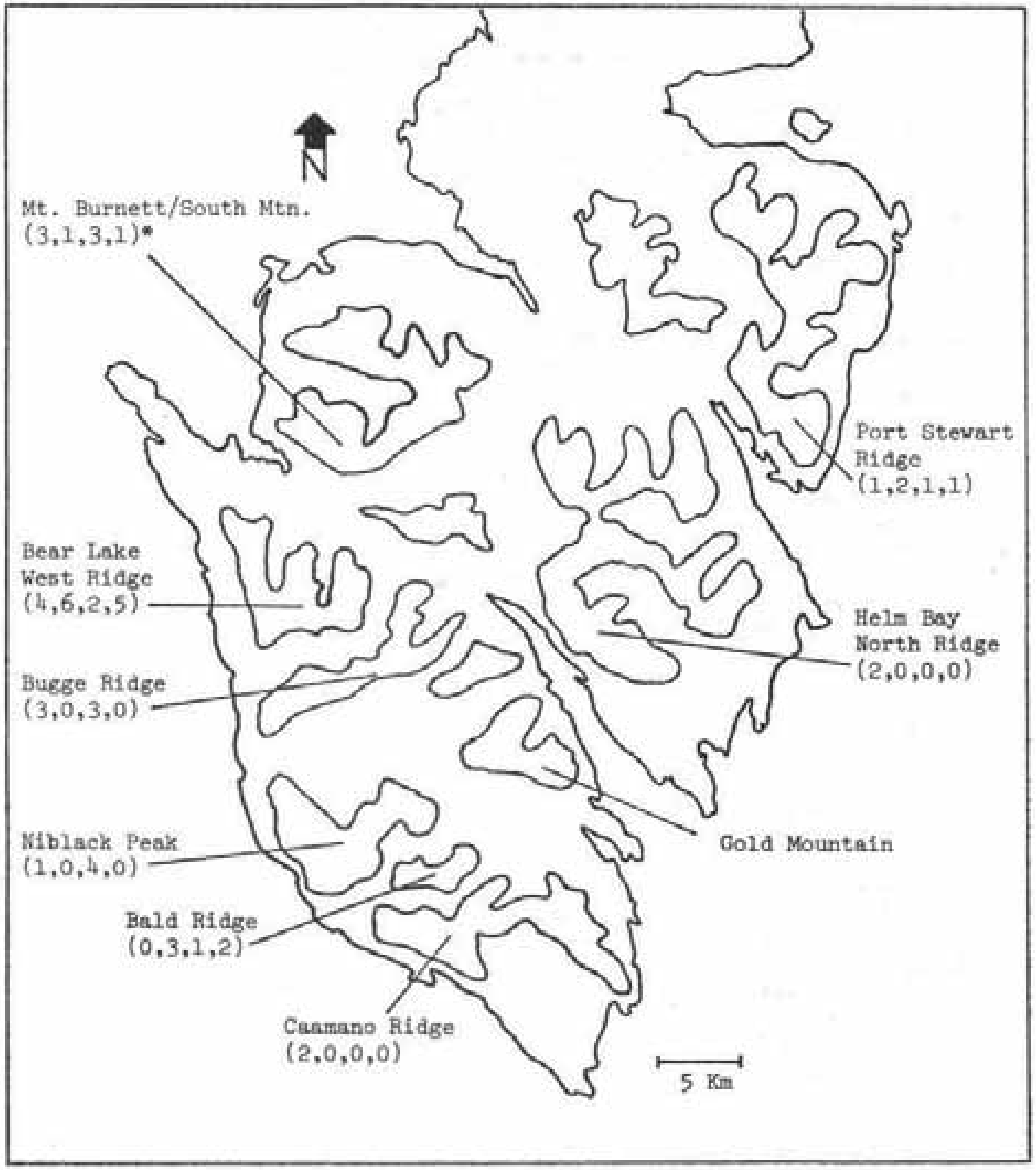

Figure 2. Midsummer distribution, minimum size and composition of mountain goat subpopulations on the lower Cleveland Peninsula. Ridge complexes differentiated by the 330 m contour. *(Males, females, Sex/Age unknown, Kids).

One additional ridge, Gold Mountain, was said to have supported goats in the past, but since the mid 1950's the only sighting reported to us was of a lone goat in July 1981 (H. Ludwigsen, pers. comm.).

Kids comprised 19.4 percent of the population in the 1980 sample (n=31) and 15.0 percent in 1981 (n=20). These figures are slightly lower than those determined for other populations in the Ketchikan vicinity which averaged 25.8 percent kids in 1980 and 24.9 percent in 1981 (ADF&G unpubl. data).

INDIVIDUAL MOVEMENTS

Eleven goats (7 females, 4 males) were captured and radio collared in 1980 and 1981. During the breeding season in 1980, the movements of 6 female and 3 males were documented. In 1981, 4 females and 3 males were followed during the rut.

Convex annual home range polygons of the radio collared female goats are illustrated in Figure 3. With the exception of the emigration of #9, no female left the ridge complex on which she was marked. Conversely, 3 of the 4 males were found to make repeated movements across low elevation timbered valleys during the November-December rut (Figure 4.) At other times, males used small seasonal ranges on single ridges (Smith 1982). The only male which did not move between ridges during the rut may have been suffering from physical disability. He died at age 10 apparently of malnutrition the following February in spite of the fact that the winter of 1980-81 was extremely mild.

DISCUSSION

The size and distribution of these goat sub-populations have particular consequences for their stability and breeding biology. Although estimated minimum group sizes may be conservative, it is evident that some of these sub-populations are at the lower end of the range of viable group sizes. Loss of only 2 members could represent 25-100 percent mortality in all but the Bear Lake Ridge group. Furthermore, some groups may lack sufficient adults of both sexes to be reproductively self sufficient at this time. Inter-ridge movements by males during the rut are important in optimizing productivity in existing groups. Without such movement, females may pass the rut without being bred as noted for isolated females in Idaho (Brandborg 1955, p.92).

Although dispersal of females could eventually result in establishment of viable sub-populations on ridge complexes which are currently vacant or occupied solely by males, female goats are generally traditional in range use and do not often explore new areas (Brandborg 1955, Chadwick 1973, Smith 1976, Kuck 177, Rideout 1977, Schoen and Kirchoff 1982). The 1 subadult female which did disperse during this study, moved 75 km to the higher ridges on the upper Cleveland Peninsula rather than to another

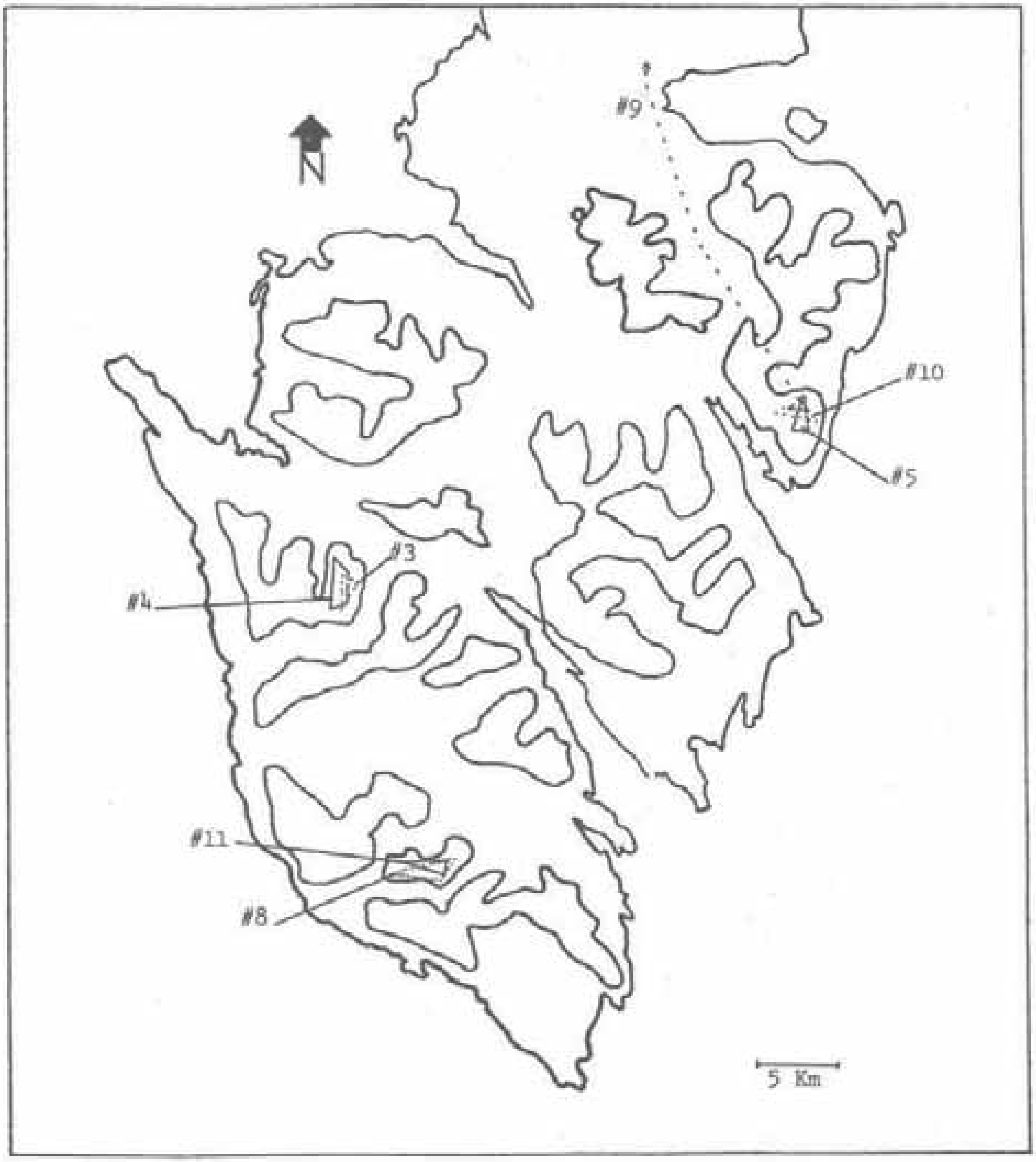

Figure 3. Home range polygons of radio-collared female mountain goats on the lower Cleveland Peninsula, August, 1980 - February 1982.

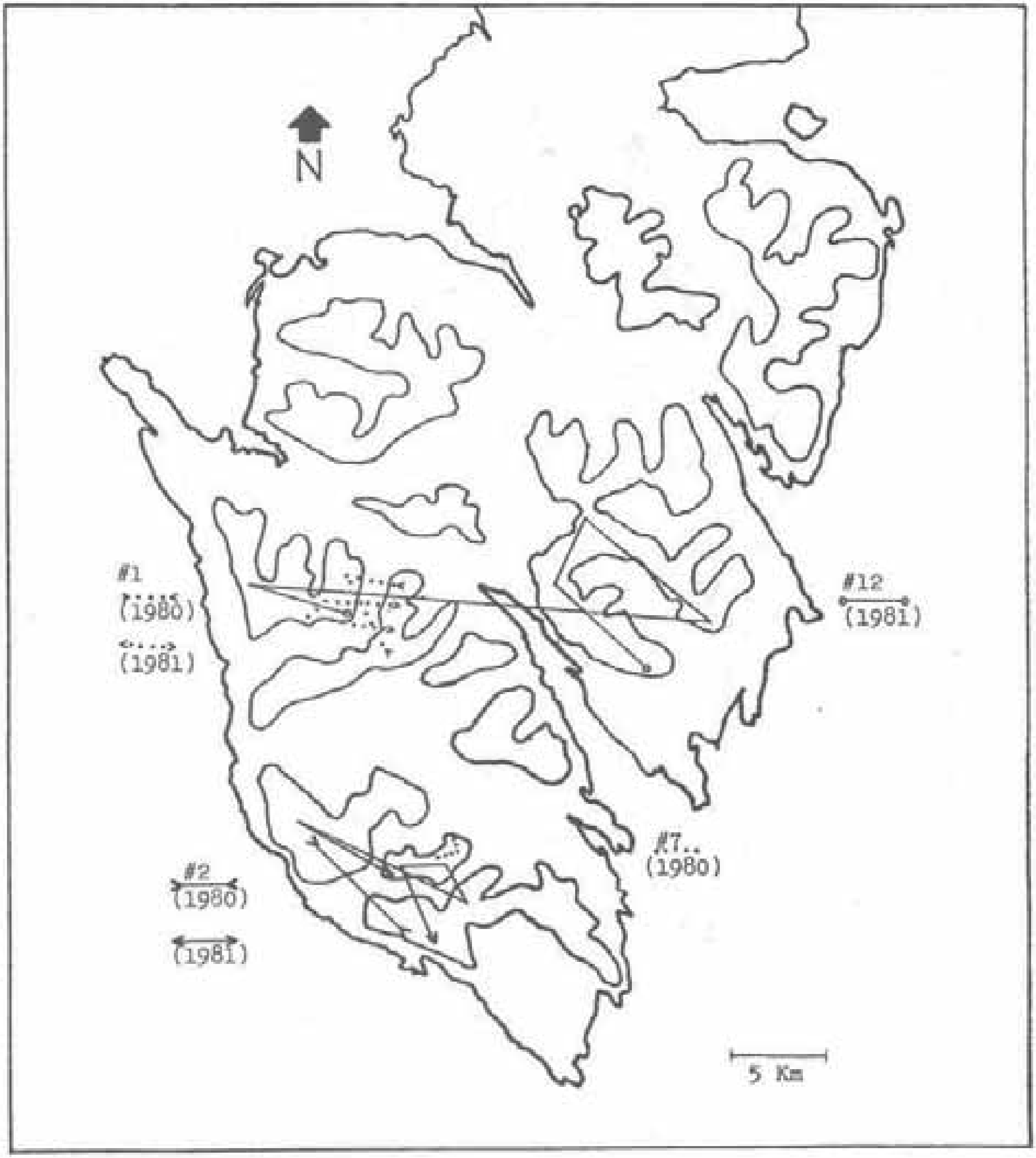

Figure 4. Movements of radio-collared male goats on the lower Cleveland Peninsula, October 20 - December 15, 1980 and 1981.

patch of habitat on the lower peninsula. The lack of observations of goats on Gold Mountain for over 20 years may indicate that once vacated, ridges on the lower Cleveland Peninsula will be recolonized very slowly.

Several authors have commented on the tendency of male goats to move between ridges occupied by females during the rut (Geist 1964; Chadwick 1973, p. 54; Smith 1976, p. 167). Geist (1971, p.90) and Rideout (1977) have suggested there are outbreeding benefits of this behavior to sheep and goat populations which frequently disperse into scattered groups of closely related females with which males associated primarily during the rut. Goats on the lower Cleveland Peninsula generally follow this pattern. Nevertheless, inbreeding cannot be discounted in this population.

Assume for example, that the reproductive portion of this population (i.e. goats over 2 years of age) consists of 12 males and 20 females which freely, and randomly interbreed. Such a population would have an effective population size, "N_e" of 30, (Wilson 1976, p. 77). Allowing for a limited amount of immigration to the population from surrounding areas, such a population can be estimated to have an average coefficient of genetic relationship, "r", of approximately 0.35 (Brown 1974, p.70). From this "r", it is possible to calculate the inbreeding coefficient, "F:, which equals 0.26. Due to the sedentary nature of females, these goats obviously violate the assumption of free genetic exchange, so this estimated "F" value is conservative.

Theoretical arguments (Crow and Kimura 1970, Wilson 1975) supported by empirical data (Preobrazhenskii 1971, cited by Geist 1971; Ralls et al. 1980) indicate that inbreeding in ungulates reduces juvenile survival and reproductive performance of adult females. Ralls et al. (1979) demonstrated that "F" values as low as 0.25 resulted in significantly reduced reproductive success in 15 of 16 ungulate species studied. Thus inbreeding may play a role in the below-average percentage of kids on the lower Cleveland Peninsula compared to larger nearby populations. Deleterious effects of limited genetic variability may compound small group size on the lower Cleveland Peninsula. The inter-ridge movements by males serve to insure genetic exchange between groups, and any decline in "effective population size" as a consequence of increased mortality or reduced movement of males beteween ridge complexes will intensify potential complications of inbreeding and decrease viability of sub-populations.

To date human impact on this population has been minimal. Although the area is open to hunting from 1 August to 31 December, harvest has averaged less than 1 goat per year since 1975 (ADF&G unpubl. data). Habitat alteration in the past was confined to small scale placer mining and logging of a few select spruce stands along the shoreline. Future human impacts may be substantial.

Current plans for logging on the Cleveland Peninsula call for the annual construction of 25 km of road and harvest of 15 million board feet of timber per year over the period 1985-2015, with slightly less activity over the remaining 70 years of the rotation. Due to the distribution of commercial timber, virtually every valley eventually will be logged and/or roaded to some extent. There will be 100-120 people involved in harvesting this timber.

Chadwick (1973) demonstrated that goats may abandon habitat, at least temporarily, as a result of road building activity. Similar responses by goats on the lower Cleveland Peninsula could have grave results. Female goats forced to abandon one ridge could spend substantial time searching unfavorable forest areas for another patch of suitable habitat. During this time they would be relatvely vulnerable to predation by bears (*Ursus arctos* and *U. americanus*) and wolves (*Canis lupus*).

Furthermore, although no reliable estimates can be made of carrying capacity of individual ridges, observations indicate that many of the preferred browse species (eg. *Vaccinium* spp.) show substantial hedging in some areas (ADF&G unpubl. data). If existing groups are currently limited by available forage resources, goats displaced from one ridge might not be able to survive even if they located another patch of occupied habitat.

Road construction, logging activities and slash in clear cuts may also affect the movements of males during the rut directly by creating barriers or indirectly as a result of human harassment or killing of goats. Although the hunting season will be permanently closed as soon as development begins, illegal hunting can be expected to occur. Given the limited number of animals in this population, even occasional poaching along the road system could substantially alter gene flow between, or viability of, sub-populations.

The goats on the lower Cleveland Peninsula exist at the marginal end of the scale in group size, available habitat and, possibly, genetic variability. Maintenance of sub-populations is tenuous under optimal conditions. Human activity of the magnitude currently planned for the area may have significant effects on mortality and inter-ridge movements by males during the rut and thus eventually result in the elimination of several, if not all, sub-populations.

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CONFERENCE DISCUSSION

Questions regarding this paper were answered by Lyman Nichols, Jr., who read the paper.

Q. I have a question for you Lyman. What do you suppose would be the limiting factor for those goat herds, those small pockets of goats?

Ans. Apparently the limiting factor is lack of suitable habitat. They have occupied just about everything that is suitable, all the little cliffs. They just don't have a large area of habitat.

Q. O.K. then you are identifying cliffy areas as suitable habitat.

Ans. Yes.

Q You don't feel that logging or opening up some of those areas will make the goats more likely to expand?

Ans. That's a good question. We don't really know. There is a study going on near Ketchikan to try determining that. Logging might open it up for movement but it will also open it up to predation, make it easier for wolves to travel, and also easier for poaching to occur.

Q Lyman, we have a similar situation on coastal B.C., similar to what Chris has in Alaska. We also have logging that has advanced probably 15 or 20 years further along than what you people have and we are finding through tracks and signs that goats are getting down into the logging slashes and they are moving across them. Regarding the question that was just broached about the opening up of some of these areas by logging, which may increase in the future, most of the evidence we have on coastal goats is similar to the stuff we have for black-tail deer. That is, the requirement of mature timber as habitat, and once that mature timber is removed, most of the goat populations decline similar to our black-tail deer populations, so without mature timber in those coastal snow situations you really aren't going to have goat populations. But, as I said, we are noticing goats moving across the logging slashes, and if you can modify the logging at all, I think you can preserve some of those forested winter ranges and possibly maintain some of those corridors for, especially the males, to move across.

Q Is it snow or the food supply that is limiting?

Comment: It's both. It's snow depth. We have had incidences of snow depths of 5 to 12 feet on our goat winter ranges, coastal snow that you can't even move through, it's so dense in terms of moisture. So definitely it's snow type and snow depth, but it's also food supply because they basically are living on conifers and arborial lichens that come out of the mature trees. There is virtually nothing available on the ground during those types of winters.

Ans. That's basically what is happening in Chris's area. He mentions heavy snow depth, 6 feet or there-abouts, but frequent lack of snow altogether below 600 feet of elevation so snow probably would not limit goats if they could get across the valleys. In my study area, I have part of my goats wintering in a coastal area, and they are wintering partly within and very dependent on dense conifers for snow shelter. I think if the conifers were gone, those goats would be out of luck.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:68-82

HORN GROWTH AS AN INDEX
TO LEVELS OF INBREEDING IN BIGHORN SHEEP

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ABSTRACT

Horn growth of 477 rams from 17 of Montana's bighorn (Ovis canadensis canadensis) populations was examined. Cumulative horn volume at 3 years of age could not be related to winter range densities for either native ($r = 0.03$) or transplanted ($r = -0.12$) populations. Horn volume was not correlated with population size for transplanted populations ($r = 0.04$), though it was significantly correlated to population size for native herds ($r = 0.75$; $p < 0.01$). Cumulative horn volume was closely correlated to historic minimum population levels for native herds ($r = 0.91$; $p < 0.0005$) and historic population size was correlated to present population size for native herds ($r = 0.81$; $p < 0.005$). Thus, horn volume appears to be related to present population size for native herds because both factors are closely correlated to historic population levels. We suggest that historic population lows resulted in high rates of inbreeding that are currently being reflected in low ram horn volumes.

INTRODUCTION

Horn growth in mountain sheep is influenced by nutritional and genetic factors. Several recent studies have demonstrated the relationship between horn growth and nutrition. Geist (1971) postulated that expanding sheep populations are characterized by more rapid horn growth than sheep in stable or declining herds. Shackleton (1973) compared horn growth characteristcs of two bighorn populations and found that the higher quality population was characterized by rams with more rapid horn growth early in life. Heimer and Smith (1975) demonstrated that horn growth was inversely related to population density for the Dall's sheep (Ovis dalli dalli) in Alaska. Bunnell (1978) found that horn growth of Dall's sheep was related to the quality and quantity of forage which was in turn directly related to the amount of spring precipitation. This paper examines the relative importance of genetics and nutrition to horn growth in 17 bighorn sheep populations in Montana.

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METHODS

Montana Department of Fish, Wildlife and Parks has enforced a mandatory examination of all bighorn sheep harvested since 1974. Examination of ram horns by department personnel includes measurements of the length of each annual increment and the circumference at each annual ring. These data were used to calculate mathematical volume of horn grown each year of a ram's life (Heimer and Smith 1975).

Bunnell (1978) demonstrated that horn growth varied between years in Dall's sheep. To avoid possible biases of this type, a mean horn volume was calcualted for each bighorn herd based on the total number of rams measured from that population since 1974. This should prevent the data from being skewed by any one particular set of weather conditions or by unusual horn growth of any cohort.

Mean cumulative horn volume for the first four growth periods was used as a basis for comparing horn growth among the 17 populations studied. Shacketon (1973) suggested that horn growth for superior quality rams was greater than that of inferior rams for only the first 4 years of growth. He further showed that the age of social maturation is advanced among animals from high quality populations. Thus, superior quality rams become socially active early in life and must budget less energy for horn growth. Inferior quality rams, being relatively less active socially, can have larger energy budgets for horn growth and can grow larger horn segments than superior quality rams during the latter part of their lives. However, Simmons and Stewart (1979) showed that this relationship held only when comparing populations of relatively similar quality. When comparing populations of vastly different quality, horn growth was found to be greater throughout the lives of superior quality rams. In any case, when a large number of populations are compared, only the first 4 years of growth should be used.

RESULTS

Mean cumulative 3-year-old horn volumes for native populations ranged from a low of 115 to a high of 177 in^3 (Table 1). Horn volumes for all transplanted populations were larger than for any native population ranging from 184 to 285 in^3 (Table 2). Since there was such a distinct difference in horn growth between the two types of populations, we treated them separately in further analysis.

Initially, we attempted to explain differences in horn growth, particularly among native populations, by relating them to various physical

Table 1. Mean cumulative 3-year-old horn volumes, population characteristics and minimum historic population levels for native Montana bighorn herds.

Herd Name	Hunting District	Horn Volume[1]	Sample Size	Population Estimate[2]	Winter Density[3]	Historic Population Low	Historical Source
West Bitterroot	250	126	13	90	18	50[4]	Klaver (1978)
Yellowstone-Gallatin	300	150	25	150	28	75	K. Keating (Montana State University, pers. comm.)
Spanish Peaks	301	134	34	175	25	60	Couey (1950)
Hilgards	302	136	12	100	100	20	Buechner (1960)
Absaroka[5]	303	177	16	300	20	150	Buechner (1960)
Sun River	420	174	159	900	13	150	Egan (1975)
Stillwater	500	135	28	50	17	35	Stewart (1975)
West Rosebud	501	115	17	50	4	35	Couey (1950)
Hellroaring	502	122	31	75	5	50[4]	Simmons & Stewart (1977)

[1] Volume in cubic inches.
[2] Based on 1980-81 surveys.
[3] Bighorns per square mile.
[4] These populations may have actually been smaller, but data are lacking.
[5] Includes portions of Yellowstone National Park.

Table 2. Mean cumulative 3-year-old horn volumes, population characteristics and history of transplanted Montana bighorn herds.

Herd Name	Hunting District	Horn Volume[1]	Sample Size	Population Estimate[2]	Winter Density[3]	Year(s) Trans-planted	Transplant Source
Kootenai Falls	100	188	23	150	14	1954, 1955	Wild Horse Island
Thompson Falls	121	212	42	450	38	1959	Wild Horse Island
Berray Mountain	123	184	9	125	22	1969, 1975	Sun River, Wild Horse Island
Flint Range	213	208	26	150	30	1967	Sun River
Rock Creek	216	285	4	150	25	1975	Sun River
East Bitterroot	270	221	9	60	20	1972	Sun River
Highlands	340	192	7	115	7	1967, 1969	Sun River
Wild Horse Island	--	186	22	150[4]	75	1939, 1947	Sun River

[1] Volume in cubic inches.
[2] Based on 1980-81 surveys.
[3] Bighorns per square mile.
[4] Population size from early to mid-1970's when horn volume data were collected.

habitat parameters such as soil fertility, chinook frequency on winter ranges and winter range elevation. These factors could not consistently explain differences in horn growth for Montana bighorns, though Wishart (1969) found them to be important parameters influencing horn growth in Alberta bighorns.

Bighorns from the Hellroaring, West Rosebud, Stillwater, Absaroka, Spanish Peaks and Hilgard populations occur on soils that are derived from the same geologic parent materials. Yet, horn volumes range from 177 in^3 for Absaroka rams to 115 in^3 for West Rosebud rams. Three bighorn populations are found in areas of frequent chinooks: Stillwater, Sun River and Absaroka. Again, horn volumes range from relatvely small for Stillwater rams (135 in^3) to relatively large for Absaroka rams (177 in^3). Rams that winter in alpine areas (Hellroaring and West Rosebud) consistently have small horn volumes, but they do not differ significantly from rams from low elevation winter ranges of the Stillwater, Spanish Peaks and Hilgard herds.

Since Heimer and Smith (1975) found that horn growth was correlated to population density for Alaskan Dall's sheep, we tested for a similar relationship. No significant correlation could be established when bighorn horn volumes and winter range densities for Montana's native populations were compared ($r = 0.03$). It appeared that areas capable of supporting a large bighorn population also supported rams with large horn volumes (Table 1). Population size and horn growth were significantly correlated for native populations ($r = 0.75$; $p < 0.01$) (Figure 1). It is also apparent (Table 1) that horn volume is closely related to historic minimum population levels. The correlation between these two factors is highly significant ($r = 0.91$; $p < 0.0005$) (Figure 2). Since historic minimum population levels are closely correlated with present population levels ($r = 0.81$; $p < 0.005$) (Figure 3), we assume that horn volumes are correlated with present population size only because both factors are highly correlated with minimum population levels.

Transplanted populations are all characterized by large horn volumes. As with the native herds, no significant relationship was found when horn volumes were correlated with winter density ($r = -0.12$). Unlike the native populations, no significant relationship was found between horn volumes and total population size ($r = 0.04$).

DISCUSSION

We suggest that minimum historic population size is the primary factor in determining horn growth rates for native bighorns. Those populations which at one or more times in their history dipped to 50 or 60 animals or less do not appear to be capable of supporting rams with rapid horn growth. Rams from populations that never declined to less than 125-150 animals are generally characterized by rapid horn growth and large horn volumes.

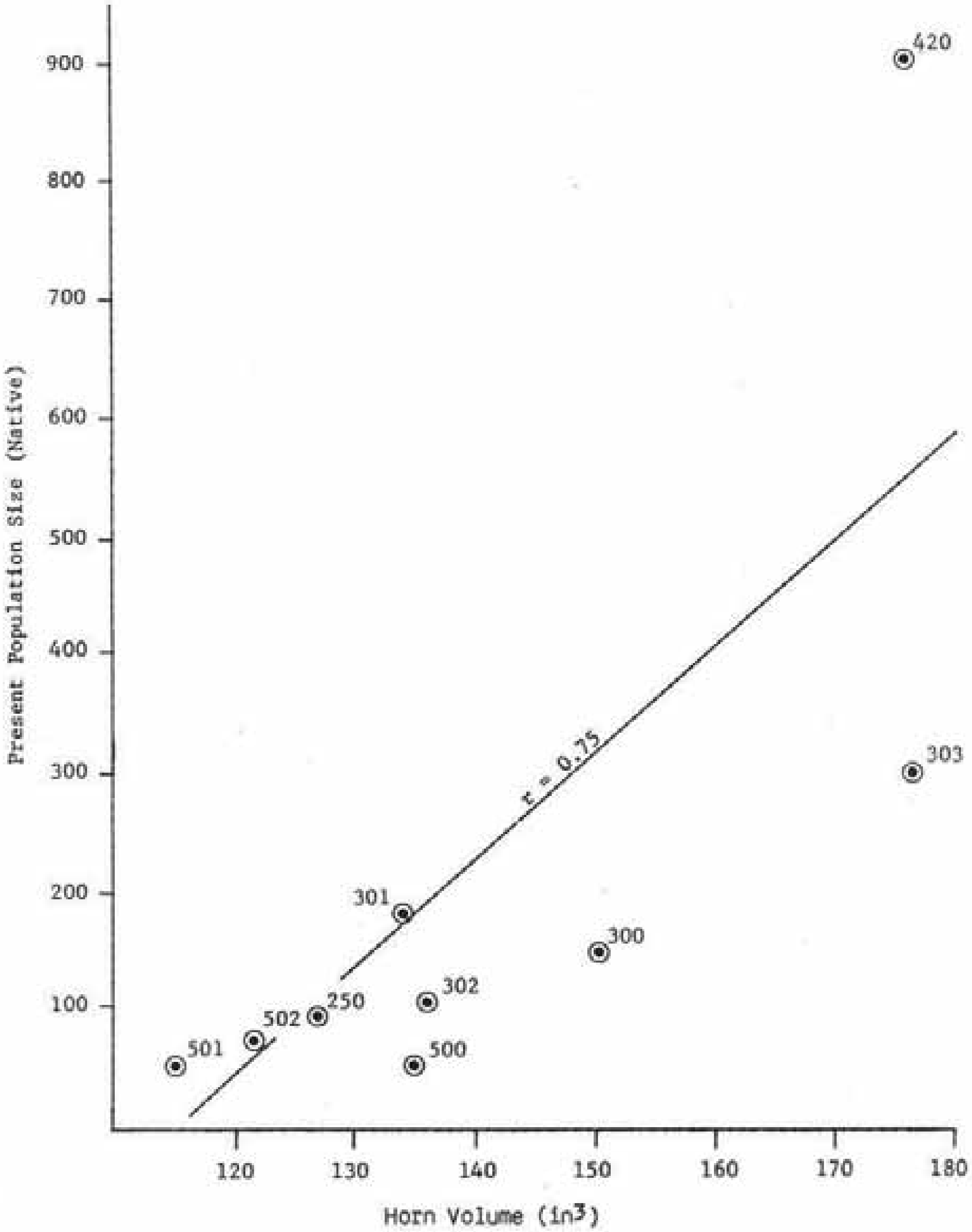

Figure 1. Relationship of horn volume and present population size for Montana's native bighorn populations.

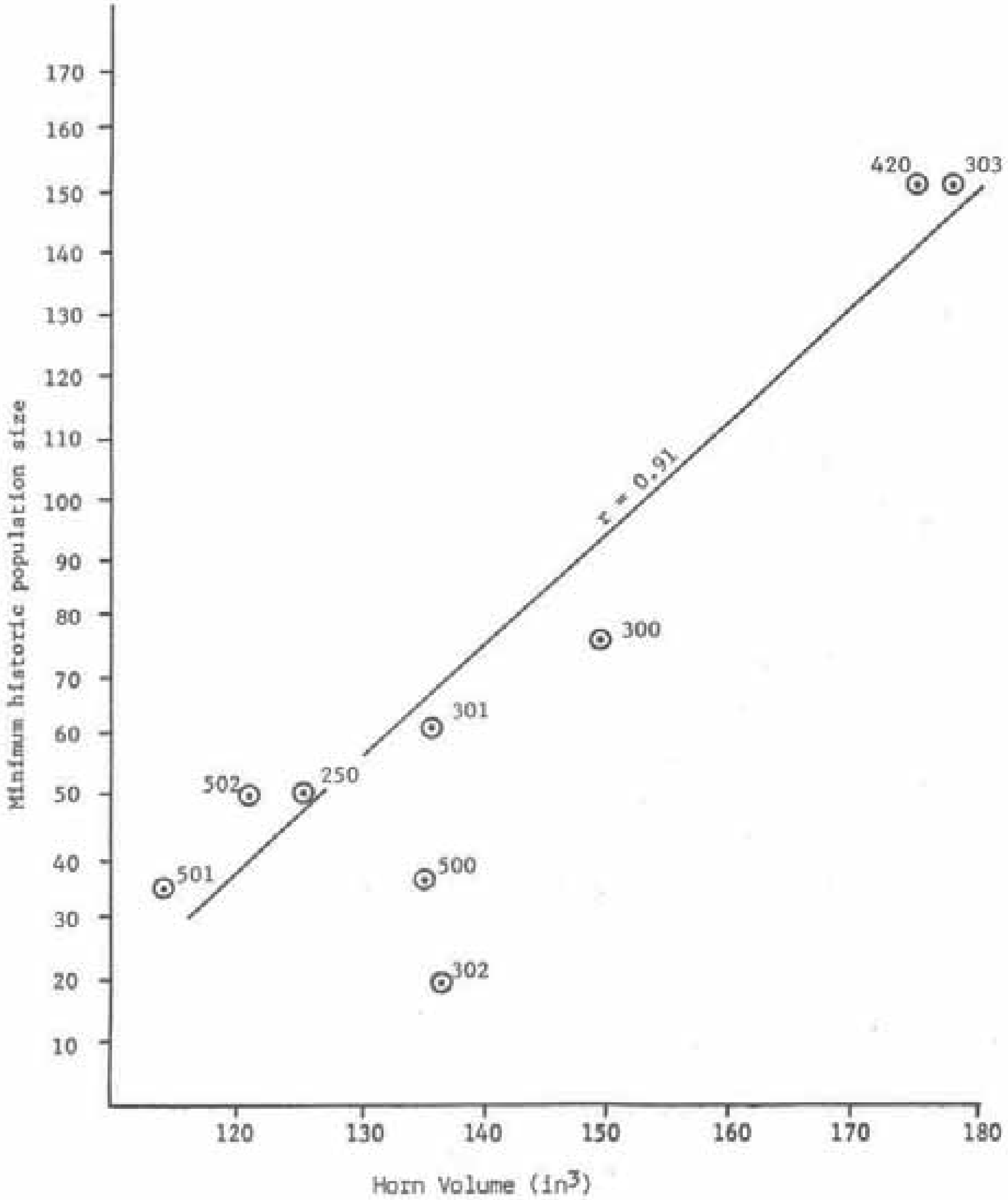

Figure 2. Relationship of horn volume and minimum historic population size for Montana's native bighorn populations.

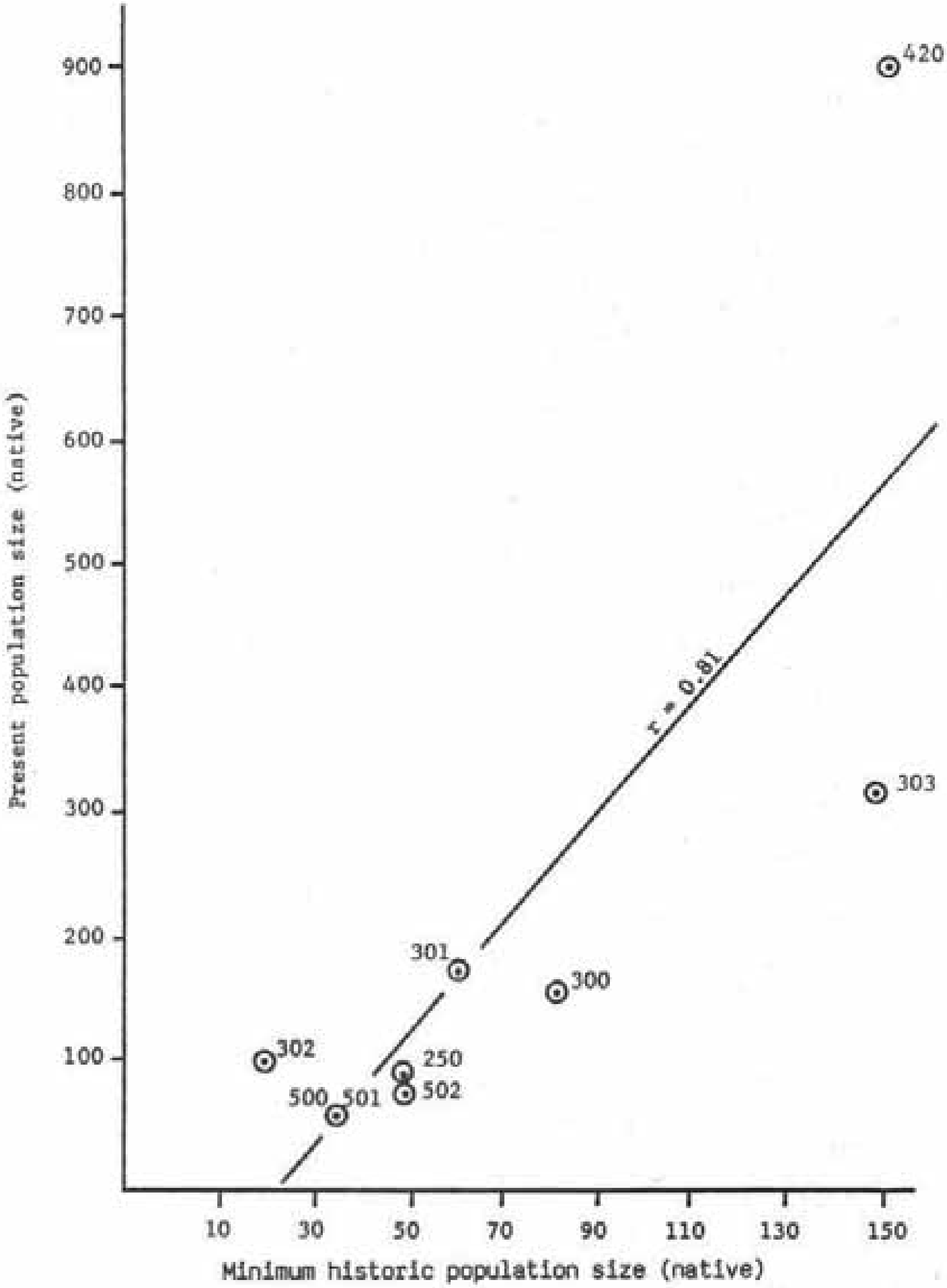

Figure 3. Relationship of minimum historic and present population sizes for Montana's native bighorn populations.

We hypothesize that differences in horn growth among native Montana bighorn populations can primarily be explained by genetics rather than nutritional differences. Most (six of nine) of these populations declined to 60 animals or less at least once during the first half of this century. During such low population periods, these herds were probably subjected to relatively high rates of inbreeding. This in turn may have affected ram horn growth in one of two ways. First, inbreeding may have reduced animal vigor which could result in decreased rates of horn growth for rams. Secondly, large horned rams may be more heterozygous than smaller horned rams. Because inbreeding increases the percentage of homozygosity, it would follow that there would be few large horned rams in an inbred population. Ryman et al. (1981) demonstrated that heterozygosity can be severely reduced in a short time in a population of 50 animals. Intensive harvest of males, such as occurred in most of these bighorn populations, would reduce the effective population size and further reduce genetic variability (Ryman et al. 1981). Population size bottlenecks have been suggested as the cause of low amounts of genetic variation in poulations of elephant seals (*Mirounga angustirostris*) (Bonnell and Selander 1974) and moose (*Alces alces*) (Ryman et al. 1977).

Native populations which have always maintained in excess of approximately 125 bighorns were probably not subject to inbreeding. Thus, a heterozygous population of relatively vigorous bighorns was maintained. These are the populations which are now characterized by rams with large horn volumes.

The hypothesis that horn growth differences among native populations is related more to genetic than to nutritional differences is further supported by the history of bighorns from two areas in Montana, Rock Creek and Thompson Falls. Both of these areas supported native bighorn populations that were characterized by small tightly curled horns (Berwick 1968, Brown 1974). When the native populations died out, they were replaced by bighorns from Sun River. Range conditions remained relatively unchanged. The resulting populations have rams with extremely large horn volumes (Rock Creek - 285 in^3, Thompson Falls - 212 in^3).

Geist (University of Calgary, pers. comm.) suggested that during population crashes, such as he observed in mule deer in Waterton Park, Alberta, only phenotypically inferior (i.e., small antlered) males survive. He further suggested that a similar relationship could be responsible for small horned rams occurring in Montana bighorn populations that declined to 60 or fewer animals at one or more times in their history. We do not feel that this suggestion adequately explains the phenomenon we observed for several reasons: 1) The Sun River sheep herd has probably "crashed" (declined to 150 animals) more often than any other Montana population with die-offs in 1924, 1927 and 1936 (Couey 1950). Yet horn growth for these bighorns remains excellent. 2) The surviving phenotypically inferior males would have the genetic potential that would allow their offspring to grow large horns when environmental conditions improve. Therefore, unless genetic change occurred during the crash, large horned rams would eventually reappear in the population. 3) During a mule deer population crash in Montana, nearly all bucks between the ages of 2 and 5 survived regardless of phenotypic expression (Mackie et al. 1980, R. J. Mackie, Montana State University, pers. comm.). Thus, population crashes do not always result in the loss of phenotypically superior males.

The Sun River sheep herd has ultimately been the source for all successful bighorn transplants in Montana. Thus, all transplanted populations are from what we consider to be genetically healthy stock. Since all transplanted populations are genetically similar, variation in horn growth among these populations must be related to habitat conditions.

It is not, however, surprising that winter range densities were not correlated with horn volumes for transplanted populations. Such a relationship could only be expected if all of these populations had reached equilibrium with their environments. This is generally not the case as most transplanted populations are apparently still increasing.

Among transplanted populations horn volumes are largest for the Rock Creek and the East Bitterroot herds. These are also the two most recently transplanted populations. The two oldest transplanted herds, the Wild Horse Island and Kootenai Falls populations, both have relatively small horn volumes for transplanted sheep. In fact, the mean cumulative horn volume for Wild Horse Island rams is not significantly ($p > 0.05$) different from that of Sun River rams, and the difference in horn volume between Kootenai Falls and Sun River rams is barely significant ($0.025 < p < 0.05$). It appears then that when sheep are put into a new and relatively unexploited habitat, the rate of horn growth is exceptional - far surpassing that of the parent stock. As the population expands, the rate of horn growth declines. Eventually, carrying capacity is reached and horn growth is reduced to a level similar to that of the parent stock with minor differences, due to differences in productivity between the ranges.

Horn volumes are not significantly ($p > 0.05$) different between Berray Mountain and Sun River bighorns. The Berray Mountain population is only 13 years old, yet horn volume is already similar to that of the parent stock. We speculate that because of the small size of the Berray Mountain area, as well as its relatively harsh winter conditions, carrying capacity has already been reached and the rate of horn growth has stabliized.

Apparently, transplants of 20-30 sheep can develop into genetically healthy populations because they come from heterozygous parent stock (i.e., Sun River). These sheep would have a relatively diverse genetic makeup. If conditions are such that the population can expand quickly, this diversity is maintained and a healthy population develops. If, however, the herd stagnates at only 50-60 animals, the population will eventually become more homozygous just as a native population would if it was at such a low population level for any extended period of time.

MANAGEMENT IMPLICATIONS

The genetic health of a bighorn herd is normally a factor that is not considered by a wildlife manager because data are seldom available. Yet, such information may be important to the survival of the herd as the following example illustrates.

Rock Creek, in western Montana, originally supported a native bighorn population, the history of which is well documented (Berwick 1968, Cooperrider 1969, Aderhold 1972). By the early 1900's, only eight bighorns were known to occur in the Rock Creek area. The population increased very slowly until 1965 when the herd was estimated at 175 animals. As we previously noted, rams from this herd were characterized by small tightly curled horns probably similar in volume to horns from other native populations that we have suggested were inbred. Indeed, Berwick (1968) demonstrated that the rate of inbreeding for the Rock Creek herd was relatively high. Between 1966 and 1969 this herd declined to only 10 animals and was for practical purposes extinct by 1974. Numerous reasons for the decline were cited including overgrazing by domestic stock, competition from large numbers of mule deer and encroachment on the winter range by human development. However, as we have previously mentioned, when the Rock Creek area was restocked with Sun River bighorns in 1975, the population thrived though range conditions had not improved substantially (Butts 1980). We suggest that a fundamental difference in ability to survive between the native and transplanted herds was genetically related. The inbred native population was unable to tolerate the stress of deteriorating habitat conditions, while the genetically healthy Sun River stock thrived under similar conditions.

Thus, inbred populations must be managed much more carefully than other bighorn herds. All efforts must be directed at minimizng stress for these populations whether that stress be from competition with native or domestic ungulates, or from human related activites such as mining, subdivisions, or even intensive studies by well-meaning biologists. We also suggest that horn growth can be used as one of the best indicators of when a tranplanted bighorn population reaches equilibrium with its forage base (i.e., reaches carrying capacity) by comparing horn growth of the transplanted herd to that of the parent stock. Of course, this comparison is only valid if range conditions for the two populations are reasonably similar.

We are presently planning to further test the hypothesis presented in this paper by introducing rams from a high quality population into a low quality herd - probably the Stillwater herd. Horn growth will continue to be monitored to determine the effects of this action. A better approach to determining the horn growth potential of various populations would be to keep captive rams on a high quality diet. If our hypothesis is correct, rams from the populations that are thought to be inbred would continue to grow smaller horns than rams from populations thought to be more heterozygous. Unfortunately, budget limitations will undoubtedly prohibit this approach.

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CONFERENCE DISCUSSION

Q. I have a comment. Have you ever seen what happens when a population crashes?

Ans. Not really.

Q. I've had the "good luck." Not with mountain sheep but with deer. I think it is revelant to this discussion; because you are suggesting that it may be inbreeding effects. I suggest that there is an alternate explanation and I will describe it for you and then you can judge for yourself. I studied deer in Waterton Park, Canada. My concern was, at that time, to find some sort of explanation for the great diversity in the phenotypes of bucks we have, some enormous monsters walking around, which of course, at the time I studied them during a population high, were the breeding bucks. Very, very busy, very actively engaged. I have the data on how long they lived subsequent to becoming breeding bucks. But during this study, which lasted 8 years, we had a number of serious winters and, lo and behold, we had a crash. At that time something became very apparent that previously I had not really noticed. I had noticed a large number of old bucks which were very small in body size and antler size. After the crash, there were no big bucks around except for one and he was a special case. After the crash what we had, and breeding, in that population when the population was at the absolute minimum, were the small-antlered, poorly grown individuals. In other words, we're talking here about natural selection. If the population crashes often enough, what you are going to have is, very frequently, the breeding of genotypes that are relatvely slow growing that produce slow growing individuals with relatively small horns. That's a possible explanation for what you have seen as well.

Ans. That would seem to be a possibility. Another thing I neglected to mention, as you talked about earlier, these small populations have been hunted since the middle 50's so not only are they small populations but we are constantly selecting against the larger males in these populatons. However, only small populations now have small horned rams despite some exceedingly heavy huntng pressure in larger populations.

Q. It sounds to me like you probably have two factors working here. These transplant areas are chosen because of the quality of their range. So the transplanted sheep could be showing large horn growth due to nutritional factors, whereas you might have some genetic factors in the native herds.

Ans. I'm sorry if I have confused you. My point was that the source of all transplanted populations, was from what we consider to be a genetically healthy population, i.e. Sun River. Any variation that we see in horn growth among them is forage-related or nutritionally related. It is only in the native populations that I feel that we really have any genetic changes. So we are talking about two different factors in the two types of populations. Horn growth in transplanted populations appears to be primarily nutritionally controlled while in native populations horn growth is probably more genetically controlled.

Q. Is horn growth for all transplanted herds greater than that of the herd they were transplanted from?

Ans. Except for the old transplants: Horn growth for the longest-term transplants is not statistically different from that of the source herd. The two oldest transplants are Wildhorse Island and Kootenai Falls.

Q. Sun River has some of your biggest rams. Aren't they natives?

Ans. Sun River and the northern end of Yellowstone National Park have the largest horn growth of our native herds.

Q. So they have a tremendous potential to get even bigger when they are moved out.

Ans. That's exactly right.

Q. Why, then, does horn growth vary among transplanted populations.

Ans. Capacities may be different in different areas. What I'm suggesting is that you can use horn size on these transplanted populations as an indicator of when you are reaching their carrying capacities. When the transplant first occurs horn growth is tremendous. But as the population grows toward the capacity of the range horn growth declines until eventually it is similar to that of the source herd.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:83-91

ELECTRONIC RELEASE SYSTEM FOR DROP NETS

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ABSTRACT

A release system for drop nets was developed to eliminate the danger and noise associated with blasting caps and prima cord. Components include five, electrically activated cargo releases, a six-piece electrical-cord harness, a 24-volt power supply/control box, and a manual trip mechanism. A remote, radio-controlled trip mechanism is optional. The release system eliminates the use of blasting caps, minimizes-net reset time, and improves the chances for several productive drops per day.

INTRODUCTION

Sufficient radio frequency (rf) energy induced into the shunted or unshunted leads of an electrical blasting cap can cause detonation (Johnston 1978). A telephone repeater and mobile radios, sources of rf energy, are within 440 m (1/4 mi) of the Whiskey Basin, Wyoming bighorn sheep (Ovis canadensis) trap sites during trapping operations. Wind and snow usually accompany trapping operations and can be sources of static electricity that add to the chance of premature cap detonations (Blaster's Handbook 1969). The blasting cap and prima cord release system used from 1974 to 1977 at Whiskey Basin did prematurely detonate on several occasions. This problem and it's potential threat to personnel stimulated the development of a release system for drop nets that did not incorporate blasting caps.

CONSTRUCTION AND DISCUSSION

The electronic release system consists of five electrically activated cargo releases, an "H"-shaped electrical cord harness, a 24-volt power supply-control box, and a manual trip mechanism. A remote, radio-controlled trip mechanism is optional. The 12-volt, 10-amp, vertical-cable cargo releases (Model 2A-15E) are available from Eastern Rotocraft, P.O. Box 110, Doylestown, PA. They can be used as manufactured if purchased with the electrical connector option. However, the connector cord is fragile and it is difficult to connect to the release in cold weather. The manufacturer's connector system can be replaced with 2 conductor 18, S.O. cord with one end wired directly into the release, and the opposite end fitted with a 3-prong, twist-lock plug for easy connection to the harness.

A fixed point of attachment is required for each of the five releases to keep them stationary after each net drop. A portable, rigid superstructure (Figure 1) provides these attachment points. The superstructure is composed of four 3.7 m (12 ft.) steel corner poles and a 6.1 m (20 ft.) steel center pole made of 5.1 cm (2 in.) interior diameter, 0.5 cm (3/16 in.) tubing. Two 1.3 cm (1/2 in.) steel rings are welded near the top of each corner pole (Figure 2) and six steel loops are welded to the top of the center pole (Figure 1) for guy wire, pully, and release attachment. The base of the center pole is screwed into a collared fitting cemented into the ground. The base can be set over a stake driven into the ground if there is need for a portable trap site. The base of each corner pole is set over a stake. The top of the center pole is secured to the top of each corner pole with a 16.8 m (55 ft.), 0.5 cm (3/16 in.) wire rope guy, and each corner pole is secured to the ground with two or three 4.6 m (15 ft.), 0.5 cm (3/16 in.) wire rope guys. One end of each center-pole guy wire is permanently attached to the top of the center pole (Figure 1). The opposite end, that attaches to the corner pole, is fitted with a 1.0 cm (3/8 in.) shank cast, eye-and-eye steel turnbuckle for final length adjustment and a carabiner for quick attachment (Figure 2). Each corner-pole guy wire is fitted with a carabiner at one end for easy attachment to the corner pole and a 1.0 cm (3/8 in.) shank cast, hook-and-eye steel turnbuckle for final length adjustment and quick attachment to a deadman.

The entire superstructure can be erected in two hours by four men. The poles and guy wires can be erected in one hour or less by four men, once the corner stakes, center stakes, and deadmen are driven. Take down time is approximately 30 minutes. The superstructure is capable of holding a 21.3 x 21.3 m (70 x 70 ft.) net suspended in winds up to 64 km (40 mi.) per hour.

A carabiner is used to attach one cargo release to the top of each of the four corner poles (Figure 2). Each release is suspended away from the pole with a nylon strap tied to the center-pole guy wire. The nylon strap prevents the release from smashing against the pole when the net is dropped. A rubber pad is wrapped around the top of the pole to provide additional protection. The fifth cargo release is attached to the top of the center pole by a carabiner with a thick rubber pad wrapped around the pole for cushioning.

Power is supplied to the releases by an "H" shaped, six piece, electrical cord harness (Figure 3). The first piece, 6.1 m (20 ft.) long, is permanently threaded through the center pole from a hole near the bottom of the pole to a hole near the top of the pole. The protruding ends are adapted for connection to the center pole release and the remainder of the harness. The "cross" piece of harness is a 22.9 m (75 ft.) cord adapted at the midpoint for connection to the center pole section of the harness, adapted at one end for conection to two "legs" of the harness, and adapted at the other end for connection to the remaining two "legs" and the control box. The four "legs" are 13.7 m (45 ft.) cords adapted at one end for connection to the "cross" piece and adapted at the opposite end for connection to a release. The harness is made of 2 conductor 14, S.O. cord. Three prong, twist-lock sockets and plugs are used in all connection adaptions for easy assembly and disassembly. Connection adaptions at the midpoint and two ends of the "cross" piece require wire splices. Soft solder and protective wire nuts are used for the wire splices and a junction box encloses each splice.

Two 12-volt batteries connected in series provide the 24-volt power supply. The batteries are enclosed in a control box with the receiver mechanism for the optional remote, radio controlled trip. The control box is designed for both a test and fire mode, and recharging (trickle and full) capability. A wiring schematic is provided in Appendix A. The manual trip consists of a 183 m (600 ft.) 2 conductor 12, S.O. cord, stored on a spool. One end is adapted for connection (2-prong, twist-lock socket) to the power supply box and the other end is fitted with a normally open push button.

The releases are desiged to trip with a short burst of 12 volts, but a 24-volt system is required to overcome the resistance in the harness wire and deliver sufficient voltage to the two releases furthest from the power supply. The 16 to 18 volts received by the releases closest to the power supply is within release tolerance. Sustained current flow, however, damages the coil enclosed in the releases, therefore sufficient safeguards should be built into the mechanism to prevent this from occurring.

The center of the drop net is tied to a steel ring that slides up and down the center pole. The net is normally laid out prior to the erection of the center pole so the pole can be threaded through the center of the net. The center of the net is then tied to the center ring. The pully and rope system, attached to the top of each superstructure pole, is used for hoisting the net for attachment to the center pole and three corner-pole releases. The net is attached to the cargo releases with a carabiner that is tied onto the four corners (Figure 2) and center ring of the net. A hand operated winch is required to hoist the last corner of the net. The tightness of the suspended net eliminates the need for side poles and reduces net flopping caused by wind.

Although initial cost of the release system is high (Table 1), the system is extremely reliable, efficient, and eliminates the danger associated with blasting caps. The prevention of one lost eye or hand is worth the cost. Rapid net reset time (15 minutes or less) and elimination of net release noise also improves the chances for several productive drops per day.

Special thanks is extended to Ed P. Novotny for building the superstructure components, and the U.S. Forest Service and Bureau of Land Management for buying the cargo releases.

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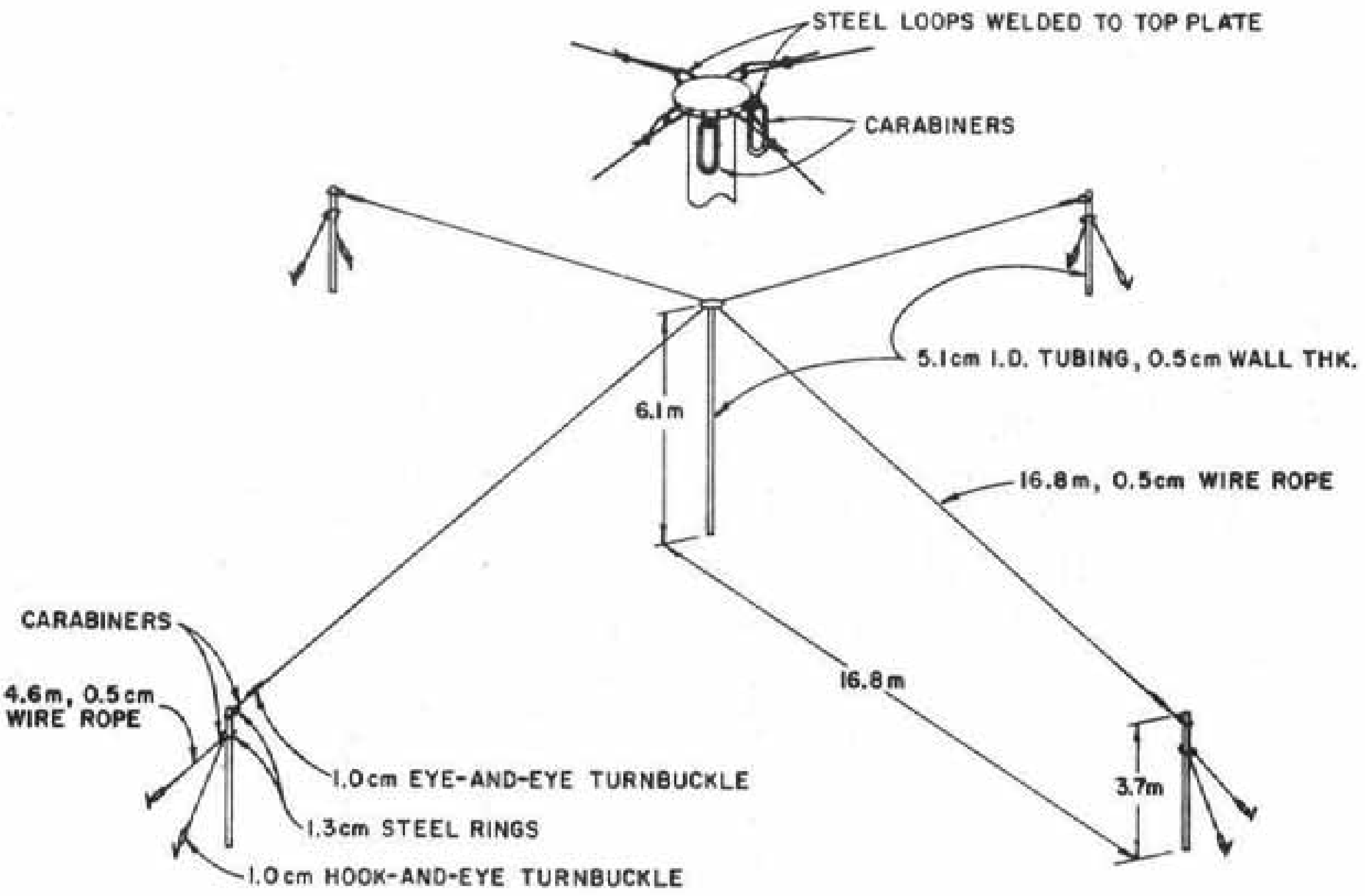


Figure 1. Sheep trap superstructure components, and center-pole attachments for guy wires, pully system (carabiner), and cargo release (carabiner).

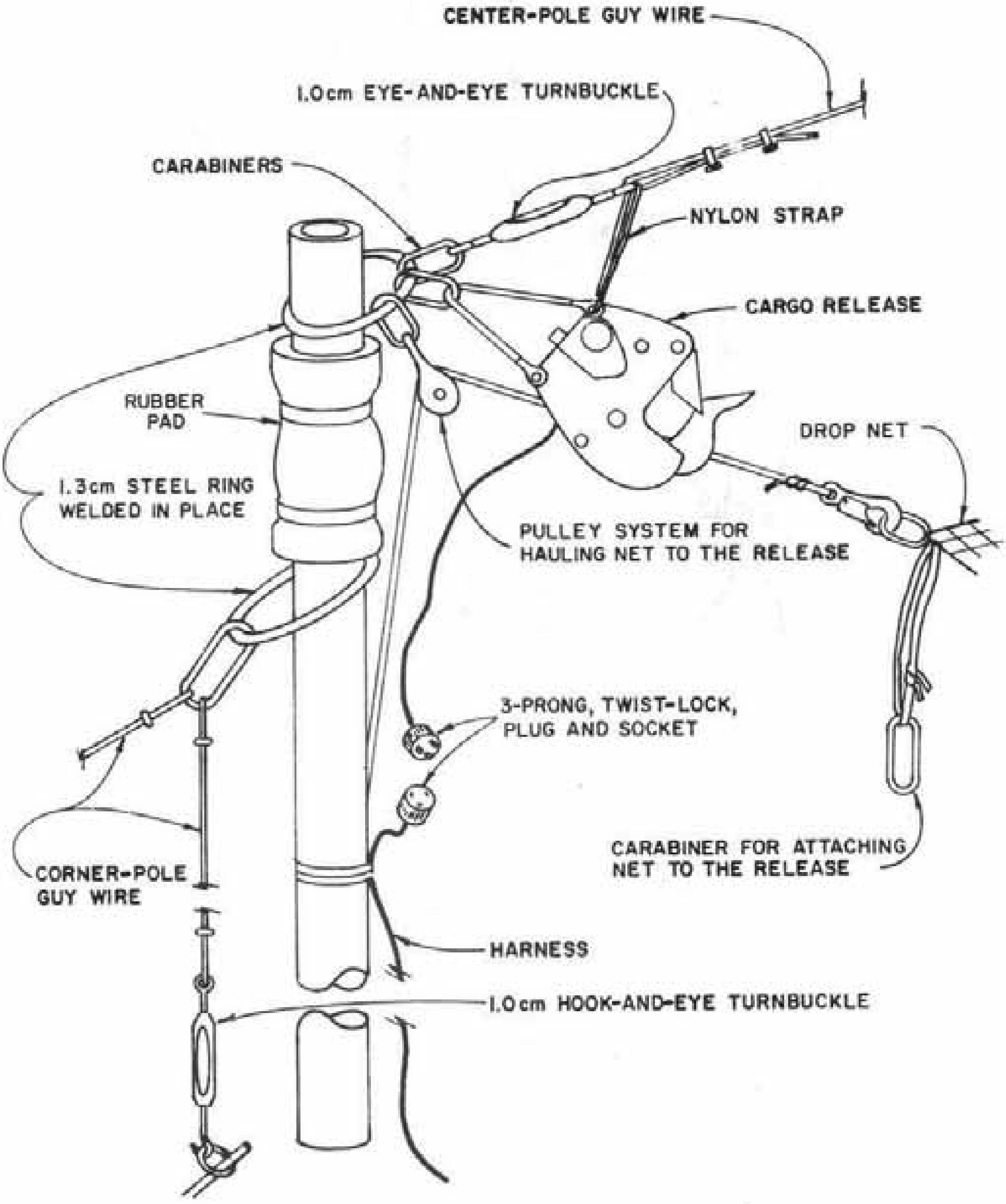


Figure 2. Corner-pole attachments for guy wires, pully system, cargo release, and harness.

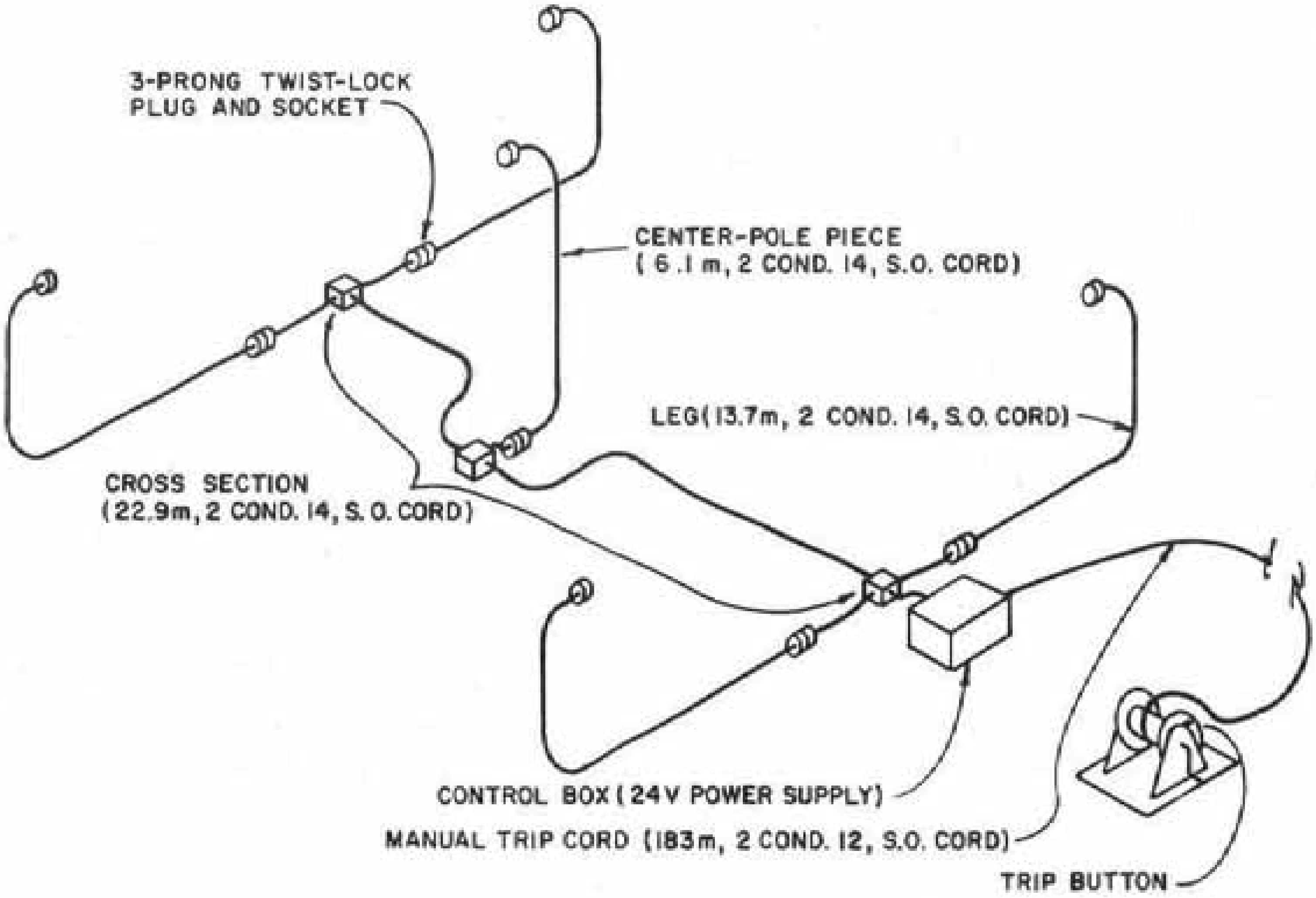
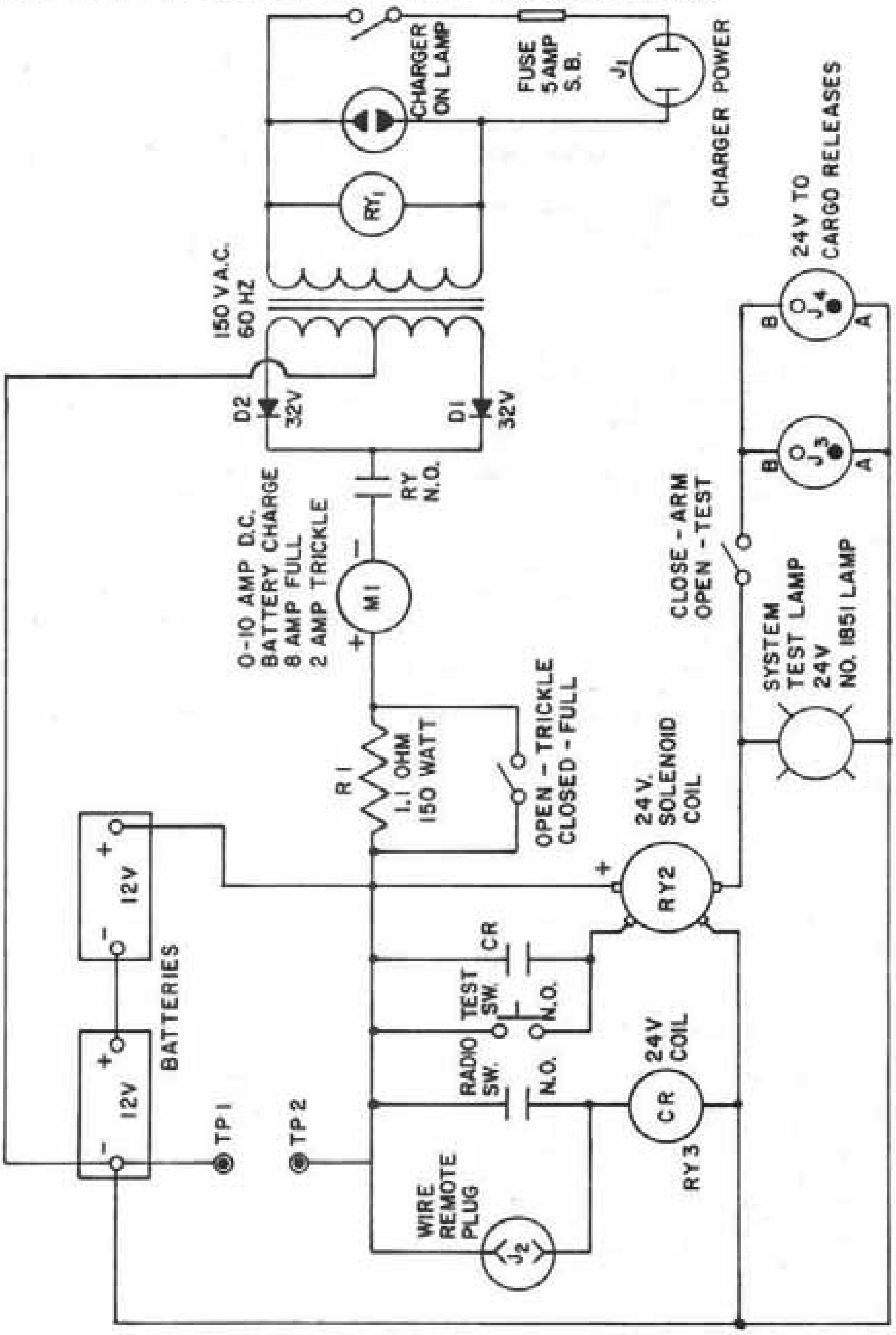


Figure 3. "H-shaped electrical cord harness, power supply, and manual trip mechanism layout.

Table 1. Cost of electronic release system components.

Component	Cost (1981) (U.S. Dollars)
Five cargo releases (model 2A-15E)	$4,530.00 ($906.00 each)
4.6 m (15'), 2 cond. 18, S.O. cord	5.00
84 m (275'), 2 cond. 14, S.O. cord	65.00
183 m (600'), 2 cond. 12, S.O. cord	180.00
Twelve sets, 3-prong, twist-lock plug and socket	100.00
Two 12-volt batteries	100.00
Misc. parts (fuses, resistors, control relays, lumber, and hardware)	200.00
Total	$5,180.00

Appendix A. Wiring schematic for power supply/control box.



Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:92-105

CUTOFF BIGHORN TRANSPLANT: THE FIRST TWO YEARS

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ABSTRACT

A herd of Rocky Mountain bighorn sheep (Ovis canadensis canadensis) was transplanted from Wildhorse Island to the Cutoff area near Paradise, Montana in January, 1979. Six of the 41 sheep were radio-collared, and several others were marked with rope collars or neck bands. Six sheep immigrated to the Cutoff area from a nearby herd, and 5 more rams were transplanted to the area in February, 1981. The population was estimated at 70 during winter 1980-81. The ewe:lamb ratio was 100:42 at the end of winter 1980-81. Reasons for the apparently low productivity are discussed. Daily movements averaged 0.6 km for ewes and 1.0 km for the radioed ram. Ewe daily movements were relatively constant through the year. The ram showed distinct seasonal variations, moving 1.6 km per day during the rut and 0.3 km per day in winter. Home ranges averaged 541 ha for the ewes and 798 ha for the ram. Ewe home ranges were the smallest during lambing (47 ha) and largest during fall (273 ha). The ram's home range was 21 ha in winter and 305 ha in spring. Ewe standard diameters were lowest during lambing (1.8 km), and the ram's standard diameter was lowest in winter (1.7 km). Both sexes ranged farthest during the rut, when the standard diameters were 5.0 for the ram and 3.1 for the ewes. Protostrongylus spp. larvae were present in feces at an average level of 1.7 larvae per gram. The pattern of range recolonization and dispersal is discussed.

INTRODUCTION

In January 1979, 41 bighorn sheep were transplanted from Wildhorse Island in Flathead Lake to an area in northwestern Montana generally known as the Cutoff. My study was initiated to gather information on seasonal home range and habitat use, migration routes, population parameters, and patterns of colonization of the newly-transplanted herd. The information gained from this study may contribute to understanding the complexities of establishing bighorn sheep herds.

The primary objectives of this study were to:

(1) locate and map seasonal ranges and movements;

(2) census the herd; and

(3) assess productivity

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STUDY AREA

The study area was situated along the Clark Fork River approximately 85 km northwest of Missoula, Montana (Figure 1). During the study, the sheep herd inhabited a strip of land approximately 1.6 km wide and 13 km long. The area along the river was predominantly rock outcrops and scree slopes. Several steep, rocky slopes and a few grassy basins were present. Areas above 1,340 m elevation and most of the shaded ravines were steep and rocky and supported open forest cover. Elevations ranged from 805 m along the river to 2,084 m at the top of Patrick's Knob.

Ponderosa pine (Pinus ponderosa) and Douglas fir (Pseudotsuga menziesii) were the major tree species on the study area. Tree canopy cover on most slopes was sparse, but ranged from 10 to 20 percent on higher elevations and in moist ravines. The canopy cover in the lower part of the Patrick Creek Drainage and on some level areas along the Clark Fork River was from 40 to 60 percent. Graminoids comprised less than 50 percent of the forest understory. Shrub density varied from 15 to 60 percent in forested areas. In unforested areas, graminoids accounted for 10 to 25 percent of the ground cover. Shrub cover in these areas ranged from 15 to 25 percent.

METHODS

DEMOGRAPHY

The number of sheep in each sex and age class was estimated from the highest number of sheep seen in each class on a single day during each season. Seasons were defined as: spring, 1 March-30 April; lambing, 1 May-31 May; summer, 1 June-30 September; fall, 1 October-31 December; and winter, 1 January-28 February. Seasonal ewe:lamb ratios were calculated by totaling the number of ewes and lambs seen during each season regardless of duplication.

MOVEMENTS

When the sheep were transplanted to the Cutoff, 6 were radio-collared, 6 marked with individually identifiable rope collars, and 14 were marked with red or blue neckbands. Five transmitters continued to work throughout the study, and I attempted to locate the radio-collared sheep at least

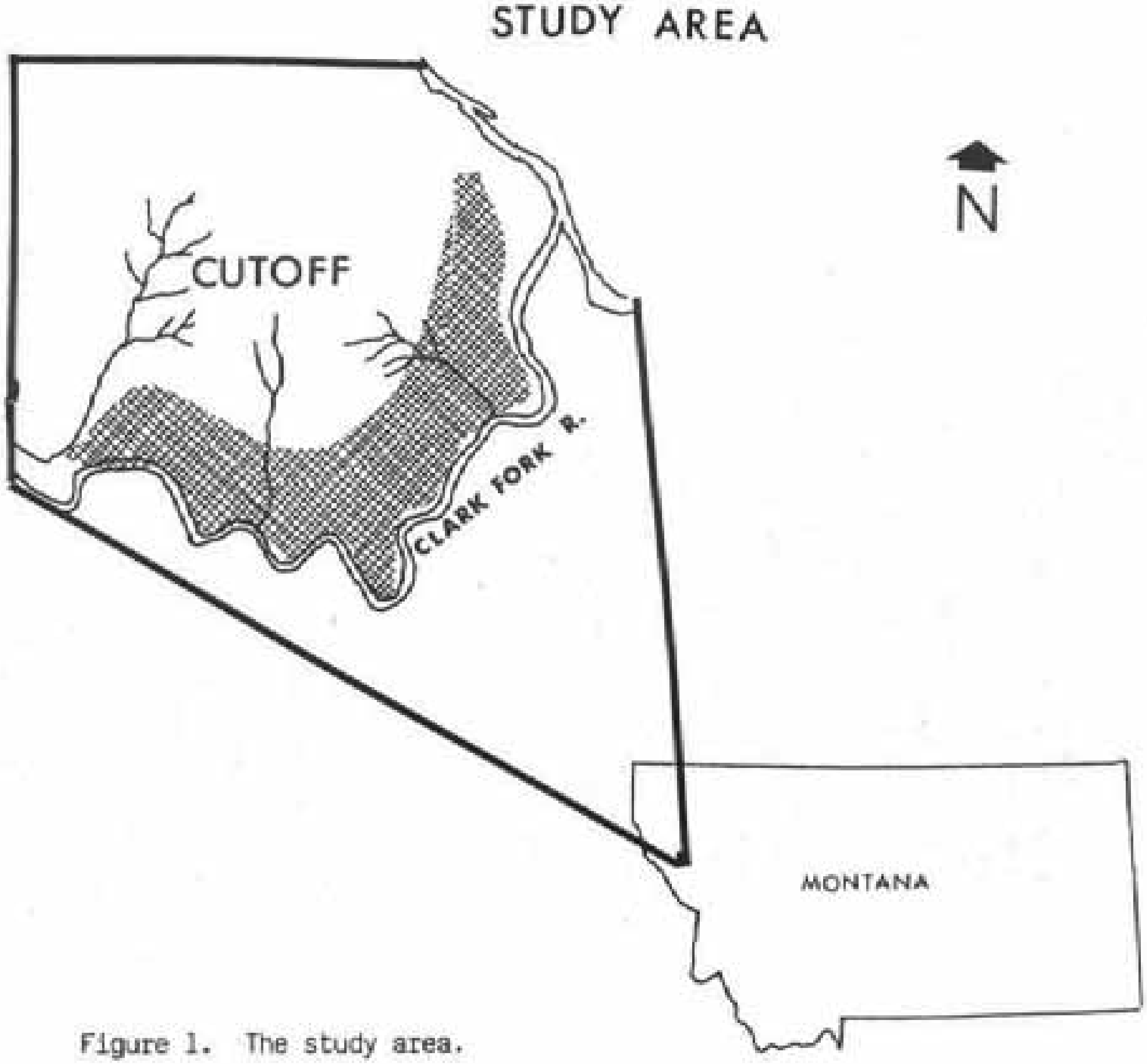

Figure 1. The study area.

twice weekly. Locations of radioed sheep were plotted on a 7.5-minute series topographic map. Seasonal and annual modified minimum home range sizes (Harvey and Barbour 1965) were plotted. The modified minimum method was chosen because the study area was crescent-shaped, and the minimum home range size method (Hayne 1949) would have included large, unused areas. Seasonal and annual centers of activity (Hayne 1949) and standard diameters (Harrison 1958) were calculated for each radio-collared sheep.

PARASITES

Fecal pellets were collected in April, 1980 from pellet groups on the Cutoff area and on Wildhorse Island. These samples were analyzed by the Veterinary Research Laboratory in Bozeman, Montana, for the presence of lungworm (Protostrongylus spp.) larvae.

RESULTS

CENSUS

The herd was estimated to contain 57 sheep during spring 1980, 73 during summer 1980, and 65 during winter 1981. The calculated ewe:lamb ratio was 100:57 during summer and declined to 100:42 by the following winter. Approximately 70 percent of the lambs known to be born in 1980 were alive by the end of the following winter. About 80 percent of the yearlings present in the herd during the summer were known to be alive by the end of the winter.

DAILY AND SEASONAL MOVEMENTS

The 4 radio-collared ewes and 1 ram were observed on consecutive days 142 times. Average daily movements during each season were calculated from those observations. Ewe groups moved an average of 0.6 km per day with relatively little seasonal variation (Table 1). The collared ram averaged 1.0 km per day during the year. Average daily movements were least during winter (0.3 km per day) and most extensive during fall (1.6 km per day).

No distinct seasonal movements or migrations were noted for the ewes. Winter centers of activity averaged 0.6 km distant from summer centers of activity, and winter ranges were contained within their summer ranges.

The ram's winter center of activity was 4.4 km distant from his summer center of activity, and his winter range did not overlap any of his other seasonal ranges. Movement to the winter range was not a direct migration, but more of a "drift" beginning shortly after the end of the breeding season.

HOME RANGE

The radio-collared ewes were each located an average of 90 times during

Table 1. Daily movements of radio-collared sheep.

Season	Average movement (km/day)	Range	Sample size
		Ewes	
Spring	0.6	0 - 1.2	8
Lambing	0.6	0 - 2.4	19
Summer	0.7	0 - 2.2	50
Fall	0.6	0 - 2.0	33
Winter	0.7	0 - 1.6	18
Total 1980-81	0.6	0 - 2.4	128
		Ram	
Spring	1.2	0.4 - 3.2	4
Summer	0.7	0 - 1.0	4
Fall	1.6	0 - 3.6	6
Winter	0.3	0 - 1.2	4
Total 1980-81	1.0	0 - 3.6	18

the study, and the average home range was 541 ha (Table 2). Average seasonal home range sizes for the ewes were smallest during lambing (47 ha) and largest during fall (237 ha). The radioed ram was located 69 times during the study and had a home range of 798 ha. Most of the area of the summer home range of the ram was separate from that of all radioed ewes, but some overlap occurred. The ram was 3 years old at the time of the study and not fully mature and was still occasionally associated with ewe groups. Also, he was the smallest ram of the 4 in his age class on the study area, and he was seen with ewe groups more often than were the other rams. His winter range was separate from those of all radioed ewes, but other ewes were seen wintering in the same area. Because of the nature of the terrain and vegetation on his wintering area, he was sighted infrequently during winter, and he was never actually seen with the ewe group. The ram's seasonal home range was the largest during spring (305 ha) and smallest during winter (21 ha). A comparison of the 1979 and 1980 home ranges of individual sheep indicated no apparent shift of home ranges or major range extensions.

STANDARD DIAMETERS

Standard diameters (Harrison 1958) for the ewes averaged 2.8 km during 1979 and 2.5 km during 1980 (Table 3). The ram's standard diameter was 3.9 km during 1979 and 4.0 km during 1980. Ewes moved the least during the lambing season when the standard diameter averaged 1.8 km. The ram moved the least during winter; the standard diameter then was 1.7 km. Both sexes ranged farthest during the fall breeding season when the standard diameter was 5.0 km for the ram and 3.1 km for the ewes.

PARASITES

Pellet analysis revealed a low level of lungworm (Protostrongylus spp.) infestation in the Cutoff herd. Larvae were present in 11 of the 20 samples collected at an average level of 1.7 larvae per gram of feces (range 0 - 13.4). Pellets from the Wildhorse Island herd averaged 16.1 larvae per gram of feces (range 0 - 70.6). Only 2 of the 34 samples collected contained no larvae. The lungworm level of both herds can be considered low, but the infestation level of the Wildhorse Island herd was significantly higher than that of the Cutoff herd ($t=3.66$, 52 d.f., $p< 0.0005$).

DISCUSSION

CENSUS

The Cutoff herd was estimated at 70 sheep at the end of winter 1981. However, 5 of these were added as a supplemental transplant, and at least 5 immigrated to the Cutoff from a nearby herd. If those 10 sheep are subtracted from the estimate, 60 sheep were present that were either members of, or produced by, the original transplant group. In spring 1980,

Table 2. Seasonal home range sizes (ha) of radio-collared sheep, 1979 and 1980-81.

	Ewe 6		Ewe 7		Ewe 8		Ewe 9		$\bar{X}$ Ewes		Ram	
	Size	N	Size	N	Size	N	Size	N	Size	N	Size	N
1979	88	13	165	13	77	13	106	11	109	12	124	13
1980-81												
Spring	42	11	145	16	135	14	97	13	104	14	305	18
Lambing	46	12	51	12	32	9	60	8	47	10		*
Summer	181	35	179	34	181	36	268	28	202	33	245	21
Fall	214	20	285	19	264	20	186	19	273	20	222	18
Winter	44	13	57	11	62	13	80	13	61	13	21	13
1980-81	417	91	621	92	570	92	554	81	541	89	798	70

* Locations during the lambing season were combined with spring locations for the ram.

Table 3. Seasonal standard diameters (km) of home ranges of radio-collared sheep, 1979 and 1980-81.

	Ewe 6		Ewe 7		Ewe 8		Ewe 9		$\overline{X}$ Ewes		Ram	
	Size	N	Size	N	Size	N	Size	N	Size	N	Size	N
1979	2.1	14	2.9	13	2.2	13	4.1	11	2.8	13	3.9	13
1980-81												
Spring	2.0	12	3.2	16	3.1	14	3.1	13	2.8	14	3.5	18
Lambing	1.6	12	1.7	12	1.8	9	2.1	8	1.8	10	*	
Summer	2.0	35	2.1	34	2.1	37	2.7	28	2.2	34	3.7	21
Fall	3.0	20	3.5	19	2.8	20	3.4	19	3.1	20	5.0	18
Winter	1.7	13	2.4	11	1.8	13	1.4	13	1.8	13	1.7	12
Total 1980-81	2.1	92	2.6	92	2.4	93	2.7	81	2.5	90	4.0	69

* Locations during the lambing season were combined with spring locations for the ram.

the population was estimated at 57, a 39 percent increase since the 1979 transplant of 41 sheep. Without immigration and the supplemental transplant, only a 5 percent increase would have occurred from spring 1980 to the end of winter 1981.

Several factors contributed to the low rate of increase during the second year after the transplant. At least 2 adult ewes, 1 ram, and 1 yearling died during the second year, and one other ram was reported hit by a train but was never found. At least 2 adult ewes left the Cutoff area and joined a nearby herd. Those 6 or more sheep lost from the small population represented a substantial portion of the herd.

Slightly less than 70 percent of the lambs born in 1980 were alive by the end of the following winter. The summer ewe:lamb ratio was 100:57, indicating either a relatively high degree of lamb mortality shortly after birth or non-breeding by some ewes. Summer ewe:lamb ratios of 100:100 and lamb survival over 90 percent have been reported for vigorous herds (Brown 1974, VanDyke 1978, Butts 1980). I believe that not all ewes in the Cutoff herd had lambs durng 1980, and that the 19 lambs I observed were about all that were born.

The Wildhorse Island sheep used as transplant stock may have been of low vigor and have had inherently low reproductive and lamb survival rates. The 1979 summer ewe:lamb ratio in the Wildhorse Island herd was 100:18 and that for 1980 was 100:4. Also, several of the transplanted ewes were quite old. Geist (1971) stated that "a population of low-quality females with an intrinsically low death rate would cause a low birth rate, and would also lag or perpetuate itself in the face of improving forage conditions.": However, even if the adult ewes are "low-quality" sheep, the lambs born on the study area appear vigorous. Horn growth on yearlings is good. The horn and body size of 1-year-old males is noticeably larger than that of adult ewes, and about as large as those of 1-1/2-year-old males from a less vigorous herd I studied in the Petty Creek, Montana drainage. The male lambs on the Cutoff are noticeably larger than the female lambs in both horn and body size by approximately 10 months of age.

The summer ewe:lamb ratio from the Cutoff herd is much higher than those reported from Wildhorse Island in recent years, but I believe that the "lag (in productivity) in the face of improving forage conditions" which Geist (1971) postulated for transplants from poor quality populations is occurring. Yearling breeding, indicative of a vigorous herd, was once common on Wildhorse Island (Woodgerd 1964), so sheep from there apparently have that potential. Given the apparent vigor of the sheep born on the Cutoff since the transplant, the change from low to high quality will probably occur as more Cutoff lambs reach breeding age. Appparenty, initial productivity may be influenced by the quality and vigor of the transplant stock, but I believe that the released herd's quality can change in a few years, and that habitat quality at the transplant site is more important in determining the long-term success of the herd.

PARASITES

Bighorn herds studied in Montana generally have low levels of lungworm (Protostrongylus spp.) infestation (less than 100 larvae per gram of feces) and infestation rates of around 75 to 100 percent (Couey 1950, Forrester and Senger 1964, Berwick 1968, Brown 1974, Klaver 1978). The infestation rate in the Cutoff herd is significantly lower than that in the Wildhorse Island herd. Both herds had infestation levels that were very low although both areas were sampled in early spring when larval output is the greatest (Forrester and Senger 1964). The difference is probably a reflection of the fact that the Cutoff sheep were introduced to an area that had been without bighorns for several years, and infectious stage larvae were not present in the intermediate hosts. Thus, a low infestation level would be expected for a newly transplanted herd until the rate of infestation of the intermediate host increases.

DISPERSAL AFTER REINTRODUCTION

The pattern of range colonization is illustrated by location of the radioed ram from the transplant date to the end of the study (Figure 2). Movements eastward from the release site were gradual, but he continuously expanded his range throughout the study. The Cutoff herd has expanded its range 3 km west and 11 km east of the release site since they were transplanted. Most of the sheep remained within 2 km of the release site during the first year, but a few occasionally moved 4 to 5 km east of the release site. The 2-year-old ram that was radio-collared was located approximately 7 km east of the release site 5 months after the release.

Sheep have dispersed 3 km west of the release site to near the Patrick Creek drainage. That drainage and most of the others to the west of the study area are timbered and appeared to be a barrier to further dispersal in that direction. However, sheep have been sighted recently near Sesame Creek, 2 km west of the area occupied by sheep during my study.

During the spring and early summer of 1980, sheep were rarely seen east of Sheep Creek (6.5 km east of the release site). As summer progressed, sheep were sighted there more frequently, and they eventually moved northeast along the Clark Fork River to near its junction with the Flathead River. During January and February 1981, a group of sheep wintered in that area. The following spring, the radioed ram and a yearling were sighted 2 km farther north along the Clark Fork near the mouth of Kennedy Creek.

In early March 1981, a marked adult ewe from the Cutoff herd was sighted near Knowles Creek on the north side of the Flathead River with a herd that had been transplanted near Perma (Figure 3). That herd was also transplanted from Wildhorse Island during the winter of 1979. Later, another marked ewe from the Cutoff was sighted with the Perma herd, and both apparently stayed with these at least through the lambing season. Those sightings were approximately 6.5 km from the release site. Movement from the Cutoff to

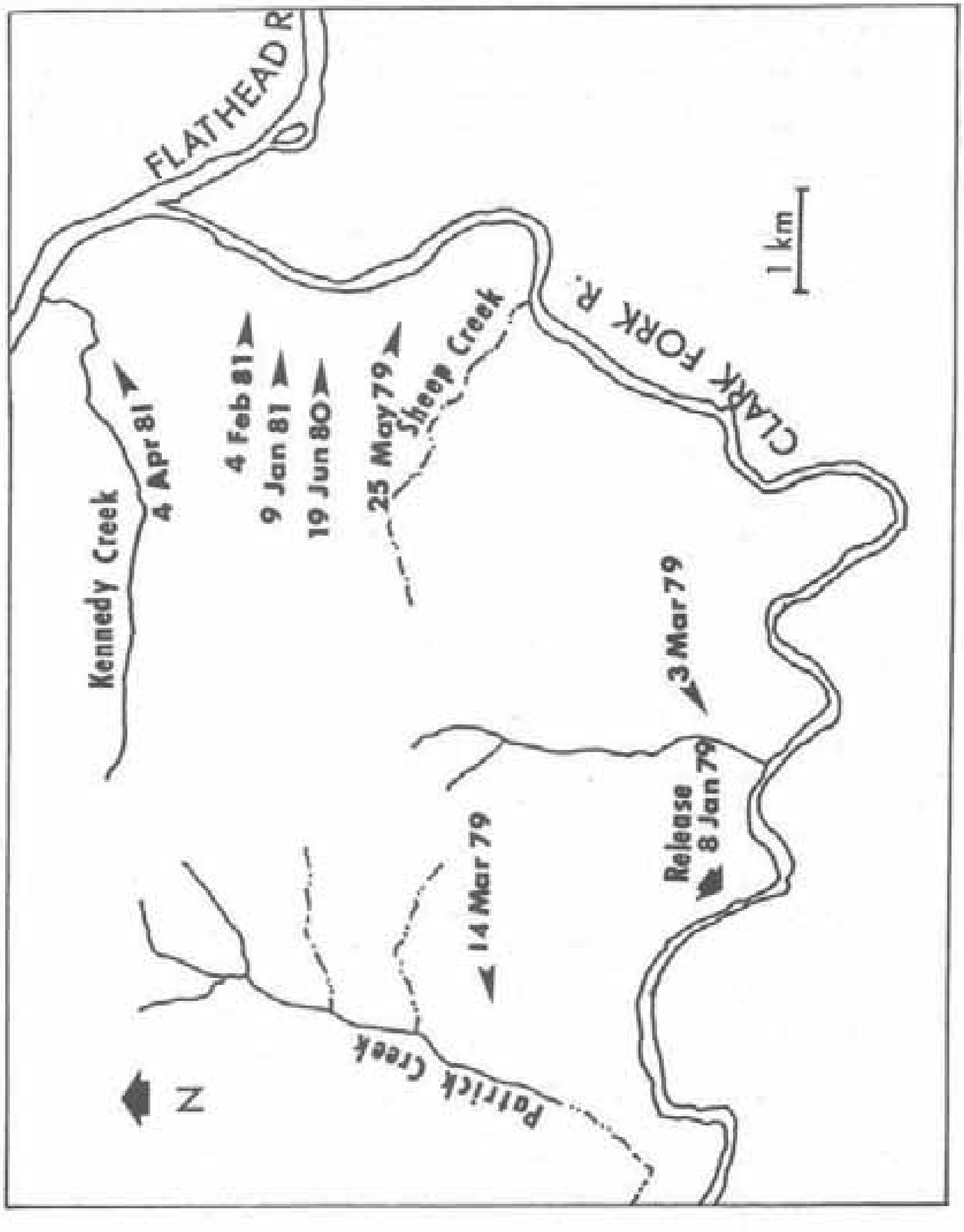

Figure 2. Pattern of range colonization by radio-collared ram.

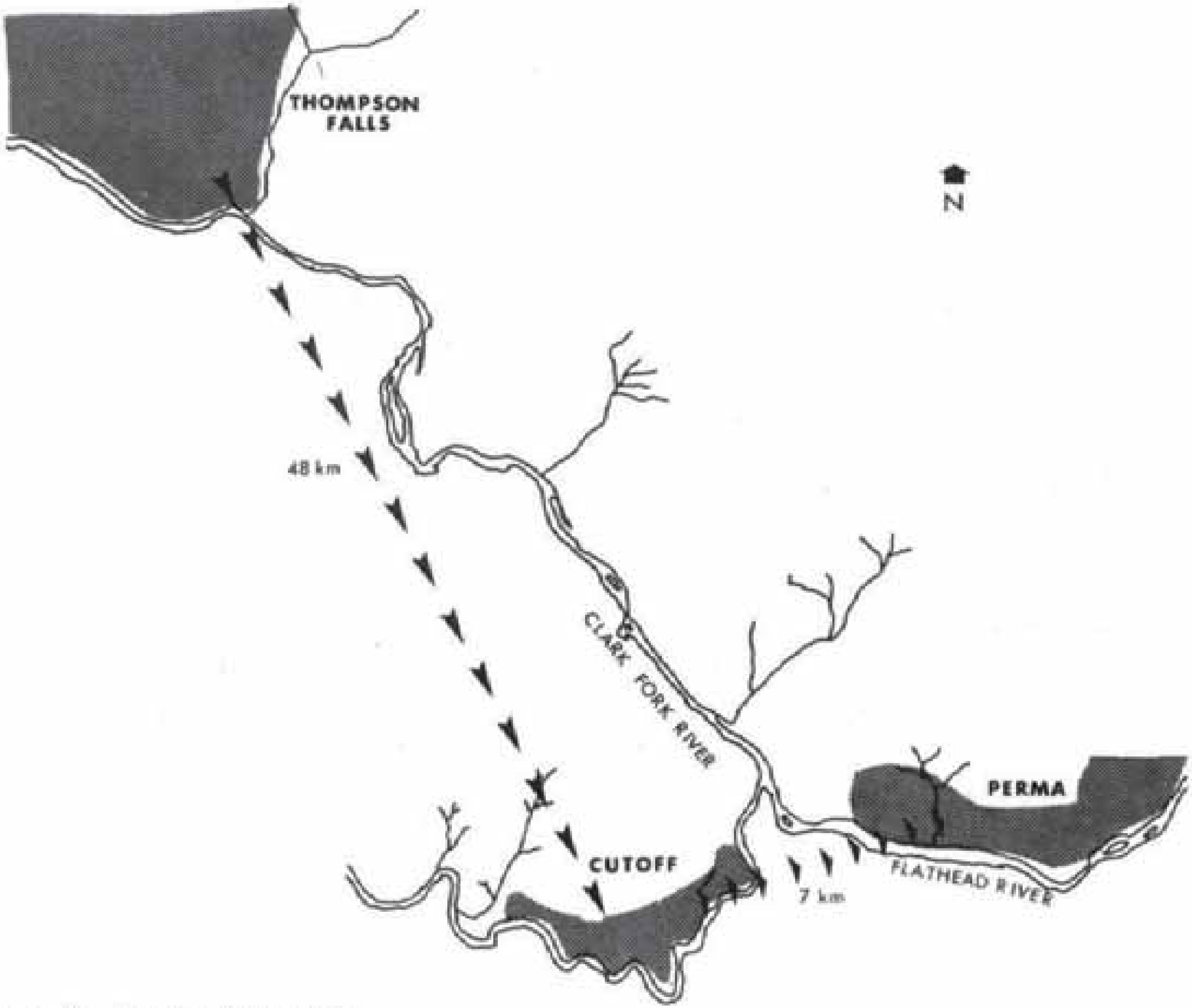

Figure 3. Interherd movement.

Knowles Creek entailed crossing at least 1, and probably 2, major rivers.

Sheep are occasionally sighted far from known sheep ranges. Geist (1971) conceded that, even though sheep do not normally disperse, rams have a "vestigial dispersal period" during their third summer and may leave their traditional range. He further stated that the presence of other sheep is necessary for habitat to appear suitable to the dispersing animals. Thus, if the dispersing sheep fail to find another herd with which to associate, they either return to their original herd or die as a result of not finding suitable habitat.

A group of sheep that was believed to have dispersed from the Thompson Falls herd, 48 km north of the study area, joined the Cutoff herd. A group consisting of 4 2-year-old males and 2 2-year-old females was sighted on the Cutoff in late May 1980. Later in the summer, a 2-year-old male was found dead and a 2-year-old female was captured. Both were too old to have been born since the transplant, and neither sheep was ear-tagged as were all members of the transplant group. The sheep could not have come from the recently transplanted Perma herd because all sheep in those sex and age classes in that herd were accounted for at that time.

The fact that immigration from the Thompson Falls herd and movement from the Cutoff to the Perma herd have occurred has several management implications. If movement between these herds occurs on a regular basis, suitable habitat between the herds may eventually be utilized by the sheep, and the herds may merge into one continuous population. Also, genetic interchange would preclude retarded vigor resulting from extensive inbreeding, which Berwick (1968) postulated as a contributing factor to the decline of the Rock Creek, Montana, herd. Even if more interchange does not occur, the immigrants have knowledge of areas outside of the present limits of the Cutoff herd's range, and that may facilitate range extension. The re-establishment of sheep herds in relatively close proximity to other herds may also eliminate some juvenile mortality by increasing the chances that dispersing sheep will find other herds.

CONCLUSION

The Cutoff transplant appears to be successful. The herd is increasing, and the sheep appear healthy and vigorous. The proximity of the Cutoff to other sheep herds resulted in herd interchange, and inter-herd movement may allow sheep to exploit available habitat between the herds' present ranges.

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TRAPPING AND TRANSPLANTING MOUNTAIN GOATS IN WASHINGTON STATE

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ABSTRACT

A variety of techniques has been used to capture mountain goats in Washington State including use of Clover traps, rope snares and dropnets. In 1981, "Operation Goatlift" required a technique to capture and remove fifty or more goats from Klahhane Ridge, Olympic National Park. The technique selected was a 12 x 12 m dropnet. The net was manually triggered but designed for remote triggering if goats became too spooky. Between 29 June and 8 July, 52 goats were trapped and transported to 3 sites in-state and 2 sites out-of-state. Under the direction of a veterinarian, all goats were given a variety of medications to counter capture myopathy and infections. Mountain goats were captured and transported in groups of 10 or 11. They were loaded into wooden shipping crates (1.2 x 1.2 x 0.4 m) at the capture site and transferred by helicopter 4 km to trucks. Up to 4 m tons of crushed ice per truck were packed in and around shipping crates in transit. No mortalities were experienced during the operation.

INTRODUCTION

Mountain goats are native to the Cascade and Selkirk Mountains of Washington and have been introduced to the Olympic Mountains. A variety of capture and transplant techniques has evolved over the past 30 years. In 1950, cowboys on horseback used lassos to capture goats on Mount Chopaka. Six goats captured at that time were transplanted to Oregon. During the early 1960's, mountain goats were captured in Clover traps as well as with a rope snare technique developed by L. Wadkins of the Washington Department of Game (pers. comm.). The rope snare technique worked quite well and over 50 goats were captured on Nason Ridge between 1960 and 1965. Some of these mountain goats were transplanted to Oregon, Nevada and Utah. Clover traps were used in the Selkirks to trap and relocate goats to adjacent ranges.

During recent years, rope snares as well as drug immobilization using M-99 have been used in Olympic National Park by park personnel and University of Washington scientists (Stevens 1980). Over 160 mountain goats were captured, marked, and released in Olympic National Park by Tory Stevens using rope snares. A dropnet technique has also been developed to more effectively trap mountain goats in several areas of the state as part of a statewide goat study (Johnson 1980).

In recent years, mountain goat populations in Olympic National Park have been increasing dramatically and causing serious habitat changes in some areas of the park. Olympic National Park (National Park Service 1981) considered several alternatives for solving the adverse habitat impact and decided to trap and transplant goats from Klahhane Ridge and other problem areas. Olympic National Park and Washington State Department of Game worked together to develop the latest trapping and transplanting procedures.

The team procedure to trap and transplant 50 mountain goats from Klahhane Ridge was dubbed "Operation Goatlift" by the press and received extensive media coverage. Over 50 newsmen from newspapers and television stations arrived to witness the trapping and transplanting operation.

TECHNIQUES

Large dropnet traps were developed in the 1960's in Texas for wild turkeys and deer (Glazener et al. 1964, Ramsey 1968) and used on Dall sheep in Alaska (Erickson 1970). In 1976, the deer net was modified by Larry Wadkins of the Washington Department of Game (Fig. 1). The dropnet used to capture mountain goats in Washington measures slightly over 12 x 12 m (40 x 40 ft.) Two different mesh sizes have been used for different situations. Nets with 25 cm (9 inch) mesh are used where gear must be back-packed to the capture site. This net weighs only 16 kg (35 pounds). A heavy, 90 kg (200 pounds) net with 10 cm (4 inch) mesh is used where helicopter service is available to transport equipment. The four corners of the net are erected tent-like atop 2 m (6 ft.) conduit poles held tightly in place by moored ropes. An aluminum center pole, 1-1/2 inches in diameter and 5 m (18 ft.) long, is used to hold the center of the net in position.

The net can be set up by 1 person but 2 or 3 crewmen make the job easier and quicker. Initial set-up requires driving corner stakes and fastening ropes to the net corners. The net can be erected for the first time at each site in 1 hour and re-set for each net drop within 10 minutes.

Two triggering procedures are used in Washington. In the Cascades, blasting caps are fastened with friction tape to ropes at 2 adjacent corners and rope holding the net up from the center pole. All 3 of the electric blasting caps are wired in series to a hand-held magneto. When the magneto is activated, all blasting caps are detonated simultaneously.

In Olympic National Park, semi-tame mountain goats can be captured with a manual release mechanism (Fig. 2). The release is a simple pull-pin device at each of the 3 severing sites described previously for blasting caps. Lightweight nylon cord (3/16 inch) is fastened to the release pins and drawn to a location about 7 m from the net. One or 2 persons trigger the net drop by pulling the 3 pins simultaneously.

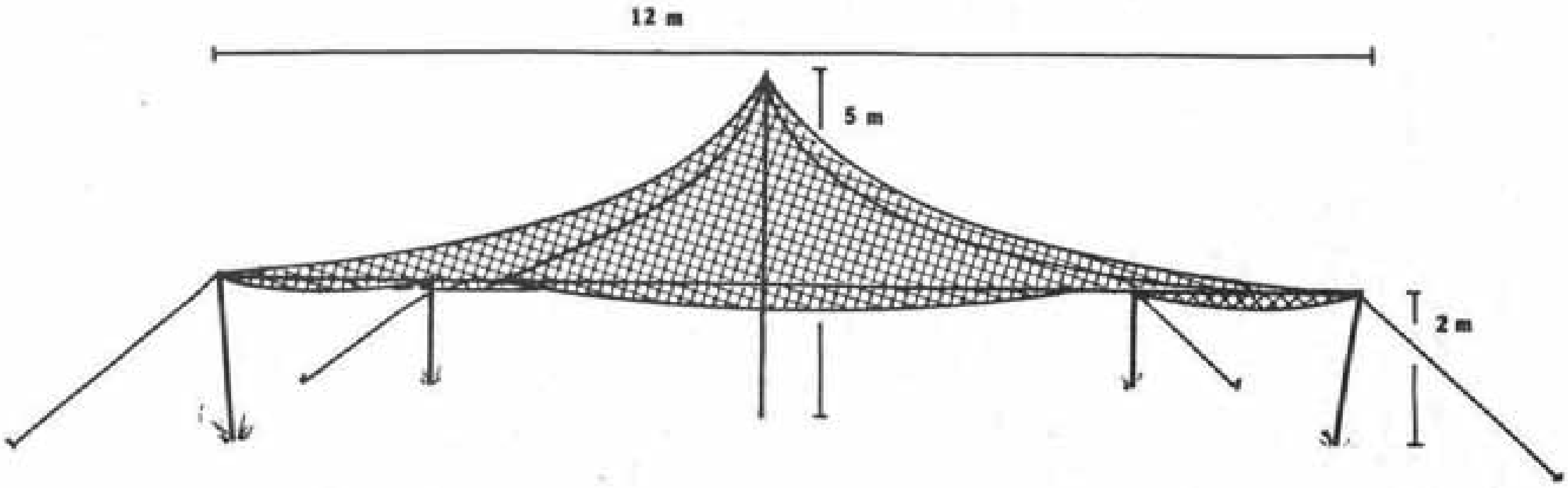

Figure 1. Nylon Dropnet Trap Used in Washington

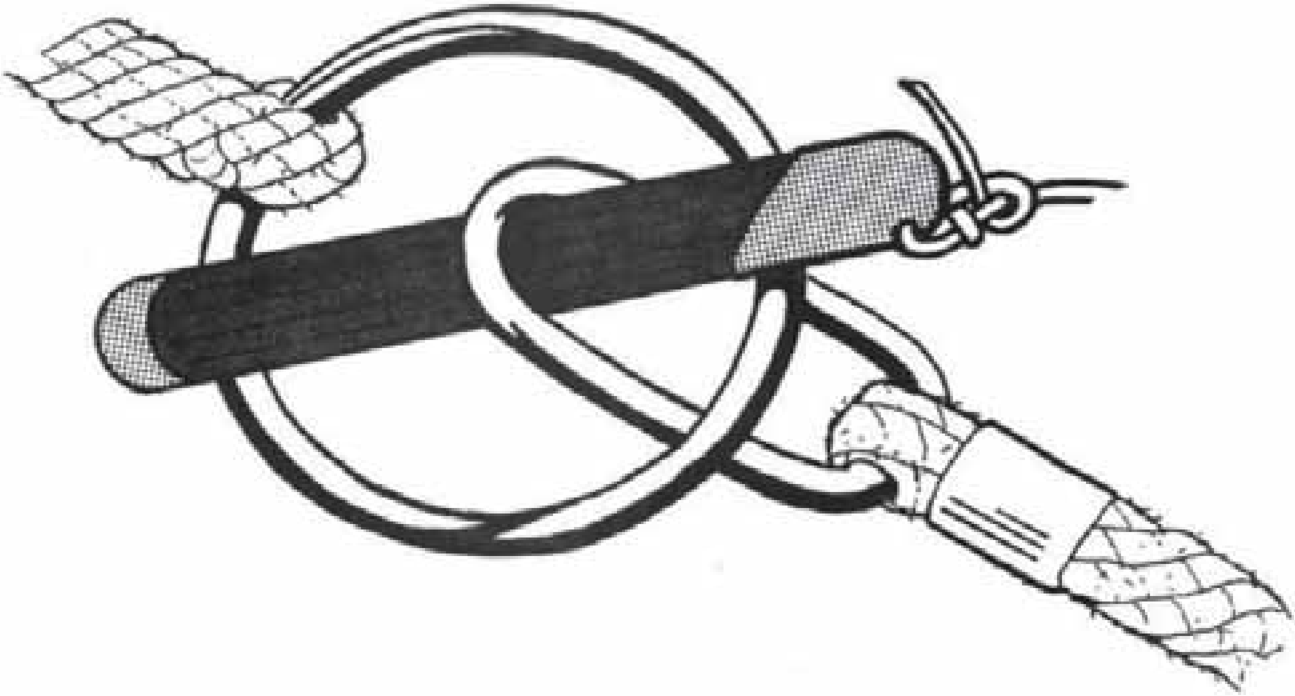

Figure 2. Manual release pull-pin mechanism for dropnet.

Trace mineral and plain salt blocks have been used for many years as bait for trapping mountain goats. In "Operation Goatlift", 50-pound-salt blocks were placed in large plastic tubs to prevent salt residues from leaching into the soil. Salt was placed at the capture site 3 weeks prior to initiation of trapping.

In the Cascades the capture crew was limited to 2 or 3 indiviuals, while in Olympic National Park, capture crews numbered 6 to 10. The processing procedure developed in Olympic National Park during "Operation Goatlift" was quite extensive because of the large scale transplant program. When the net was triggered, each goat was immediately immobilized by physical restraint, blindfolded, hobbled and removed from the netting. Horn guards (15-cm pieces of garden hose) were taped over each horn. Initial processing procedures included ear tagging for individual identification, weighing, and other standard measurements. Mountain goats were then given various medications in a protocol developed by Dr. James Foster, of Seattle's Woodland Park Zoo and Dr. William Foreyt of Washington State University. Each animal was given the following:

1. Valium--muscle relaxant and tranquilizer.
2. Sodium bicarbonate--intravenously and orally for immediate and prolonged effect to counter possible acidosis.
3. Clostridial vaccine--a precautionary measure to establish immunity to infectious Clostridium organisms.
4. Ripercol[1]--an injectable vermicide for intestinal parasites; known also to enhance immune responses.
5. Flocillin--a long-acting penicillin to prevent secondary bacterial infections resulting from the trauma of trapping and confinement.
6. Selenium--Vitamin E--a precautionary treatment because deficiencies may predispose animals to capture myopathy.
7. Vitamin d--assists in stimulating appetite, also promotes a feeling of well-being.

After all medications were given, goats were unhobbled and placed in plywood transplant crates measuring 119 cm high, 121 cm long, and 41 cm wide (inside dimensions). The crates were ventilated with openings (5 x 15 cm) on all sides and further cooled as necessary with snow or crushed ice.

During "Operation Goatlift" goats were transplanted as social groups of 10 or 11 with nearly equal sex ratios. Transport crates were sling-loaded in cargo netting from a Bell 206 B-III Jet Ranger helicopter. Depending on

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[1] The experimental drug albendazole has been given orally instead of ripercol in some areas of the state.

weight, 2 to 4 crates were airlifted at one time from capture to off-loading sites. Mountain goat transport crates were off-loaded into stock trucks and cooled with up to 4 m tons of crushed ice. Goats were transported as quickly as possible to release sites for earliest daylight release.

RESULTS AND DISCUSSION

In "Operation Goatlift", 52 goats were captured and transferred from Klahhane Ridge in Olympic National Park to five locations (Table 1). No mortalities were experienced. While similar procedures are used to trap goats in the Cascades of Washington, trapping is much less productive because goats are less tame and densities are low.

TABLE 1. MOUNTAIN GOAT RELEASE SITES FOR GOATS CAPTURED DURING OPERATION GOATLIFT 1981.

Release Location	Number Goats
Hooknose Mountain, Colville National Forest, Northeastern Washington	11
Lime Mountain, Mt. Baker-Snoqualmie National Forest, Northwestern Washington	10
Higgins Mountain, Mt. Baker-Snoqualmie National Forest, Northwestern Washington	10
Humboldt Range, Northwestern Nevada	11
Mt. Timpanogos, Wasatch Range, Utah	10
TOTAL	52

The rope snare technique is effective in capturing mountain goats especially where they are fairly tame and densities are high, as in Olympic National Park. The disadvantage of the snare technique is that only 1 goat can be captured at a time, and it is nearly impossible to capture both a female and her offspring together. The dropnet trapping technique developed in Washington has been very effective and has several advantages over other capture methods. A dropnet enables capture of intact social units including females with kids. This is an important consideration when establishing a new population. A net also enables capture of large males which may be dangerous if captured in a snare. Large billies (113 kg+) are very powerful and can be aggressive. The dagger-like horns of a mountain goat shold be treated with a great deal of respect. Mountain goats are much more dangerous than mountain sheep, although once immobilized and hobbled they are easily handled.

Another advantage of the dropnet is that one can be selective about how many and which animals to capture. In Olympic National Park, one person occasionally had to "herd" some goats away from the net to prevent excessive capture of unwanted individuals. An even mix of males and females was desired and attempts were made to avoid trapping old animals which would not adapt to transplant. The dropnet was not dropped until the desired number and spatial distribution of goats occurred under the net. Usually no more than 6 goats were taken at one time, but occasionally a good mix of younger goats enabled more animals to be captured with each net drop.

Mountain goats in the Cascade Mountains appeared to be disturbed by the presence of the net overhead and approached trap sites cautiously. Frequently, a goat walked around the perimeter of the net for 10 or 15 minutes before going under to the salt. At other times goats have been spooked away from the trap site by the presence of the net. In 1979 a female with 5 kids approached the trap site on Chopaka Mountain. She became alarmed at the presence of the net when only 3 to 4 m away, and deliberately herded all 5 kids down the mountain away from the net. In Olympic National Park, goats are quite tame and, while curious about the overhead net, showed little reluctance to go under it for the salt bait. Most goats hesitated briefly and then proceeded directly to the salt.

Trapping goats with 10 cm mesh net is preferred over a 25 cm mesh size. Goat kids are small enough to escape through the larger mesh, but cannot escape through a 10 cm mesh. The weight and bulk of transporting a net to capture sites rules out the smaller mesh where backpacking is required. The bulky 90 kg (10 cm mesh) net is nearly impossible to transport to capture sites without helicopter support.

CONCLUSIONS

The dropnet technique is very effective in capturing mountain goats and especially recommended where transplant of entire social units is desired. Medication was given to prevent capture myopathy and other stress-related disorders. Plans are underway to trap and transplant similar numbers of goats for the next 2 years using this technique.

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CONFERENCE DISCUSSION

<u>Q</u>. When using the drop net, how do you determine which goats to trap?

<u>Ans</u>. It isn't easy. If you took one with the rope-noose technique, the rest would run away for a while. We had one person watching each goat, hopefully. The scientist for the National Park Service wanted us to know which nanny had a kid at heel and which yearlings were associated with adult females. We also wanted the sex - and age-ratios right so it sometimes took us 15-20 minutes to figure which goats we were going to take. It was organized well and the operation went well.

<u>Q</u>. Do you have places to transplant suprlus goats from Olympic National Park:

<u>Ans</u>. Yes. The state of Idaho requested 100 goats and other states have additional requests. There is more demand than there are goats available.

<u>Q.</u> What will the long-range plan be for goats in Olympic National Park?

<u>Ans.</u> I really don't know. The Park Service will make a decision after this 3-year removal program. The Park figured it cost them about $350 per animal, to get them to the Park boundary, and thats only Park costs, mostly helicopter expense. It doesn't count State costs.

<u>Q</u>. How do you decide where goats will be relocated?

<u>Ans</u>. The state is responsible for determining release locations. We have a prioritized list of locations. We like to see them go to native ranges where goat populations have been depleted. I guess you can say we are considering zoos, but we have a large demand for releases on native ranges first.

<u>Q</u>. How many goats reside outside Olympic National Park on the Olympic Peninsula?

<u>Ans</u>. Its about 150.

<u>Q</u>. What effect will removal of 50 goats per year from Klahhane Ridge have on the population? Will you decrease the number of goats and the habitat degradation?

<u>Ans</u>. I think we are going to stimulate production. It's going to take removal of at least 50 goats per year because there are goats in adjacent areas that are going to move in. And we're going to get better productivity than we have up there now; and that is as high as 80-100 kids per 100 nannies.

<u>Q</u>. How many sets of twins do you find on Klahhane Ridge?

<u>Ans</u>. It's highly variable, but quite low on the average. Some years there are no twins, and other years I think I have detected up to 8 sets of twins.

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CAPTURE AND RADIO TELEMETRY

OF MOUNTAIN GOATS IN ALASKA

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ABSTRACT

Between August 1979 and June 1981, 41 mountain goats (Oreamnos americanus) were captured and radiocollared in the Kenai Mountains, Alaska. Capture was by drugged darts fired from a helicopter, using the drug M-99 (etorphine hydrochloride). The method was efficient and selective. No goats were killed or seriously injured during capture. Drug effects appeared more consistent and predictable in early summer than in late summer when goats were fat. Goats were equipped with color-coded radiocollars and subsequently relocated periodically by means of a Piper Supercub fixed-wing aircraft equipped with directional antennas and scanning receiver. Except for 1 collar that failed initially and 8 goats that subsequently died, all collars were still functioning in January, 1982.

INTRODUCTION

Several methods have been used with varying degrees of success to capture, mark, and relocate Rocky Mountain goats. In the early 1950's, goats were captured in Alaska for a transplant while swimming or by commercial trappers. Attempts to catch them by foot traps, baited corral-tarps, lassoing, and running down newborn kids met with poor success (Burris and McKnight 1973). Rideout (1974a) successfully captured goats in Montana with baited Clover traps; he tried drop nets and darts drugged with phencyclidine hydrochloride (Sernylan, Parke-Davis Co.), but had limited success.

Hebert et al (1980) captured goats in Canada with Clover and corral traps. These methods were slow, inflexible, required considerable manpower and time, and resulted in losses from capture myopathy. Cannon-netting was used by Thompson and McCarthy (1980), but, while successful, was cumbersome, slow, and also required a fixed, baited site.

Quaedvlieg et al. (1973) utilized Clover traps in Alberta, but then immobilized the captured goats with the drug etorphine hydrochloride (M-99, D-M Pharmaceuticals) for ease in handling. Free-ranging goats were captured by Kuck (1977) utilizing M-99 and darts fired from the ground and from a helicopter.

This technique and/or drug has been used on numerous wildlife species in Africa (Young 1975) and in America on moose (Alces alces) (Ballard and Gardner 1980, Gasaway et al 1978, Lynch 1981, Roussel and Patenaude 1975), bighorn sheep (Ovis canadensis) (Thorne 1971), pronghorn antelope (Antilocapra americana) (Autenrieth et al 1981), woodland caribou (Rangifer tarandus) (Fuller et al. 1981), black bears (Ursus americanus) (Beeman et al. 1974), Sitka blacktailed deer (Odocoileus hemionus) (Schoen et al. 1981), and others.

Schoen (1978) tried snares and helicopter-dropped nets, but finally settled on the drugged dart fired from a helicopter as the best method to date for capturing free-ranging goats in Alaska. He used 2.5 - 3 mg of M-99 per goat injected intramuscularly with a Cap-chur gun (Nasco-west, Modesto, CA) from a Hiller 12E helicopter. Of 8 goats hit, 5 were captured; no losses occurred. He captured these goats in winter in deep snow to avoid losses caused by falling from precipitous terrain.

Installation of radio-collars has proven one of the best methods by which captured animals can be identified and relocated as needed. Relocating collared goats was initally accomplished by use of fixed directional antennas and triangulation or by hand-held directional antennas (Rideout 1974b). More commonly, free-ranging animals have been relocated by utilizing directional antennas mounted on aircraft, either fixed-wing or helicopter (Ballard et al. 1979, Hoskinson 1976, Inglis 1981, Mech 1974). Schoen (1979) used double, 3-element Yagi antennas mounted on a Helio Courier for locating collared goats with excellent success in southeastern Alaska.

This paper presents updated and detailed methodology and results utilizing these highly successful techniques on mountain goats in Alaska. The capturing, collaring, and radio-tracking work was part of a larger study on goat movements.

METHODS

CAPTURING AND COLLARING

Twenty goats were captured in the Kenai Mountains, Alaska, in August 1979; 3 in August 1980; and 18 in June 1981. The same technique was used in all 3 sessions with but minor variations. Habitat was generally goat summer range consisting of very rugged, heavily glaciated mountains. All goats were captured in the alpine between elevations of about 762 m (2500 ft) and 1372 m (4500 ft); some on open tundra or fellfields, some on snowbanks, glaciers, or icefields, and some on precipitous slopes or cliffs. No serious injuries or fatalities occurred.

A Bell 206 B Jet Ranger helicopter was used in all operations. The crew consisted of 3 men: pilot, shooter, and assistant, except that only the pilot and shooter were present in 1980. Crew size, which was adequate, was limited to 3 to reduce weight and allow more maneuverability of the helicopter in dangerous terrain. Communication between crew members was enchanced by use of a three-way, portable intercom system (Genie Electronics Engineering, Inc., Red Lion, PA) which allowed continuous conversation and direction.

Etorphine (M-99) was used for all capturing. It was fired in darts from a standard Cap-chur gun using green (intermediate-range) propellant charges. Dart needles were modified by cutting off most of the barb and shortening needles to just ahead of the barb attachment. Less tissue damage resulted from the shorter darts which were then easier to remove with the smaller barbs. A dosage of 4 mg (4 cc) of M-99 was used on all but the largest adult males, some of which were given 5 mg. However, 4 mg was used on all goats from yearlings to adult males in the June 1981 operation.

In practice, goats were located in terrain where it appeared we had a good chance to effect a capture before darted animals could reach extremely precipitous areas where they might become injured by falling when narcosis occurred. An animal or group was selected and the helicopter maneuvered in a slow hover behind the target until a favorable shot was presented. Goats usually reacted to close pursuit in one of three ways: if in sloping terrain, they would frequently climb; when rock outcrops were present, they often would flatten against the downhill side; on relatively level ground, they would run straight away. If they reached dangerous terrain, the chase was abandoned. Their deliberate and relatively predictable flight pattern allowed close approach from the rear or side in most cases, and with patience, easy shots of under 15 m (49 ft) could be obtained. Continuing voice communication between shooter and pilot via the intercom contributed substantially to efficiency and success.

When dart placement was confirmed, the helicopter would back off to avoid unnecessary harassment, and the goat would be observed from a distance until it went down. Only if it began running for dangerous cliffs would attempts to herd it be made. Usually, goats would respond to herding until the drug began taking effect, after which, they would go their own way regardless of helicopter approach.

When the goat became and remained prostrate the helicopter would land nearby and the crew could proceed with their equipment to the goat. However, in steep terrain where the helicopter could not land, it was often necessary for the shooter and assistant to jump from the hovering machine to be picked up later.

The anesthetized goat was sexed, aged from horn annuli, weighed and measured, and biological samples taken. Weight was obtained from slinging the goat beneath a portable 300 lb (136 kg) capacity spring scale suspended from a stout pole which was then lifted by 2 men. We found it impossible for 2 men to lift full-grown males high enough for weighing by this method.

A numbered eartag (Rototag, Nasco-West, Modesto, CA) was installed, and finally a color-coded radiocollar was fastened to the drugged goat. Radiocollars (Model MKVM, configuration 5 B with mortality-sensing option, Telonics, Inc. Mesa, AZ) were individually color-coded for visual identification by wrapping with various colors of plastic electrical tape in different patterns. The collars used were in the frequency range 150.000 to 152.000 MHz.

When work with the goat was completed, an injection of the antagonist diprenorphine hydrochloride (M-50-50, D-M Pharmaceuticals) was given intravenously in an amount equaling the original injection of M-99. Injection site was commonly the radial vein which was raised for easy access by using a lightweight, surgical-rubber-tubing tourniquet proximal to the site.

RADIO LOCATING

A Piper PA-18-150 Supercub has been the vehicle used in this project for all relocating of radio-collared goats. It has been used on wheels in spring and fall, floats in summer, and skis in winter with equal success. A pair of Hy-gain model RA-3 (Telonics, Inc.) 3-element Yagi antennas are mounted, 1 on each side of the airplane, on the lift struts. Mounting is similar to that described by Inglis (1981) except that the antennas point outward at 90 degrees to the axis of the fuselage rather than forward as in his description. Thus, the loudest signals are heard directly off either wing. The antennas lead via coaxial cables down the wing lift struts and through the control cable openings into the interior of the cockpit. They are connected to a Telonics TAC II right-left-both toggle switch, which in turn is connected to a Telonics mated TR-2 receiver and TS-1 scanner. Earphones can be plugged into the receiver. However, since I both fly the plane and operate the receiving electronics, I have found it more convenient to connect the telemetry receiver to an intercom system (Telonics model TADS-2) which integrates this system with the aircraft's avionics through 1 headset, as well as allowing a passenger with a second headset to hear all incoming signals and to communicate with me vocally.

In use, frequencies of collars to be located are programmed into the scanner and the antenna switch is set on "both". When a signal is heard, the scanner is locked on and the antenna switch moved to "right" or "left" for the loudest signal and to determine which direction to fly. If the goat appears to be at some distance away, the airplane can be turned slowly until a signal of equal strength from each antenna is heard. It is then pointing toward the collared animal. Because of the topography inhabited by mountain goats, this usually entails flying directly toward a mountain and is the main reason for not using Inglis' (1981) forward-pointing antennas and search method for final transmitter location.

Although the search method used is roughly similar to that described by Mech (1974) and others, the mountainous terrain necessitates some special techniques. Upon reaching the general area of the collared goat (indicated by an increasingly loud signal), the plane is flown close to and parallel with the mountain slope with the receiver volume turned low and tuned to the antenna facing the mountain. A rapid build-up and peak in sound level indicates the vertical plane occupied by the goat, but not the elevation. When the plane is flown close to the slope and the volume is loudest from the antenna facing the mountain, the target transmitter is either just off the wing tip or above the flight level. If it is of equal strength from both antennas at peak level, the transmitter is directly below; if stronger from the antenna facing away from the mountain, the goat is downslope.

Once the goat has been located, or its location approximated with appropriate precision, its position may be plotted on a map. I use clipboard-sized segments of U.S.G.S. 1:63,360 topographical maps with mylar plastic overlays. Four clipboards cover my study area. Further data on companions, habitat, etc. may be recorded on other forms or recorded in a small cassette recorder slung from my neck for that purpose.

RESULTS AND DISCUSSION

CAPTURING AND COLLARING

Because of their behavior when closely pursued by helicopter and their favorable response to etorphine, mountain goats are well suited to this method of capture. Efficiency of capture was high in all 3 collaring sessions to date. In the first, with no previous crew experience in capturing goats, and despite inclement weather, 19 goats were successfully captured with 22 hits. One more adult male was captured, but, because of an initial underdose, took 4 more darts before he could be caught. Thus, 20 were captured in a 5-day period. Three others were hit but not captured. One of these, a yearling, climbed into the clouds before narcosis occurred. It was seen the next day, apparently fully recovered. Another yearling vanished into a jumble of rocks after being hit, but apparently recovered; no carcass could be found later. An adult female, hit in the flank with injection directly into the rumen probable, showed no effect of the drug and escaped beneath a glacier.

During the second attempt in August 1980, 3 goats were captured with 3 hits in 1 afternoon. Eighteen goats were captured in the final operation in June 1981, with 19 darts (every shot hit) in 4 days. One adult male received a partial injection, only, and escaped into unsuitable terrain without complete narcosis. No mortalities occurred out of the 45 goats darted. Althrough several animals fell or slid considerable distances, no serious injuries resulted.

Recovery of anesthetized goats occasionally was hazardous due to terrain. Ice axes were used to good advantage on steep slopes and snowbanks. Rock climbing equipment, although always carried, was required only once when it was found necessary to rappel down to an animal on a cliff ledge. A major contribution to success was the skill and interest displayed by the helicopter pilot, as well as the ability of the machine to perform as required.

Mean weights of goats captured and dosage levels of etorphine are listed in Table 1 by month of capture (August 1979 and August 1980 are combined). sex, and age class. Because most adult males could not be weighed, listed dosage levels for that class are biased on the high side. Dosage levels and animal weights were compared between month and class by standard t-tests. In almost all cases, dosages used resulted in deep anesthesia and ease of handling with no struggling or obvious awareness.

Statistically significant differences between mean weights and dosages in mg/kg of M-99 were found between June and August in "adult" females (those older than 1 year). Animals were lighter in early summer and, consequently, dosage rates were higher. Suggestive differences ($P < 0.10$) were found in weights and dosage levels between June and August in yearlings, while no significant difference ($P > 0.10$) could be detected for these parameters in "adult" males. The latter 2 anomalies were probably results of small sample size. Had more yearlings and adult males been captured, and more of the latter weighed, significant differences probably would have been found.

When all sexes and ages were combined, significant differences ($P < 0.05$) between June and August weights and dosage levels were noted, as they were between adult males and adult females when months were combined. Thus, goats generally received higher per kg dosages of M-99 in early summer when they were lighter in weight, and adult males received lighter dosages than adult females. The range overall in dosage levels was between 0.0304 mg/kg for a large adult male (and possibly lower for larger, unweighed males), and 0.1176 mg/kg for a small yearling. The overall mean dosage level for all animals and both seasons was 0.0680 mg/kg (SD=0.0185,N=32).

One adult male, estimated to weigh well over 136 kg (300 lb) was insufficiently dosed with the first 4 cc dart at a dosage level of about 0.0294 mg/kg or less. He subsequently took 4 more darts (one did not inject) for a total of 15.5 mg of M-99 (approximately 0.1140 mg/kg) before capture. Although this required considerable harassment during pursuit, he recovered with no apparent ill effects.

No differences in mean induction time could be detected between months or sex/age classes. The mean induction time was 7.5 minutes, with a range of 2 to 15 minutes. Not all induction times were recorded; however, it appeared that these were more uniform and capture more certain in June when the animals were lighter and dosage rates in mg/kg higher at 4 mg/dart.

Quaedvlieg at al. (1973) reported a mean dosage level of 0.0375 mg/kg and induction time of 3.3 minutes for trapped goats, but lost one, presumably from underdosing and consequent excitement. Schoen (1978, 1979) first used 2.5 - 3 mg/goat in capturing free-ranging animals for a mean induction time of 15 minutes. Increasing dosage to 3.5 mg/goat decreased his mean induction time to 12 minutes. In this study, the average dosage of 4 mg/goat further reduced mean induction time to 7.5 minutes. Reduced induction time, obviously, is advantageous in preventing escape and reducing exertion in darted animals. Autenrieth et al. (1981), working with pronghorns, and Lynch (1981), working with moose, both felt underdosing with M-99 was more dangerous than overdosing due to the prolonged pre-induction excitement and exertion. I agree, and believe that a safe and workable dosage for mountain goats is 4 mg/goat in early summer (3 mg/yearling probably would be adequate, but 4 mg appears safe), and 4 to 4.5 mg/goat in fall except that adult males should be given at least 5 mg in fall.

Kuck (1977) and Quaedvlieg et al. (1973) gave the antagonist M-50-50 at double the rate of M-99 in the capture dose. Schoen (1978) gave it at equal dosage intramuscularly and reported a mean recovery time of 8 minutes. In this study, M-50-50 was givin at the same dosage as M-99 but intravenously. Mean recovery time was 1.5 minutes, with a range 0.5 minutes to 4 minutes. The 1 male given 15.5 mg of M-99 was given 10 mg of M-50-50 and recovered in 2.3 minutes. No differences in mean recovery time could be found between sex/age class or month of capture. Recovery typically was sudden with the animal up and walking off within seconds of first opening its eyes. Although most appeared disoriented at first, their sense of balance returned rapidly and no falls occurred during recovery. Two animals which inadvertantly received their antagonist intramuscularly took over 15 minutes each to recover. Thus, intravenous is the preferred route for the antagonist where rapid recovery is desirable.

The cost of capturing 18 mountain goats in June 1981 (exclusive of manpower) included the following:

Helicopter	20 hours @ $381.00/hr	$ 7620.00
Darts	19 @ $9.24 (many were recovered)	175.56
Drugs (M-99 and M-50-50)		484.50
Collars	18 @ $262.20	4719.60
	Total	$ 12,999.66

The cost per goat captured was $722.20. Ballard and Spraker (1979) estimated the cost of capturing wolves (<u>Canis lupus</u>) by helicopter and dartgun at $578 per wolf, exclusive of collar and manpower. Including a radiocollar would have brought their cost up to about $840 per wolf. In 1953, the State of Alaska paid trappers $100 per male goat and $400 per female for a transplant (Burris and McKnight 1973), and had difficulty obtaining enough animals. The present method is cheaper (allowing for inflation), more selective, and much more efficient.

RADIO LOCATING

Locating radiocollared mountain goats by the method described has proven relatively simple and certain. On nearly every search, all goats have been located, although not always visually. During summer, it has been easier actually to see the animals than during winter when they blend in with the numerous snowbanks or are under tree canopies. Even when the collared goat could not be spotted, it has been possible to narrow its location to a circle of about 100 m (300 ft) in diameter or less by careful flying and search. During hot summer days, goats have been found by persistent search even when under snowbanks or in shallow caves.

One problem encountered occasionally has been signal echos in certain valleys. These indicate false positions and sometimes require considerable searching to overcome. They appear more prevalent in narrow canyons in winter.

I do not know the maximum range of these collars. Sharp signals have been received from as far away as 25 km (15 mi). However, most searching is done in valley systems where ranges are much less and unwanted signals from adjacent valleys are blocked out by high ridges. Valley-by-valley searching acquires signals only from those animals within the valley and assures the operator that any signals heard emanate from nearby animals.

Another minor problem encountered has been signal drift, particularly in cold weather. However, this drift has been less than 1.0 KHz and only by a few transmitters. Since no collar frequencies have been spaced closer than 10.0 KHz, there has been no confusion created in identificaton, but merely a requirement to program the scanner 1.0 KHz to one side or the other of the listed frequency on a few collars.

Transmitter longevity has been very satisfactory. Except for 1 possible complete failure initially, all collars have functioned as advertised. Expected life upon installation was 2 years. All collars put on in August, 1979 and on still-living goats (13) were functioning in January, 1982--29 months later. One collar on a goat killed by an avalanche in early winter 1979, and buried under tons of packed snow all that winter, all the next, and part of the third, finally ceased to function in December, 1981. All this time it had been operating on "mortality mode" at twice the normal pulse rate, resulting in a higher battery drain. Other collars continued to operate under avalanches and after the goat carcasses had been eaten later by scavengers and the collars much chewed, even by grizzly bears (Ursus arctos). This speaks well for their construction. In fact, all the electro ic equipment purchased from Telonics, Inc., has performed remarkably well under adverse conditions.

Time required to radio locate 34 collared goats--the maximum number operating at any time--on a study area of approximately 609 km^2 (235 mi^2), was about 7 to 8 flying hours, including about 1 hour of ferry time to and from the area. This required 2 flights in a Supercub and could be accomplished in 1 day during summer, but took 2 in winter when days are short. More goats could be located visually in summer than in winter.

Color-coding collars makes it possible to identify individuals visually, an advantage when several collared animals are in the same group. Individual identification is necessary, for example, to determine which collared females are accompanied by kids in a group with several radiocollars. Bright collars also make it easier to sight a collared goat. Color-coding by plastic electrical tape has worked well, although sometimes it has been necessary to fly rather close to identify certain patterns. Collars so marked in 1979 were still recognizable in January, 1982.

Flight performance of the airplane use in radio tracking mountain goats is of great importance to both efficiency and safety. I have found the Piper Supercub to be an excellent vehicle, especially when flying and tracking alone. It is simple, may be flown slowly with safety, and has the tight turning radius necessary to search small valleys. Schoen (1979) used the Helio Courier, an aircraft of similar performance, with good success. Kuck (1977) used a Cessna 182 for radio locating mountain goats in Idaho; I believe such a fast, heavy aircraft would be both inefficient and dangerous for this work in the rugged mountainous terrain of Alaska's goat habitat.

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Table 1. Mountain goat weights and dosages of M-99 by month of capture, sex, and age class.[1]

Month	Sex	Age class	N	Mean weight in kg	Difference significant?	Mean dosage mg/kg	Difference significant?
June	both	yrl.	3	38.4	no; $P > 0.10$	0.1042	no; $P > 0.10$
August	both	yrl.	2	50.4		0.0794	
June	F	2+	10	52.9	yes; $P < 0.001$	0.0759	yes; $P < 0.001$
August	F	2+	12	73.1		0.0577	
June	M	2+	2	70.3	no; $P > 0.10$	0.0600	no; $P > 0.10$
August	M	2+	3	97.8		0.0417	
Both	F	2+	22	63.9	yes: $P < 0.01$	0.0660	yes; $P < 0.025$
Both	M	2+	5	86.8		0.0500	
June	Both	1+	15	52.3	yes; $P < 0.001$	0.0796	yes; $P < 0.001$
August	Both	1+	18	74.8		0.0566	

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[1] Exclusive of all animals which were not weighed.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:127-142

AN EVALUATION OF HORN AND SKULL CHARACTERS AS A MEASURE OF POPULATION QUALITY IN ALBERTA BIGHORNS

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ABSTRACT

Rocky Mountain bighorn sheep (Ovis canadensis canadensis) in southern Alberta have several skull characters which exceed those of bighorns north of the Bow River. In the south, both sexes have longer rostra, tooth rows, and higher crowns than northern bighorns. Southern rams have more massive horns than northern rams. Although brain case volume was significantly larger ($p<0.05$) in southern rams, that measure did not differ between southern and northern ewes.

INTRODUCTION

Bubenik and Bellhouse (1980) cite several references that indicate undernourishment during pregnancy and/or during the nursing period are major causes of a small and under-developed brain. They measured 53 moose skulls (Alces alces) from north central Ontario and proposed that brain case volume could be a valuable tool for measuring population quality. We tested brain case volume as a measure of population quality in Rocky Mountain bighorn sheep from high quality and low quality populations from southern and northern Alberta respectively. In southern Alberta there is an optimum combination of climate, soil and vegetation that produces large bighorns (Blood et al. 1970) with the southern rams growing significantly larger horns than rams north of the Bow River (Wishart 1969). Since high quality mountain sheep populations are characterized by more massive horns and skulls than lower quality populations (Geist 1971, Shackleton 1973, Heimer and Smith 1975), comparison of bighorn skulls from northern and southern Alberta appeared appropriate for the brain case volume test.

METHODS

After plugging foramina with modeling clay, brain case volume was measured by filling the cavity with #6 lead shot and then pouring the shot into a calibrated cylinder. Measurements were recorded to the nearest 5 cc.

Skull measurements were made to the nearest millimeter using a steel tape, lock-joint outside calipers and a Vernier caliper. Standard skull measurements described by Cowan (1940) were taken on 17 characters. We measured six additional characters after Shackleton (1973) to describe the rostral cranial relationships of each skull. The skull measurements are defined in the Appendix and illustrated in Figure 1. Comparison of interpopulation skull dimensions were restricted to age classes 5 years and older (Cowan 1940, Baker and Bradley, 1965).

Horn measurements were made to the nearest millimeter using a cloth tape. Measurements included the base circumference from animals aged 5 years and older and the lengths of annual increments for each horn from all ages. Annual increments were measured for only the first three years in ewes, since annuli were not accurately discernible thereafter.

A "t-test" for samples of unequal size and unequal variances was used to compare population sample means. The level of five per cent probability had been selected a priori for tests of hypotheses. A total of 90 ewe skulls and 70 ram skulls was measured.

RESULTS

1. Ewe Skulls

Southern specimens were almost invariably larger. Differences ($P<0.05$) between southern and northern ewes were found in the basilar length, naso-cranial length, molar lengths, maxillary width and rostral depth (Tables 1 and 2). In the cranial region significant differences were found in the basisphenoid crown height, occiput-frontal length, supraorbital width and occiput width, however, there was no difference in brain case volumes (Table 2).

2. Ram Skulls

As with the ewes the southern specimens were almost invariably larger. Significant differences were found in the naso-cranial length, palatal length, molar lengths, occiput frontal length and basisphenoid crown height (Tables 3 and 4). Brain case volumes were significantly larger in southern Alberta rams (Table 4).

Table 1. Skull measurements of bighorn ewes, 5 years and older from northern (N) and southern (S) Alberta.

Measurement	Pop.	x_n		$\overline{X}$	$SE\overline{X}$	SD	CV	R
A. Basilar length	N	23	*	246.2	1.37	6.58	2.67	232-256
	S	22		252.4	1.08	5.06	2.00	241-260
B. Nasal length	N	24		94.7	1.09	5.35	5.65	86-106
	S	22		97.5	1.12	5.29	5.42	92-109
C. Nasal width	N	22		37.4	0.56	2.63	7.03	32-41
	S	21		37.4	0.58	2.69	7.20	32-41
D. Orbital width	N	23		108.3	0.56	2.70	2.49	102-114
	S	22		108.1	0.82	3.84	3.55	101-117
E. Zyomatic width	N	23		114.6	0.64	3.08	2.69	108-119
	S	21		115.1	0.55	2.53	2.19	108-119
F. Maxillary width	N	26		80.8	0.51	2.60	3.22	77-84
	S	23	*	82.8	0.60	2.89	3.49	78-88
G. Mastoid width	N	19		79.7	0.53	2.30	2.89	76-83
	S	20		80.1	0.59	2.64	3.29	76-86
H. Palatal br.M_3	N	26		47.3	0.53	2.72	5.76	43-51
	S	23		47.3	0.52	2.48	5.24	42-52
I. Palatal br. Pm_2	N	26		29.5	0.54	2.76	9.34	23-35
	S	23		29.9	0.41	1.96	6.56	27-34
J. Post-palatal width	N	22		26.1	0.29	1.39	5.32	23-28
	S	22		25.8	0.22	1.05	4.07	23-38
K. Palatal length	N	23		90.8	0.90	4.32	4.76	84-99
	S	22		90.9	1.37	6.45	7.09	71-100
L. Upper Molar length	N	26		81.9	0.65	3.30	4.03	75-87
	S	23	*	85.2	0.62	2.98	3.50	79-91
M. Lower Molar length	N	29		82.4	0.55	2.95	3.59	78-88
	S	15	*	86.2	0.96	3.72	4.32	81-91
N. Prealveolar length	N	25		78.1	0.63	3.18	4.07	74-84
	S	23		79.3	0.50	2.38	3.00	75-83
O. Postdental length	N	25		82.2	0.81	4.08	4.96	71-89
	S	22		83.6	0.65	3.06	3.67	79-89
P. Basioccipital width	N	23		30.2	0.31	1.50	5.26	28-33
	S	22		30.7	0.34	1.61	4.96	27-34
Q. Premaxilla width	N	21		29.5	0.35	1.63	5.53	27-31
	S	23		29.2	0.41	1.95	6.68	25-33

x_n- sample size
$\overline{X}$- mean
$SE\overline{X}$- standard error of mean
SD- standard deviation

CV- coefficient of variation
R- range
*- $p<0.05$

Table 2. Rostral and cranial measurements and brain case volume of bighorn ewes, 5 years and older from northern (N) and southern (S) Alberta.

Measurement	Pop.	x_n	$\overline{X}$	SE$\overline{X}$	SD	CV	R
W. Basisphenoid-crown height	N	25	88.1	0.74	3.71	4.21	82-94
	S	22	*92.9	0.88	4.14	4.45	86-103
X. Occiput-frontal length	N	24	121.2	0.71	3.47	2.84	118-128
	S	21	*125.9	0.91	4.19	3.33	120-134
Y. Rostral depth	N	24	65.8	0.56	2.76	4.20	61-71
	S	22	*68.6	0.62	2.92	4.26	65-76
Z. Naso-cranial length	N	24	198.2	1.38	6.75	3.41	184-209
	S	21	*203.5	1.37	6.26	3.08	192-215
AA. Supraorbital width	N	25	105.0	0.84	4.18	3.98	98-112
	S	23	*107.4	0.73	3.48	3.25	101-113
BB. Occiput width	N	23	61.9	0.66	3.15	5.09	56-68
	S	21	*64.1	0.56	2.57	4.01	61-69
Brain case volume	N	23	213.9	3.09	14.84	6.94	190-250
	S	22	216.6	2.89	13.57	6.26	190-245

x_n- sample size
$\overline{X}$- mean
SE$\overline{X}$- standard error of mean
SD- standard deviation
CV- coefficient of variation
R- range
*- $p<0.05$

Table 3. Skull measurements of bighorn rams; 5 years and older from northern (N) and southern (S) Alberta.

Measurement	Pop.	*n		$\bar{X}$	SE$\bar{X}$	SD	CV	R
A. Basilar length	N	6		271.2	2.96	7.25	2.67	259-278
	S	9		278.4	3.57	10.71	3.84	266-295
B. Nasal length	N	7		104.3	2.99	7.91	7.58	92-114
	S	7		108.8	2.15	5.70	5.23	103-118
C. Nasal width	N	10		51.8	1.20	3.79	7.32	46-59
	S	10		53.2	1.50	4.75	8.94	46-60
D. Orbital width	N	10		121.3	1.55	4.90	4.04	115-128
	S	10		123.3	2.27	7.19	5.84	115-135
E. Zygomatic width	N	10		126.1	1.36	4.30	3.41	116-131
	S	10		128.5	1.01	3.21	2.49	124-133
F. Maxillary width	N	11		89.4	0.98	3.27	3.65	85-94
	S	10		92.2	1.38	4.37	4.73	86-98
G. Mastoid width	N	9		93.4	0.62	1.88	2.01	91-96
	S	10		96.1	1.42	4.51	4.69	90-103
H. Palatal br. M_3	N	11		50.9	0.97	3.24	6.36	45-57
	S	10		51.6	0.60	1.89	3.68	49-54
I. Palatal br. P_{m2}	N	12		32.2	0.42	1.47	4.56	30-35
	S	10		32.9	0.69	2.18	6.64	29-37
J. Post-palatal width	N	11		30.4	0.43	1.44	4.73	28-33
	S	10		31.8	0.51	1.62	5.09	29-34
K. Palatal length	N	8		85.9	1.51	4.29	4.99	81-91
	S	10	*	99.3	2.08	6.58	6.63	93-108
L. Upper molar length	N	12		86.0	1.17	4.07	4.73	79-94
	S	10	*	91.2	0.95	3.01	3.30	88-96
M. Lower molar length	N	8		87.6	1.66	4.69	5.35	80-95
	S	9	*	92.8	1.38	4.13	4.45	87-100
N. Prealveolar length	N	6		83.7	1.02	2.50	2.99	79-86
	S	9		85.3	1.16	3.50	4.10	80-93
O. Postdental length	N	10		92.8	1.50	4.76	5.12	87-102
	S	10		90.8	2.35	7.45	8.21	84-102
P. Basioccipital width	N	12		32.6	0.50	1.73	5.31	30-36
	S	10		34.0	0.71	2.26	6.65	29-37
Q. Premaxilla width	N	6		34.6	0.87	1.95	5.64	32-40
	S	9		35.1	0.76	2.24	6.78	32-38

*n- sample size
$\bar{X}$- mean
SE$\bar{X}$- standard error of mean
SD- standard devoation
CV- coefficient of variation
R- range
*- $p < 0.05$

Table 4. Rostral and cranial measurements and brain case volume of bighorn rams, 5 years and older from northern (N) and southern (S) Alberta.

Measurement	Pop.	^{x}n	$\overline{X}$	SE$\overline{X}$	SD	CV	R
W. Basisphenoid-crown height	N	12	132.9	1.14	3.96	2.98	172-141
	S	10	*142.1	3.04	9.63	6.78	125-156
X. Occiput-frontal length	N	12	150.6	1.09	3.80	2.52	144-155
	S	10	*157.0	2.73	8.65	5.51	147-171
Y. Rostral depth	N	12	80.1	0.96	3.34	4.17	75-86
	A	10	82.5	1.14	3.60	4.36	78-88
Z. Naso-cranial length	N	10	228.0	1.62	5.12	2.24	220-235
	S	10	*239.6	4.21	13.31	5.55	226-265
AA. Supraorbital width	N	12	156.3	1.00	3.47	2.22	152-162
	S	10	159.3	2.91	9.19	5.77	149-180
BB. Occiput width	N	12	67.6	0.95	3.29	4.86	63-74
	S	10	67.5	1.51	4.76	7.06	62-78
Brain case volume	N	14	223.2	3.04	11.37	5.09	205-240
	S	10	*234.5	4.18	13.22	5.63	210-250

^{x}n- sample size
$\overline{X}$- mean
SE$\overline{X}$- standard error of mean
SD- standard deviation
CV- coefficient of variation
R- range
*- $p<0.05$

3. Ewe Horns

The horn base circumference of southern ewes is notably larger than northern ewes, however, the difference is not significant at $P<0.05$ (Table 5). The annual increment length of southern ewes is longer in the first year ($P<0.05$) and shorter ($P<0.05$) in the third year compared to northern ewes (Table 6). This initial rapid growth followed by a reversal and *vice versa* has been noted by Shackleton (1973) in high and low quality ewe populations from Kootenay National Park and Banff National Park respectively.

4. Ram Horns

Horn bases of southern rams are larger ($p<0.05$) than northern rams (Table 5) as previously noted by Wishart (1969). Annual increment lengths are longer ($p<0.05$) in southern rams during the first four years (Table 7). However, a significant reversal in increment length compared to the northern rams occurs during the sixth and seventh years. This increment growth phenomenon between high and low quality populations in bighorn rams has also been noted by Taylor (1962), Geist (1971) and Shackleton (1973).

Table 5. Horn base circumferences of ewe and ram horns 5 years and older from northern (N) and southern (S) Alberta.

Ewes	Pop.	[x]n	$\overline{X}$	SE$\overline{X}$	SD	CV	R
Left horn	N	25	129.8	1.79	8.95	6.90	113-145
	S	21	134.8	2.23	10.25	7.60	116-153
Right horn	N	27	129.2	2.03	10.57	8.18	108-146
	S	19	133.3	2.18	9.53	7.15	115-151
Rams							
Left horn	N	15	365.3	3.44	13.32	3.65	345-400
	S	11	*386.4	7.32	24.28	6.28	349-431
Right horn	N	14	365.5	2.94	10.99	3.01	345-390
	S	11	*386.2	6.80	22.55	5.84	354-430

[x]Symbols as in previous tables.

Table 6. Mean lengths of the first three annual increments of ewe horns (left and right sides) from northern (N) and southern (S) Alberta.

Increment	Pop.	[x]n	$\overline{X}$	SE$\overline{X}$	SD	CV	R
1	N	57	46.1	2.24	16.91	36.68	20-80
	S	30	*61.2	2.28	12.51	20.44	33-87
2	N	72	101.7	2.00	16.96	16.67	60-133
	S	34	103.4	3.11	18.11	17.52	74-143
3	N	81	61.7	1.28	11.50	18.64	28-86
	S	34	*51.5	2.74	15.96	31.00	30-75

[x] Symbols as in previous tables.

Table 7. Mean lengths of the first eight annual increments of ram horns (left and right sides) from northern (N) and southern (S) Alberta.

Age	Pop.	[x]n	$\overline{X}$	SE$\overline{X}$	SD	CV	R
1	N	36	82.2	4.84	20.53	24.99	50-130
	S	42	*105.9	5.37	24.62	23.23	57-150
2	N	60	185.5	5.23	40.49	21.83	90-274
	S	49	*206.5	5.24	36.71	17.78	130-295
3	N	68	176.8	2.52	20.80	11.78	133-213
	S	50	*187.1	3.11	21.97	11.74	145-246
4	N	46	147.0	2.79	18.96	12.90	123-196
	S	32	*156.5	2.89	16.35	10.44	136-188
5	N	29	119.7	3.11	16.75	14.00	91-163
	S	26	118.7	3.10	15.81	13.32	98-163
6	N	30	99.2	2.71	14.85	14.97	71-121
	S	18	*88.4	4.02	17.05	19.29	71-130
7	N	22	80.3	3.26	15.31	19.11	54-108
	S	12	*64.8	4.89	16.94	26.13	31-87
8	N	19	59.9	4.16	18.16	30.29	28-90
	S	8	50.4	4.32	12.21	24.24	37-67

[x] Symbols as in previous tables.

Table 8. Summary table of skull and horn measurements that show significant difference (*$p<0.05$) between northern (N) and southern (S) Alberta bighorns. S>N unless otherwise noted by (N).

	Ewes	Rams
A. Basilar length	*	n.s. (not significant)
F. Maxillary width	*	n.s.
K. Palatal length	n.s.	*
L. Upper molar length	*	*
M. Lower molar length	*	*
W. Basisphenoid-crown height	*	*
X. Occiput-frontal length	*	*
Y. Rostral depth	*	n.s.
Z. Naso-cranial length	*	*
AA. Supraorbital width	*	n.s
BB. Occiput width	*	n.s
Brain case volume	n.s.	*
Horn base circum.	n.s.	*
Horn increment length		
1	*	*
2	n.s.	*
3	* (N)	*
4	-	*
6	-	* (N)
7	-	* (N)

DISCUSSION

In mountain sheep, population quality has been defined in terms of horn size of rams by various authors (op. cit). This study has shown that in addition to horn size there are a number of skull characters in bighorns that can be used to note differences in population quality (Table 8). Skull features that are significantly larger in both sexes of southern Alberta bighorns are the upper and lower molar series, occiput-frontal length, basisphenoid crown height and naso-cranial length. The ewes have five additional skull characters that are significantly larger than the northern group: basilar length, maxillary width, rostral depth, supraorbital width and occiput width. Rams have significantly longer palates; there was no overlap in this measurement between the two population samples. The results of this study are similar to a population quality study of bighorn skulls by Shackleton (1973). He noted that cranial and facial development are correlated with prepartum and postpartum nutrition respectively. Rapid cranial development and delayed facial development are characteristic of most mammalian species. This skull growth sequence has been described by Cowan (1936) in deer (Odocoileus) and by Hutton (1972) in wapiti (Cervus). In this study, several anterior and posterior measurements of the skull were found to be larger in southern Alberta bighorns. Five of these measurements are significantly larger and common to both sexes (Table 8) and they provide a better measure of population quality than brain case volume which differed only in rams.

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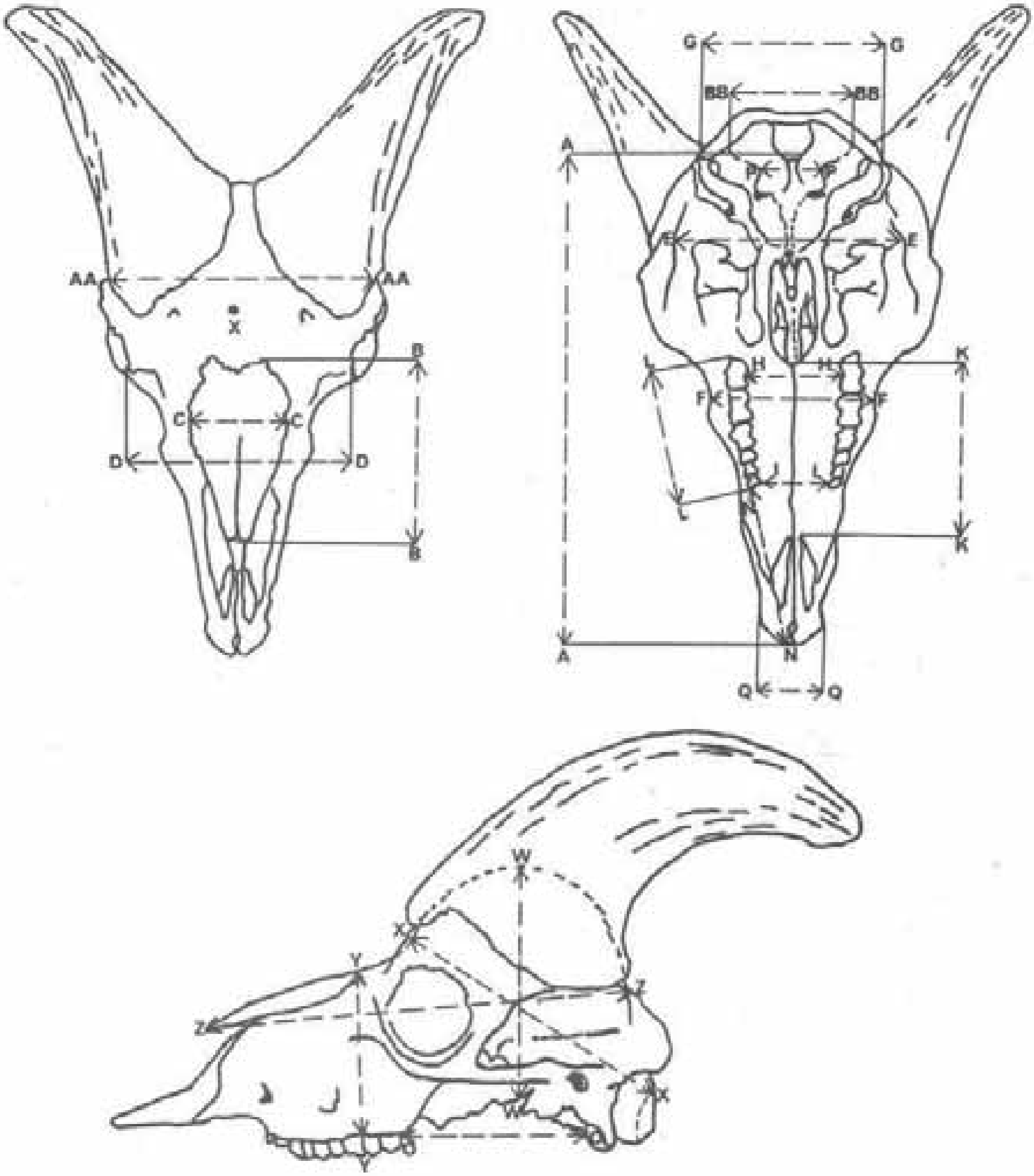

Figure 1. Reference points for 21 measurements taken of bighorn skulls (after Shackleton 1973).

APPENDIX I

Definition of Skull Measurements from Cowan (1940)

A Basilar length: Greatest distance between inferior lip of foramen magnum and tip of premaxillae on mid-line.

B Greatest length of nasals: Greatest distance from anterior margin to posterior margin of left nasal unless this is broken or otherwise malformed.

C Width of nasals: Greatest combined width of nasals.

D Orbital width: Least distance in straight line taken with calipers resting in notch on orbital rim at lower edge of lachrymal bone.

E Zygomatic width: Greatest distance between external margins of zygomatic arches taken on jugo-squamosal suture.

F Maxillary width: Least distance across rostrum behind maxillary protuberances.

G Mastoid width: Greatest distance across occiput with calipers resting on external (lateral) surfaces of paroccipital processes.

H Palatal breadth at M^3: Greatest distance across palate with calipers resting in re-entrant notch on lingual side of M^3.

I Palatal breadth at Pm^2: Least distance across palate between alveoli of first premolar.

J Post-palatal width: Least palatal width posterior to third upper molars.

K Palatal length: Least distance from posterior margin of anterior palatine foramen to posterior margin of palate.

L Upper molar series or upper tooth row: Greatest alveolar length of combined upper molars and premolars.

M Lower molar series: Greatest alveolar length of combined lower molars and premolars.

N Prealvolar length: Least distance between alveolus of second upper premolar (first tooth of upper series) and gnathion.

O Post dental length: Least distance between alveolus of third upper molar and anterior margin of paroccipital process on same side.

P Width of basioccipital: Least width of this element between foramina ovale.

Q Width of premaxillae: Greatest width of combined premaxillae opposite anterior end of anterior palatine foramina.

Definition of Rostral Cranial Measurements from Schackleton (1973)

(W) Basisphenoid - crown height: Greatest distance between the highest point of the crown between the horn cores, and the point on the basisphenoid near its junciton with the presphenoid.

(X) Occiput - frontal length: Least distance between the superior lip of the foramen magnum and the center of the frontals in line with the two frontal foramina.

(Y) Rostral depth: Vertical distance between the point on the midline of the palatines, opposite to the junction of the second and third upper molars, and the mid-point of the nasal suture.

(Z) Naso - cranial length: Least distance between the midline of the anterior end of the nasals and the depression of the parieta parietals in adult males or to the parietal crest in females and juveniles.

(AA)Supraorbital width: The least width, superior to the orbits but inferior to the lip of the horn cores, across the cranium.

(BB)Occiput width: Greatest width across the occipital condyles at right angles to the longitudianl axis of the skull.

CONFERENCE DISCUSSION

Q. Do they have big horns because they have big brains or big brains because they have big horns?

ANS. It appears that big brains and big horns in rams are synonymous, they need that large brain area or cranial area to support large horns, so it follows that the brain capacity would also approach a large size.

Q. I liked your paper but can you really assure us that those differences are not genetic?

ANS. I guess what I would like to do to show that the differences are not entirely genetic is to bring northern bighorns down to the south as lambs and watch them grow. Actually, there is already that sort of evidence from captive flocks: for example, at the University of British Columbia and the Penticton Game Farm they brought in sheep from various parts of Alberta and B.C. and generally they all grew large on an *ad libitum* diet. However, there are enough individual differences in the species that some animals will respond differently to an unlimited forage supply. I tried to demonstrate that the growth rates, i.e., the chance to grow was much better in the chinook belt of southern Alberta. If you trap an animal down there in February or March you will find a 2-3 year old ram will have 2 to 3 inches in new horn growth. I can't believe that a northern ram under those circumstances wouldn't also have a 2 to 3 inch jump in horn growth vs. putting a southern ram up north, into a longer, colder winter in an alpine situation.

Q. I don't know if anybody has looked at this, and Ken, you may know that in Colorado we have a similar situation only it's tied to elevation. We have probably a dozen rams that could be found within a couple of days with horns better than full curl pushing 40 inches in low elevation herds around the states and the herds that tend to range above timberline in the alpine areas tend to have horns significantly shorter. In a similar situation relative to the amounts of growth at different times, the hypothesis which has been raised a number of times is that the lower elevation rams are growing horns for 2 to 3 to 4 months longer a year than are the rams at the higher elevation. Very commonly in some of the sheep areas in the southwest where rams from the high mountain areas and a lower elevation area have to be checked through the same game warden, animals of the same age will have 3 to 5 inches difference in horn length and body size differences as much as 30 or 40 or 50 pounds. Does elevation tie into what you are doing at all?

ANS. Elevation is tied in with latitude, right. In this study I have compared lower latitude sheep to higher latitude sheep. Meteorologically we use a 1,000 foot elevation as equivalent to about 150 miles in latitude so it ties in very well. In some situations we grow very large rams that have discovered new low elevation ranges that have been recently logged or burned.

Q. Bill, you have been threatening to transplant your northern and southern bighorns for about 10 years, I just wonder why you haven't done it yet?

ANS. Why haven't I done it? I don't think I have to, but I might have to for this group.

Q. We have been measuring horns for a number of years from the entire Yukon, and we cannot generalize that the horns are poorer in the north. There are populations which are very poor in the north but we also have very good populations in the north. What we did find, though, is that very often in the north the growth was delayed and very often the third increment was largest when in the south it was almost always the second increment.

ANS. That is similar to the growth-increment phenomenon between high-and low-quality populations in bighorns.

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HORN GROWTH AND HORN WEAR IN DALL RAMS
AND THEIR RELEVANCE TO MANAGEMENT

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ABSTRACT

Investigations were carried out on captive dall rams and trophies submitted by hunters to determine the annual growth period of horns and the wear rates of horn tips.

Horns begin to grow in lambs during the second week in July at an average age of ten weeks. Growth in the lamb year continues to late December, and by the end of January the second horn increment begins to develop. Likely, there is no complete stoppage of growth between the first and second periods, only a slowing down to an immeasurable amount. By the first birthday of the rams, already 20 to 25 percent of the second increment is completed. In the seocnd year, horn growth continues to the latter half of November. As rams age, horn growth periods shorten and dormant periods become correspondingly longer. In mature rams, 5 to 6 years of age and older, growth and dormancy are each about six months in duration. At the beginning of the hunting season in the Yukon, August 1, about 75 to 80 percent of the current years growth is completed, after October 1, no further growth occurs.

There is a gradual wearing down of the horn tips, or the first year's horn increment, with age. This gradual wear at the horn tip is correlated with age and is independent of so-called "brooming", in which part of the horn breaks off during fighting. In the southern Yukon, horn growth during the lamb year is about 100 to 120 mm, and by the age of 10 years, only 40 mm of the lamb growth remains. At the age of eight rate of horn wear at the tips exceeds growth put on at the horn base, and no further increase in horn length can be expected in the average ram.

METHODS AND MATERIALS

Dall rams kept at the Yukon Game Farm at Whitehorse were inspected at about monthly intervals for a four-year period and subsequently twice a year until the last ram of this initial captive band died at the age of ten in 1979. These periodic inspections included measurements of the rams' horns to determine growth periods and growth rates in length and circumference and wear rates of the horn tips. This experiment started in 1969, when the rams were caught as day-old lambs in Kluane National Park.

Concurrently, the Yukon Wildlife Branch began to inspect the horns of hunter killed rams in 1973. During the first few years submissions of trophies were voluntary, and the measurements taken were those necessary to compute scores according to the Boone and Crocket formula. Submission of trophies has been compulsory since 1976, and the types of measurements taken have become more elaborate, particularly during the past two years. Measurements used in this analysis are of rams from the southwestern Yukon, where inspections began in 1973 and a fairly large, representative sample size is available.

In this paper, we will confine our discussion to two aspects of horn growth dynamics: firstly, the periods of horn gowth and secondly, the wear rates of horn tips. Both have management implications, particularly in respect to aging accuracy. Horn growth rates, which are influenced by heredity, nutrition and other factors, will be addressed in another publication.

To determine "percent of current horn growth completed" for rams shot by hunters, the current horn growth increments of the respective rams were compared to the mean completed increment length for that population.

RESULTS AND DISCUSSION

HORN GROWTH PERIODS

Based on observations of up to six captive rams and four ewes, the following summary can be made: Horn growth started in both male and female lambs when they were about 10 weeks old. The mean date of birth of these captive lambs was May 2nd; the first measurable growth was noticed on July 12th, on the average. Growth was slow in the first few weeks, but proceeded rapidly through the months of August to November. In the latter part of November and early December, growth slowed down considerably. The mean growth period during this first year was six months ± 13 days. Because the lambs could only be captured and inspected every three to four weeks during winter, it was not possible to determine exactly at what date growth ceased and new growth for the second increment began. It appeared that there was no measurable growth from late December to late January.

In some short-yearlings, growth was initiated during the last week in January, and by February 20th, new growth amounted to 5 percent of the second increment. Growth proceeded slowly until late March, but it accelerated during April. By May 2nd, when these sheep reached their first birthday, the mean growth accomplished amounted to 22 percent of the 2nd increment. Growth proceeded at a more or less steady rate to November 1st when 94 percent of the second increment was completed. After November 25th, very little further growth was observed. The second growth period was 10 months ± 12 days, and is the longest, and the mean rate of horn growth, 34.2 mm/month, was the greatest. After the second growth period, there was a cessation of growth for about three months. The third period was initiated in mid February, and the growth rate was relatively faster than during the second year, with 28 percent of the third increment put on by May 1st when the rams reached their 2nd birthday. By September 22nd, 95 percent of the annual growth was completed, and after November 6th, no further growth was observed. The dormant period increased, being about 4 months after the 3rd growth season. Again, in the latter part of February, horn growth was initiated for the fourth year, and by May 1st, 30 percent of the fourth increment had been accomplished. By September 5th, 94 percent of the annual growth was completed, and after October 5th, no further growth was observed. The growth rates for these four periods are shown in Figure 1; for comparative purposes they are expressed as "Percent of annual growth completed", rather than in absolute amounts. The relevant statistics which include annual growth increments as measured at the end of the respective years, horn growth periods, and absolute growth rates expressed as mm/month, are given in Table 1.

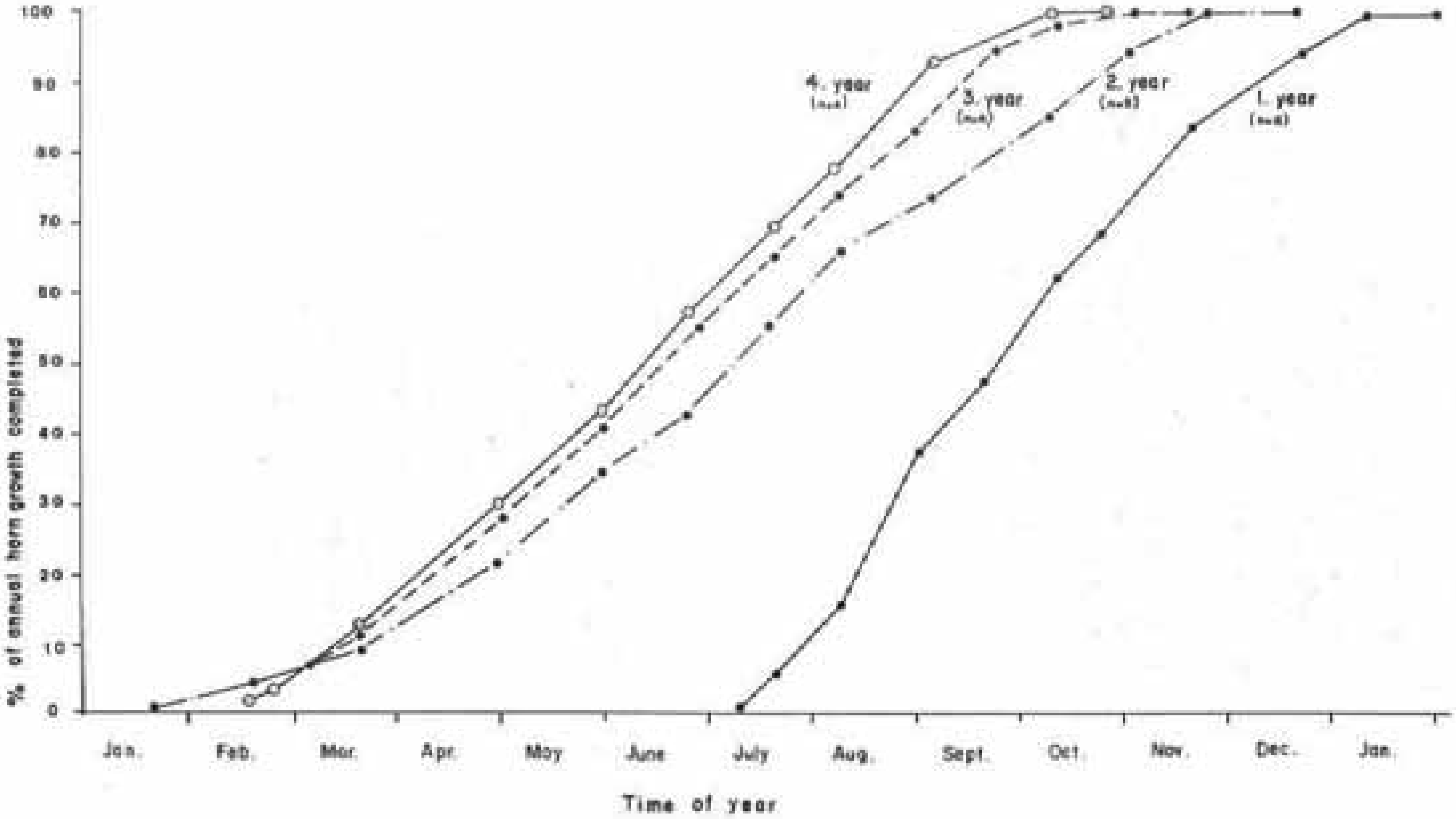
Table 1. Statistics on Horn Growth of Captive Dall Rams

Year	n	Increment in mm ($\bar{x}$)	Horn Growth Period	Absolute horn growth rate in mm/month ($\bar{x}$)
1.	6	145	6 months ± 13 days	24.2 mm/month
2.	5	342	10 months ± 12 days	34.2 mm/month
3.	4	205	9 months ± 15 days	22.8 mm/month
4.	4	133	8 months ± 15 days	16.7 mm/month

After the fourth year this experiment could not be continued with the previous regularity; however, periodic assessments were carried out two to three times per year until the last ram died at the age of 10.

From these assessments, from inspections of many hundreds of hunter-killed rams shot in the period of August 1st to October 31st, and from measurements of 117 winter-killed rams in Kluane National Park we have concluded that horn growth periods continue to shorten with increasing age of rams and the winter dormancy periods become correspondingly prolonged. However, beyond the age of 5 to 6 years, these changes are not significant anymore. Mature rams initiate horn growth in early April and practically all growth has ceased by October 1st. The growth period and dormancy period in these older age classes are, therefore, both about six months in duration.

Fig. 1 Horn growth periods of captive Dall rams.



Trends observed in growth period lengths of captive and wild rams were comparable, which supports conclusions of other investigators (Hansen and Denning 1980, Bendova 1979, Türcke and Schmincke 1965, Schmincke 1958, and Taylor 1962) that this period is determined by photoperiodicity and sex hormones and not by quality of forage. Little work has been done on this topic, but the following few citations from the literature essentially support our observations. Hemming (1969), after inspecting 129 skulls of dall sheep, most of which were shot by Eskimos in the Anaktuvak Pass area of Alaska's Brooks Range, writes, "Little, if any, growth was taking place in the horns of animals killed from October through January. In a sample of 18 sheep killed in February, the horns of one had a new annual ring. By May, new growth was evident in all horns. Growth appeared to be most rapid during early summer, and by the end of September, had essentially ceased".

Hansen and Deming (1980) wrote, "Each year during the rutting period in the fall, horn growth subsides for several months, but resumes again, usually in January". "Bighorns raised in pens had good feed in front of them all year long. These artificially fed bighorns also formed horn rings and went through the same sequence of growth". "From this evidence and because horns are secondary sexual characteristics, it appears that periods of horn growth are governed by sex hormones".

Both Goss (1969) and Cowan (1940) also related the cessation of horn growth in the fall to the rutting season and, thus, to hormone influence. The influence of sex hormones on horn growth is obvious in two bighorn rams, used as experimental animals for food selection studies by the Colorado Division of Wildlife, which were castrated at six weeks of age. While the first growth increment developed normally, the second and third were greatly reduced, and after the third growing period, horn growth stopped completely. The horns of these rams, now about five years old, have the appearance of horns from yearling rams, (T. Hobbs, personal communication). Hoefs (1982) documented hormonal influence on horn growth of mufflon rams.

The age at which the horns first appeared on lambs differed by as much as 10 days in this captive population, and may differ with locality. Hemming (1969) wrote, "I found that the horns of Dall sheep begin to develop when lambs are about 4 months old".

Wells and Wells (1961) reported the appearance of horns on male lambs of the desert bighorn at three months of age. A male lamb born on Wildhorse Island and placed in captivity is reported to have lost hair from the horn site at one and a half months of age and horn buttons were evident soon afterward (Ogren, 1954).

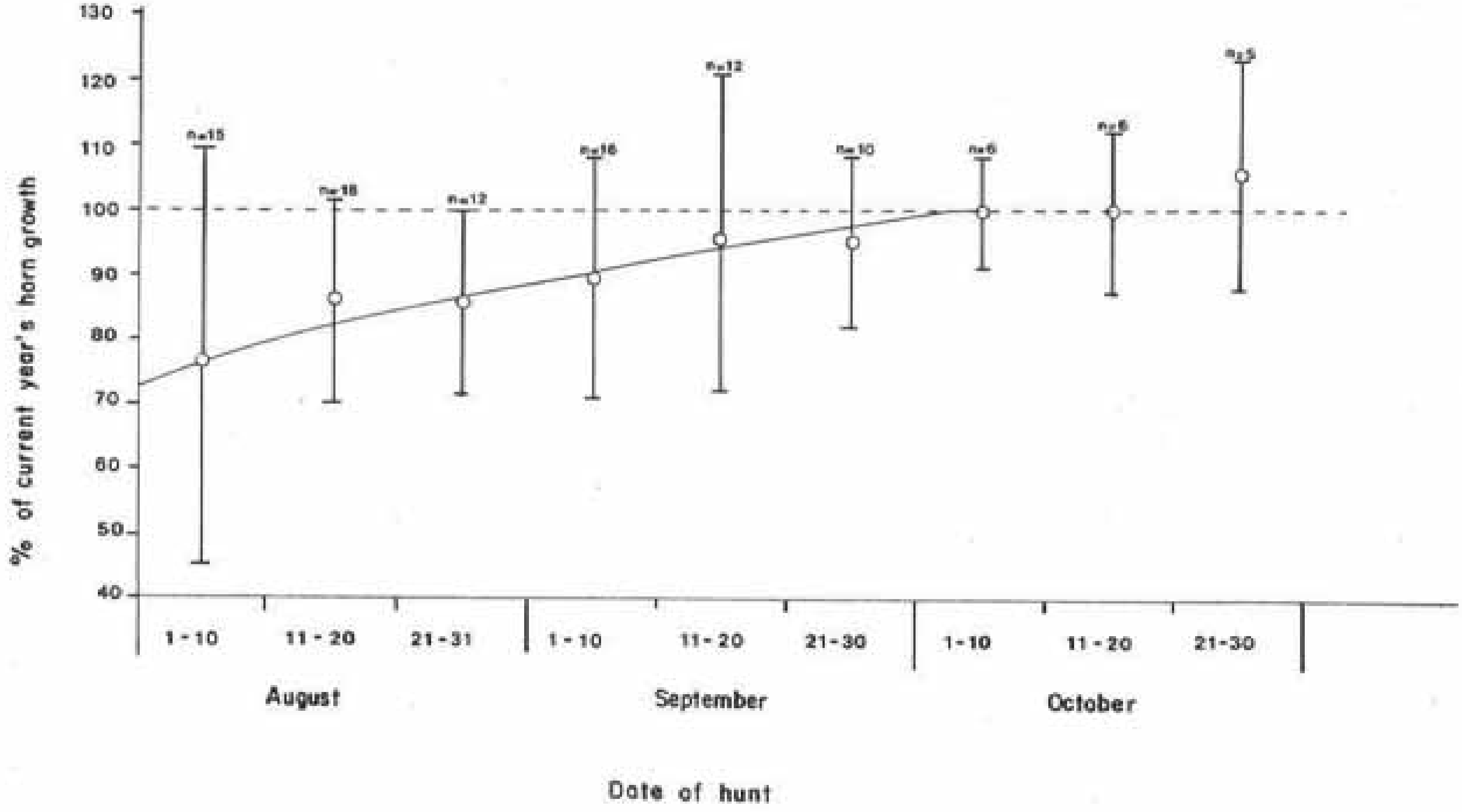
For mature rams, Taylor (1962) reported: "The appearance of new growth was first evident in a ram from the National Bison Range collected on April 17, 1969. This ram was approximately 57 months old, new growth amounted to 3 inches". "A ram collected on May 10, 1939, aged at 71 months, had 9 mm of new blue-grey colored horn". Taylor (1962) also reported that growth had stopped in a 41 month old ram collected October 17th.

Investigations of the European mufflon essentially show a similar trend (Bendova 1979, Turcke and Schmincke 1965, Schmincke 1958). Türcke and Schmincke stated that horn growth in male lambs begins at 3 to 5 months of age, and stops in late December for only one "moonphase". These dormant periods increase with age. Bendova (1979) made similar observations on the mufflon rams of C.S.S.R. She reported that the period of growth stoppage in 1 and 2 year old rams is 6 to 8 weeks; in mature rams, it may be 4 to 5 months.

Some of these observations made on horn growth periodicity have practical relevance: (1) The initiation of horn growth in the lamb year is dictated by the animal's age, while termination of growth is determined by the photoperiod. Since there is considerable variation in lambing dates in the Yukon, from April 18 to June 30th, lambs born late do not have as much time to grow horns than those born early. The variations observed in horn growth during the lamb year, which are greater than during any other year, will therefore to a large extent be a reflection of different birth dates, and not necessarily one of range productivity or pupulation quality. The growth during the first year should therefore be omitted if comparisons of horn growth quality are made between different populations. (2) The horn growth period is synchronized with the calendar year more so than with the chronological age of the animal. This factor may lead to errors in age determination by the uninformed. As indicated above, new horn growth begins 3 to 4 months before the animal's birthday and, by its birthday, has already completed 20 to 30 percent of the current year's increment. The age of an animal may at that time be overestimated by one year. (3) It is difficult to determine the boundary between the first and second year's horn growth increments because the distinct growth ring or annulus, which is formed at later ages, does not form between the first and second year. This can lead to underestimation of a ram's age. While observations on horn growth periodicity will not help overcome this problem, they do point to an explanation. There is a strong possibility that horn growth during the lamb's first winter does not stop completely. Rather it slows to a rate not measurable by conventional field techniques. Therefore, no typical annulus is formed. This assumption is shared by Bendova (1979), who measured horn growth rates of mufflon rams.

Horn growth, even in old rams, continues to the latter part of September and this has relevance to the timing of the hunting season. In the Yukon the sheep hunting season extends from August 1st to October 31st; in the N.W.T. it begins on July 15th. By July 15th only 70 to 75 percent and by August 1st 75 to 80 percent of the current year's horn growth is completed. We have shown this relationship in Figure 2 for 100 rams shot in the southwest Yukon during 1980 and 1981. Percentage current year's horn growth completed is plotted against the date at which the ram was shot. These data show the same trend as observed in captive rams. In early August about 75 percent of the current horn growth is completed; after October 1st no significant growth was documented. The practical relevance is that a delay in the hunt from early August to the latter part

Fig. 2 Completion of current year's horn growth in relation to hunting season.



of September in the southwestern Yukon would add about 20 mm in horn length to a 6 year old ram and about 15 mm to an 8 year old. For outfitters in remote areas, with no competition from resident hunters, this may be a factor worthwhile to consider in planning their hunts.

WEAR OF HORN TIPS

Two factors contribute to reduction in horn length: (1) Breakage of part of the horn, usually as a result of fighting or accidents (Shackleton and Hutton, 1971), leaving behind so-called "broomed" ends; and (2) gradual wearing off of horn tips as a result of a ram rubbing his hide, supporting himself when bedded down, or scraping the horn tips against rocks or vegetation. This gradual wear occurs in all rams, while brooming is much rarer in Dall than in Bighorn rams. Of 319 horns inspected by the Yukon Wildlife Branch after the 1981 hunting season, only 24 percent showed brooming; and in only 8 percent of the skulls submitted, was brooming evident on both sides. Brooming usually affected more than only the first year's horn increment.

Two methods were applied to document this wear rate of the horn tip and its correlation with age. Two captive rams already referred to reached ages of 9 and 10 years respectively. Both had one broomed horn and one which was not broomed. Lengths of the first growth increment-the so-called lamb tip-measured at the end of each growing season, are shown in Figure 3. In December of their first year these rams had horns of 152 mm and 140 mm respectively. One ram, "Pat", died at the age of 9, at which time only 48 mm of the lamb growth remained; the other ram "Mike" lived to be 10 years, at which time his lamb growth was hardly noticeable and amounted to about 4 mm. Both lamb tips showed a continuous reduction with years, but the annual wear rates varied considerably between these two rams.

The second method consisted of the inspection of hunter-killed rams. For this analysis, 502 horns of rams taken in the southwestern Yukon since 1973 could be used. In Figure 4, the lengths of the first horn growth increments are plotted against age of the rams. No rams were avilable younger than five years, since 3/4 curl horn growth in these populations is reached in the 6th growing season. The correlation appears to be linear, and extrapolation to the first year reveals that horn growth in the lamb year will be about 100 mm. Most rams were shot in the 9 to 10 year age class, at which time the remaining lamb tip averaged 40 mm in length, 5 rams 14 and 15 years of age had no lamb tips left.

Hemming (1969) made similar observations in Alaskan Dall Sheep. He wrote, "The horn tips of Dall sheep are rarely broomed, but they may show considerable wear on animals more than 5 years old. In some cases, the first year's growth may be almost completely worn away, but the first annual ring was not visible in only 13 of 47 specimens in the 5 to 17 year age classes".

Fig. 3 Wear of lamb horn growth with age in two captive Dall rams

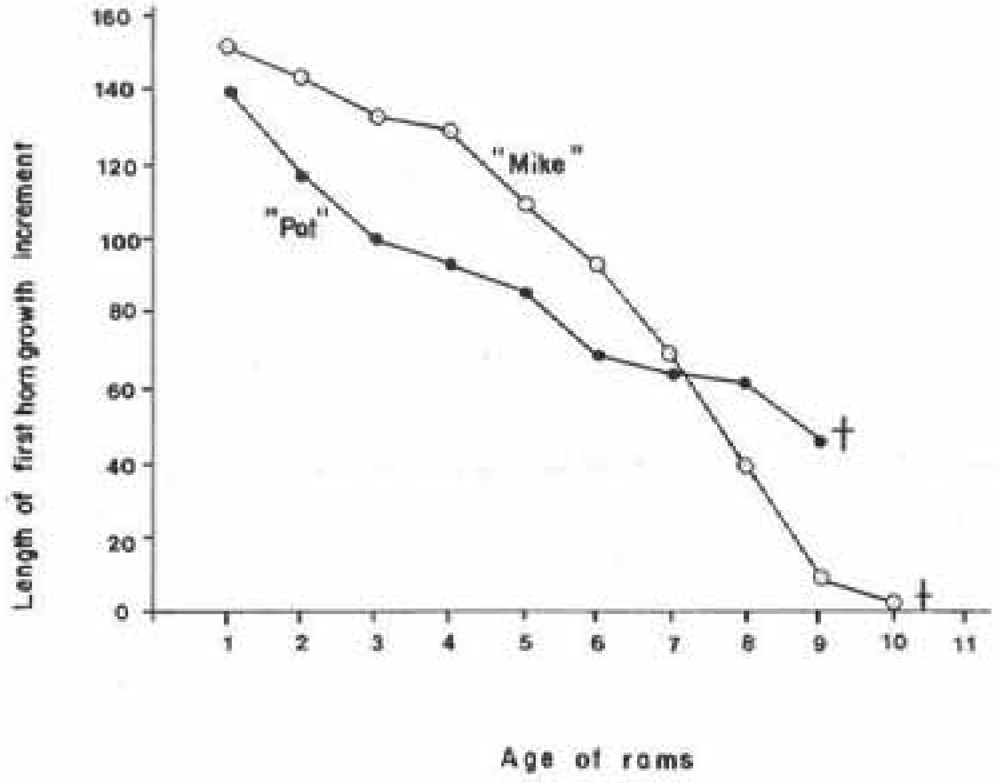
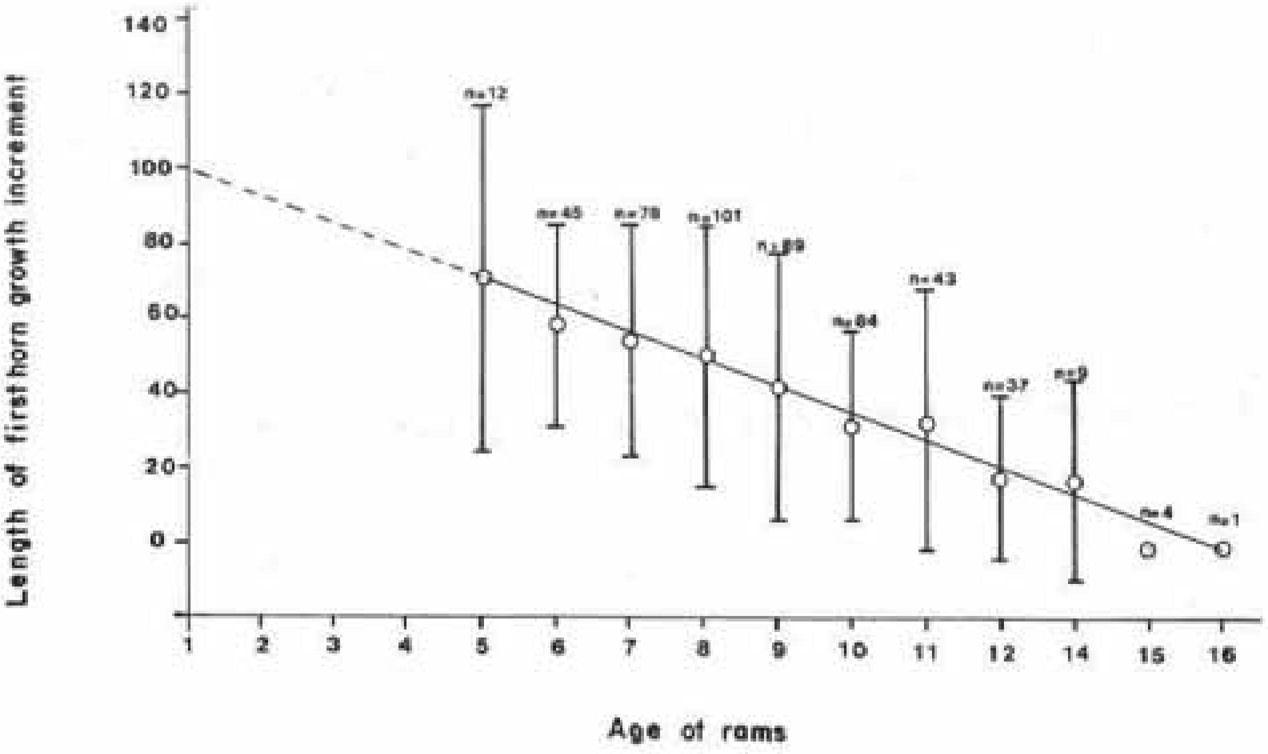


Fig. 4 Wear of lamb horn growth with age of hunter - killed rams



This wearing down of the horn tip has management implications:
(1). It may result in an underestimation of the ram's age by one year. Our experience in the Yukon has shown, that this problem is particularly important in old rams, in which very little of the lamb horn growth remains. Horn wear reduces not only the length of the lamb growth, but it also polishes the horn's surface, making it even more difficult to detect the interphase between the first and second growth increments. Inexperienced trophy evaluators are inclined to demonstrate the existence of a first annulus, and if such is not obvious, the second annulus is mistaken for it, leading to an underestimation of the ram's age.

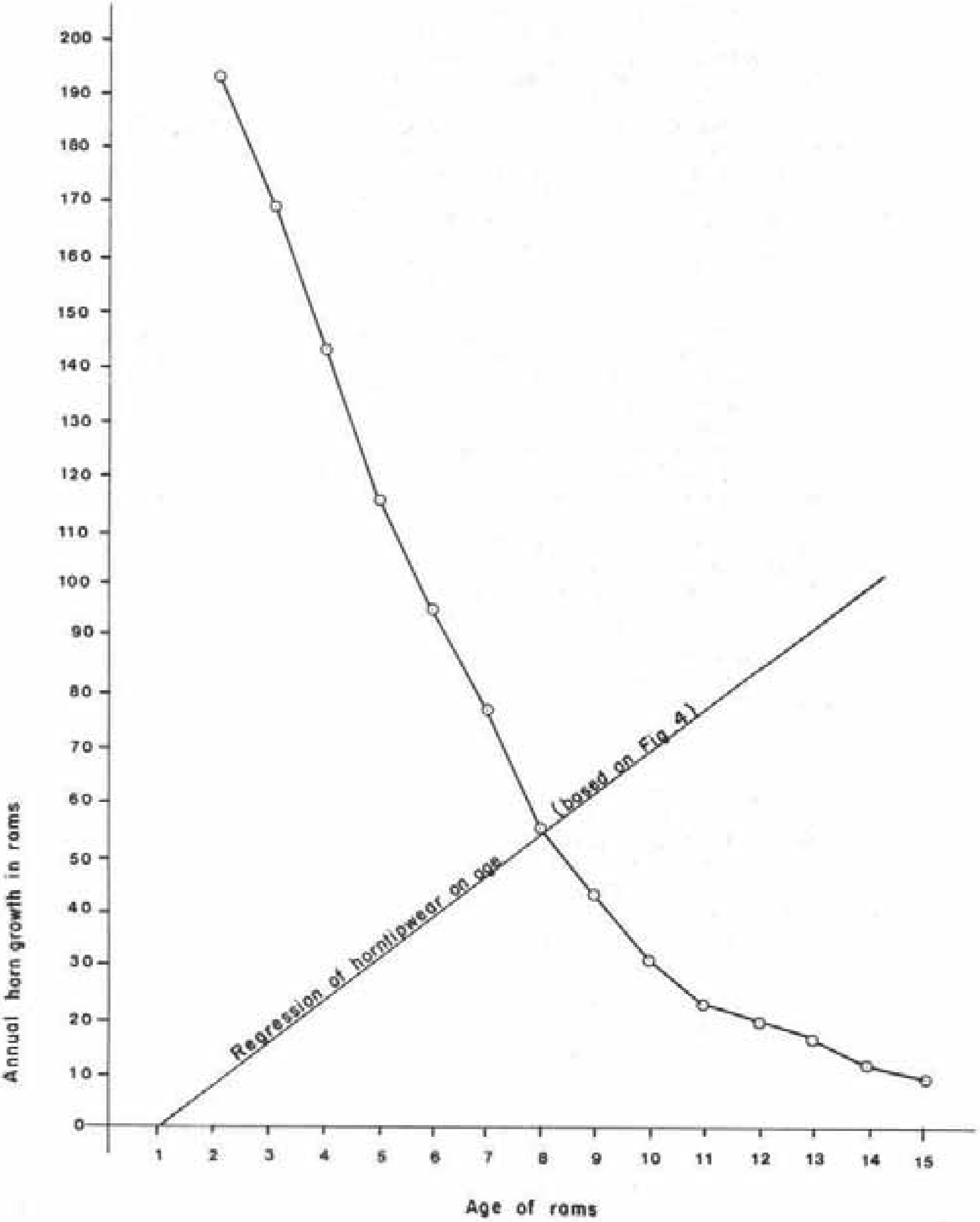
(2). This horn tip wear affects trophy quality because horn length is used in computing scores according to Boone and Crocket standards. In Figure 5, we have shown the mean horn growth rate per year for rams in the southwestern Yukon and we have superimposed on this horn growth curve the regression line of horn tip wear on age obtained from Figure 4. This wear rate exceeds new growth put on at the base of the horns after the 8th year. The implications are, that in intensely hunted populations, where all legal rams are removed annualy, no improvement of horn length with age should be expected on the average if rams live longer than 9 years. In many remote Dall sheep populations in the Yukon and the N.W.T. hunting pressure is less severe and only 50 to 70 percent of the legal rams are removed annually. Under these circumstances hunters can still select the best trophies, those rams with above average horn growth rates and below average horn tip wear, in which an increase in horn length could still occur into the 10th and 11th years.

Interesting is the observation that this age of 8 was also observed in the European mufflon sheep, a species with otherwise different horn morphology and growth dynamics, to be the point at which horn tip wear begins to exceed new growth, (Hoefs 1982, Hromas 1979).

ACKNOWLEDGEMENTS

We are grateful to Mr. D. Nowlan, owner of the Yukon Game Farm, for being able to undertake these studies on his captive Dall sheep. Financial support for these analyses was provided by the North American Foundation for Wild Sheep and by the Yukon Wildlife Branch. Many individuals assisted with the capturing of sheep for inspections and with the evaluations of trophies submitted by hunters. To all those individuals and agencies we express our most sincere gratitude.

Fig. 5 Horn growth rates of Dall rams in S.W. Yukon



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CONFERENCE DISCUSSION

Q. Manfred, when did you say you were going to commence seasons, in order to allow more growth? Was it the end of September?

ANS. I didn't make any recommendation. I just said, if the hunting would be delayed from early August until the end of September, you could improve the length of the horn of a ram by about 20 mm if the was 6 years old, and by about 10 to 15 mm if he was 8 years old. The relevance is in regard to restricted areas, where we have permit hunts, allowing only a certain number of rams to be shot annually. It is also relevant to an outfitter who hunts a remote area without competition from resident hunters. If he can take 4 rams for instance, the delaying of the hunt would make such difference in their horn sizes.

Q. What is the weather like toward the end of September? I get the impressson that it's not very nice up there by then.

ANS. It depends. In southern Yukon, it's still O.K. In October you will run into trouble.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:157-162

A SIMPLE MEASURING DEVICE FOR SHEEP HORNS

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ABSTRACT

A simple measuring device as described, is used by the Yukon Wildlife Division to evaluate the trophies of sheep. The device has allowed a standardization of trophy assessments and has thereby helped to overcome legal problems with the definition of "full-curl" rules.

INTRODUCTION

Since initiation of regulated sheep hunting in the Yukon early this century, there have been repeated changes in the definition of "legal" sheep. Often those changes were not based on biological rationale, but were precipitated through legal disputes. Biologists, enforcement officers, hunters and the courts have interpreted definitions of "legal" sheep differently, and a given trophy was sometimes considered "legal" by the hunter, who shot it, but "illegal" by Government enforcement officers. For those reasons, charges have been dismissed by the courts, and "so-called" offenders of game laws were not prosecuted.

Most jurisdictions in North America, which allow the hunting of wild sheep, use morphological parameters of the horns in the definition of "legal ram". Often the term "degree curl" is applied, which means that the horns of a ram have to circumscribe an angle of 270°, if the law states that "3/4 curl" rams are legal; or where "full-curl" is the rule, jurisdiction may accept rams with horns circumscribing angles of 315° or 360°.

In the Yukon a "full-curl" rule is in effect for sheep hunting, but the definition of "full-curl" has been changed repeatedly over the years to make it acceptable to hunters, government officials and courts alike.

In the following summary, we describe the present definition of "full-curl" and more specifically we deal with a simple measuring device, which has been developed to demonstrate the "legality" of a trophy ram, in a convenient, standardized manner, according to legal definition.

DEFINITIONS OF "LEGAL RAM"

The Yukon hunting regulations state that only "full-curl" rams can be hunted and define it as follows:

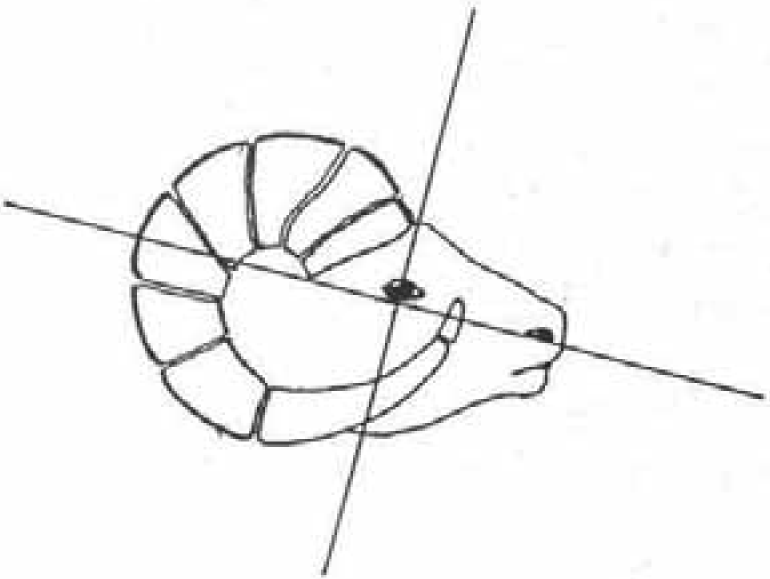
"Full-curl" with respect to mountain sheep means any male that:

(a) has attained the age of 9 years as determined by the horn annuli, or

(b) when viewed from the side with both anterior horn bases in alignment has at least one horn tip extending upwards of a straight line projected through the centre of the nostril and the lower most edge of the eye, or

(c) if the intact head is not presented for examination, when viewed from the side with posterior horn bases in alignmnt, has at least one horn tip extending upwards of a straight line projected through the posterior horn base and a point three centimetres below the highest part of the inside of the eye socket rim:" (Fig. 1).

Fig. 1 "Full-curl" ram as defined in Yukon Hunting Regulations.



Age has been used in addition to morphological features of the skull to allow the hunting of old rams whose horns may not attain "full-curl" requirement because of brooming or extreme flaring of horn tips.

Of the 2 sections (b and c) of this definition using horn and skull morphology, section (b) is referred to as the "field definition", because it is this, which has to be applied during the hunt, while section (c) constitutes a substitute for (b) used for trophy inspections after the hunt, as elaborated below.

Nostrils and eyes are used as reference points in the field definition. It is common practice to skin the sheep after it has been shot and to saw off part of the skull with the horns attached for mounting purposes. Nostrils and eyes are, therefore, often not present when the skulls are submitted for legal inspection. It was therefore necessary to establish additional reference points for the evaluation of trophies.

Measurements on a representative sample of skulls revealed that an imaginary line connecting the center of the nostril with the lower most edge of the eye, if extended, also touches the posterior base of the horn. This therefore, provided an additional reference point, that can be used on a skinned head. In addition, we established through repeated measurements, that the lower most edge of the eye in an unskinned head, corresponds - liberally interpreted - to a point approximately 3 cm below the highest portion of the eye socket in a skinned specimen. The eye sockets are therefore, used in connection with posterior horn bases for assessments of specimens that are submitted in a skinned and capped state, and the device described in the following section, was designed to make use of these anatomical features.

As pointed out, a "liberal" interpretation was used in the assessment of these 2 imaginary lines, giving the benefit of the doubt to the hunter. Anatomical features such as eyes, nostrils and horn bases are "areas" and not fixed reference points, and variations exist among skulls. Under our interpretation a ram that was legal under the field definition, will always be legal using the laboratory inspection method.

DESCRIPTION OF MEASURING JIG

Over the years a number of devices have been used by Yukon wildlife managers to evaluate sheep trophies. They have undergone repeated modifications, and the final version, described here, is easy to use, establishes standardization of measurements, and is accepted by government officials as well as the hunting fraternity. It is being used in all Yukon district offices and interest in its use has been expressed by N.W.T. nd B.C. Wildlife staff. The device will briefly be discussed by means of photographs and a narrative. Readers interested in more detail can obtain a full scale plan on request.

Fig. 2 shows a picture of this sheep horn measuring device and Fig. 3 gives a reduced technical drawing of it. The device is constructed of 3/4" plywood, its external dimensions being about 23" x 13" x 11". The fork-shaped upper plane allows for the insertion of the sheep skull and its exact positioning according to the legal definition (section c) of "full-curl" by means of horn base plates, eye pin assemblies and a skull clamp. "Clamped-in" skulls are shown in Fig. 4 and 5. The following "instruction for use" refers to parts of this device, by means of letters, which are also indicated on the photos for clarification.

1. Remove skull clamp (B) from clamp slide (C).
2. Loosen eye pin assembly (A) and move aside.
3. Place sheep skull in jig with the posterior edges of the horn bases on the horn base plates (D).
4. Slide eye pin assembly (A) back into position so that upper rim of eye socket is resting on the eye socket pin.
5. Replace skull clamp (B) onto slide (C) and lower it down until it hits skull. Tighten clamp (B) while holding skull firmly on horn base plates (D) and eye socket pin assembly (A).

With the skull firmly clamped into position, at least 1 horn tip must extend above the plane created by the measuring arms (E). This plane can be defined by placing a straight edge across the measuring arms (E). Fig. 4 shows a ram skull whose horn tip does not reach the plane created by the measuring arms. It is, therefore, not legal. In Fig. 6 a skull is shown whose horn tip extends above this plane. This is a legal trophy. By modifying the eye pin assembly it is possible to accommodate other legal definitions; i.e. those that use the bridge of the nose as reference point.

DISCUSSION

Application of this sheep horn measuring device has not only helped to overcome legal problems by allowing an accepted standardization of evaluation, it also is useful in the assessment of various horn morphological parameters for biological purposes.

In the Yukon, photographs are taken of all ram skulls submitted, by placing the camera at the same level as the measuring arms of this jig, and taking frontal (Fig. 5) as well as lateral photos (Figs. 4, 6). Prior to taking these pictures the annual rings are marked with chalk, to allow easy detection on the prints. On the prints evaluations can then be conducted of such factors as "angular horns growth" (Fig. 6), extent of horn tip wear, extent of brooming, horn curl diameter and horn spread. These photos constitute a permanent record, while most sheep trophies themselves are exported from the Yukon and available to wildlife officials for only a very short time.

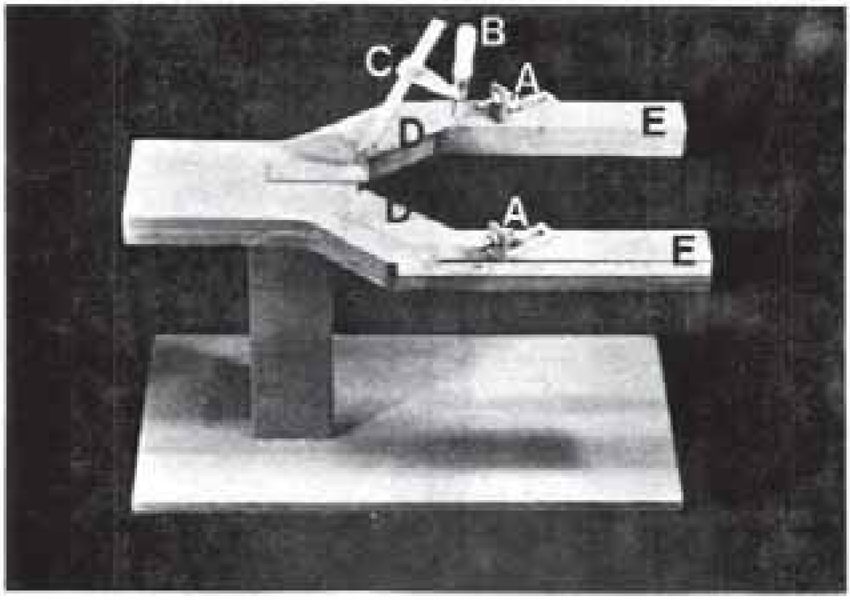


Fig. 2.

Oblique view of sheep horn measuring devise.

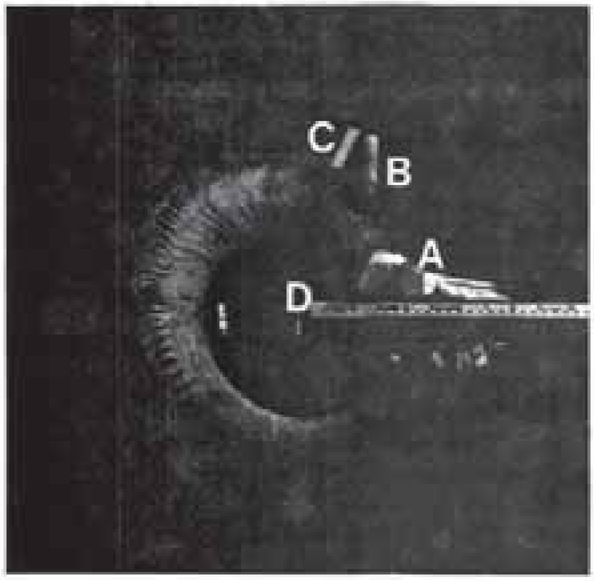


Fig. 4. "Clamped-in" illegal skull of ram (lateral view).

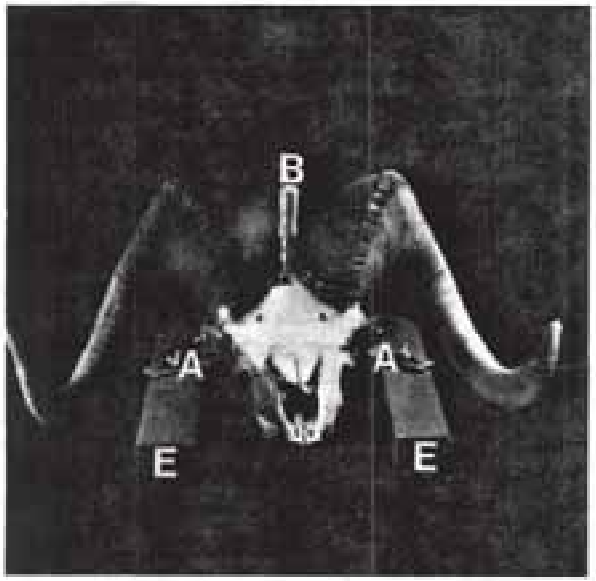


Fig. 5. "Clamped-in" skull (frontal view).

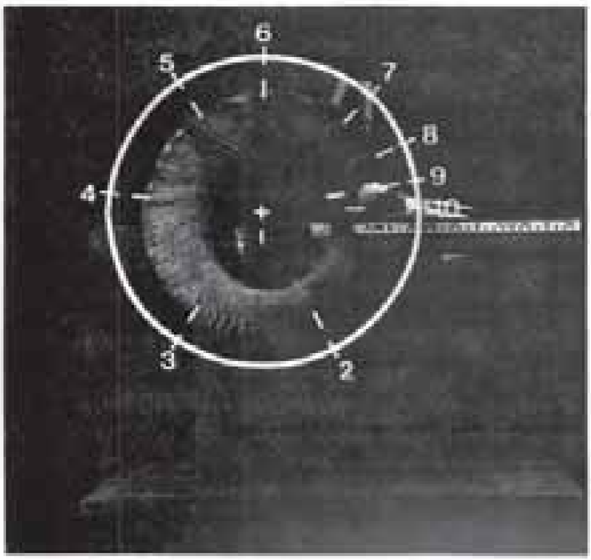


Fig. 6. "Clamped-in" legal skull of ram (lateral view), showing annuli and assessment of "angular" horn growth.

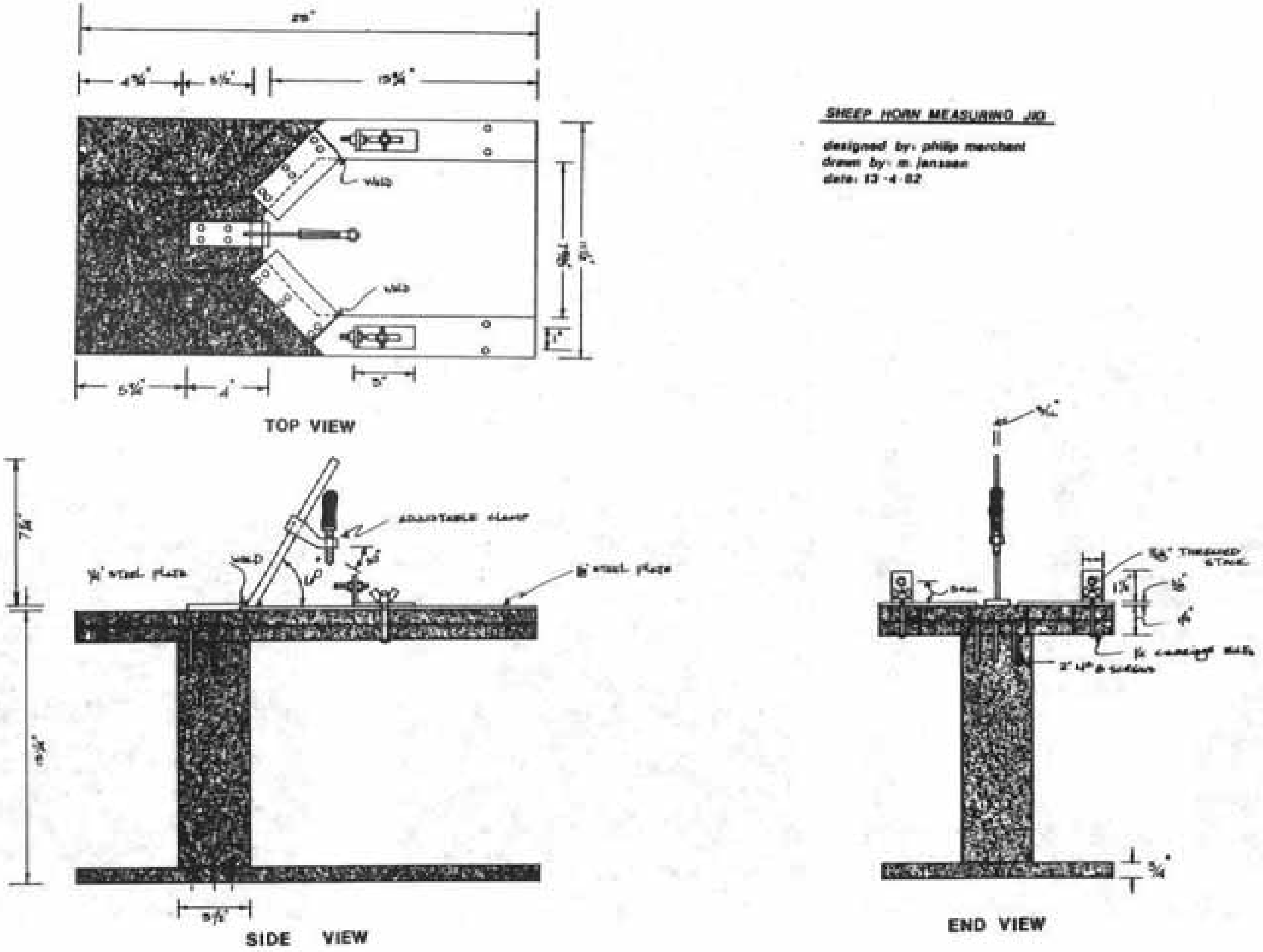


Fig. 3. Sheep Horn Measuring Jig

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3: 163-172

AN OVERVIEW OF THE CLINICAL SIGNS, GROSS AND HISTOLOGICAL LESIONS OF THE PNEUMONIA COMPLEX OF BIGHORN SHEEP

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ABSTRACT

Bronchopneumonia is a commonly diagnosed disease in both captive and free ranging bighorn sheep. Three categories of mortality are recognized in bighorn sheep: the classical all-age die-offs and two types of summer-lamb mortality. The all-age die-offs and the summer-lamb mortality following all-age die-offs appear to be induced by a variety of stress factors where as the verminous types of summer-lamb mortality appears to be induced by transplacental transmission of numerous parasites (Protostrongylus stilesi). Herein is described the clinical features, gross and histological lesions found in these types of bronchopneumonia in bighorn sheep.

INTRODUCTION

Die-offs in bighorn sheep have been documented from the late 1880's to the present. Some of the reasons for the decline in populations have included market hunting (Shields, 1890; Grinnell, 1928; Seton, 1929; Honess, 1942; Packard, 1946; Buechner, 1960), loss of winter range, (Honess, 1942; Packard, 1946;) and diseases (Baillie-Grohman, 1882; Marsh, 1938; Honess, 1942). Some of the specific diseases that have been diagnosed as causing die-offs include mange or scab (Baillie-Groham, 1882; Seton 1929; Bailey, 1936; Wright, 1933; Spencer, 1943; Jones, 1950; Lange, 1980), anthrax (Grinnel, 1904, 1928) and pneumonia (Rush, 1927; Marsh, 1938; Potts, 1937; Honess, 1942; Packard, 1946). At the present time a major cause of mortality in bighorn sheep populations appears to be pneumonia (Beuchner, 1960; Spraker, 1979; Foreyt, 1982).

Currently the authors recognize two different field manifestations of mortality of bighorn sheep. The first is the classical all-age die-off that usually occurs in winter but can occur at any time of the year and has been seen under range conditions as well as in captivity (Rush, 1927; Marsh, 1938; Honess, 1942; De Martini, 1977; Spraker, 1977; Foreyt, 1982). Generally this is a bacterial and/or verminous pneumonia. The second type of mortality is referred to as summer-lamb mortality. This summer-lamb mortality usually occurs in July-September and affects only lambs. There appers to be two different types of summer lamb mortality, one in which lungworm plays a primary role and the other where lungworm does not play a primary role (Spraker, 1979 and unpublished data). This second clinical type of lamb mortality appears to be stress related. The purpose of this overview is to describe these three basic types of pneumonia, hopefully, to help wildlife biologists better evaluate the causes of mortality in bighorn sheep herds.

SUMMER-LAMB MORTALITY

Mortality of lambs during the summer months was first noted by Norton in 1933 in the National Bison Range of western Montana and two of these lambs were examined at necropsy by Marsh (1938). Others have also observed a summer lamb mortality in which pneumonia was the cause of death (Honess, 1942; Packard, 1946; Honess, 1955; Buechner, 1960, Woodward, 1970). Research into the summer lamb mortality has shown two clinical types of pneumonia: verminous pneumonia and a stress related pneumonia which follows a previous all-age die-off (Spraker, 1977, 1979, unpublished data).

VERMINOUS TYPE

Verminous pneumonia of bighorn lambs is usually first observed in late July or early August and occurs in lambs 1 to 5 months of age. The clinical signs in these lambs include weight loss, loss of luster of their hair coat which progresses to a dull yellow, violent paroxysmal coughing, and lagging behind in the herd. Some of the lambs fail to shed their lamb pelage, whereas other lambs do shed this rough lamb pelage and have a fairly slick appearing hair coat when they die.

Gross pathological changes are found in the integumentary, cardiovascular, respiratory and lymphopoietic systems. Lambs 6 to 8 weeks of age have a subtle loss of sheen of their hair coat, which becomes more apparent in older lambs. Lambs 8 to 12 weeks of age usually have a dull, yellow, rough, hair coat. Some lambs with pneumonia shed this rough, yellow, pelage and die with a fairly normal appearing pelage. Some lambs are in good condition with an abundance of abdominal and subcutaneous fat, but most lambs are in poor condition when they die.

The mucosa of the nasal turbinates and septum, ethymoidal labyrinths, trachea, and main stem and primary bronchi are usually reddened and covered by small amounts of white mucoid exudate. The lungs partially collapse. Several large, gray-white, firm raised nodules (lungworm nodules) are located in the posterior dorsal aspects of both diaphragmatic lobes of the lung. The cut surfaces of these nodules are gray-to-white and have an irregular appearance. The freshly cut edges slightly bulge. Usually a small amount of white, mucoid exudate can be expressed from cut bronchioles within these nodules.

The anteroventral aspects of the lungs are dark red to lavender and firm. The pleura covering the consolidated lobes is thin, most, and shiny in most cases. The entire anteroventral aspect of the lungs in some cases is covered with a thick (2mm) layer of yellow, friable material (fibrin). Adhesions to the diaphragm and the costal pleura are present between these consolidated lobes.

Usually there is a sharp line of demarcation between the consolidated areas and the normal lung. Emphysema near this line of demarcation often can be found. The consolidated areas are actually level with or slightly depressed from the normal lung tissue. The subpleural pulmonary parenchyma and the cut surface are dark red-to lavender and have a "cobble-stone" appearance. This is due to many small cloverleaf-shaped, gray, raised areas surrounded by red, collapsed parenchyma. This "cobblestone" appearnace is subtle in acute cases of pneumonia, but becomes more prominent in chronic cases. A small amount of a white mucoid exudate can be expressed from cut bronchioles in these consolidated areas. Necrosis is uncommonly found in the consolidated areas. Chronic cases can have small (.5cm to 1cm) abscesses in the consolidated, pulmonary parenchyma. Small, fibrous adhesions often occur between the consolidated lungs and the costal pleura in chronic cases. Few lambs have fibrinous adhesions between the pericardial sac and the medial aspects of the lungs (fibrinous pericarditis). Fibrinous epicarditis is found occasinally.

The spleen is normal. The retropharyngeal, hilar, and mediastinal lymph nodes are enlarged and the cut surfaces are wet. The cortical areas of the lymph nodes are hyperplastic. The thymus is of normal mass and extends from the base of the heart to the mid-cervical region.

The histological lesions are predominantly within the respiratory and lymphoid systems. The epithelium of the nasal cavity, trachea, and bronchi usually contain areas of hyperplasia and atrophy. Bronchioles and respiratory bronchioles are usually cuffed by a mild-to-marked number of lymphoid cells and have mild to marked hyperplastic and hypertrophied epthelium. The severity of these lesions usually correlates with chronicity. The lumens of these air passages usually contain exudate and, occasionally, a first-stage, protostrongylid larva. The alveoli usually are partially collapsed and contain a mixture of macrophages and neutrophils. A small amount of fibrin and edema can sometimes be found the alveoli. Alveoli nearest to the alveolar ducts usually contian more neutophils. Degenerate and live, first-stage, protostrongylid larvae can often be found surrounded by macrophages within alveoli of the anteroventral aspects of the lungs.

Often times the pleura of the lung is coated with fibrin and, in chronic cases, granulation tissue. Lungworm nodules located in the posterior dorsal aspects of the diaphragmatic lobes are characterlized by numerous viable parasites (*Protostrongylus stilesi*) surrounded by either lymphocytes, plasma cells, macrophages, with a few eosinophils and multinucleated giant cells. In older lambs the lungworm nodules are usually composed of predominantly multinucleated giant cells and dead parasites.

Microbiological agenta have been isolated from the upper and lower respiratory system of the lambs with pneumonia. Viral agents include Parainfluenze type 3; mycoplasma agents include *Mycoplasma arginini*; bacterial agents include *Pasterurella multocida*, *P. hemolytica*, *Neisseria* sp., *Hemophilis ovis*, *Corynebacterium pyogenes*, *Streptococcus* sp., *Staphylococcus* sp. and a *Mima* sp.; and parasitic agents include *P. stilesi*.

The pathogenesis of this "verminous" variety of bronchopneumonia has been studied. The progession of events leading to pneumonia in these lambs correlates well with the activity of a *Protostrongylus* larvae crossing the placenta of the adult ewe and entering the fetal liver in the latter stages of pregnancy. These third-stage larvae remain in the liver until parturition. Following birth of the lamb, the larvae then migrate to the lungs of the newborn. The third-stage larvae lodge in small pulmonary arterioles, enter the lung parenchyma, and migrate to the dorsal posterior aspects of the diaphragmatic lobes. Development of the parasites begins simultaneously with birth of the lamb; therefore, the activity and maturation of the parasites correlate well with the age of the lamb. The parasites mature when lambs are 3.5 to 4 weeks of age and begin to produce thousands of ova which mature to motile first-stage larvae in about one week. Numerous first-stage larvae are aspirated in to the anteroventral aspects of the lungs predisposing lambs to subacute to chronic suppurative bronchopneumonia complicated by viral, mycoplasmal, and bacterial agents of low pathogenicity. (Hibler 1972, 1974; Spraker 1977, 1979).

STRESS RELATED TYPE

This stress related type of pneumonia has been observed in 5 or 6 cases and have included lambs born in captivity, and in lambs born in the wild following a previous all-age die-off. The clinical signs, gross and histopatholobical changes of the lambs are similar to the verminous pneumonia except that the thymus is atrophied whereas it is normal in the verminous pneumonia lambs. The gross and histological lesions in this stress related type of pneumonia can be more acute than the verminous pneumonia. Fewer lambs have been studied in this group but of these studied the agents isolated include: *Pasteurella multocida*, *P. hemolytica*, *Corynebacterium pyogenes*, *Neisseria* sp., *Hemophilis ovis*, *Streptococcus* sp., *Staphylococcus* sp., *Mima* sp., *Herella* sp., and immature protostrongylid lungworms. Thus far, mycoplasma and viral agents have not been isolated from these lambs. The pathogenesis of this stress related pneumonia is believed to be similar to the pathogenesis of the pneumonia in the all-age die-offs.

ALL-AGE DIE-OFFS

All-age die-offs were first described by Rush and Fisher (Rush, 1927) and Marsh (1938) and has been documented by others (Buechner, 1960; Griner, 1974; Foreyt, 1982; Davison, 1982). This type of die-off has been documented in both captive (Spraker, 1977, DeMartini, 1977) and free ranging sheep. The pathogenesis of this disease process is believed to be induced by stress.

Clinical signs in sheep during an all-age die-off may vary from acute death to chronic pulmonary cripples. Animals demonstrate a moderate degree of coughing. Some lose weight and die in an emaciated condition, whereas others die acutely and are in an excellent body condition. This disease condition affects all ages and usually occurs in the winter months but can occur in the warmer months especially in captive herds.

The main gross lesion found in animals dying during an all-age die-off is a bronchopneumonia. Animals that die acutely will usually be in excellent body condition. The nasal cavity, trachea and bronchi are usually slightly reddened and contain a small degree of white mucoid exudate in acute cases. The anteroventral or sometimes only the diaphragmatic lobes of the lung are dark red, firm, and slightly raised from the interface with unaffected pulmonary parenchyma. The pneumonic lung is firm and a moderate degree of exudate can be expressed from severed bronchioles. Firm, yellow-grey, raised, lungworm nodules are located in the posterior, dorsal aspects of the diaphragmatic lobes and the lungworm burden varies from light to heavy. Usually the surface of the lung is coated with a thin coat of fibrin which allows the lung to be easily separated from the costal pleura. The mediastinal, tracheal, pharyngeal, and prescapular lymph nodes and the lymphoid tissue located in the posterior aspects of the nasal septum are mildly enlarged in these acute cases.

The animals with the subacute-to-chronic form of this pneumonia have similar gross lesions except they are of longer duration. There is mild-to-severe weight loss and, even, emaciation in some animals. The fibrinous adhesions are now fibrous. The parenchymal and subpleural surfaces have a classical "cobble-stone" appearance, with small, pale, cloverleaf-shaped foci surrounded by a slightly depressed, red-grey parenchyma. Small abscesses are common within the lung parenchyma. Lymphoid tissues are usually hyperplastic and the thymus is atrophied. The hair coat is usually dull and rough. A mild to moderate degree of adrenal cortical hyperplasia is often found.

The histopathological lesions found in this type of pneumonia are typical of a bronchopneumonia. Acute cases are characterized by mild rhinitis, tracheitis and bronchitis. There is a mild degree of hyperplasia of bronchiolr epithelium. Exudate is often found in bronchioles. Alveoli are usually open and filled with edema, neuthrophils, and fibrin admixed with a few macrophages. Fibrin is often on the surfac of the pleura. A few lungworm larvae are often in the anteroventral aspects of the lungs. The lungworm nodules contain adult male and female parasites, eggs and larvae. These parasites usually are surrounded by lymphoid cells, macrophages, plasma cells with a few neutrophils and eosinophils in healthy sheep; however, with this acute pneumonia there is often a severe suppurative bronchitis and bronchiolitis within lungworm nodules. Thus, in some cases, the lungworm nodule histologically appears to be similar to the ventral consolidated portions.

Chronic cases are similar to acute cases except for more atrophy of tracheal epithelium, and hyperplasia of bronchiolar and alveolar duct epithelium. Air passages are often cuffed by lymphoid cells and plasma cells. Fibrosis surrounds bronchioles in some areas. Exudate (mostly neutrophils and desquamated epithelial cells) usually fills the lumen of bronchioles. Alveolar ducts are often filled with neutrophils. The alveoli are usually partially collapsed and contain macrophages with an admixture of neutrophils. A few degenerate or live lungworm protostrongylid larvae sometimes can be observed in the anteroventral aspects of the lungs. The pleura is often covered with granulation tissue and overlayed by fibrin admixed with neutrophils and macrophages. Fibrous tags and adhesions and micro-to-macro abscesses are often found. The cellular reactions within lungworm nodules are similar to the nodules described with the acute cases. Mediastinal and bronchial lymph nodes are often hyperplastic and sometimes contain first-stage lungworm larvae. The thymus is atrophied and the adrenal cortex is slightly-to-moderately hyperplastic.

Etiological agents thus far isolated from sheep with the acute to chronic, fibrinopurulent bronchopneumonia include _Pasteurella multocida_, _P. hemolytica_, _Neisseria_ sp., _Corynebacterium pyogenes_, _Streptococcus_ sp., _Staphylococcus_ sp., Parainfluenza type-3 (isolated from one die-off of captive sheep (Parks, 1972;), _Protostrongylus stilesi_ and _P. rushi_. No mycoplasma or chlamydia have been isolated to date.

The pathogenesis of this fibrinopurulent bronchopneumonia that occurs in the all-age die-offs appears to be stress induced. Animals normally carry bacterial agents of low pathogenicity in their upper respiratory system and have low to heavy lungworm burdens. These sheep become stressed in some means such as encroachment by man or his domestic animals, loss of range, crowding, change of range conditions, lack of water, inclement weather, deep snow, malnutrition, captivity, dust, etc. This "stress" leads to an adrenal cortical hyperfunction and elevated serum cortisol. Increased cortisol causes the animal to be less resistant to the microbiological agents of low pathogenicity already within the animal. This either allows the bacteria to proliferate and invade the depths of the lungs or inhibits the body's mechanisms of removing bacteria that are inhaled into the depths of the lungs. The bacteria then proliferate within small bronchioles and induce inflammation. If the bacteria multiply rapidly and are moderately pathogenic, such as with _Pasteurella_, the animal may die quickly, or if the bacteria multiply more slowly a subacute to chronic bronchopneumonia will develop. Heavy burdens of lungworm can initiate this bronchopneumonia as with the verminous pneumonia of lambs, (Spraker, 1977, 1979) but in many cases the lungworms, as with the bacteria, are on of the low pathogenic agents that are allowed to proliferate under stress conditions.

SUMMARY

Bronchopneumonia is a common disease in bighorn sheep, even though there are several field manifestations of pneumonias, i.e., two types of summer-lamb mortality, and the classical pneumonia associated with all-age die-offs. The basic clinical signs, gross and histopathology are fairly similar in these three different field manifestations of pneumonias. The agents isolated from those cases are similar also: lungworms, bacteria and sometimes viruses and mycoplasma. A combination of stress factors appears to play a vital role in all-age die-offs, mortality in captive lambs, and summer-lamb mortality following a previous all-age die-off. Transplacental transmission of heavy lungworm burdens with maturation of the parasites when the lambs are 3.5 to 4.5 weeks of age appears to be the most important predisposing factor for the verminous type of summer-lamb mortality. Ultimately, and regardless of the predisposing factors, many bighorn sheep die due to an acute to chronic fibrinopurulent bronchopneumonia.

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CONFERENCE DISCUSSION

Q. I have some questions that deal with ecological patterns more than anything else. To begin with, where do you find this pneumonia occuring primarily and do you find it with low-elevations or high-elevation populations?

ANS. We've seen the pneumonia in low- and high-elevation populations in Colorado.

Q. May I suggest that these pneumonias will become increasingly less frequent as you go to higher altitudes or higher latitudes.

ANS. If you ask the question about evolution, you must get into some detail. The mountain sheep is basically a relatively recent immigrant to this continent. It has been here probably about 45,000 years, which is a pittance. In these latitudes it is even more recent. As far as altitudes are concerned, it probably hasn't been at the low altitudes for a very long time either. It's like the elk, like the grizzly, like the wolf: spread basically after the megafaunal extinctions. For this reason you'd expect that northern animals adapted to high altitudes and high latitudes, adapted to glacier environments, will have terrible troubles if they get into contact with other environments which are notoriously rich in their biota and notoriously rich in pathogens.

So the behavior of the bighorn sheep in the southern latitudes here in the United States is fully expected to be one of a troubled species in relation to what it is in the northern environment where it is highly adapted. You don't have to go to bighorn sheep, you can go to human beings. If you look at the North American Indian and how the American Indian does when they come into contact, particularly in South America, with really adapted people, people adapted to the tropics, the negros, the South American Indians do notoriously very poorly. They are full of disease. Their reproductive rates decline, native tribes go down the drain literally because the African, by in large, is very well, in a biological since, adapted to tropical environments and South American Indians are not. They are very recent immigrants to that land.

You should find for instance, that if you take an old emigrant, horses or burros, and put them into competition with bighorn sheep, it's hands down that sheep will lose in southern environments. The reason: the horse is an old American genus which still should carry, in its geno type messages from ages passed which make it perfectly adapted to the conditions it finds here. So if you approach the question of, have the bighorn sheep adapted to these many pathogens, remember it is facing very different environmental conditions today than it did 50,000, 200,000 or a million years ago.

ANS. This may be so, but some of the first die-offs of sheep were described from Montana and some of the most wide-spread and devastating die-offs occurred in Canada. I think that die-offs, occur at both low- and high elevations.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:173-187

SURVEY OF COLORADO AND WYOMING BIGHORN SHEEP AND MOUNTAIN GOATS FOR PARATUBERCULOSIS

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ABSTRACT

The lymphocyte blastogenesis (LB) test was used to test 157 free-ranging bighorn sheep (*Ovis canadensis*) from eight herds in Colorado and Wyoming for paratuberculosis. Of 49 blood samples from bighorns in the Grant, Colorado herd where paratuberculosis has been confirmed, 33 (67%) were positive. Positive results were obtained from most bighorn herds tested, including those where paratuberculosis was presumed absent. All 155 serum samples from seven bighorn herds tested by complement fixation were negative. Fecal samples from nine herds were culture negative for *Mycobacterium paratuberculosis*.

Sixteen blood samples were collected from two herds of mountain goats (*Oreamnos americanus*); one sample from the Mount Evans, Colorado herd was positive on the LB test. Tissue from one of five hunter-killed goats was culture positive and one of 11 goats was diagnosed as having paratuberculosis by microscopic examination of tissues. Eight fecal samples from goats in the Mount Evans area were culture negative for *M. paratuberculosis*.

INTRODUCTION

Paratuberculosis, or Johne's disease, is an infectious enteric disease of ruminants caused by the bacterium *M. paratuberculosis*. It is an important disease of domestic livestock and is responsible for economic losses in many areas of the United States, but it is seldom a problem in the intermountain west. The disease has been reported in a variety of captive wild bovids and cervids (Williams and Spraker 1979), but has been infrequently identified in free-ranging populations. An early report from France mentions paratuberculosis in free-ranging mouflon (*Ovis musimon*) (Lucas, cited by Thiery 1953) and several recent papers describe the disease in tule elk (*Cervus elaphus nannodes*) (Jessup et al. 1981), axis deer (*Axis axis*) and fallow deer (*Dama dama*) at Pt. Reye's National Seashore in California (Riemann et al. 1979). Other free-ranging populations with paratuberculosis include the bighorn sheep and mountain goats in the Grant-Mount Evans area of Colorado (Williams et al.1979).

Paratuberulosis was diagnosed in bighorn sheep from the Grant and Mount Evans bighorn sheep herds in 1977. Movement of marked sheep between the Mount Evans and Grant herds was demonstrated by Martin and Stewart (1977). Retrospective study of tissues in files of the Wild Animal Disease Center, Colorado State University identified an additional case from Mount Evans in a bighorn ram in 1972. In 1979, paratuberculosis was identified in a ram in the Laramie Range, Wyoming (Williams 1981). An affected mountain goat from Mount Evans was examined in 1978 (Williams et al. 1979). During the period 1972 to 1981, 12 clinical cases of paratuberculosis in bighorn sheep and one mountain goat have been studied (Williams 1981).

Streeter (1969) conducted an extensive study of the demography of the Mount Evans sheep population from 1965-1968. During the 3 year study he observed seven sheep showing evidence of emaciation, scours, eye discharges and failure to shed hair coats normally. These clinical signs suggest paratuberculosis may have been present in the herd as early as 1965.

The present study was undertaken to determine the efficacy of several diagnostic tests for paratuberculosis in bighorn sheep and to apply them to free-ranging herds of sheep and goats in Colorado and Wyoming to establish the distribution of paratuberculosis in these species. Results of the tests were used to estimate the incidence of paratuberculosis in the Grant bighorn sheep.

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METHODS

Nine bighorn x mouflon hybrid sheep were experimentally infected with _M. paratuberculosis_; blood and fecal samples were collected monthly from infected and two uninfected control sheep for 1 year postinoculation. In addition, 24 bighorns were captured by drop net near Grant, Colorado and transported to pens at the Wild Animal Disease Center. Blood and fecal samples were collected at the time of capture and at post-mortem examination. Additional samples were collected from some of these sheep during the period of captivity. Twelve cases of clinical paratuberculosis were examined by various diagnostic tests from 1977 to 1981. All sheep were examined postmortem for gross and microscopic evidence of paratuberculosis and a variety of tissues were cultured for _M. paratuberculosis_. Results of tests on spontaneously and experimentally infected sheep were used to determine the efficacy of diagnostic tests to be used in the field.

During winter trapping operations, serum for complement fixation (CF) tests, heparinized blood for the lymphocyte blastogenesis (LB) tests, and fecal samples were collected from sheep in eight bighorn herds in Colorado (Grant, Chalk Cliffs, Sagauche, Pikes Peak, Tarryall, Gunnison, Waterton Canyon, Poudre) and one in Wyoming (Whiskey Mountain).

A survey of hunter-killed bighorn sheep for paratuberculosis was conducted in September and October 1979. Packets containing small plastic bottles of formalin, plastic bags, blood tubes (plain and heparinized) and an instruction sheet were sent to all bighorn hunters with permits for the Grant-Mount Evans hunt areas. Packets were usually returned within 48 hours of death of the animal. Fifteen were distributed and three were returned. Serum, heparinized blood and fecal samples occasionally were obtained from mountain goats trapped in the Collegiate Range, Colorado and on Mount Evans for the LB test, CF test and fecal culture. During August and September 1979 sample collection packets were sent to goat hunters in the Mount Evans hunt area. Packets were the same as those described for bighorn sheep. Six of 12 packets were returned. In October 1980, blood tissues and fecal samples were collected from five mountain goats shot during the hunting season on Mount Evans. Samples were collected directly from the carcasses within 0.5 hours of death.

Lymphocyte blastogenesis tests were conducted essentially as described by Alhaji and coworkers (1974) and Burrells and Wells (1977). Jugular blood samples were collected into 20 milliliter glass evacuated blood tubes containing 20 USP units sodium heparin[1] per milliliter of blood and into tubes without heparin which were allowed to clot. Serum was usually drawn off the latter within 24 hours of collection, a portion saved for use in the LB test and the remainder frozen for serologic tests. Heparinized blood was held at room temperature for 2 to 48 hours until used in the LB test. Tests were usually conducted within 24 hours after sample collection. In unusual circumstances, such as samples obtained from hunter-killed animals, blood held for as long as 72 hours was used in the assay.

Fifteen milliliters of heparinized blood was diluted 1:1 with Hank's balanced salt solution (HBSS) containing 100 units penicillin and 100 micrograms streptomycin[2] per milliliter. Mononuclear cells were separated from blood by the ficoll-diatrizoate gradient technique. Specific gravity of the gradient was adjusted to 1.077. Dilute blood was carefully layered onto 10 milliliters of gradient in 50 milliliter polypropylene centrifuge tubes using the technique of DeRock and Taylor (1977) which allowed 12 samples to be processed at once. All procedures were conducted in a laminar flow hood to prevent contamination of the cultures.

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[1] Sodium heparin injection, 5000 USP units/ml. Dell Laboratories, Inc., Teaneck, N.J. 07666. Benzyl alcohol preservative.

[2] Penicillin-Streptomycin Solution, Grand Island Biological Company, 3175 St. Aley Road, Grand Island, New York 14072

Loaded tubes were centrifuged for 40 minutes at 670 relative centrifugal force units (RCF) at room temperature. The layer of mononuclear cells was drawn off using a Pasteur pipette and placed into a second tube. Cells were washed twice using HBSS and 10 minute centrifugation at 2000 RCF. Washed cells were suspended in 1 milliliter RPMI 1640[3] medium containing 100 units penicillin and 100 micrograms streptomycin. Cells were counted and diluted to 1×10^6 per ml in RPMI 1640 with 20% heat inactivated fetal bovine serum or autologous serum. Two hundred microliters of cell suspension (2×10^5 cells) were pipetted into round bottom wells in plastic microtiter trays containing 10 micrograms concanavalin A (con A)[4] or mycobacterial antigens. Each test was run in triplicate. Purified protein derivative (PPD) of M. bovis, M. avium, and in some cases, M. paratuberculosis were used as antigens in the tests. Five micrograms M. bovis PPD or M. avium PPD or 12.6 micrograms M. paratuberculosis PPD were used per 2×10^5 mononuclear cells. Mycobacterial antigens were supplied by Dr. Dale Angus, Veterinary Services Laboratory, National Animal Disease Center, Ames, Iowa. Lymphocyte cultures were incubated at 37 C in 5 percent CO_2 humid atmosphere for 5 days. Eighteen to 20 hours prior to harvest 1 microcurie thymdine methyl-3H[5] was added to each well. Cultures were terminated by harvesting contents of each well onto glass fiber filter paper using a vacuum microtiter plate cell harvester. Dried filter paper discs were counted in a liquid scintillation counter. Results were recorded as counts per minute (CPM). The mean CPM of each set of triplicate cultures was used to determine a stimulation index:

$$\text{Stimulation index} = \frac{\text{Mean CPM of wells containing mitogen or antigen}}{\text{Mean CPM of wells without mitogen or antigen}}$$

Fecal and/or tissue samples were obtained for mycobacterial culture from bighorn sheep and mountain goats when trapped or during postmortem examinations. Most samples were cultured within 2 days of collection; some samples were frozen at -70C for up to 2 years prior to culture. Cultures were conducted as described in Laboratory Methods in Veterinary Mycobacteriology[6] using Herrold's egg yolk medium. Three tubes containing mycobactin and one without were used for each sample. Tubes were incubated at 37C for 16 weeks. Identification of M. paratuberculosis. was based on slow growth, acid-fast staining properties and mycobactin dependence.

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[3] RPMI-1640 with L-Glutamine, Grand Island Biological Company, Grant Island, New York, 14072

[4] Highly purified lyophilized powder, Sigma Chemical Co., P.O. Box 14508, St. Louis, MO. 63178.

[5] Thymidine Methyl-3H, 6.0 Ci/mmol spec. act., Schwartz-Mann, Orangeburg, New York 10962, or Thymidine Methyl-3H, 6.7 Ci/mmol, New England Nuclear, 549 Albany Street, Boston, Mass. 02118.

[6] Veterinary Services Diagnostic Laboratory, Animal Plant Health Inspection Service, U.S. Department of Agriculture, Ames, Iowa, 77 pp.

One milliliter of frozen serum from selected animals, including known infected and known uninfected animals was submitted to Dr. B. D. Blackburn, Veterinary Services Diagnostic Laboratory, Ames, Iowa for CF testing for paratuberculosis. A microtiter method was used and a CF titer of less than or equal to 1:8 was considered negative, 1:16 suspect and 1:32 or greater positive.

Sensitivity and specificity of the tests were determined on experimentally infected bighorn hybrid sheep (Rogan and Gladen 1978, Brown and Newman 1979). Sensitivity is defined as the chance a test will be positive when applied to animals which are infected and specificity is the chance a test will be negative when applied to uninfected animals. Estimates of prevalence of paratuberculosis in the Grant bighorn sheep were determined by the method of Rogan and Gladen (1978).

RESULTS

EFFICACY OF TESTS IN EXPERIMENTAL AND SPONTANEOUSLY INFECTED BIGHORN SHEEP.

In experimentally infected hybrid sheep, highest mean stimulation indexes on the LB test to antigen were obtained using *M. avium* PPD; thus, *M. avium* antigen was used in all subsequent tests. Tests using fetal calf serum and a stimulation index greater than or equal to 3.5 as positive had 82 percent sensitivity and 94 percent specificity (Table 1). By two months postinoculation, most infected hybrid sheep responded to the test.

The CF test was not useful in diagnosis of paratuberculosis in hybrid sheep (Table 1); sensitivity was 0 and specificity was 100 percent. No false positive responses occurred; however, there were no true positive responses either. Fecal culture of subclinically affected hybrid sheep was 3 percent sensitive and 100 percent specific.

The LB test was run on 16 bighorn sheep from Grant which were found to be infected with *M. paratuberculosis* either by culture or visualization of acid-fast bacteria within typical lesions of paratuberculosis. Twelve responded positively (stimulation index 23.5) when fetal calf serum and *M. avium* PPD was used (Table 1). When the CF test was conducted on sera of 13 known infected bighorns a positive response was obtained on only one occasion (8% sensitivity). Eight fecal cultures from known infected bighorn sheep were negative for *M. paratuberculosis* (0 sensitivity).

RESULTS OF DIAGNOSTIC TESTS ON FREE-RANGING BIGHORN SHEEP AND MOUNTAIN GOATS

The LB test was used to test 157 free-ranging bighorn sheep for paratuberculosis from eight herds in Colorado and Wyoming (Table 2). Positive results were obtained from most herds, including herds where paratuberculosis was presumed absent (Chalk Cliffs, Pikes Peak, Tarryall, and Whiskey Mountain). Thirteen percent (10/77) of the samples from these herds reacted positively (stimulation index 23.5) using *M. avium* PPD as antigen.

Over a 2 year period, 45 percent (14/31) of bighorns samples from the Saguache herd responded positively to the LB test. Of 49 blood samples collected from bighorns at Grant over 3 years, 33 (67%) were positive. Twenty-seven percent (3/11) of blood samples from bighorn lambs at Grant were positive. The reactor rate increased in the yearling and older age classes.

All 155 serum samples from seven bighorn sheep herds tested with the CF test for paratuberculosis were negative (Table 2). In 1978, fecal samples collected at the time of trapping from nine bighorn sheep herds were culture negative for _M_. _paratuberculosis_.

Examination of tissues collected from hunter-killed bighorn sheep in 1979 did not result in the diagnosis of paratuberculosis. One sheep, however, had granulomas suggestive of paratuberculosis in the intestinal tract and mesenteric lymph nodes but acid-fast organisms could not be demonstrated.

Results of tests for paratuberculosis in samples from mountain goats are shown in Table 3. Four heparinized blood samples collected from mountain goats trapped in the Collegiate Range were negative on the LB test for paratuberculosis. One positive LB test response was obtained from mountain goats trapped on Mount Evans; culture of eight fecal samples from this herd was negative for paratuberculosis.

Examination of tissues collected from hunter-killed mountain goats in 1979 and 1980 resulted in the diagnosis of paratuberculosis in two of 11 mountain goats on the basis of histopathology in one case and culture of _M_. _paratuberculosis_ from the mesenteric lymph node in the other case.

DISCUSSION

Specificity and sensitivity of the LB test were calculated to be 75 percent and 87 percent, respectively, based on test responses of known infected bighorns from Grant and responses of free-ranging bighorns from herds thought not to be infected with _M_. _paratuberculosis_. These responses are lower but comparable to the 82 percent sensitivity and 94 percent specificity of the LB test in experimentally infected bighorn x mouflon sheep. Thus false positive and false negative results may cause problems in use of the LB test in bighorn sheep. The test, however, appears to be more accurate than other available tests.

False positive responses to the LB test could be explained by prior exposure to another antigenically related organism. _Corynebacterum_ _renale_ (Gilmour and Goudswaard 1972), _C_. _equi_ (McKenzie and Ward 1981), acid-fast saprophytic organisms (Hole and Maclay 1959, Jensen 1956), and other mycobacteria, especially _M_. _avium_ (Wilks et al 1981), have been shown to cause false positive reactions on tests for paratuberculosis. Free-ranging bighorn sheep could easily come in contact with saprophytic mycobacteria, _M_. _avium_ from free-flying birds or with _Corynebacterum_ spp. _Corynebacterium_ spp. frequently have been recovered from bighorn sheep in

Colorado and Wyoming. False negative responses on the test would be expected before an immune response to M. paratuberculosis is counted. This period may be several months long for most mycobacterial diseases and would result in a lowered sensitivity of the test. By any mechanism, suppression of the LB test response in individuals infected with paratuberculosis, as has been described in other species (Williams 1981), could result in false negative responses.

The CF test was unreliable as a diagnostic test for paratuberculosis in spontaneously and experimentally infected bighorn sheep and could not be recommended for this species. Few fecal samples from experimentally infected hybrid sheep and none from known infected bighorn sheep were culture positive for M. paratuberculosis. The low rate of positive fecal cultures in infected animals could be explained by low sensitivity of the cultural procedure; 50 to 100 organisms per gram of feces must be present before culture will be positive (Merkal 1970). Many fecal samples from bighorn and hybrid sheep were frozen prior to culture which may have decreased titer of viable organisms (Richards and Thoen 1977).

Most bighorn herds surveyed contained at least one sheep that responded positively to the LB test. These were assumed to be false positive responses because there was no clinical or cultural evidence of M. paratuberculosis within these herds. As described previously, false positive rsponses were probably due to sensitization of an animal by an antigenically related organism. If these herds are actually free of paratuberculosis, a false positive result occurred in 13 percent of the free-ranging bighorn sheep tested.

Positive responses on the LB test in the Grant bighorn sheep were 56 percent (5/9), 62 percent (16/26) and 86 percent (14/16) for the years 1978, 1979 and 1980, respectively. These were considerably higher than the 13 percent expected false positive rate and correctly reflect the fact that this herd is infected with M. paratuberculosis. It is unclear if the increase in positive responses over 3 years reflected increased prevalence of disease. In this herd, prevalence of M. paratuberculosis infection was estimated to be 87 percent using the method of Rogan and Gladen (1978) which takes sensitivity and specificity of the test into account in determining results of screening tests.

It is interesting to speculate on the high rate of positive LB test responses in the Saguache bighorn sheep herd. Fifty percent (9/18) of sheep responded positively in 1978 and 38 percent (5/13) in 1980. This 45 percent reactor rate is considerably greater than the expected 13 percent false positive response rate. The sheep might be sensitized to cross-reacting organisms, or they could be infected with M. paratuberculosis or M. avium. This herd comes into close contact with domestic cattle. A similar situation exists in the Laramie Range in Wyoming where a clinical case of paratuberculosis has been diagnosed. An emaciated diarrheic ewe was observed in the summer of 1980 at Saguache, but was not collected for postmortem examination. Although there is no definitive evidence, the Saguache bighorn sheep herd may be infected with M. paratuberculosis. and deserves further study.

Evidence from hunter-killed and trapped mountain goat tissues and blood samples indicate M. paratuberculosis is present within the goat population on Mount Evans. This is of concern because goats appear to be emigrating from the area of original transplant on Mount Evans and could be carrying the bacteria into new areas. The significance of mountain goats in the epizootiology of paratuberculosis on Mount Evans deserves additional study.

With a few exceptions, it seems unlikely that paratuberculosis is of much importance in free-ranging wildlife. Most wild ruminants are susceptible to M. paratuberculosis infection and once introduced into a free-ranging population the probability of the disease remaining in that population would depend upon habitat and behavioral characteristics of the species. The free-ranging bighorn sheep in the Grant-Mount Evans herd are able to maintain M. paratuberculosis within the population because the sheep maintain a relatively high ecological density within certain areas of their range. This serves to enhance transmission of M. paratuberculosis between animals. The importance of congential infection with M. paratuberculosis is unknown but it has been shown to occur in bighorn sheep (Williams 1981). Congenital infection with M. paratuberculosis could serve to maintain infection in the population without the bacteria being exposed to harsh environmental conditions.

The effect of paratuberculosis on the Grant-Mount Evans bighorn sheep population is unknown because data on the dynamics of the herd are insufficient to determine what impact the disease has on the population. The population grew since the 1920's to approximately 200-225 animals but has been relatively stable for the last 10 years (Streeter 1969, Loessberg 1972, Martin and Stewart 1977, Goforth 1979, 1980). If bighorn sheep are like domestic sheep, mortality in adult bighorns due to paratuberculosis is unlikely to exceed 10 percent per year (McEwen 1939, Doyle 1956). Approximately three cases of paratuberculosis per year have been examined for 4 years from a population of about 200 animals. This gives a known mortality rate of 1.3 percent per year. This undoubtedly represents only a portion of the sheep which have died of paratuberculosis. In domestic animals, prevalence of infection may be 20 times greater than actual clinical disease (Buergelt et al 1977). If an 87 percent infection rate is accurate, based on LB test survey data, nine sheep a year would be expected to die of paratuberculosis in the Grant-Mount Evans herd for an annual mortality rate of 5 percent. This is comparable to mortality rates in domestic species.

Table 1. Sensitivity and specificity of diagnostic tests for paratuberculosis in sheep spontaneously or experimentally infected with _Mycobacterium paratuberculosis._

Test animals	Diagnostic Test	Sensitivity	Specificity
Subclinically affected experimentally infected bighorn x mouflon sheep	Lymphocyte blastogenesis[1] (n = 119)	82%	94%
	Complement fixation (n = 119)	0	100%
	Fecal culture (n = 119)	3%	100%
Spontaneously infected bighorn sheep	Lymphocyte blastogenesis (n = 16)	75%	-
	Complement fixation (n = 13)	8%	-
	Fecal culture (n = 8)	0	-
Free-ranging bighorns from herds assumed free of paratuberculosis	Lymphocyte blastogenesis (n = 77)	-	87%
	Complement fixation (n = 100)	-	100%
	Fecal culture[2] (n = 30)	-	100%

[1] All lymphocyte blastogenesis test results are for tests run using _M. avium_ PPD as antigen, fetal calf serum and a value of 3.5 positive test.

[2] R. Keiss, personal communication. Fecal samples collected from 9 bighorn sheep herds in 1978.

Table 2. Lymphocyte blastogenesis and complement fixation test results from bighorn sheep herds in Colorado and Wyoming, 1978 to 1980.

Herd	Year	Lymphocyte blastogenesis test No. positive/No. tested (% positive)	Complement fixation test[1] No. positive/No. tested (% positive)
Grant	1978	5/9 (56%)	0/21 (0)
Grant	1979	16/26 (62%)	0/26 (0)
Grant	1980	12/14 (86%)	0/5 (0)
Chalk Cliffs	1978	4/17 (24%)	0/16 (0)
Chalk Cliffs	1979	1/9 (11%)	NT
Saguache	1978	9/18 (50%)	0/2 (0)
Saguache	1980	5/13 (38%)	0/23 (0)
Pikes Peak	1978	3/10 (30%)	0/9 (0)
Tarryall	1978	0/4 (0)	0/33[3](0)
Tarryall	1980	1/11 (9%)	NT
Gunnison	1978	0/2 (0)	0/7 (0)
Waterton Canyon	1979	0/12 (0)	NT
Whiskey Mountain	1980	1/12 (8%)	NT
Poudre	1978	NT	0/13 (0)

[1] Tests performed by Veterinary Services Diagnostic Laboratory, Ames, Iowa.

[2] Not tested.

[3] One test was anticomplementary.

Table 3. Paratuberculosis test results on samples collected from mountain goats, 1978 to 1980.

Herd	Date	Histopathology No. positive/No.tested (% positive)	Lymphocyte blastogenesis No. positive/No. tested (% positive)	Culture No. positive/No. tested (% positive)
Mount Evans	Sept 1978	ND[1]	0/1 (0)	ND
Collegiate Range	July 1979	ND	0/4 (0)	ND
Mount Evans	Sept 1979	1/6 (17%)	ND	ND
Mount Evans	March 1979	ND	0/1 (0)	ND
Mount Evans	Sept 1980	0/5 (0)	0/3 (0)	1/5 (20%)[2]
Mount Evans	Sept & Oct 1980	ND	1/7 (14%)	0.8 (0)[3]

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[1] Not determined.

[2] Culture of tissues.

[3] Culture of feces.

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CONFERENCE DISCUSSION

Q. I gather that it is likely that the sheep have had this for a long time, presumably since at one time they were in contact with livestock. Can you tell us if there has been a declining trend in sheep and goats on Mt. Evans over the last 20 years?

ANS We don't know when the infection got into the herd, but it's likely that it came in with domestic animals. Streeter, in work on Mt. Evans, indicated that he saw animals that were emaciated and had diarrhea as early as about 1965-1967, so the disease has likely been there since then.

Q. I just wondered, has the Mt. Evans sheep herd showed a decline over these years?

ANS Surveys suggest that the herd is relatively stable though good data are lacking.

Q. As I understand it, it's been decided that this infection in the herd at Grant, on the south side of Mt. Evans, is a threat to other wild ungulates, particularly deer and elk on that range, and that the herd of sheep should be reduced or eliminated to reduce the possibility of that infection getting into the deer and elk populations. A couple of things make me wonder about that. (1) Do we know whether or not the disease is already in the elk and deer? It's in the goats which are nearby. (2) Do we need to control goats also if we are going to continue this philosophy? (3) You said the disease lasts for 3 years on the ground. Would you comment about this approach to handling the disease, that is reducing or eliminating that herd of sheep.

ANS I think Gene might be able to say something more about the management decision that was made. Paratuberculosis is a very difficult disease to control. You mentioned some of the big problems with trying to control it. There is not a good diagnostic test. You can't go in, as they do with some types of diseases in domestic animals, and test and slaughter. If paratuberculosis appears in a cattle ranch, in Colorado, the ranch is put under a modified quarantine. In other words, they are not supposed to sell their animals and it becomes a considerable economic hardship to the rancher. The domestic-animal people have been working for a long, long time, trying to control the disease in livestock, and they haven't been very successful. The options available are not very satisfying. In a few situations, paratuberculosis has been managed by slaughtering, the animals. This approach has been used with the less valuable stock. Vaccination could be another way to approach the problem. There is a vaccine that protects to some extent in domestic sheep and has been shown to greatly reduce the infection rate in a very large field study in Iceland. Another option is to live with the paratuberculosis problem and risk the chance of the infection getting into the other ungulate populations on Mount Evans. I have some evidence, though not definitive, that the disease is already in the elk and deer. Certainly elk are quite susceptible and so are deer, as shown by my experimental work and also by some recent reports in the literature. We know that the mountain goats on Mount Evans have paratuberculosis, and I believe these animals must be considered in any management plan.

The fact that the organisms are viable on the ground for a long time greatly complicates management. If it were possible to remove the infected populations, ruminants should not be put back on that range for three years, to be safe, because those animals could potentially become infected. My understanding is that the Division of Wildlife has taken the approach that it would be better to give up on the sheep and to try to decrease the chances for paratuberculosis to become a problem in the valuable elk herd in the area. I'm not satisfied with the management decision but there are problems with all the other options.

Q. Sheep from the Mt. Evans herd were transplanted over near Dinosaur National Park. Do you happen to know if any symptoms have shown up in that population?

ANS I haven't heard of any. I doubt if they have been watched closely enough to find out.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3: 188-197

DISEASE SURVEYS IN DALL SHEEP IN ALASKA
(preparing for domestic grazing)

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ABSTRACT

Agricultural development in Alaska will likely involve an expanded red meat industry. History has shown that mountain sheep in the western United States do not interact favorably with domestic grazers. One major problem for native sheep may be transmission of diseases from domestic livestock. In anticipation of expanded domestic grazing, and in an effort to minimize the potential for disease transmission to native Dall sheep (Ovis dalli), a serologic survey for diseases of Dall sheep has been conducted for several years. Dall sheep sera were tested for evidence of previous exposure to Anaplasma spp., Brucella spp., Toxoplasma spp., Leptospira spp., Campylobacter fetus, bovine viral diarrhea, bluetongue, contagious ecthyma, ovine progressive pneumonia, parainfluenza, and infectious bovine rhinotracheitis. Tests revealed serum antibody to Campylobacter fetus in 22 (30%) of 73, Brucella spp. in 3 (3%) of 90, contagious ecthyma virus in 24 (25%) of 96, and parainfluenza III virus in 1 (1%) of 73 Dall sheep sampled. Lumpy-jaw data were also gathered.

INTRODUCTION

Small-scale agriculture has been present in Alaska since the days of Russian settlement. The United States purchased Alaska in 1867, and government surveys in the late 1890's implied that food production would be possible in Alaska (USDA 1898). Agricultural stations were first established in the early 1900's, and during the next 50 years, various efforts were made at commercial agriculture with limited success and with little environmental consequence. A brief surge of agricultural production occurred in the 1950's and 1960's but proved to be generally unprofitable due to comparatively inexpensive transportation costs of imported food and intensive marketing efforts by out-of-state producers. Still, agriculturists, particularly those employed by govenment agencies, never abandoned the idea of Alaska as an agricultural state. These agencies encouraged gardening and carried out research on plant varieties adapted to

Alaska. They showed that vegetable crops were viable and suggested that some seed crops could be profitable in Alaska if given sufficient agricultural infrastracture and large-scale development.

During the mid-1970's, the political and economic climate changed (though little change was noted in the physical climate), and, suddenly, agriculture took on a new importance. Alaska began receiving substantial oil revenues, and projects formerly unthinkable (such as major agricultural development) became candidates for investment of the State's new-found wealth. Agricultural economists, agronomists, and marketing consultants vigorously promoted agriculture (Alaska Rural Development Council 1974). During the renewed advocacy phase, Alaskans were made painfully aware that they were not self-sufficient for food and that the food supply line was long and potentially fragile. The spectre of world hunger was raised and it suddenly seemed important for Alaska to produce food for itself and the world. Agriculturists also asserted that an agricultural industry would ensure an economic future based on renewable resources rather than oil and mineral agricultural developments.

In 1978, the State disposed of 60,000 acres (243 km^2) (principally Class II and Class III soils) which were to be rapidly cleared and put into production of barley, a small grain with a short growing season. So far, production and quality of barley have been much lower than anticipated, the infrastructure necessary to export crops has been slow to develop, and the State has made an extensive investment in very expensive, energy- and capital-intensive farmsteads. In addition, the State has made political promises to continue agricultural development.

Agriculturists now suggest that the best use of this low-quality barley is not the export market, as originally planned, but production of domestic red meat within Alaska. Applications for grazing leases on State land are becoming commonplace. One lease was recently issued for an area 3 miles (5 km) north of Dall sheep habitat which lies within Denali (formerly Mount McKinley) National Park.

Experience shows that wild sheep do not cope well with diseases which are routinely carried by domestic grazers. Recent literature indicates domestic sheep which appear to be healthy can in fact be carriers of diseases which can cause die-offs in wild sheep populations which they contact (Jessup 1981, Foreyt and Jessup 1982, also see Goodson's paper in this proceeding). As the red meat industry expands in Alaska, it seems inevitable that some Dall sheep habitat will be grazed by domestic livestock. Fortunately, the Alaska Department of Fish and Game (ADF&G) has the mandated opportunity to comment on grazing lease applications on State land. In the past, ADF&G has relied heavily on information from other locations for data regarding the potential threat posed by domestic species as carriers of diseases which may be transmitted to wildlife. We realize the limitations of this approach and seek to provide more well-informed comments on these potential threats to wildlife in general and, particularly, Dall sheep. Therefore, we have begun disease (primarily serologic) surveys. The purpose of this paper is to share preliminary results of these studies and solicit advice from others in the field regarding disease surveys.

METHODS

Dall sheep were captured at two naturally occurring mineral licks in the Alaska Range using methods described previously (Heimer et al. 1980). One mineral lick serves a low-quality (Geist 1971) population of sheep near Dry Creek, south of Fairbanks. The other serves a high-quality group of sheep near Tok, Alaska about 320 km to the east. Population characteristics for these two groups of sheep have been reported by Heimer (1978).

Sheep were bled and examined for overt signs of disease. Mandibles were palpated to determine whether lumpy-jaw was present. Biopsy specimens were collected from active lumpy-jaw lesions. Bacterial and fungal isolations were attempted on these biopsy specimens.

Blood samples were allowed to clot at ambient temperature; serum was collected by aspiration after 12 to 18 hours. Serum was kept cool by packing it in snow or storage in a cool spring before transport to Fairbanks where it was frozen and stored until analysis. When timely transport (2 to 5 days) was not possible, sera were stored in liquid nitrogen until they could be transferred to mechanical freezers in Fairbanks. Samples from the Tok capture site were analyzed at the Washington State Diagnostic Laboratory, Washington State University, Pullman, WA. Sera from the Dry Creek site were tested at the National Veterinary Services Laboratory, Ames, Iowa.

RESULTS

Results of the serologic tests performed on samples from the Tok, Alaska area (from Smith et al. 1982) show antibody titers to C. fetus, contagious ecthyma (CE) virus, Brucella spp., and parainfluenza III (PI III) virus (Table 1). Results of serologic tests performed on samples collected at the Dry Creek site showed antibody titers to Brucella, PI III, bovine viral diarrhea (BVD), infectious bovine rhinotrachetitis (IBR), and Liptospira spp. Prevalence of lumpy-jaw lesions from the present study and comparsions with data from past studies are presented in Table 3.

DISCUSSION

We shall briefly discuss those agents which were indicated to be present by serologic titers. Based on the results in Table 1, there is no evidence of exposure of the Tok area Dall sheep populations to Anaplasma spp., Leptospira spp., Toxoplasma spp., bovine viral diarrhea virus, bluetongue virus, infectious bovine rhinotracheitis virus, or ovine progressive virus.

Campylobacter fetus is the causative agent of the disease known as vibriosis which can cause abortion in domestic sheep. The prevalence reported here indicates that the disease is common in the Sheep Creek population. This is the first reported evidence of C. fetus infection in

Dall sheep (Smith et al. 1982). There have been no observations of widespread abortion in this population. The specificity of this test is sufficiently suspect that we doubt the presence of vibriosis in this population (Andrews and Frank 1974).

Thirty-five percent of 73 sheep sampled near Tok had serologic evidence of past exposure of contagious ecthyma (CE). Sixteen (70%) of 23 specimens from two earlier collections of Dry Creek also had serologic evidence of past infection. In addition, an active case of CE was documented in a ewe trapped near Tok in 1979 (Smith and Heimer 1982). This disease has also been diagnosed in captive Dall sheep and captive muskoxen (Dieterich et al. 1981). The disease has also been reported in bighorn sheep and mountain goats from the western U.S. and Canadian provinces (Carr 1968, Samuel et al. 1975, Lance et al. 1981). The prevalence reported here (Table 1) and other evidence of CE in Alaska suggests exposure to the agent is quite common. However, the disease does not appear to pose a major threat to Alaskan sheep populations as a whole. Both populations studied have lamb productions which approach 70 lambs/100 ewes (weather permitting), and survival to yearling age is considered normal (at about 55%) for Alaskan Dall sheep. The source of the virus is uncertain, but it is possible that Dall sheep throughout much of Alaska could have historically been exposed to the virus from domestic sheep and goats. These domestic grazers frequently accompanied white men who roamed Alaska in search of fur and gold. It is also possible that CE has been a natural element in the assemblage of diseases with which Dall sheep have evolved since long before the introduction of domestic sheep into Alaska. In such a case, Dall sheep may be susceptible and more adversely affected by a CE virus of domestic sheep previously foreign to them. Sample collections from remote populations where chances of previous exposure are lessened will provide more data about the historical presence of this disease agent. These collections are planned.

Brucellosis is a bacterial disease of both domestic and wild animals. There are several separate species and biotypes within the genus Brucella. These species are host specific to varying degrees, and one particular species, Brucella ovis, causes clinical symptoms in various types of domestic sheep. Aliquots of the 73 samples from the Tok population were tested by the same methodology (bovine) utilized in the study by Smith et al. (1982). A low titer was found in only one sample. This low titer may represent nonspecific agglutinating substances. Nieland (1968) reported Brucella titers in Dall sheep from the Brooks Range. Based upon the low prevalence of serum antibody, and the low titer of the specimen in which agglutination occurred, it appears brucellosis is not a major disease element in the natural history of these sheep populations.

Parainfluenza III virus is a member of a group of epizootiologically related agents commonly referred to as the bovine respiratory viruses (Dieterich 1981). These viruses are frequently found in domestic cattle and cause or initiate pneumonia. Wild sheep are very susceptible to pneumonia-like syndromes caused by bacteria and viruses as well as

Table 1. Results of serologic tests performed on sera collected from Dall sheep near Tok, Alaska during 1979.

Organism	Test Procedure[a]	Prevalence[b]	Range of Titers (median)
Campylobacter fetus	CG	22/73 (30)	1:100-1:200 (1:100)
Contagious ecthyma virus	SN	17/73 (23)	1:5-1:320 (1:10)
Brucella spp. (bovine)	SPT	3/73 (4)	1:50 (1:50)
Parainfluenza III virus	SN	1/73 (1)	1:100
Bovine viral diarrhea virus	SN	0/73	0
Bluetongue virus	AGID	0/73	0
Infectious bovine rhinotracheitis virus	SN	0/73	0
Ovine progressive pneumonia virus	AGID	0/73	0
Leptospira spp.	SPT	0/73	0
Anaplasma spp.	CG	0/73	0
Toxoplasma spp.	IHA	0/73	0

[a] CG = card agglutination, SPT = standard plate agglutination, SN = serum neutralization, AGID = agar gel immunodiffusion, IHA = indirect hemagglutination

[b] Number positive/number tested (% positive)

Table 2. Results of serologic tests performed on sera collected from Dall sheep near Dry Creek, Alaska 1977 and 1981.

Organism	Test Procedure[a]	Minimum titer for classification as possitive	Prevalence[b]
Brucella spp. (bovine)	SPT	1:25	0/17
Parainfluenza III virus	HI	1:10	0/17
Bovine viral diarrhea virus	SN	1:16	0/17
Infectious bovine rhinotracheitis virus	SN	1:16	0/17
Leptospira spp.	MAT	1:100	0/17

[a] SPT = standard plate agglutination, HI = hemagglutination-inhibition, SN = serum neutralization, MAT = microscopic agglutination

[b] Number positive/number tested.

Table 3. Frequency of lumpy-jaw occurrence in Alaska Range sheep.

Location	Data gathered by	Prevalence[a]
Denali (McKinley) Park (Murie 1944)	skull collection	213/829 (26)
Dry Creek (1969-70)	trap and palpate	26/89 (29)
Dry Creek (1973-79)	collected by shooting	14/71 (20)
Dry Creek (1981)	trap and palpate	8/23 (35)
Dry Creek - total	all methods	48/183 (26)
Sheep Creek (1976-79)	collected by shooting	3/21 (14)
Sheep Creek (1979)	trap and palpate	10/86 (12)
Sheep Creek - total	all methods	13/107 (12)

[a] Number positive/number tested (% positive).

roundworms, so any penumonia-causing agents are of special interest where Dall sheep are concerned. Serologic evidence of past exposure to parainfluenza III has been reported for bighorn sheep (Howe et al. 1966). This virus was also isolated from clinically ill Rocky Mountain bighorns (Parks et al. 1972) which subsequently died with pneumonia (Thorne 1982, pers. commu.). The significance of the single sample with evidence of past exposure reported here is not known.

Both study populations have lumpy-jaw disease, and the frequency of the condition appears to be about twice as great among the lower quality group. The frequency of lumpy-jaw among the sheep from Mount McKinley (now Denali) National Park (Murie 1944) seems to confirm this higher prevalence among sheep of the western end of the Alaska Range. Denali National Park is about 70 km west of the Dry Creek area and has population characteristics, particularly density, which are similar to those of the Dry Creek area. We don't think lumpy jaw is a primary contributor to the observed differences in population quality. Heimer (1982) found more old ewes present in the Dry Creek area than near Tok. Lumpy-jaw frequency may be a function of age, but we doubt the differences in age are sufficient to account for a doubling in occurrence of lumpy-jaw.

So-called "sulfur granules" have been described in lumpy-jaw lesions caused by Actinomyces spp. infection. No such granules were found in five Dall sheep with active cases of lumpy-jaw. Further, attempts to culture this fungus from lumpy-jaw cases have failed. We have frequently found Corynebacterium pyogenes in these lesions. The ability of this bacterium to cause periodontal disease (Davis et al. 1973) suggests to us that it may be the cause of lumpy-jaw condition in Alaska's Dall sheep.

Dall sheep of Alaska appear to be in a relatively pristine condition with respect to exposure to disease agents of domestic grazers. The best course to advocate is separation of domestic species from Dall sheep populations. Mixing of the two groups of sheep should be precluded until further surveys have been concluded. If it becomes apparent that either group poses a potential health hazard to the other, such separation should become permanent policy.

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Comment

I have two quick comments. One of them is about the serology of _Campylobacter_ bacteria. Serologic tests for _Campylobacter_ are nearly worthless. From what I understand, many labs hardly run this test any more. The reason is there are several intestinal flora of the _Campylobacter_ group that do cross-react with _Campylobacter fetus_. There are some research labs in the United States that do this test on an experimental basis, but if you just run it in a routine lab, I sure wouldn't consider the results dependable. Second, we've seen the lumpy-jaw problem in captive antelope in Wyoming. Seven or 8 years ago we went through the same testing you did, trying to isolate the organism, and we came up with _Corynebacterium_ just as you did. From what I can understand with domestic sheep, there is a condition like lumpy jaw called broken mouth. In domestic sheep, they do culture several different types of bacteria from these cases, but it is not the classical lumpy jaw or _Actinomyces bovis_ like you first suspected. I think you are on the right track. Sometimes you can look at these animals and see the erosion of teeth and stair-stepping of the teeth. This might point to rougher forage which causes these symptoms.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:198-201

AN OUTBREAK OF PINKEYE IN BIGHORN SHEEP, YELLOWSTONE NATIONAL PARK:

A PRELIMINARY REPORT

Mary Meagher, National Park Service, Yellowstone National Park, WY 82190

ABSTRACT

Blindness in a number of bighorn sheep (Ovis canadensis) rams was first reported to park personnel December 13, 1981. Initial field surveys of sheep wintering in the Mt. Everts area indicated eye problems in both sexes and all age classes. Prevalence was highest in rams. Prevalence was less or nonexistant in bighorn sheep groups elsewhere on the northern winter range. Keratoconjunctivitis or pinkeye was suspected by consulting veterinarians when the condition as observed in the field was described. Necropsies conducted by the Montana Dept. of Livestock Diagnostic Laboratory at Bozeman, Montana, confirmed the condition; diagnostic procedures indicated the causative organism was Chlamydia sp. Mortality occurred directly because of accidents to blind animals and destruction of affected individuals which were helpless on a main road. Mortality occurred indirectly through impairment of foraging and sheltering ability. Individuals were observed in which affected eyes appeared to be healing naturally. Effects of the outbreak on the population will be assessed after an aerial count in the spring.

REPORT

Blindness in some of the rams of the bighorn sheep population which winters on the west and north lower slopes of Mt. Everts (Figure 1) was first reported to park personnel December 13, 1981. Initial field surveys indicated that both sexes and all age classes were affected. Surveys of 117 and 107 sheep on December 14 and 22 respectively showed a prevalence of 25 percent, with 60 percent of the rams affected. Ratio of affected rams: ewes was approximately 10:1. As winter progressed survey results appeared more biased, apparently because healthy animals were better able to move to shelter.

Prevalence of pinkeye in bighorn sheep elsewhere on the northern winter range appeared less or nonexistent. Ten of 60 sheep observed during a ground survey in the less accessible area of Junction Butte - Specimen Ridge on January 1, 1982, had signs of pinkeye. One affected ram, and possibly a second individual, were observed in a group of 11 near Junction Butte during an aerial survey of 109 sheep in that general area and eastward in early January. No cases were reported among the bighorns just north of the park near Cinnabar Mountain.

Keratoconjunctivitis, or pinkeye, comparable to that reported for livestock and some other species of wildlife, was suspected by consulting veterinarians when the condition as observed in the field was described (Dr. W. Quinn, Dr. T. Thorne, pers. comm.[1]). Necropsies conducted by the Montana Department of Livestock Diagnostic Laboratory at Bozeman, Montana, confirmed the condition; diagnostic procedures indicated the causative organism was _Chlamydia_ sp. (Dr. W. Quinn, pers. comm.). The disease had not been reported previously in bighorn sheep (Dr. T. Thorne, pers. comm.).

The outbreak probably began in mid to late October; a ewe apparently suffering from this condition was seen October 31, but not reported then. The extent of the outbreak was influenced by the movement of the bighorns to winter ranges and the onset of the rut. Transmission apparently peaked during the rut and dropped abruptly thereafter in late December.

Based on the field observations, the course of the disease appeared as follows: incubation for perhaps a week; a period of intense irritation of the eyes with copious discharge (the eye or eyes were partly to completely closed, sometimes with obvious swelling of the lids); affected eyes a cloudy, milky, blue-white, generally open, sometimes less so in bright light, discharge generally less, and eye ruptured, animal blind _or_ healing process began. Dense white scar tissue was seen in some eyes which in some cases appeared to be a permanent condition of a blind eye. Eyes of individuals were commonly observed to be in differential stages of the disease.

Affected animals were noticeable by their circling behavior when disturbed. Some undisturbed animals also circled; apparently they were restless and wished to move but could not see to travel. Animals also used a rather stilted "testing" walk, especially down grades. Afflicted animals appeared to adjust to some degree in making short range movements and later moved more normally when undisturbed. Blind individuals in the company of other bighorns moved more easily, apparently using their hearing ability.

Mortality appeared to have peaked during the first part of January, but continued at a lower rate at least through February. Mortality occurred directly through falls and destruction of blind animals which become helpless on the main road through a canyon. Mortality occurred indirectly through inability to forage and shelter adequately. Individuals continued to die during and after recovery from the infection because of loss of energy reserves while their vision was impaired.

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[1] Dr. W. Quinn, Montana Department of Livestock Diagnostic Laboratory, Bozeman, MT. Dr. T. Thorne, Wildlife Research Laboratory, Laramie, WY.

The exposed population units may have totaled 300 bighorn sheep out of an estimated park population of 550-600. Expected mortality was estimated conservatively at 50-70 individuals; by early February known mortality, mostly related to the outbreak, was 50. That number included 22 rams of various ages, 16 ewes, 5 lambs or yearlings, and 6 unknowns. A further assessment of the effects on the population will be made after an annual aerial count in the spring.

ACKNOWLEDGEMENTS

I thank the Foundation for North American Wild Sheep for financial assistance with the monitoring effort, much of which was done by Dave DelSordo. Field surveys were conducted with the assistance of many park people; Sandi Fowler was particularly helpful.

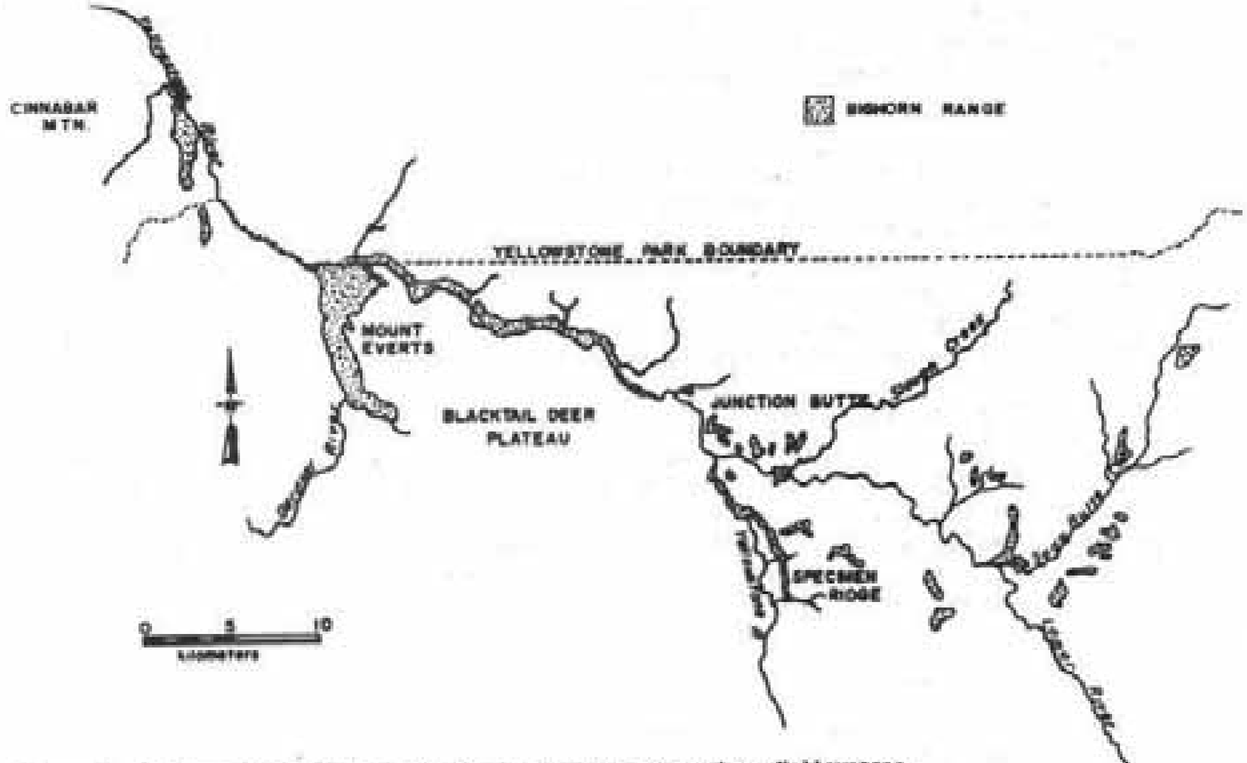

Figure 1. Bighorn sheep winter range in and adjacent to northern Yellowstone National Park. Adapted from Houston, D.B., The Northern Yellowstone Elk, in prep.

CONFERENCE DISCUSSION

Questions regarding this paper were answered by Tom Thorne, who read the paper.

Q. Was there any contact with domestic livestock?

Ans. If there had been livestock on the range, I probably would have been quick to blame them also, but in the absence of livestock it would be pretty hard to say how bighorns might have contacted the infection from livestock. There was a great deal of controversy regarding whether or not to try to deal with the disease by treating the sheep. The Park Service caught a lot of flak and a lot of grief over it. I personally feel they probably did the right thing, but if it occurred outside the Park where we had access to the animals and they are managed by the Game and Fish Department for different purposes, I'm sure we'd handle it differently.

Q. In Bear and Jones (1973) there is a report of a ewe that was found in about 1954 in the Gore Range of Colorado, which was grazed by domestic sheep. The people who found the ewe said she had pink eye. She was blind.

Ans. Did they demonstrate Chlamydia?

Q. No.

Ans. Pink eye is about the worst term this disease could be called by. Pink eye is catch-all term. You could poke your finger in a sheep's eye and his eye would run and you could call it pink eye. He could have Moraxella sp. infection, it could be due to a sequala of blue tongue, a number of other bacteria and so on. So one individual way back when, when no etiologic agent was identified, does not make a diagnosis as far as I'm concerned.

Ans. Yes, I understand that, but that was one incident that was at least reported. Another thing, Mary Meagher told me that domestic sheep were recently moved onto the range of the Cinnabar herd, and that the Cinnabar herd exchanges individuals with the Mt. Everts herd.

Ans. (Shawn Stewart) However, I believe no infection has been documented in the Cinnabar herd.

quantities (Lehr 1941, Black 1968, Brownell and Crossland 1972). Low availability may reduce what little Na is accumulated by plants. Regions far removed from the influence of marine aerosols generally have low Na content in soil and rainwater (Eriksson 1952, Jordon et al. 1973), and alpine soils may be severely dificient of Na because of leaching by melting snow (Denton 1965).

Na is an essential mammalian macronutrient comprising approximately 92 percent of all extracellular fluid cations (Guyton 1976). Its primary functions include the regulation of osmotic pressure, maintenance of acid-base balance and conduction of nerve impulses (Mills 1969, Guyton 1976, Lloyd et al. 1978). The importance of Na is accentuated in ruminants because of the large, alkaline salivary secretions buffering the acidic products of microbial fermentation in the rumen (Denton 1956, 1957, Kay 1960, Church 1976). Ungulates in Na-deficient regions may be limited, at least seasonally, by an inability to maintain a positive Na balance (Jordan et al. 1973, Botkin et al. 1973). However, it can be assumed that wild ungulates balance their annual Na budget since death from Na deficiency rarely occurs, although wild animals apparently incur severe Na deficiency during spring and summer (Blair-West et al. 1968). Seasonal utilization of natural licks, mineral springs, and/or plants which accumulate this ion, recurrently combats Na deficiencies induced by forage depauperate in Na and ecological conditions e.g., (succulent spring forage) which accelerate the depletion of body Na (Blair-West et al. 1968).

Mountain goats were transplanted into the Gore Range between 1968 and 1972. During the initial transplants, three NaCl blocks were placed on Dora Mountain to hold the goats in the area. Mountain goat utilization has formed licks at these sites. In recent years, additional salt blocks deposited for goats by local ranchers and localized areas around camps where recreationists and hunters persistently urinated have caused a proliferation of new licks on the mountain. The purpose of the following study was to investigate the role of artificial salt licks in mountain goat ecology by documenting patterns of lick use and environmental Na availability.

Research was supported by the Dillon Ranger District, U.S. Forest Service, the Colorado Division of Wildlife, and the University of Wyoming. I thank B. Foster for reviewing the manuscript.

STUDY AREA

The Eagles Nest Wilderness is located in north-central Colorado, northwest of Dillon (Figure 1). The study area is defined by the boundaries of the ENW, which contains the high peaks of the Gore Range. The area encompasses 542 km^2, 54 percent above timberline (U.S. Forest Service 1979).

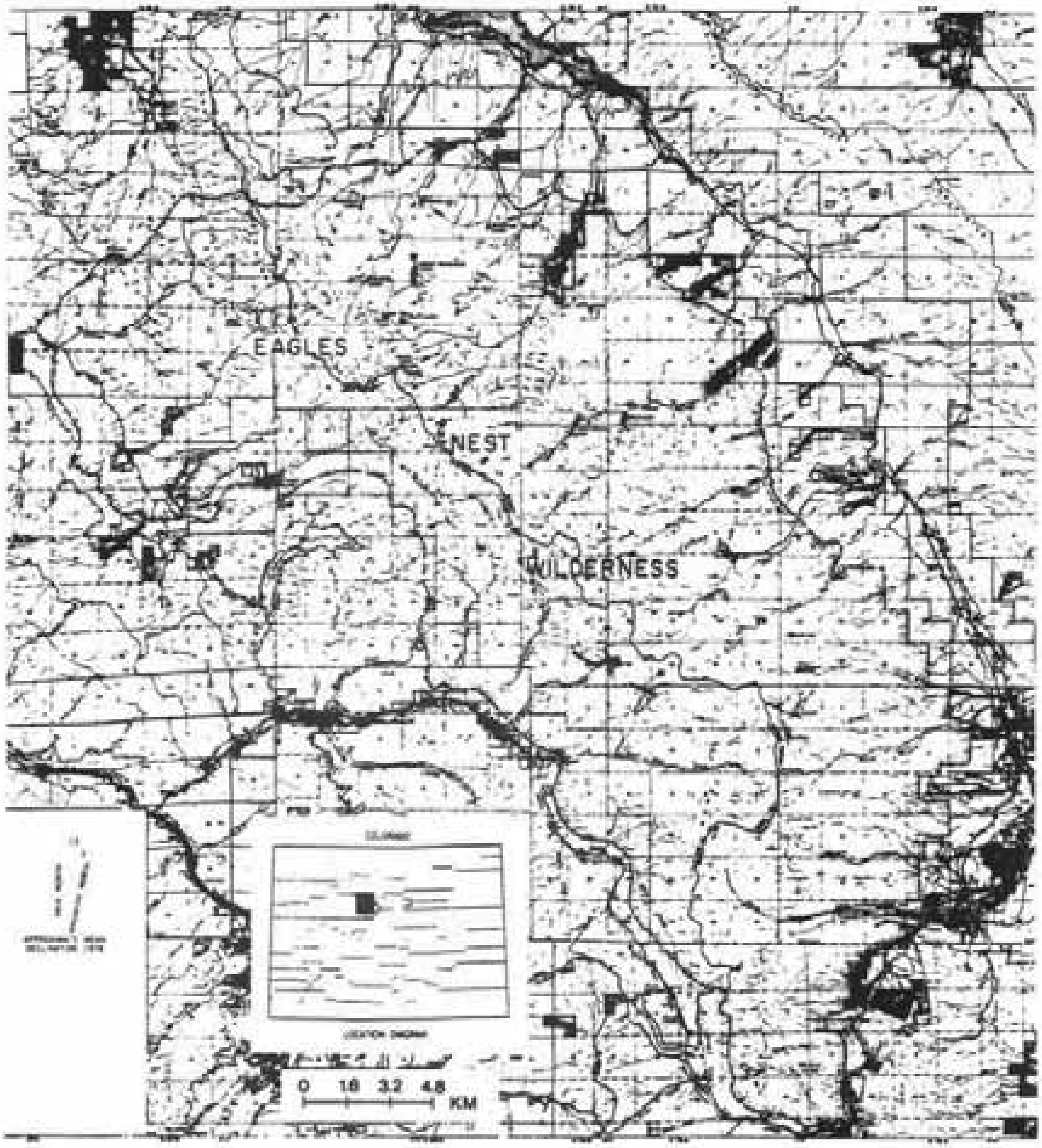

Figure 1. Eagles Nest Wilderness study area in north-central Colorado.

Intensive research was conducted on Dora Mountain in the northern half of the study area, due to the distribution of mountain goats and the salt licks located on Dora Mountain.

Dora Mountain is a large, horseshoe-shaped, mesa-like peak gently sloping to the northeast from Eagles Nest Mountain (4,084 m) and the main divide (Figure 2). The summit ranges from 3,658 m - 3,780 m and is a remnant of a preglacial erosion surface (Tweto et al. 1970).

Summer typically have cool, short growing seasons while winters are long and cold. Annual precipitation varies from 51 cm to over 102 cm at higher elevations, falling primarily as snow (U.S. Forest Service 1977). Severe thunderstorms are common in July and August. Permanent snowfields are common on north and east headwalls, and snowpack from normal winters often persist into fall.

Flora of the study area varies according to exposure and elevation. Lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), and Douglas fir (*Pseudotsuga menziesii*) occur in the montane zone. Dense stands of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) dominate the subalpine zone. Timberline occurs between 3,413 m and 3,504 m. Above treeline, the spruce-fir become dwarfed and give rise to alpine vegetation such as carices (*Carex* spp.), sheep fescue (*Festuca ovina*), spike wood-rush (*Luzula spicata*), and forbs such as alpine avens (*Geumturbinatum* [= *G. rossii*]), clover (*Trifolium* spp.), blueleaf cinquefoil (*Potentilla diversifolia*), and marsh marigold (*Caltha leptosepala*). Willows (*Salix* spp.) myrtle whortleberry (*Vaccinium myrtilus*), and Rocky Mountain sage (*Artemisia scopulorum*) are the most significant shrubs in the alpine.

Approximately 14 artificial salt licks were located on the flat summit of Dora Mountain between 3,701 m and 3,734 m (Figure 2). Mountain goats used these licks extensively. Licks were named by their location on the mountain. The main licks, Northeast Lick #3 (NEL3), Southwest Lick (SWL) and Northwest Lick #1 (NWL1), originiated from three salt blciks placed by Division of Wildlife personnel shortly after the initial transplants to hold the mountain goats in the area (Denny 1977). None of the original salt was present aside from that which had leached into the soil. However, attempting to recover what little salt remained, the goats dug into the mineral soil. The Northeast Lick #1 (NEL1), Northeast Lick #2 (NEL2), and smaller associated Northeast Licks resulted from a local rancher dropping salt blocks for the goats from a fixed-wing plane in 1976. The Northeast Lake Licks (NELL 1&2) resulted from mountain goats ingesting the urine-soaked soil from the camp of a 1978 hunting party. The recent origins of the remaining licks are uncertain.

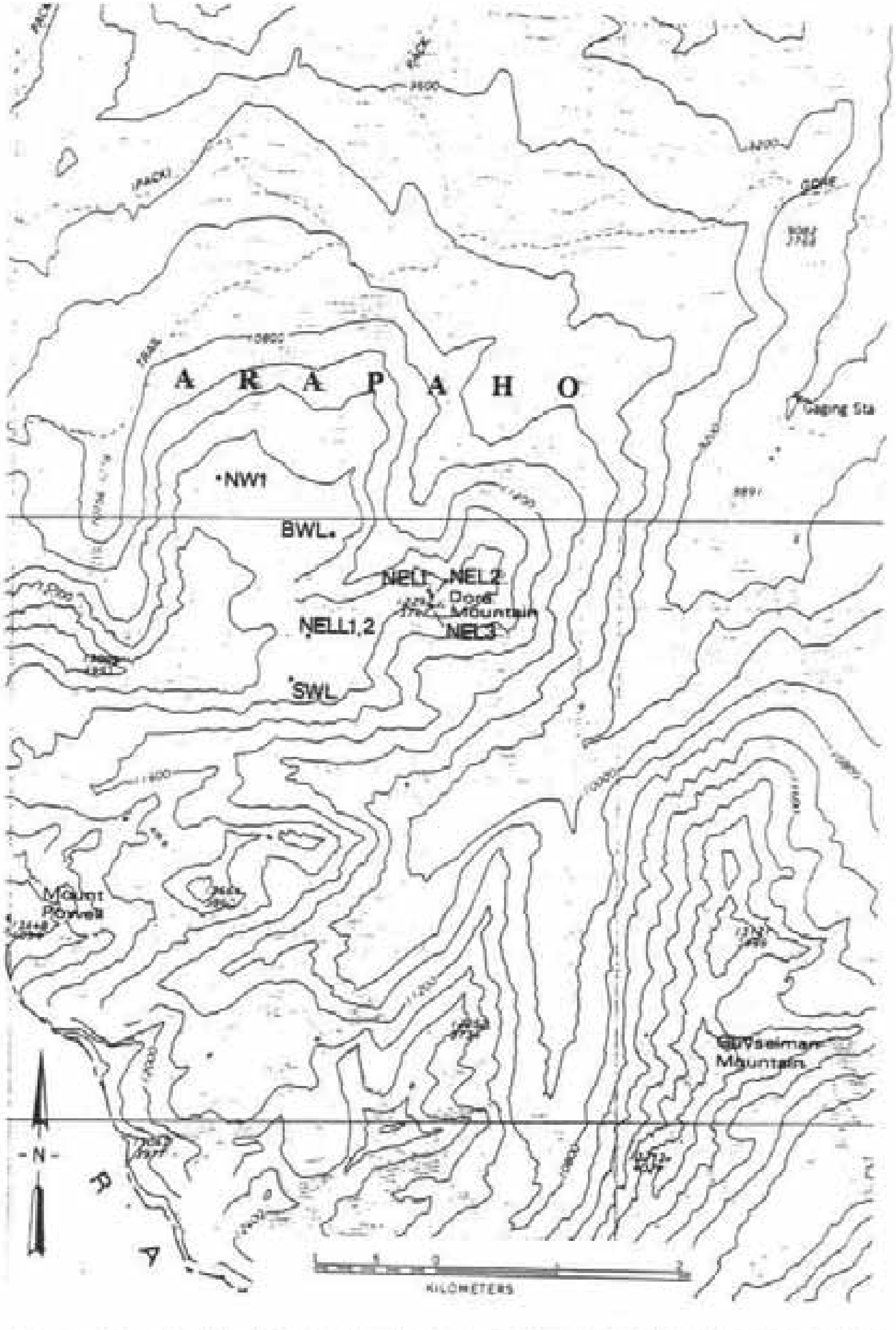

Figure 2. Detail of Dora Mountain in Eagles Nest Wilderness showing locations of major artificial salt licks.

METHODS

Mountain goats were observed in the study area from 8 June 1977 to 8 September 1979, primarily during the summer months. Direct observations were aided by the use of 7 x 35 binoculars and a 20x spotting scope.

Animals were classified into eight sex and age classes based on external genitalia, nanny-kid (NwK) or nanny-yearling (NwY) associations, urinating posture, horn morphology, tooth succession rostral width/length, and discerning the vulva (Brandborg 1955, Hibbs 1967, Thompson 1981). A combination of these criteria was used whenever possible because of inconsistencies of individual characters.

The role of Na, K, and salt licks in mountain goat ecology was investigated by field observation and laboratory analyses. Behavioral patterns of lick use were determined from field data. Recognizable goats were identified by characteristic shedding patterns, unique horns, group associations, telemetry collars, facial scars, and behavior. Laboratory methods determined the Na and K content of the animals, vegetation, water, and lick soils.

Samples of mountain goat serum, urine, milk, hair, and organic and inorganic feces (feces composed largely or entirely of lick soil) were obtained from five goats, one hunter-killed on 8 September, and four captured with rope nooses at the SWL on 25 and 28 July and 1 August. Additional fresh fecal samples were collected. Blood samples were extracted via jugular veinipuncture using nonheparinized 5-milliliter Vacutainers and 18-gauge needles. Serum, urine, and milk samples were immediately cooled in Dora Lake, packed in snow during transport out of the field, and later frozen. Blood serum was separated on a portable centrifuge. Feces and hair were air dried and stored in plastic bags. All samples were frozen until required for analysis.

In July (1979), 46 forage species were collected from Dora Mountain, taking special precautions to avoid contamination, particularly from our hands. An array of phenological growth stages was collected for each species. Chemical composition of plants, therefore, reflected average values. Collecting consisted of clipping a minimum of 20 individual plants just above the base, simulating the lower extent of a bite. Chemical content of specific plant parts (Dailey 1981) was not investigated. Browse samples were limited to the current year's growth of leaves and stems. Clipped plants were air dried and stored in paper bags until needed for chemical analysis.

Composite lick samples and soil from high use licking sites were collected from 14 licks on Dora Mountain. Only surface soils were taken at each site, representing what goats were actually ingesting. Samples were air dried and stored in plastic bags.

Samples were collected from areas where backpackers, campers, and hunters had urinated. At these specific sites, mountain goats were consuming the urine-soaked vegetation and soil. The vegetation-soil samples collected were not separated into their vegetative and soil components. Analysis results, therefore, reflected the ionic composition of the complex ingested. Control samples containing a similar vegetative and edaphic composition were collected for comparison. Samples were frozen in plastic bags.

Analyses for Na and K were modified from Isaac and Kerber (1971) and Walsh (1971). Random subsamples of all vegetation, feces, hair, lick soils, and recreationist samples were ground and dry-ashed in a muffle furnace at 500°C for four hours. Dry weight, ash weight, and the ash weight/dry weight were calculated for all subsamples. At this point, one of two procedures was followed, depending upon whether the sample was normally ingested or excreted from a mountain goat.

Analysis of solid samples ingested by mountain goats (vegetation, lick soils, and recreationist samples) followed a 0.1 NHCL extraction procedure suggested by Keiss (1976 pers. comm.), the results of which reflect only those minerals available to animals upon ingestion, rather than an absolute chemical composition. All samples were analyzed a minimum of three times. Values reported are dry weight values ($\overline{x} \pm$ SE). Na and K concentrations were measured on a Coleman model-21 flame photometer and associated Coleman Junior IIA linear absorption spectrophotometer. Ash weights of samples ranging from 0.025 g for vegetation to 1.5 g for lick soils were weighed to ± 0.1 mg. on a Sartorius 2400 digital analytical balance. The ashed sample, quantitatively transferred into a 12 x 75 mm culture tube, was dissolved in 3 milliliters of 0.1 NHCL to approximate the pH of a ruminant's large and small intestine, the primary sites of Na absorption (Mills 1969). The solution was agitated on a mixer, covered with Parafilm, and refrigerated for two hours. After centrifugation at 7000 rpm for 20 minutes to remove any suspended particles, 50 microliters of the clear, supernatant fluid were transferred to a beaker containing 5 milliliters of micropore distilled water. An additional 5 milliliters of micropore distilled water were subsequently added and the solution placed into the flame photometer for analysis. Standard NaCl and KCl solutions were used to calibrate the spectrophotometer. Ion concentrations were calculated from the curvilinear regression equation representing the standard curve. Mountain goat serum, urine, and milk were analyzed as shown using a 50-microliter aliquot directly from the sample.

Solid samples shed or excreted from mountain goats (hair, organic feces, and inorganic feces) followed a 2NHCL extraction procedure to reflect the absolute chemical composition of nutrients lost. The procedure follows the 0.1 NHCL extraction as described above.

Orchard Leaves (Standard Reference Material 1571, National Bureau of Standards) were used as a reference to evaluate the efficiencies of the total extraction (2 NHCL) and in vitro simulation (0.1 NHCL) techniques.

Based on known Na and K quantities in the reference materials (Na, 82 ± 6 ug/g; K, 1.47 ± 0.03 percent dry weight), 100 percent of the Na (84.6 ppm) and 95.1 percent of the K (1.37 percent dry weight) were recovered using the 2 NHCL extraction. The low recovery of K was probably due to an inadequate sample of reference material rather than intrinsic inefficiency of the method. Critical values for Orchard Leaves were based on a minimum sample of 250 mg. A sample of only 56.8 mg was used in the assay. Using the in vitro simulation in comparison with results of the total extraction, a goat's digestive tract extracts approximately 96.2 percent and 91.7 percent of the total Na and K content of the ingested material, respectively. If the K value obtained from the total extraction technique is equated to 100 percent for reasons described above, the comparative in vitro simulation efficiency for K would be 96.4 percent. In vitro Na extraction efficiency results march well with Mills (1969) who stated that essentially all Na in ingesta is available to ruminants through digestion.

RESULTS AND DISCUSSION

LICK USE

Inception of mountain goat lick use on Dora Mountain varied annually with the onset of the growing season and, specifically, with the ingestion of new, succulent spring forage. A similar temporal onset has been noted for mule deer (*Odocoileus hemionus*) (Black 1955), white-tailed deer (*O. virginianus*) (Chapman 1939, Weeks and Kirkpatrick 1976), elk (*Cervus elaphus*) (Dalke et al. 1965, Knight and Mudge 1967), and mountain goats (Hebert and Cowan 1971) across North America, suggesting some common environmental perturbation effecting a Na deficiency and, therefore, a salt drive (Weeks and Kirkpatrick 1976). Weeks and Kirkpatrick (1976) postulated that the temporary negative Na balance results from a high obligatory intake of K and water in the new spring forage. Increased water flux and high K levels in the glomerular filtrate of the proximal tubule reduce intestinal and nephridic Na resorbtion resulting in excessive Na loss through fecal and urinary routes (Frens 1958, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976). This excessive loss appears to initiate Na drive, hence lick use. Na drive declines during summer with increasing plant maturity and simultaneous declines in forage moisture content and K/Na ratios (Weeks and Kirkpatrick 1976). At this time and in early fall conservatory mechanisms are thought to be at peak efficiency (Weeks and Kirkpatrick 1976).

Lick use on Dora Mountain was confined to the spring and summer months beginning between 7 and 14 June, peaking between 1 and 7 July and terminating around 1 August, though goats infrequently visited the licks into September. Additionally, while the onset and cessation of lick use varied annually, the annual duration of lick use was essentially constant. There was no evidence indicating licks on Dora Mountain are used outside this period. Singer (1975) reported goats using the Walton Goat Lick in Glacier National Park from 15 April to 15 September 1975 with peak use in late June and early July. A natural lick in the Sapphire Mountains, Montana, was utilized by goats from June through December, although post-August visits to the lick averaged only three per month compared to a peak of 191 visits during July (Rideout 1974). Hebert (1967) observed lick use by goats in British Columbia from late April to early September with use of high elevation licks beginning and ending later. Variability in the onset of lick use between these areas probably reflects different local climatic and phenological influences.

All sex and age classes 1-year-old and over utilized the salt licks. This concurs with data from Hebert and Cowan (1971). Although kids were observed ingesting lick soil on five occasions, they consumed little. Each observation consisted of only a few bites or licks of soil. They appeared to be emulating their nannies who were always nearby. All kids observed ingesting lick soils either appeared to have been bored from lying outside the lick waiting for their nannies to finish licking or were forced into the lick (next to their nannies) because of a large number of aggressive goats around the lick. Based on this and Na data presented below, kids would receive little Na from lick soil relative to their nannies' milk.

Lick use differed temporally between the sexes; billies utilized licks approximately two weeks earlier than female groups. Peak use occurred around 1 and 14 July for adult males and females, respectively. Differential lick use has been observed in other studies (Brandborg 1955, Hebert 1967, DeBock 1970, Rideout 1974, Singer 1978) and has been attributed to the selection of isolated terrain by nannies until after parturition (Hebert and Cowan 1971). My data support this contention, however, even after parturition when nannies and their neonates are no longer in seclusion, nannies hesitate to bring their kids into or near the large groups found at licks until after a week or two. In general, kids accompanied their nannies to licks for the first time when they were no less than two weeks old. For the kid, this delay is probably adaptive because it allows for more advanced physical development before involvement is highly aggressive lick situations. Duration of lick use was similar between male and female groups. Peak use for male and female groups is offset one week earlier and later than peak use for all groups, respectively (Thompson 1981).

Licks were not used with consistent frequency or intensity throughout the summers, nor were areas within individual licks. At least some goats visited licks throughout the lick season and all licks were visited at least during portions of each summer, although utilization of individual licks varied. This may have been due to the moisture content of the lick and the surrounding vegetation. Licks receiving the highest use changed from NEL3 in June to the SWL in early July. During July, the SWL had a greater moisture content than the NEL3, a trend paralleling the forage moisture content-grazing trend from these same respective areas (Thompson 1981). Singer (1975) found water seeping into licks was a major factor determining late summer use.

Specific areas within each lick were "perfered" over others. In group situations, these sites were contested and first utilized by the most dominant animals, then by goats in order of decreasing hierarchial status. The "prime" areas were sites of recent goat urine deposition and their locations continually changed within the lick. Prime areas were moister than other lick sites and had a greater mean Na content (discussed below).

Small depressions within licks collected and temporarily held water from thunderstorms. Such areas also received more frequent use than drier areas, lending support to the theory that late summer lick use is a function of moisture content.

Three small new licks were formed in 1979 and four in 1980 as a result of human urine from 1978 and 1979 hunting camps. Although at least two of these licks (NELL1 and NELL2) had a high mean Na content (see discussion below), their use in early summer and midsummer was predominantly by NwK and small nursery and female groups who may have sought to avoid the agressive behavior and large groups at the SWL.

NA INTAKE

Mean vegetative Na concentrations of 46 alpine species was 48.69 ± 36.0 ppm (Table 1). Na values ranged from 7 - 142 ppm. Hebert and Cowan (1971) reported a similar mean Na value of 49 ppm for 13 alpine spring species on British Columbia goat range. Mean values from the present study are also similar to spring and summer forage values from Indiana deer range (Weeks and Kirkpatrick 1976). Since plants do not require Na, it is not surprising that the Na values are extremely low.

Seven plant species (*Antennaria alpina*, *Oreoxis alpina*, *Trifolium dasyphyllum*, *Besseya alpina*, *Primula angustifolia*, *Oxyria dignea*.and *Salix arctica*) contained Na concentrations over twice the mean value. With the exception of *Antenaria* and *Primula*, all species were eaten by mountain goats, although only *Trifolium* was consumed in significant quantities (Thompson 1981).

Vegetative K concentrations averaged 1.41 ± 1.05 percent dry weight and ranged from 0.23 - 5.54 percent (Table 1). This mean concentration mediates values reported for Indiana forage (Weeks and Kirkpatrick 1976) and alpine vegetation from British Columbia (Hebert and Cowan 1971). Four species, *Oxeoxis alpina*, *Vaccinium myrtilus*, *Lloydia serotina*, and *Castilleja occidentalis*, had K concentrations exceeding twice the mean value. These species were utilized to a low degree by goats, although *Lloydia* was ranked sixth in importance (Thompson 1981).

The mean forage Na/K ratio was 0.0082 ± 0.0074. *Trifolium dasyphylum*, *Abies lasiocarpa*, and *Juniperus scopulorum* had the highest Na/K values (Table 1). *Trifolium* are the most important forage species of goats on Dora Mountain; no utilization was recorded on *Abies* or *Juniperus* (Thompson 1981). Lowest Na/K ratios occurred in *Geum*, *Lloydia*, *Potentilla*, *Castilleja*, and *Vaccinium* whose Na concentrations were low (*Geum* and *Potentilla*) or whose K levels were elevated well above mean values.

Chemical content of 1977 composite soil samples from the NEL3 and SWL are presented in Table 2. Magnesium (Mg), iron (Fe), calcium (Ca), K, Na, and phosphorus concentrations are within the range of values reported from licks across North America (Cowan and Brink 1949, Stockstad et al. 1953, Dalke et al. 1965, Knight and Mudge 1967, Hebert and Cowan 1971, Weeks and

Table 1. Mean Ash, Na, K and Na/K values from vegetation collected 11 and 12 July 1979 on Dora Mountain, Gore Range, Colorado. Extraction employed 0.1 NHCL. Values reflect only those nutrients available to animal through digestion.

Species	Ash % Dry Wt.	Na ppm[a](meq/1)[b]	K % Dry Wt. (meq/1)[b]	Na/K meq/1/meq/1
Antennaria alpina	7.92	142(6.17)	1.56(400.00)	0.0154
Oreoxis alpina	19.94	127(5.52)	5.54(1,420.51)	0.0039
Trifolium dasphyllum	8.15	124(5.39)	0.52(133.33)	0.0404
Besseya alpina	18.60	123(5.35)	1.78(456.41)	0.0117
Primula anugustifolia	8.49	113(4.91)	1.18(302.56)	0.0162
Oxyria dignea	9.67	105(4.57)	1.50(384.62)	0.0119
Salix arctica	16.86	103(4.48)	1.52(389.74)	0.0115
Vaccinium myrtilus	2.85	72(3.13)	5.14(1,317.95)	0.0024
Trisetum spicatum	5.68	71(3.09)	1.02(261.54)	0.0118
Hymenoxys grandiflora	17.00	69(3.00)	2.02(517.95)	0.0058
Erigeron simplex	7.65	63(2.74)	2.33(597.44)	0.0046
Saxifraga rhomboidea	6.55	57(2.48)	1.25(320.51)	0.0077
Artemisia scopulorum	11.15	53(2.30)	1.97(505.13)	0.0046
Pedicularis parri	7.38	53(2.30)	1.04(266.67)	0.0086
Poa epilis	5.62	53(2.30)	1.04(266.67)	0.0086
Carex capitata - C. rupestris	4.89	53(2.30)	0.90(230.77)	0.0100
Pentaphylloides floribunda	3.92	51(2.22)	0.77(197.44)	0.0112
Gentianoides algida	3.67	48(2.09)	0.92(235.90)	0.0088
Erigeron pinnatisectos	15.39	47(2.04)	2.13(546.15)	0.0037
Eritrichium aretoides	8.00	47(2.04)	0.75(192.31)	0.0106

[a] Dry weight basis rounded to nearest ppm.
[b] meq/1 Na = ppm/23; meq/1 K = (% Dry Wt.) · 10,000/39.

Table 1 (continued). Mean Ash, Na, K, and Na/K values from vegetation collected 11 and 12 July 1979 on Dora Mountain, Gore Range, Colorado.

Species	Ash % Dry Wt.	Na ppm^a(meq/1)^b	K % Dry Wt. (meq/1)^b	Na/K meq/1/meq/1
Agropyron scribneri	6.36	46(2.00)	1.36(348.72)	0.0057
Sedum rhodanthrum	8.15	46(2.00)	1.31(335.90)	0.0060
Senecio fremonti	13.57	44(1.91)	1.70(435.90)	0.0044
Trifolium nannum	8.03	44(1.91)	0.73(187.18)	0.0102
Aquilegia caerulea	8.39	43(1.87)	1.64(420.51)	0.0044
Pedicularis groenlandica	7.71	43(1.87)	1.10(282.05)	0.0066
Juniperus scopulorum	3.33	42(1.83)	0.30(76.92)	0.0237
Castilleja occidentalis	18.73	40(1.74)	2.84(728.21)	0.0024
Zygadenus elegans	8.96	40(1.74)	1.98(507.69)	0.0034
Abies lasiocarpa	3.54	40(1.74)	0.23(58.97)	0.0295
Trifolium parryi	6.91	32(1.39)	0.63(161.54)	0.0086
Lloydia serotina	9.92	31(1.35)	3.02(774.36)	0.0017
Trollius laxus	10.93	31(1.35)	1.36(348.72)	0.0039
Picea englemannii	3.22	28(1.22)	0.36(92.31)	0.0132
Polemonium viscosum	7.94	26(1.13)	1.18(302.56)	0.0037
Luzula spicata	6.83	23(1.00)	1.05(269.23)	0.0037
Thlaspi alpestre	8.22	22(0.96)	1.10(282.05)	0.0034
Cirsium scopulorum	13.44	21(0.91)	1.05(269.23)	0.0034
Potentilla diversifolia	8.35	19(0.83)	1.46(374.36)	0.0022
Salix brachycarpa	3.56	17(0.74)	0.40(102.56)	0.0072
Dryas octapetala	5.41	17(0.74)	0.38(97.44)	0.0076
Polygonum bistortoides	8.71	15(0.65)	0.62(158.97)	0.0041
Festuca ovina	5.73	15(0.65)	0.48(123.08)	0.0053
Carex albonigra	7.69	12(0.52)	0.92(235.90)	0.0022
Geum turbinatum	7.48	11(0.48)	1.33(341.03)	0.0014
Mertensia viridis	10.70	7(0.30)	1.43(366.67)	0.0008

Table 1 (continued). Mean Ash, Na, K, and Na/K values from vegetation collected 11 and 12 July 1979 on Dora Mountain, Gore Range, Colorado.

Species		Ash % Dry Wt.	Na ppm[a](meq/1)[b]	K % Dry Wt. (meq/1)[b]	Na/K meq/1/meq/1
Orchard Leaves[c]					
0.1 NHCL extraction[d]		16.86	81.42(3.54)	1.32(338.46)	0.0082
2 NHCL extraction [e]		16.86	84.6 (3.68)	1.37(351.28)	0.0074
Mean ± SE	(46)[f]	8.72 ± 4.33	48.69 ± 36.00 (2.12 ± 1.57)	1.41 ± 1.05 (361.54 ± 269.23)	0.0082 ± 0.0074
Graminoids	(7)[f]		39.1 ± 22.54 (1.70 ± 0.98)	0.97 ± 0.26 (247.99 ± 67.30)	0.0068 ± 0.0035
Forbs	(30)[f]		54.51 ± 37.72 (2.37 ± 1.64)	1.57 ± 0.97 (401.71 ± 247.86)	0.0073 ± 0.0074
Woody Plants	(9)[f]		46.92 ± 27.6 (2.04 ± 1.20)	1.23 ± 1.59 (315.38 ± 407.09)	0.0123 ± 0.0089

[c] Standard Reference Material 1571, National Bureau of Standards. Certified values are: Na = 82 ± 6 ppm; K = 1.47 ± 0.03%. Orchard leaves results not included in mean values.

[d] *In vitro* simulation based on Keiss (1976, pers. comm.). Results reflect only those minerals available to animal through digestion.

[e] Results reflect total chemical composition of sample.

[f] Number of species.

Kirkpatrick 1976, Weeks 1978, Fraser et al. 1980). Furthermore, since manganese (Mn), copper (Cu), and zinc (Zn) are thought to be in approximately normal concentrations (Keiss, pers. comm.), Na was probably the attracting element at these licks.

Composite Na and K concentrations in the SWL and NEL3 declined significantly between 1977 and 1979 (Tables 2 and 3). Considering the Na in these two licks is a product of weathering from the original salt blocks, the apparently declining Na concentrations are probably attributable to the annual consumption and continual leaching of lick soils. However, the cause of the K decrease is uncertain. Since the 1977 samples were composites, subsamples of local Na and K concentrations ("preferred" sites) may have had elevated composite values. Na and K content of prime lick sites is greater than composite values. Indeed, at prime sites in the SWL, Na is almost nine times as concentrated as mean lick values (Table 3).

Mean Na and K concentrations of all licks on Dora Mountain (Table 3) were 77.94 ± 60.02 ppm and 118.0 ± 82.0 ppm, respectively. Both values lie within the range of other North American licks, although Na values are comparatively low (Cowan and Brink 1949, Stockstad et al. 1953, Dalke et al. 1965, Knight and Mudge 1967, Hebert and Cowan 1971, Botkin et al. 1973, Vaughan 1974, Weeks and Kirkpatrick 1976, Weeks 1978, Fraser et al. 1980). Na/K values were similar to natural salt licks (Hebert and Cowan 1971) and were over 117 times greater than mean vegetation values (compare Tables 1 and 3). Mean Na concentration of composite Northeast Lick (NEL1, NEL2,

Table 2. 1977 composite chemical content of the NEL3 and SWL on Dora Mountain, Gore Range, Colorado, using 0.1 NHCL[a]. Values reflect only nutrients available to animal through digestion.

	ppm								%
Lick	Mg	Fe	Ca	Mn	Cu	K	Na	Zn	P
NEL3	1,000	450	7,500	125	50	200	450	20	0.03
SWL	575	760	1,750	40	25	400	700	10	0.01

[a] Analysis conducted by Robert Keiss, Colorado Division of Wildlife, Fort Collins.

Table 3 Na and K content of licks on Dora Mountain, Gore Range, Colorado, 1979. Extraction employed 0.1 NHCL. Values reflect only those nutrients available to animal through digestion.

Lick	Degree of Use	Sample	Na ppm[a](meq/l)[b]	K % Dry Wt. (meq/l)[b]	Na/K (meq/l/meq/l)
SWL	H[c]	Composite[d]	27(1.17)	0.007(1.79)	0.654
SWL	H	Prime[e]	238(10.35)	0.03 (7.69)	1.345
NELL1	M[c]	Composite	113(4.91)	0.012(3.08)	1.597
NELL2	M	Composite	103(4.48)	0.01 (2.56)	1.747
NW1	L[c]	Composite	93(4.04)	0.027(6.92)	0.584
NW2	L	Composite	157(6.83)	0.009(2.31)	2.958
NWML	L	Composite	33(1.43)	0.008(2.05)	0.699
NWWL	L	Composite	37(1.61)	0.009(2.31)	0.697
BWL	M	Composite	130(5.65)	0.013(3.33)	1.696
BEL	L	Composite	23(1.00)	0.006(1.54)	0.650
BSL	L	Composite	23(1.00)	0.006(1.54)	0.650
NEL3	H	Composite	50(2.17)	0.005(1.28)	1.696
NEL3	H	Prime	93(4.04)	0.026(6.67)	0.607
NEL2	L	Composite	30(1.30)	0.008(2.05)	0.636
NEL1	L	Composite	50(2.17)	0.007(1.79)	1.211
NE Control [f]		Composite	27(1.17)	0.009(2.31)	0.509
CL	L	Composite	47(2.04)	0.006(1.54)	1.328
Cabin Lick[g]	N[c]	Composite	3,705(161.09)	0.032(8.21)	19.632

[a] Dry weight basis.

[b] Dry Weight · 10,000 = ppm.

[c] H = High, M = Moderate, L = Low, N = None.

[d] Sample reflects mean composition of lick.

[e] Sample reflects specific "preferred" area of lick.

[f] Composite control sample for area of the Northeast Licks.

[g] Natural lick located outside goat range in montane zone approximately 0.4 km north of Lower Cataract Lake.

Table 3 (continued). Na and K content of licks or Dora Mountain, Gore Range, Colorado, 1979.

Lick	Degree of Use	Sample	Na ppm[a](meq/1)[b]	K % Dry Wt. (meq/1)[b]	Na/K (meq/1/meq/1)
Mean ± SE[h] (16)[i]			77.94 ± 60.02 (3.39 ± 2.61)	0.0118 ± 0.0082 (3.03 ± 2.10)	1.172 ± 0.659
Composite [h] (14)			65.32 ± 44.62 (2.84 ± 1.94)	0.0095 ± 0.0055 (2.44 ± 1.42)	1.200 ± 0.688
Prime Sites [h] (2)			165.60 ±102.6 (7.20 ± 4.46)	0.028 ± 0.0028 (7.18 ± 0.73)	0.976 ± 0.522

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[h] Results of Cabin Lick and control sample for Northeast Licks do not enter into calculations.
[i] Sample size.

NEL3) samples is 43.3 ± 11.5 ppm, only 1.6 times the mean value of a composite control sample from the area. If Na concentrations of licks continue to decline at the rate observed between 1977 and 1979 (NEL3: 450 to 55 ppm), in several years licks will have no greater Na concentrations than the surrounding soils. Indeed, the vegetation will have a greater concentration. Already two licks, BEL and BSL, have Na concentrations below the Northeast Lick control sample and four other licks, NEL2, NWML, NWWL, and SWL, have equal or slightly high Na values, although all these except the SWL receive low use (Table 3).

The NEL3 and SWL contained localized, "preferred" or "prime" sites within each lick which were areas of recent mountain goat urine deposition. Goats were observed urinating in these licks eight times throughout the study although additional deposits were suspected. As the urine-soaked soil was consumed and fresh urine deposited, a new "preferred" site was formed. The apparent intraspecific recycling of urinary Na was restricted to the NEL3 and SWL excavations. However, because of quantitative limitations this represented an insignificant Na source for the goat population. In British Columbia, goats "preferred" localized areas in mineral licks which had naturally higher Na concentrations than adjacent "less preferred" areas (Herbert and Cowan 1971).

If goats differentially consume soil from "prime" sites because of their greater Na content, this explicitly suggests goats can detect Na differences as small as 43 ppm (in the case of NEL3, Table 3). However, if this is the case, why do goats heavily utilize the NEL3 and SWL (high use licks averaging 38.5 ppm Na) when medium- and low-use licks on the average contain greater Na concentrations (115.3 and 54.8 ppm Na, respectively)? Indeed, why use the SWL at all if its composite Na content is identical to a control soil sample from the Northeast Lick area (Table 3)? I suggest the NEL3 and SWL are now traditional social centers. Kindel (1958) suggested that natural licks were an important social center for elk and that animals visit licks not because of a physiological need, but to remain in a herd. However, socialization associated with licks could only be developed after lick use was established (Knight and Mudge 1967). The NEL3 and SWL were heavily utilized for their Na content while the salt blocks were still intact. After the blocks weathered and leached into the ground, goats began excavating and consuming the soil. This behavior persists in groups of up to 41 animals; however, based upon the present Na content of the NEL3 and SWL, lick use now appears to be less related to fulfilling Na needs, although it probably ameliorates seasonal dificiencies.

The Cabin Lick, located 5.7 km outside the goat distribution about 0.4 km north of Lower Cataract Lake, was the only natural lick identified in the Gore Range. The Na concentration (3,705 ppm) and Na/K value (11.578 ppm) are extremely high. This lick is heavily utilized by deer, marmots (Marmota flaviventris), and porcupines (Erethizon dorsatum) during the spring and summer months. Although goats may travel up to 24 km, partly through forests, to visit licks (Brandborg 1955, Hebert and Cowan 1971), goats have either not found the lick yet or are avoiding the heavy recreational pressure of the surrounding area.

Seven small new licks were formed in 1979 (n = 3) and 1980 (n = 4) as a result of human urine deposits from 1978 and 1979 backpacker and hunter camps. This source of Na represents a substantial contribution to the Na supply on the mountain. At least two of these licks (NELL1 and NELL2; the four new lick located in 1980 that were formed through recreational activities were not analyzed) had Na concentrations higher than the mean licks value, though lower than "preferred" lick sites. Na and K values from the vegetation-soil complex where recreationists urinated are presented in Table 4. Mean Na concentration of the sample complex was 1,070 ± 511 ppm, 22 times the mean value of vegetation and nearly 14 times the average lick value. Furthermore, human urine (n = 1) deposited in these areas was nearly nine times as concentrated as the mean vegetation-soil complex values (Table 4). The human kidney can excrete up to 40 g of NaCl per day (Guyton 1976, Lloyd et al. 1978). K levels of the recreationist samples are also high, making the mean Na/K value an order of magnitude higher and lower than the mean vegetation and lick values, respectively.

Localized, persistent human urination gives rise to new salt licks; however, most human Na input on the mountain appear to have occurred in single, distinct urine deposits surrounding recreationists' camps. Goats readily located these sites and consumed only the urine-soaked vegetation and soil, at times within 2 hours after deposition. The first goat arriving at a recent depost, if not displaced by a more dominant individual, consumed most, if not all, of the vegetation and soil affected. No use or a highly limited use of these sites occurred after the initial animal finished, unless a new urine deposit was made. Several deposits on the same area initiated a lick.

The relationship between mountain goats, recreationists, and salt licks was not discerned until 1978. Towards the middle of the 1978 field season, small, shallow bare spots were noticed around our alpine camps. These spots appeared between the time we left camp in the morning and our evening return. On 28 July, we witnessed a 2-year-old goat consuming vegetation and soil from a site near camp where my assistant had urinated the night before. Upon investigating the area surround camp, every area where we recalled urinating had been disturbed in a similar manner. Goats apparently visited camp in our absence and consumed the vegetation and soil where we had recently urinated. This type of goat behavior is a common occurrance in Olympic and Glacier National Parks (Moorhead 1973, Bansner 1976).

In 1979, after discovering two new licks adjacent to prior hunting camps, we confirmed this unusual method of lick procreation by empirically initiating a small lick (CL) through persistent urination in a localized area for approximately 4 days. Goats abandoned this lick shortly after urine deposits were discontinued. Sampling for lick analysis occurred subsequent to the termination of use. The low Na concentration of this lick (47 ppm) was probably due to the consumption of most, if not all, of the urine-soaked soil. As such, Na content of the sample represented little more than a soil sample of the area.

Table 4. Mean Na and K values of the urine-soaked vegetation-soil complex for recreationist samples collected on Dora Mountain, Gore Range, Colorado. Extraction employed 0.1 NHCL. Values reflect only those nutrients available to animal through disgestion.

Species	Ash % Dry Wt.	Na ppm[a](meq/1)[b]	K % Dry Wt. (meq/1)[b]	Na/K meq/1/meq/1
RE2	53.26	552(24.0)	1.856(475.9)	0.0504
RC2[a]	62.89	56(2.4)	0.751(192.6)	0.0126
RE3	60.05	1,084(47.1)	1.563(400.8)	0.1176
RC3[a]	49.71	66(2.9)	0.809(207.4)	0.0138
RE4	56.9	1,573(68.4)	2.125(544.9)	0.1255
RC4[a]	61.59	123(5.3)	0.771(197.7)	0.0271
Human Urine		9,183(399.3)	2.156(552.8)	0.7222
Mean ± SE[b] (3)[c]	57.4 ± 512	1,070 ± 511 (46.52 ± 22.2)	1.848 ± 0.281 (473.85 ± 72.1)	0.0978 ± 0.0413

[a] Control sample.
[b] Excludes control and urine samples.
[c] Sample size.

There is little Na input through any water source on Dora Mountain (Table 5). Mean Na concentration of 11 water samples was 0.35 ± 0.129 meq/liter, roughly 30 percent of the Na in the Northeast Lick control sample. Two samples were not discernible from micropore distilled water. The mean K value was nearly identical to the mean content of lick samples, but was 131 percent higher than the control sample for the Northeast Licks. Na/K values were roughly similar to mean lick values.

Table 5. Mean cation concentrations of water collected on Dora Mountain, Gore Range, Colorado.

Sample	n	Na (meq/l)	K (meq/l)	Na/K (meq/l/meq/l)
Dora Lake	3	0.3	2.3	0.130
Small Lake	2	0.4	2.1	0.190
Snowfield Runoff	3	0.2	3.4	0.059
Standing Water	3	0.5	4.3	0.116
Mean ± SE		0.35 ± 0.129	3.03 ± 1.02	0.124 ± 0.054

SYSTEMIC VALUES

Serum Na values (Table 6) were within the noraml range reported for mountain goats (Hebert 1967) and similar to values reported for other ungulates (Franzmann and Thorne 1970, Anderson and Medin 1972, Seal et al. 1972 a, b, Turner 1973, Barrett and Chalmers 1977, Mautz et al. 1980). Due to the regulatory function of the kidney, serum Na levels are thought to remain essentially constant despite the Na status of the animal (Smith and Aines 1959, Beilharz et al. 1962, Hebert 1967, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976). Hebert (1967) was unable to detect differences in mountain goat serum Na levels due to lick use. Serum K values were similar to plasma K values reported for desert bighorn sheep (Ovis canadensis) (Turner 1973).

The single saliva sample analyzed in this study was from a tame, hand-reared yearling goat used in a Division of Wildlife food habits study. This animal received mineral supplements and, therefore, probably had Na and/or K levels elevated from those of wild goats. Nevertheless, the Na and K values (Table 6) compare closely to values reported by McDougall (1948), Kay (1960), and Blair-West et al. (1964) for domestic sheep on "normal" forage. Na status of the animal has a marked effect on salivary Na and K content (Denton 1956, 1957, Kay 1960) and even under ordinary dietary conditions the salivary concentration of these two cations is widely variable (McDonald 1969). Denton (1956) demonstrated that commensurate with negative Na balance, the Na content of parotid sheep saliva decreased from 180 meq/liter to 60 meq/liter with a concomitant K increase from 10 meq/liter to 120 meq/liter.

NA OUTPUT

Urinary Na concentrations were high averaging 5.7 ± 2.4 meq/liter (Table 6). Although this elevated level was possibly an artifact of sample size, it may also be attributable (particularly in the adult male) to increased K intake inhibiting Na retention (Suttle and Field 1967, Weeks and Kirkpatrick 1976), excretion of large quantities of K resulting in concomitant Na loss (Eisenstein 1967, Weeks and Kirkpatrick 1976), a sudden intake of high Na levels on a system of adapted to conserve limited Na intake (Weeks and Kirkpatrick 1976), diuresis caused by the abrupt shift to succulent spring vegetation analagous to increased fecal Na loss (Frens 1958, Hebert and Cowan 1971, Weeks and Kirkpatrick 1976), or any combination of these factors. Weeks and Kirkpatrick (1976) found 21 percent of 78 deer urine samples were well above 4.35 meq/liter Na, yet 40 percent had Na concentrations below 0.435 meq/liter. Even under closely controlled conditions, sheep exhibit wide fluctuations in urinary Na content (Denton 1956, Suttle and Field 1967). Through similar environmental Na limitations, nephric Na retention efficiency of the mountain goat should rival or exceed that of the deer. The Na value for the tame yearling (Table 6) confirms this animal was receiving supplements.

As previously mentioned, urinary K may influence Na excretion through nephric interaction. Mean urinary K levels (Table 6) were extremely variable and significantly higher than comparable values from deer (Weeks and Kirkpatrick 1976).

Mean fecal Na concentrations for all organic samples (Table 7) were higher than those reported from mountain goats and other ungulates (Hebert and Cowan 1971, Botkin et al. 1973, Weeks and Kirkpatrick 1976); however, this was attributable to the high Na content of rectal samples which averaged almost four times the mean value of fresh organic pellets. Na content of fresh organic and inorganic feces were not significantly different ($P > 0.5$). This result differs statistically with Hebert and Turnbull (1977) who postulated that salt lick soil reduces the alimentary passage rate, thereby enhancing resorbtion of salivary, vegetative, and lick Na from the ingesta. Hebert and Cowan (1971) and Weeks and Kirkpatrick (1976) found fecal Na losses increased significantly with the abrupt spring dietary shift from dried, winter forages to new, succulent vegetation as a result of excessive water and K levels. This phenomenon probably occurs during spring in most ungulates. Mean organic and inorganic fecal K values (Table 7) are similar to values reported for white-tailed deer (Weeks and Kirkpatrick 1976).

Although quantitatively insignificant, Na and K loss through shedding was high. Na and K values averaged 260.5 ± 104.2 ppm and 1,880 ± 938.3 ppm, respectively (Table 7). Na values were low compared to moose (*Alces alces*) hair (Botkin et al. 1973, Franzmann and Arneson 1974).

Na content of milk from a 3-year-old goat was 46.5 meq/liter (Table 6). Female mountain goats probably have far greater Na demands than billies because of losses to fetal and associated tissues, amniotic fluid, and lactation. Assuming the birth weight of an average mountain goat kid is 2.96 kg (Brandborg 1955, Lentfer 1955) and based on data extrapolated from Weeks and Kirkpatrick (1976), the average nanny must supply 3.32 g Na to her fetus prepartum. Approximately 10 g Na are lost via isotonic amniotic fluid (Weeks and Kirkpatrick 1976) and during the lactational peak, nannies may lose 1.12 g Na per day via milk (Silver 1961, Cook et al. 1970, Moen 1973, Weeks and Kirkpatrick 1976).

NA BALANCE

The Na requirements of mountain goats are unknown; however, it appears that for most of the year their Na intake is far below levels recommended for comparable domestic ruminants. The general recommended Na intake for domestic sheep is 0.04 - 0.1 percent of dietary dry matter (National Research Council 1975), although this level may exceed maintenance requirements. Domestic ewes are commonly provided 7.3 - 11.3 g NaCl per day (National Research Council 1975). If a 65-kg goat consumes 1.62 kg of dried forage per day (extrapolated from Morrision 1959) at an "average" vegetative Na value of 48.69 ppm, its daily Na intake would be 78.9 mg, a level 8.2 - 20.5 times lower than the general recommended intake (0.648 - 1.62 g Na/1.62 kg dried forage) for domestic sheep.

Even through selective feeding, utilization of licks and consumption of sites soaked with recreationist urine, Na intake would fall far short of domestic requirements. Considering the five most frequently selected forage species (Thompson 1981), *Trifolium* spp., *Carex* spp., *Gentianoides algida*, *Geum turbinatum*, *Salix* spp., and the mean forage value consumed in frequencies observed (33, 15, 13, 7, 7, and 25 percent, respectively), the Na intake would still only be 87.7 mg per day. Mean lick Na content is only slightly higher than mean forage values. However, exclusive intake of vegetation and soil from recretionist sites would provide 1.73 g Na per day, a value slightly exceeding the recommended 0.04 - 0.1 percent domestic level.

The Na deficit calculated above between mountain goat intake and recommended levels for equivalent domestic sheep marches well with deficits calculated for British Columbian mountain goats (Hebert and Cowan 1971) and white-tailed deer (Weeks and Kirkpatrick 1976).

Mean vegetative K intake exceeds levels required for domestic sheep. A minimum K ration of 0.5 percent of dietary dry matter is recommended by the National Research Council (1975). Mean K content of 46 forage species was 1.41 percent (Table 1), over twice the required allowance.

Table 6. Cation concentrations in Mountain goat tissue and fluid samples collected on Dora Mountain, Gore Range, Colorado

Sample	n	Na(meq/1)		K(meq/1)		Na/K(meq/1/meq/1)	
		Mean	SD	Mean	SD	Mean	SD
Hair[a]	10	260.5[a]	104.2[a]	1,880[a]	938.3[a]	0.271	0.093
Serum	4	150.0	2.6	5.7	0.73	26.87	3.38
2M(28 July)	1	150.3		4.9		30.67	
3F(barren, 1 Aug.)[b]	1	153.3[b]		6.5		23.58	
3F(with kid, 8 Sept.)	1	147.0		6.0		24.50	
5M(25 July)	1	149.4		5.2		28.73	
Saliva[c]	1	162.7		28.0		5.81	
Urine	2[d]	5.7[d]	2.4[d]	357.5[d]	406.6[d]	0.056[d]	0.07[d]
3F(with kid, 8 Sept.)	1	4.0		645.0		0.006	
AM(19 June)	1	7.4		70.0		0.106	
YM(24 Sept.)[c]	1	132.3		169.0		0.783	
Milk (3F, 8 Sept.)	1	46.5					

[a] Values in ppm. 2NHCL used in extraction. Values represent total cation composition.

[b] Sample hemolyzed.

[c] Sample from tame, captive goat. Animal may have received mineral supplements. Saliva may be lost via drooling.

[d] Yearling male data excluded from total.

Table 7. Na and K values (mean ± SE) of mountain goat fecal material collected on Dora Mountain, Gore Range, Colorado. Extraction technique employed 2NHCL. Values reflect total composition.

Sample	n	Na	K	Na/K
		ppm (meq/1)	ppm (meq/1)	meq/1/meq/1
> 90% organic material[a]	9[b]	285.4 ± 224.8[b] (12.41 ± 9.77)	6,496 ± 1,567[b] (166.6 ± 40.2)	0.078 ± 0.0564[b]
fresh pellets	5	126.0 ± 51.2[c] (5.48 ± 2.23)	6,672 ± 1,665 (171.1 ± 42.7)	0.034 ± 0.0179
rectal samples[d]	4	484.6 ± 189.9 (21.07 ± 8.26)	6,275 ± 1,654 (160.9 ± 42.4)	0.132 ± 0.0329
tame, captive goats[e]	4	425.3 ± 20.4 (18.49 ± 0.89)	1,360 ± 314 (34.9 ± 8.1)	0.553 ± 0.1372
> 90% inorganic material[a] fresh pellets	10	110.3 ± 45.0[c] (4.8 ± 1.96)	3,085 ± 1,077 (79.1 ± 27.6)	0.149[f] ± 0.3073[f]

[a] All samples collected fit this classification.
[b] Total values of organic material exclude tame, captive goat data.
[c] Na content of fresh organic and inorganic feces is statistically identical ($t = 0.599$, $P > 0.5$).
[d] Collected on 25 and 28 July, 1 August and 8 September.
[e] Yearling study animals from Colorado Coop. Wildl. Res. Unit food habits study.
[f] Fecal pellets collected on 24 September. Animal may have received mineral supplements. Includes anomalous Na/K value of 1.022. Excluding this datum, mean ± SE is 0.0516 ± 0.0175.

During spring and summer, for reasons previously stated, mountain goats and other wild ungulates are confronted with increased Na loss and, particularly in females, increased Na demand. At that time, Na intake via plausible proportions of vegetation, water, licks, and recreationist urine is inadequate to meet even Na losses through urine, feces, shedding, and lactation. However, without lick and recreationist Na, the Na deficit would be even greater. Lick use is a highly seasonal phenomenon occurring coincident with the abrupt dietary shift to succulent, K-rich, forage and declining after dietary K and water rapidly subside to lower levels (Weeks and Kirkpatrick 1976). The shift to spring forage, with elevated K and water levels, is thought to be the environmental factor effecting the annual Na deficiency in wild ungulates. Because lick use is restricted to the spring and summer months coinciding with peak vegetative K and water values, this strongly suggests not only that ungulates utilize salt licks as supplemental Na sources to balance their Na budget, but that mountain goats, like white-tailed deer (Weeks and Kirkpatrick 1976) and probably most other wild ungulates, can maintain a positive Na balance outside the period of increased forage K and water levels on vegetative sources alone. Consequently, maintenance Na requirements of the mountain goat appear to be far below recommended levels for comparable domestic ruminants as in white-tailed deer (Weeks and Kirkpatrick 1976).

Although some form of mineral licks (mineral springs, "muck" licks or dry earth licks) are generally available to wild animals throughout most of the United States, they may be locally absent (Guest 1969, Hebert and Cowan 1977). The relative success of ungulate populations in such areas may reflect their ability to locate supplemental Na sources (bioaccumulators), conserve Na, or otherwise maintain a positive Na balance.

Several studies have related environmental Na availability to population density, distribution, and size. Aumann and Emlen (1965) noted a strong correlation between the density of microtine rodents (Microtus spp.) and the abundance of soil Na. Cyclic population fluctuations occurred independent of Na intake, but the densities at population peaks were many times higher in areas of high soil Na. They speculated that in areas replete with soil Na, enough was ingested with the forage to meet increased requirements of crowded animals, allowing continued population growth to a point where some other factor became limiting. Similarly, Jordan et al. (1973) and Botkin et al. (1973) suggested the availability of Na controlled the size of Isle Royale's moose population. In Wankie National Park, central Africa, Weir (1972) demonstrated the spatial distribution of elephants (Loxodonta africanus) was closely correlated to the Na content of the soil and water. Few elephants were observed where little Na was avialable in the soil or water, in spite of suitable forage abundance.

Since ungulates can probably maintain a positive Na balance outside the spring period of increased forage K and water levels on vegetative sources alone, only resorting to lick use for balancing periodic Na deficits, it is plausible that in areas depauperate of supplemental Na sources, ungulates simply require a longer period to balance their Na budget. The delay is probably inconsequential, but may limit potential population growth (Aumann and Emlen 1965, Jordon et al. 1973, Botkin et al. 1973) or be so costly that animals are locally absent from such areas (Weir 1972). Minor chronic Na deficiencies may only have subclinical effects on population productivity and quality. In more acute cases, managers might observe that "the population is just not doing as well as it should be." Of course, this does not imply the problems of unsuccessful, static or "unthrifty" ungulate populations are solely or in any way the result of Na limitations.

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EVALUATION OF THE BAERMANN TECHNIC FOR RECOVERY OF LUNGWORM (NEMATODA, PROTOSTRONGYLIDAE) LARVAE FROM WILD RUMINANTS

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ABSTRACT

An evaluation of the Baermann technic, using first-stage larvae of *Parelaphostrongylus odocoilei* from mule deer and *Protostrongylus* spp. from bighorn sheep, was made to determine the effects of condition and amount of feces, time, funnel size, and water volume on the number of larvae recovered. Highest counts of *P. odocoilei* larvae occurred when 10 grams of fresh feces were put in 100 milliliters of water in a 10 or 15 centimeter glass funnel and allowed to stand 24 hours. Highest counts of *Protostrongylus* spp. larvae occurred when 10 grams of slightly-crushed, dry pellets were put in 280 or 490 milliliters water in a 15 centimeter glass funnel and allowed to stand 24 hours. A convenient, standardized technic for recovery of *Protostrongylus* spp. from bighorn sheep feces is presented based on results of this study, literature, and subjective assessments.

INTRODUCTION

Rocky Mountain bighorn sheep (*Ovis canadensis*) have had a history of periodic die-offs. High populations of lungworms (*Protostrongylus stilesi* and *P. rushi*), frequently complicated by bacterial and/or viral infections and known collectively as "the lungworm-pneumonia complex" (Buechner 1960, Stelfox 1971, Uhazy et al. 1973), have been associated with most of those die-offs. Infection of bighorns with *Protostrongylus* spp. is not a rare or isolated event; most sheep throughout their range are infected (see Forrester 1971 and many other papers).

The main method of diagnosing *Protostrongylus* infection in live bighorn sheep has been by recovery of first-stage larvae from feces utilizing the Baermann technic. The technic involves placing sheep in a water-filled funnel and, later, recovering larvae that have left the pellets and dropped to the stem of the funnel. The qualitative value of the technique (i.e., the ability to determine whether or not a sheep has *Protostrongylus*) has never been questioned. What has been questioned is whether or not the technic provides useful quantitative information given the pellet-to-pellet, seasonal, and within and between pellet group variations in larval numbers.

Perhaps one reason little quantitative information has appeared in the literature is the lack of similar technic between laboratories in set-up of the Baermann apparatus and in the actual process. Many modifications of the basic technic are apparently employed, but these and other essential details are seldom provided in publications.

The objective of this paper is to recommend a standardized, convenient technic that provides repeatable results for recovery of Protostrongylus larvae from bighorn sheep feces. Data for a related "protostrongylid" nematode, Parelaphostrongylus odocoilei of mule deer, are provided for comparison.

This research received financial support from the Alberta Fish and Wildlife Division and the Natural Sciences and Engineering Research Council of Canada. We thank E. S. Williams, Colorado State University, for collection of the fecal samples from Wyoming.

MATERIALS AND METHODS

COLLECTION-HANDLING OF FECES

Pelleted fresh feces from two, captive mule deer experimentally infected with P. odocoilei were collected from cement-floor, individual pens. Only feces less than one day old were used. They were mixed thoroughly within two hours of collection, separated into 10, 20 or 30 gram subsamples, bagged in plastic, and stored at 4C for up to two days or at -20C for up to eight days. Prior to running Baermann's, frozen feces were left one hour at 18C, then stored up to one day at 4C.

Frozen fecal pellet groups of bighorn sheep were collected from snow and frozen ground in Banff and Kootenay National Parks in late February, 1982. Additional samples were collected at the same time from Whiskey Mountain, approximately 10 kilometers south of Dubois in western Wyoming. Most pellets in the Park samples appeared freshly-deposited (i.e., a few days old), but in some cases this was difficult to determine. The samples from Wyoming appeared older. Feces from Banff and Kootenay were mixed thoroughly, separated into 10 gram portions, and stored at 4C for up to one week. Those from Wyoming were air-dried in paper bags for approximately one month. They were mixed thoroughly and separated into 10 gram portions prior to beginning the experiment.

THE BAERMANN TECHNIC

Pellet group subsamples (usually 10 grams, but see below) were placed on a double layer of cheesecloth (Grade 150) and put in water-filled glass funnels. Five water volumes (32, 100, 280, 490 and 780 milliliters)[1] were tested in three funnel sizes (10, 15, + 20 centimeters maximum diameter) at six time intervals (2, 4, 6, 12, 24, and 48 hours). Generally, three replicates of each condition were run.

A short piece of rubber tubing was attached to the stem of the funnel and clamped. Tap water used in the funnels was 24-28C.

A maximum of 100 milliliters of fluid was withdrawn from the funnel and put into two 50 milliliter centrifuge tubes. Tubes were centrifuged at 1100 r.p.m. for 10 minutes and all but five milliliters of supernatant suctioned from each tube. The two 5 milliliter portions of fluid were pooled in a plastic petri dish 50 millimeters in diameter. This dish was placed in a glass petri dish 200 millimeters in diameter which had a grid etched on the bottom to facilitate counting. The fluid was examined using a dissecting scope at 12X (see below) and larvae separated into one of four morphologic types (see below).

If larvae were very numerous and overlapping in the petri dish so that it was obvious that counting would be difficult, the 10 milliliter suspension was added to 90 milliliters of water, mixed thoroughly, and a 10 milliliter subsample removed, and larvae counted. Generally, counts were converted to larvae per gram (LPG) wet weight feces, however, the fecal samples from Whiskey Mountain were air-dried and, therefore, converted to LPG dry weight feces.

The frequency distribution of the numbers of larvae per gram of wet or dry feces in bighorn sheep samples is not random (Uhazy et al. 1973, and unpub.). For all bighorn samples we've studied, except for the Whiskey Mountain samples of this study, a natural logarithmic transformation of the counts results in a normal distribution. Thus, for statistical analysis, this transformation was made. Normal distributions of Whiskey Mountain larvel counts were not achieved by natural logarithmic or square root transformations. Thus, nonparametric statistics were used in data analysis of this sample.

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[1] Added details of choices:

funnel size (centimeters)	water volume (milliliters)	diameter of funnel at water line (centimeters)
10	32	5
10	100	7
15	100	7
15	280	10
15	490	13
20	490	13
20	780	15

LARVAL TYPES

First-stage larvae of the two Protostrongylus lungworms of bighorn sheep are indistinguishable. The lungworms are P. Stilesi Dikmans, 1931 and P. rushi Dikmans, 1937. The mule deer nematode is Parelaphostrongylus odocoilei (Hobmaier and Hobmaier, 1934) a parasite of the dorsal musculature. First-stage larvae of both genera are similar in size and morphology, but Protostrongylus has a straight, symmetrically-tapered, pointed tail and P. odocoilei has a curved tail with a dorsal spine in the anterior part of the curve.

In this study, "straight-tailed" larvae belonging to Protostrongylus spp. predominated in sheep feces. Larvae with dorsal spines that closely resembled those of Parelaphostrongylus were present. They are geographically widespread in feces of bighorns and possibly comprise a number of protostrongylid lungworms one of which is Muellerius capillaris (Muller, 1889) (Pybus, unpub.). There is recent evidence that mountain sheep and goat have several protostronglylid nematodes with spined larvae not reported from these hosts previously (Pybus et al., unpub.) We separated dorsal-spined larvae from Protostrongylus larvae at 120X or 250X depending on experience of the observer. (Those new to the method should examine tails of larvae at 400X until a "feel" for identification is acquired). Of the three areas sampled in this study, only sheep from Banff yielded dorsal-spined larvae.

Large and small free-living mematode larvae were also recovered; the latter were similar in size to dorsal-spined and Protostrongylus larvae. Free-living larvae were granule-filled (Protostrongylus were not), light green (Protostrongylus were pale), and did not have a dorsal spine.

EXPERIMENTAL PROTOCOL

Experiment 1.

This expermiment, which was designed to determine the optimum amount of feces to use in the Baermann technic, was divided into two trails. In trail one, each of 10 groups of mule deer fecal pellets between 3 and 100 grams (wet weight) were placed in a 15 centimeter funnel with 350 milliliters water and run 15-19 hours. In trial two, two each of 10, 20, and 30 grams of deer pellets were placed in 150 milliliters water in 15 centimeter funnels and baermannized for 4 and 24 hours, respectively.

Experiment 2.

Funnel size, water volume and duration of baermannization were evaluated for larvae of P. odocoilei and Protostrongylus spp. from pelleted feces (Table 1).

RESULTS

EXPERIMENT 1. OPTIMUM AMOUNT OF FECES.

There was little to choose from when varying amounts of mule deer feces were baermannized for 15-19 hours. Results for the varying weights of feces (with LPG's in parentheses) were similar: 3 grams (3038), 5 grams (3340), 8 grams (3467), 10 grams (4225), 15 grams (3804), 20 grams (3460), 30 grams (3910), 50 grams (3607), 70 grams (2576), and 100 grams (3355). Recoveries were highest for the 10, 15 and 30 gram samples.

Results for the second trial, likewise, gave little to choose from between 10, 20 and 30 gram samples although 10 and 20 gram samples were slightly superior to 30 gram samples. LPG from 10, 20, and 30 grams of feces baermannized 4 and 24 hours were 1569, 1304, 1133 and 2952, 2956 and 2533, respectively.

EXPERIMENT 2. EFFECT OF TIME, FUNNEL SIZE, WATER VOLUME AND CONDITION OF FECES ON LARVAL RECOVERY.

Levels of infection for experiments outlined in Table 1 as reflected by LPG's were subjectively assessed as being moderate.

P. odocoilei

With one exception (32 milliliters of water in the 10 centimeter funnel), more larvae were recovered at 24 hours than at any other time interval regardless of funnel size or amount of water in the funnel (Table 2). However, statistically, time of baermannization was generally not an important factor (pairwise comparisons were all $P > 0.05$ except for 2 vs. 24 hours, $P < 0.001$). There was no significant interaction between duration of baermannization and funnel size ($P > 0.05$) or water volume ($P > 0.05$).

Larval yields were significantly higher ($P < 0.001$) from the 10 and 15 centimeter funnels than from the 20 centimeter funnel, however, as shown clearly on Table 2, water volume, not funnel size was the key treatment parameter of the two. More LPG feces were recovered using 100 milliliters water than with 32, 280, 490 or 780 milliliters water ($P < 0.001$). Also, there was no difference ($P > 0.05$) in LPG feces between the 10 and 15 centimeter funnels with 100 milliliters water or the 15 and 20 centimeter funnels with 490 milliliters water.

In summary, we recommend filling a 10 or 15 centimeter funnel with 100 milliliters of water and baermannizing for 24 hours (less time in the funnel is acceptable).

Protostrongylus spp. (Canada-source feces)

Time had the greatest influence on the number of larvae recovered from fresh feces (Table 2). More LPG feces ($P < 0.001$) were recovered at 24 hours than at any other time except 48 hours (24 vs. 48 hours, $P > 0.05$).

As with *P. odocoilei*, larval yields were higher from the 10 and 15 centimeter funnels than from the 20 (actually, the following comparison were significantly different, 10 vs. 20, 15 vs. 20). Also, as with *P. odocoilei*, there was no difference $P > 0.05$) in LPG feces from the 10 and 15 centimeter funnels with 100 milliliters water or the 15 and 20 centimeters with 490 milliliters water. Unlike results for *P. odocoilei*, water volume did not generally have a significant influence on the number of larvae recovered. In fact, at 24 hours there were no significant differences ($P > 0.05$) between the various water volumes used. The highest counts at 24 hours were achieved when 100 milliliters of water were used. Thus, for counting larvae of *Protostrongylus* spp. from fresh, pelleted feces, we recommend filling a 15 centimeter funnel with 100 milliliters of water and baermannizing for 24 hours.

Protostrongylus spp. (Wyoming-source feces)

Cutting the dried fecal pellet into quarters (halved along its length and width) greatly ($P < 0.001$) improved numbers of larvae recovered when compared to results from intact pellets (Table 2). Although highest LPG "cut" feces were acheived at 24 hours of baermannization at all three water volumes (100, 280, 490 milliliters) in the 15 centimeter funnel, there were few statistically significant differences (2 hours vs. 12 hours and 12 hours vs. 24 hours). Likewise, although lower LPG "cut" feces were recorded when 100 milliliters of water were used than when 280 or 490 milliliters were used, there were no significant differences.

We do not recommend using 100 milliliters of water when baermannizing air-dried "cut" feces. Variable amounts of water are absorbed by the feces and 100 milliliters of water is not available for removal after 24 hours.

In summary, when counting larvae of *Protostrongylus* spp. from air-dried feces stored in paper bags (the most often-used method), we recommend first cutting the pellets, adding them to a 15 centimeter funnel filled with 280 or 490 milliliters of water, and letting them stand for 24 hours.

DISCUSSION

It has long been recognized that "diagnosis of lungworm infection in bighorn sheep is best accomplished by finding first-stage protostrongylid larvae in fresh fecal samples" (Forrester, 1971). A variety of modifications of Baermann's original method (Baermann, 1917) for doing so has been described (Pillmore, 1958, 1959, 1961; Forrester and Senger, 1964; Uhazy et al., 1973). Pillmore's version (1961) received some recognition (Forrester, 1971) and may be very reliable as he contends, but it has not been adopted widely.

Adoption of a standardized version of the Baermann technic that would permit comparisons of larval counts between areas, investigators, laboratories, etc. has not occurred. It appears that, over the years, each laboratory using the Baermann technic has discovered and employed modifications of the basic technic the details of which are never published.

Our work may not improve the situation, but it has substantiated that a number of specific factors influences the efficiency of recovering larvae from the Baermann apparatus. Based on results of the present study, published literature (for example, Forrester and Senger, 1963 and Uhazy et al., 1973), and general impressions of what is practical to accomplish in the wildlife laboratory, we recommend the following as a standard technic for diagnosis and quantification of Protostrongylus infections in bighorn sheep:

1. Collect 10 to 20 grams of freshly-deposited sheep feces. Highest counts of larvae have been reported (Uhazy et al., 1973; Gates, 1975) from January to April and very low counts from May to October, so collect accordingly.

2. Store feces in paper bags at room temperature (20-21C) for 3-4 weeks.

3. Crush from 4 to 10 grams dried pellets by either quartering each pellet as described in this paper or by squeezing each pellet gently lengthwise with large, blunt forceps.

4. Add 280 milliliters of warm (24-28C) water to a glass funnel 15 centimeters in diameter.

5. Place the feces on a double layer of cheesecloth, then place both in the funnel for 24 hours. We usually setup Baermanns in mid-day and make no changes to usual office lighting; thus, samples overnight in dark.

6. Remove 100 milliliters of fluid from the funnel stem into two 50 milliliter centrifuge tubes.

7. Centrifuge 10 minutes at approximately 1100 r.p.m.'s (or allow tube to stand for 1 to 2 hours) and remove all but 5 milliliters of the supernatant from each tube.

8. Place the 10 milliliters of fluid suspension in a disposable 50 millimeter plastic petri dish and put that into a 100 millimeter glass petri dish with a grid etched on the bottom.

9. Examine at 12-25X (depending on experience) using sub-stage illumination.

10. Distinguish between and count larvae as described in the Materials and Methods section. Convert counts to larvae per gram (LPG) dry-weight feces.

Clean glassware (funnels, centrifuge tubes, pipettes, and slides) is essential. All glassware is washed thoroughly with hot water. Plastic petri dishes are used only once.

Contamination of glassware by larvae between samples occurs readily. Some sheep in a herd may be passing 600-1000 LPG or more while others may be passing none. If such samples are run consecutively in improperly washed glassware or in funnels side by side, contamination is possible. Consequently, care must be taken in handling glassware, etc. when running many samples at once.

Adoption of the technic as described here is appropriate for laboratories where other modifications of the Baermann technic have been used in the past. This entails dividing a pellet group in half and following procedures that have been used and the one described here. We have found (Wishart and Jorgenson, pers. comm. and W.M.S., unpub.) relatively consistent, similar differences between technics enabling use of a multiplication factor to update and unify data.

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Table 1. Design for Experiment 2.

Parasite (Source) Condition of feces	Funnel Size*	Water Volume	Duration of baermannization in hours	Number of replicates at each time
Protostrongylus spp.				
(Alberta-British Columbia)				
Pelleted:	10	32 ml.	2,4,6,12,24	3
	10	100 ml.	2,4,6,12,24	3
	15	100 ml.	2,4,6,12,24,(48)	3(2)
	15	280 ml.	2,4,6,12,24	3
	15	490 ml.	2,4,6,12,24	3
	20	490 ml.	2,4,6,12,24,(48)	3(1)
	20	780 ml.	2,4,6,12,24	3
Parelaphostrongylus odocoilei				
(Alberta)				
Pelleted:		as above**		
Protostrongylus spp.				
(Wyoming)				
Pelleted:	15	100 ml.	2,6,12,24,48	3
	15	280 ml.	2,6,12,24,48	3
	15	490 ml.	2,6,12,24,48	3
Pellets cut:***	15	100 ml.	2,6,12,24,48	3
	15	280 ml.	2,6,12,24,48	3
	15	490 ml.	2,6,12,24,48	3

* Maximum diameter in centimeters.

** Delete 48 hr.

*** Each pellet was cut once along its length and width with scissors.

Table 2. Effect of funnel size, water volume and time on recovery of first-stage P. odocoilei and Protostrongylus spp. larvae.

Funnel Size (max. dia.)	Water Volume	Time in Funnel in hr.	Larvae Per Gram Feces*			
			P. odocoilei	*Protostrongylus* spp.		
				Canadian Sheep	Wyoming Sheep	
					Pellets Intact	Pellets Cut
10 cm.	32 ml.	2	380 ± 26	33 ± 4	-	-
		4	384 ± 9	44 ± 7	-	-
		6	393 ± 11	50 ± 23	-	-
		12	430 ± 70	51 ± 16	-	-
		24	425 ± 95	94 ± 37	-	-
	100 ml.	2	480 ± 85	45 ± 7	-	-
		4	453 ± 54	43 ± 23	-	-
		6	499 ± 113	51 ± 29	-	-
		12	538 ± 115	59 ± 13	-	-
		24	566 ± 37	108 ± 61	-	-
13 cm.	100 ml.	2	479 ± 52	41 ± 14	7 ± 1	111 ± 46
		4	491 ± 60	60 ± 8	-	-
		6	472 ± 30	45 ± 23	64 ± 41	287 ± 96
		12	481 ± 59	63 ± 35	60 ± 8	264 ± 27
		24	527 ± 41	206 ± 77	229 ± 92	330 ± 110
		48	-	257, 138	252 ± 114	354 ± 121
	280 ml.	2	353 ± 40	26 ± 6	9 ± 6	90 ± 2
		4	361 ± 44	47 ± 9	-	-
		6	394 ± 36	58 ± 10	86 ± 23	285 ± 204
		12	390 ± 44	82 ± 20	136 ± 23	441 ± 52
		24	472 ± 20	138 ± 53	239 ± 32	841 ± 137
		48	-	-	247 ± 88	364 ± 244
13 cm.	490 ml.	2	240 ± 27	17 ± 6	6 ± 4	82 ± 14
		4	289 ± 23	26 ± 6	-	-
		6	257 ± 17	27 ± 2	59 ± 28	323 ± 181
		12	325 ± 25	36 ± 8	70 ± 42	374 ± 110
		24	359 ± 50	113 ± 31	134 ± 30	572 ± 110
		48	-	97	153 ± 9	553 ± 125
20 cm.	490 ml.	2	155 ± 84	27 ± 7	-	-
		4	290 ± 98	29 ± 3	-	-
		6	318 ± 64	29 ± 13	-	-
		12	278 ± 39	48 ± 24	-	-
		24	327 ± 38	153 ± 109	-	-
	780 ml.	2	78 ± 21	10 ± 2	-	-
		4	52 ± 17	15 ± 2	-	-
		6	149 ± 15	9 ± 3	-	-
		12	194 ± 64	29 ± 15	-	-
		24	258 ± 86	104 ± 84	-	-

* Mean ± SD

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:244-253

BIGHORN SHEEP MANAGEMENT IN ROCKY MOUNTAIN NATIONAL PARK

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ABSTRACT

The objectives of bighorn sheep management in Rocky Mountain National Park are to preserve the integrity of the ecosystem and maintain bighorn as a viable component controlled by natural forces; to reduce the effects of visitor use on the sheep population and to restore bighorn to the historic ranges within the park. Meeting these objectives has required a research program and continued monitoring of the populations. Direct management action to reduce stress has been control of visitor use on critical bighorn habitat on Specimen Mountain and in Horseshoe Park. In cooperation with the State of Colorado, sheep have been reintroduced on one major historical winter range within the park and another range in close proximity. Initial analysis indicates some success with the sheep populations responding with more normal movements and behavior.

INTRODUCTION

About 1970 it was recognized that stress was probably adversely affecting the bighorn sheep (Ovis canadensis) populations in Rocky Mountain National Park and that some action was needed to reduce the impact at several locations. As early as 1939, Packard (1946) had described bighorn sheep leaving the Sheep Lakes area because they were "annoyed by camera enthusiasts". He also discussed the physiological drive by the sheep to get to salt licks and the apparent importance of these licks to their welfare. The presence of Pasteurella also as early as 1935 was identified by Potts (1937). These events and the intervening 40 years of observation were analyzed in the light of stress relationships as discussed by George Post (1976). Stress may be a major entity in bighorn sheep pneumonia. Range usurpment and disturbance caused by human activities as experienced in Rocky Mountain National Park could place bighorn sheep in such a stress situation. These same conditions may also aggravate the effects of lungworm (Protostrongylus), which has been reported in the population.

With a 19% increase in visitation to the park from 1971 to 1981, the potential for harassment of wildlife has increased considerably. With more people on the highways an even greater increase is apparent in the back-country where harassment may be even more detrimental.

With research findings indicating areas of potential conflict with people, it was decided that just the overall protection offered by the National Park was insufficient to prevent potential stress situations. Therefore a management program was instituted to provide the protection deemed necessary to reduce the stresss on the sheep.

ENVIRONMENT

Rocky Mountain National Park, with an area of 108,032 hectares, lies along the Continental Divide in northcentral Colorado. Elevations range from 2,329 meters on the east side to 4,345 meters on Longs Peak. The mountains were formed by precambrian metamorphic schists and gneiss created by large masses of granite and pegmatite (Richmond 1974). The northwest portion of the park is overlain by deposits of volcanic ash flow, the origins of which were in the northern part of the Never Summer Mountains. Present physiography demonstrates the extent of alternation by pleistocene glaciation. The soils are relatively infertile and low in essential elements, being very sandy with poor development from decomposed granitic substrates.

The climate is typical of mountainous regions. At lower elevations, annual precipitation is 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 occurs in late March and April, with heavy wet snows. In winter, precipitation falls as snow, but severe winds in December and January may blow many areas free, especially in the alpine, depositing it in drifts in protected sites.

Vegetation of the park represents 3 climax regions (Marr 1961), all of which are utilized by the bighorn sheep. On the lower east slope, the upper montane climax region occurs from 2,300 to 2,740 m. elevation. Dominant vegetation types are 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 are grassland, meadow, willow (*Salix* spp.), and big sagebrush (*Artemisia tridentata*) types. Aspen *Populus tremuloides*) is present in small stands. Above the montane, from 2,740 to 3,500 m., is the subalpine forest region. This is an Engelmann spruce/subalpine fir forest, interspersed with lodgepole pine and limber pine (Pinus flexilis) stands. In the openings are willow and herbaceous meadow types. Above the forest (3,500 m.) is the alpine tundra. Vegetation of the alpine is a complex mosaic of types related to numerous environmental factors as described by Willard (1979).

Ungulates sharing the park ranges with the bighorn sheep were the elk (*Cervus elaphus nelsoni*) and the mule deer (*Odocoileus hemionus*). The elk, the dominant ungulate in the park, with a population of about 3,000, utilize all vegetation types in the summer. Although mostly moving to the upper montane in winter, some remain on the alpine tundra. About 200-300 deer, a portion of a much larger summering population, remain in the park to winter.

HISTORY OF THE SHEEP POPULATION

Early settlers in the Estes Park area found bighorn sheep abundant, with an estimated population of 4,000. This population, however, declined rapidly as a result of market hunting, usurpation of winter range by human activities, and scabies, according to Packard (1946). Only when the scabies epidemic subsided in about 1907 did the population appear to recover. Packard (1946) estimaed over 1,000 bighorn in the park when it was established in 1915.

By the early 1920's, however, the population had entered another decline. This decline was probably related to competition on the range with domestic livestock, but disease may also have been an important factor (Goodson 1978). Packard believed mineral deficiencies to be most important and mentioned lungworm and pneumonia a possible contributing factor.

In 1935, Potts estimated the population at 192, which was lower than previously noted. He documented the presence of pueumonia as a factor in several mortality cases (Potts 1937). Packard's study in 1935 and 1940 indicated more sheep, probably the result of a better and more intensive count.

The sheep population appears to have hit a low point in about 1958, when Contor (1958) attempted to duplicate Packard's work. His total of 211 sheep documented the loss of populations from MacGregor Mountain, Castle Mountain and the Needles. There were probably still a few sheep in the Cow Creek area at that time. By 1967, Capp (1967) indicated an increase, or at least more sheep present in the Mummy Range than Contor's study. Goodson (1978) estimated the population at 81 in the Mummy Range and 124 in the Never Summer Mountains.

The native bighorn generally utilize the northern half of the park, with two main population centers (Goodson 1978), Figure 1. On the west, the primary range is the Never Summer Mountains, including the Specimen Mountain area and the Continental Divide down to Bighorn Flats. The northern herd is primarily in the Mummy Range north of Trail Ridge Road. Goodson (1978) believed little interchange occurred between the two groups, with the possible exception of mature rams. Both populations utilize the alpine tundra year-round, only periodically using the lower ranges. These movements are made to gain access to natural mineral licks. The primary licks are located in the "Crater" on Specimen Mountain and in Sheep Lakes area of Horseshoe Park.

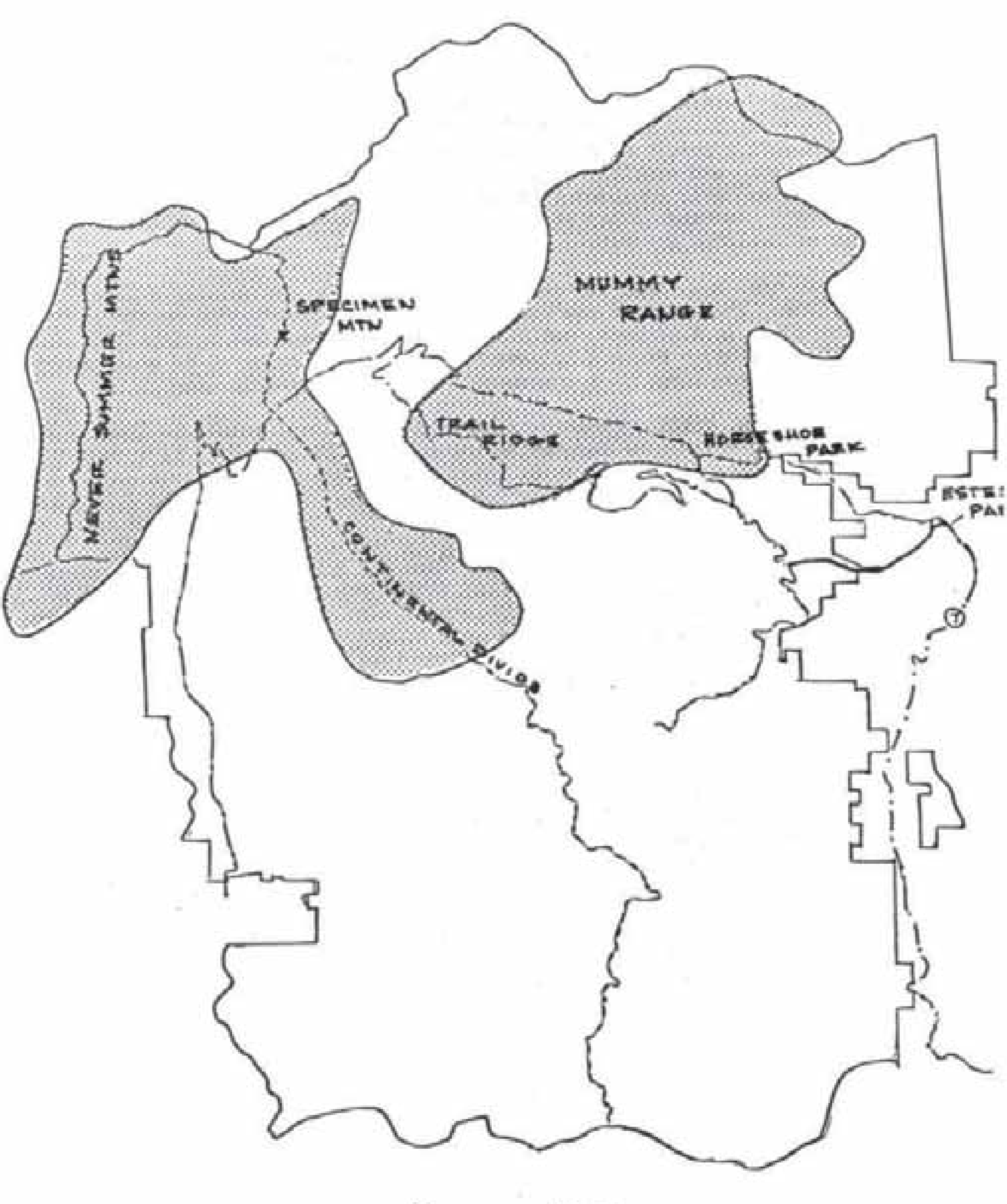

Figure 1. Primary distribution of native sheep population in Rocky Mountain National Park.

MANAGEMENT OBJECTIVES

The objectives of bighorn sheep management in Rocky Mountain National Park are:

1. To preserve the integrity of the Park ecosystem and maintain the bighorn as a viable component controlled by natural factors.

2. To reduce conflict between human beings and bighorn sheep.

3. To restore sheep to historic ranges and movement patterns within the park.

THE PROBLEM

Early investigators had identified problem areas that may affect bighorn sheep survival. First priority for the research effort when it was renewed in 1965 was therefore range competition, which had been identified by Packard (1946) and Contor (1958) as a problem area.

In 1965, John Capp (1967) initiated research on competition with elk and mule deer in the Mummy Range. He was followed by Fred Harrington (1978) on the Specimen Mountain area. Capp found that little competition existed on the Mummy Range in the summer of 1967; however, both Goodson (1978) and Bauman (1978) believed the potential for competition was very great. Forage competition was believed by all investigators to be less in the Never Summer and Specimen Mountain areas than in the Mummy Range. Harrington (1978), however, described the ecological segregation by the three species of ungulates on Specimen Mountain. He showed that these ungulates have evolved into niches which are separate and tend to reduce competition. Although the forage competition question has not been entirely resolved, it is not believed to be as severe as noted earlier. The only management action currently is the control of elk and deer populations through public hunting outside the park.

Loss of range to livestock goes back to 1859, when Joel Estes first arrived in the valley. In the early days, livestock was numerous and grazed far into the park, often on the bighorn sheep range. Grazing by domestic sheep occurred on the alpine tundra in the Never Summers and Comanche Peak areas. This grazing was removed gradually after 1932. In Horseshoe Park and Moraine Park, grazing was eliminated by 1962 and in Cow Creek by 1974. Removal of the grazing provided forage for the ungulates, but where the ranges had been abandoned by the bighorn sheep, use was not resumed after the vegetation became available.

The mineral deficiency question which was first noted in the 1930's has never been resolved. Harrington documented the movement of sheep from the Never Summer Mountains across the Colorado River valley to Specimen Mountain for the mineral licks. He felt that these licks had particular importance for the sheep in a social way. The need for the licks physiologically has not actually been documented. Keiss (1976), studying 23 licks in and out of Rocky Mountain National Park, said that the only consistent pattern was that the total dissolved solids was higher in the licks than in surrounding areas. Goodson (1978) analyzed these data from the Park licks and thought that the licks might be important for copper, iron, sodium, and manganese. It is well documented that the sheep have a tremendous drive to visit these licks.

Lungworm and the pneumonia complex have also been present in the Rocky Mountain National Park sheep population for a long time. Goodson (1978), however, reported the lungworm level low compared to other populations in Colorado, but was not sure if this was significant. She did believe that the herd composition on the west side in 1975 and 1976 indicated summer lamb mortality, typical of lungworm effects. Post (1976) believed that pneumonia and the acute effects of lungworm can be aggravated by "psychological stress".

Effects of visitors, although present in the 1930's have continued to increase with the increase in total visitation. Goodson (1978) noted that visitors bothered sheep most where they were not expected. The critical situations, however, appeared to be at the 2 major mineral licks.

In Horseshoe Park, the sheep would be turned back from crossing the highway or, once they were in the meadow using the licks, they would be disturbed sufficiently for them to vacate the area. Either of these apparently are quite stressful, although the sheep outwardly were calm.

On Specimen Mountain, the sheep used the mineral licks in the "Crater" and, generally, this is where the disturbance took place. Visitors would enter the "Crater" to view the sheep and get close pictures. Further investigation, however, revealed more disturbance when the sheep would leave the rocky outcrops of the "Crater" to feed on the east slope tundra. The trail to the top of Specimen runs along the ridge, separating these areas. Visitors in their rush to attain the summit would chase the sheep back into the rocks. Usually the sheep would only withstand this disturbance for a short time before leaving that portion of Specimen and the mineral licks.

These actions all were viewed as possible souces of stress as described by Post (1976). Post stated that "I am of the opinion that psychological stress is a major entity in bacterial and possibly viral or mycoplasmal pneumonia." This statement essentially links these factors together and may give us the key to bighorn management: the reduction of stress in the population.

MANAGEMENT ACTION AND RESULTS

CONTROL OF VISITOR USE

The plan was conceived and implemented incrementally based on available information. The first step in 1971 was to close the trail on Specimen Mountain to public use from May 1 to July 1. This was designed to reduce visitor effects during the lambing period, which was considered the most critical time for sheep. After a few years of observation with several research studies in progress, it was evident that this was not sufficient. Heaviest sheep use in the "Crater" extended well into July and included the nearby tundra areas (Harrington 1978). Therefore, in 1977 the total "Crater" was closed to public use. At the same time, an effort was made to get public opinion on a total closure of the trail to the top of the mountain. A sign explaining the plan and its justification was established at the "Crater" saddle. The public input was supportive of the move for the benefit of the sheep, so the trail was closed in 1978.

Although it is difficult to assess results of this action, the sheep do appear to be staying on the Specimen-Shipler area longer than in the past. They are certainly more observable on the alpine tundra feeding areas. Available data, however, are still not sufficient to document any improvement. Using reproductive success as an indicator of herd condition, no difference has been noted.

In Horseshoe Park, a similar situation existed, but since it was beside a major highway it was considerably more aggravated. The first step was taken in 1974, when signs were erected to keep visitors on the road when sheep were present in the meadow. This helped until the sheep wanted to cross back over the road to their escape terrain on the north side. It appeared that an avenue across the road had to be maintained to allow easy access for the sheep. Therefore, two crossing zones were established in 1976. Each one is 100 m. long and signed to prohibit stopping, standing, or walking within the zone. In 1980 a visitor contact station was established and has been run during the busy season each day by a uniformed park interpreter.

The efforts in Horseshoe Park did not appear to have much effect on the sheep the first few years. In 1965 to 1966, before any visitor control was implemented, sheep utilized the licks an average of 15 days each year in the three months' of heavy visitor use (June, July and August). With the signs in place in the meadow and the crossing zones in place from 1976 to 1978, the average number of days increased annually to 23 during the same period. In 1980, however, with the park interpreter in uniform on-site, the number of visits increased to 43 and in 1981 to 46. Although observation of the area was more intense, it is doubtful that this would account for an 87 percent increase. Often the interpreter had to ask people to return to their vehicles or to not park in the crossing zones, in order to reduce disturbance.

TRANSPLANTS

Since the nutritional status of the sheep may also be a possible stress factor, an improvement in available forage was considered as another mitigating measure. The technique chosen to improve the nutritional status was to increase the winter range used by a transplant to previously abandoned historic low elevation areas. None of the native sheep presently migrate to low elevation winter ranges. The objectives of this transplant were to expand the sheep population to the low elevation winter ranges and to redevelop historic migration routes between the low elevation range and the alpine tundra range. The initial transplant was to come from another non-park population with migratory habits which would interbreed and intermix with the native sheep.

On March 17, 1977, 20 bighorn sheep were transplanted from the Tarryall Range west of Pike's Peak and released on Cow Creek. This area had maintained a bighorn population until about 1960, when they disappeared. The exact cause was not determined, but most thought it was related to livestock grazing and forest succession. Grazing by the McGraw Ranch had taken place there since about 1880. In 1964, that portion of the ranch within the park (393 acres) was purchased by the National Park Service. However, a grazing permit for 300 AUM was allowed for the following ten years. During this time, grazing by 30-40 head of horses severely impacted the area. In 1973, this grazing was eliminated.

Relocations of the marked sheep indicated distribution (Figure 2) from Mummy Mountain to Castle Mountain and from Chasm Falls to Eagle Rock. This range was about what was expected, since they are using both the alpine and subalpine ranges. Good reproduction is present, with a lamb: ewe ratio of 58:100. The highest count of 50 sheep was made on Fall River this fall.

This year a radio telemetry study has been initiated to better document the distribution of these sheep and their utilization of habitat types.

In keeping with this program, the Division of Wildlife made another transplant to the Button Rock Reservoir site in March 1980. This site is 7 miles east of the park boundary on the North St. Vrain River. The situation is very similar to the Cow Creek area, and it is hoped the sheep may repopulate the south end of Rock Mountain National Park.

DISCUSSION

Although the success of various management techniques is still far from being documented, it appears progress is being made. Since the National Park Service policy is to allow the ecosystem to function with the least interference by man, management action must be limited to minimizing or eliminating those impacts on the population caused by man's activities. The theory that an ecosystem which is essentially intact as it evolved, requires little or no management action, is the primary basis of the National Park Service policy. If this theory is true, then the closer that we can restore the ecosystem to its original condition, the more normal it should function. In the case of bighorn sheep in Rocky Mountain National Park, an attempt has been made to reduce man-caused stress on the population and to restore the use of available historic low elevation winter range. Granted, this does not eliminate the effects of men or other decimating factors. The total low elevation winter range will never be restored, and we will continue to have large number of visitors. Hopefully the efforts that we do make, however, will be sufficient to maintain the animals as a viable part of the park ecosystem.

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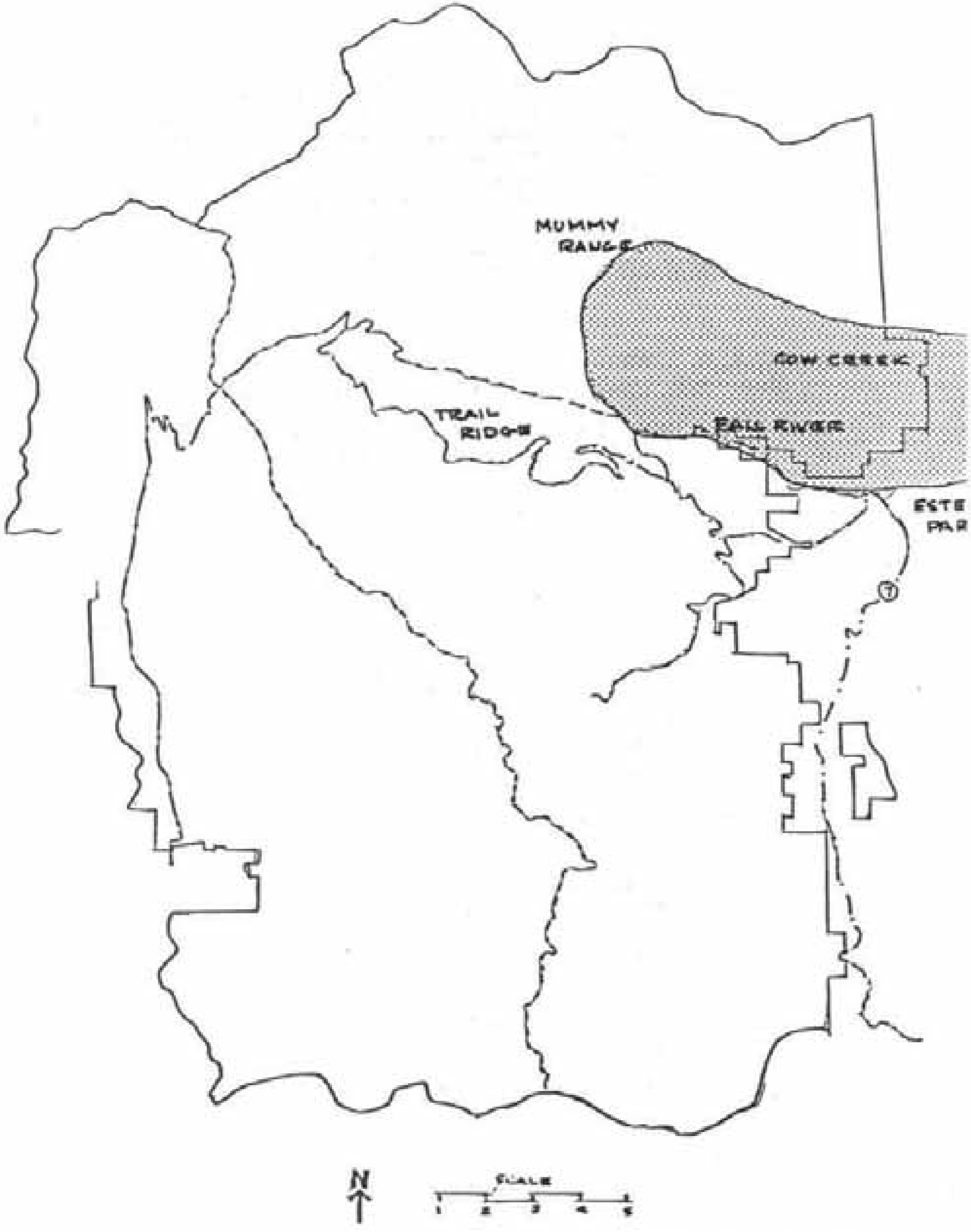

Figure 2. Primary distribution of bighorn sheep population introduced in 1977 in Rocky Mountain National Park.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:254-261

APPLICATION OF OPTIMAL FORAGING THEORY
FOR BIGHORN SHEEP HABITAT EVALUATION

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ABSTRACT

Characteristics of forage resources commonly used in evaluating forage quality are palatability, based on food habits and preferences, and chemical compositions of forages in relation to nutrient requirements of animals. An additional characteristic of a forage resource is the distribution and sizes of potential bites. This attribute influences the efficiency with which a forage may be harvested by a herbivore. Concepts of optimal foraging theory related to this characteristic of forage resources are reviewed. A method for measuring foraging efficiency of bighorns is presented. Preliminary results, comparing efficiencies of bighorns when browsing vs. grazing and when browsing shrub resprouts vs. older shrub growth, are presented.

INTRODUCTION

Studies of bighorn sheep (Ovis canadensis) feeding ecology have included habitat selection, food habits, and forage preferences (Constan 1972, Todd 1972, Stelfox 1976, Wikeem and Pitt 1979, Johnson 1980, and others). Chemical-physical compositions of bighorn forages have also been studied (Demarchi 1968, Hebert 1973). Nutritional requirements of ruminants are fairly well known. Using such information, valuable bighorn forages can be identified as those forages in appropriate habitats, preferred by bighorns, and containing high levels of digestible energy and nutrients.

Risenhoover (1981) demonstrated that habitat visibility and distance from escape terrain influenced bighorn foraging efficiency. He measured foraging efficiency as the percent of time spent foraging as opposed to being alert or social. Bighorn preferred habitats wherein they foraged most efficiently. Thus, occurrence in a habitat that does not require bighorns to divert time from foraging activity is a factor influencing the value of bighorn forages.

Another characteristic of a forage resource may influence its value to sheep. This characteristic is harvestability and is a function of the spatial arrangement and sizes of potential bites. Therefore, valuable forages must be available in suitable habitats, palatable, nutritious, and distributed so they may be efficiently harvested. A desirable food which cannot be harvested efficiently may be eaten only incidentally during foraging activities dictated by less nutritious, but more easily harvested foods.

Objectives of this paper are to briefly review concepts and literature in optimal foraging theory applicable to large generalist herbivores and to present a method for measuring bighorn foraging efficiency which may provide insight into herbivore diet selection as it relates to the spatial arrangement and sizes of food items.

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REVIEW

OPTIMAL FORAGING THEORY

A complete discussion of optimal foraging theory is beyond the scope of this paper and only a cursory review is presented. For a more complete review, see Schoener (1971), Pyke et al. (1977), and Krebs (1978).

Although optimal foraging theory was originally conceived to predict foraging behavior (search and acquisition) and diet selection (food choice) of granivores (Emlen 1966) and insectivores (MacArthur and Pianka 1966), recent developments have provided insight to factors influencing diet selection by large generalist herbivores (Westoby 1974, Pulliam 1975, Ellis et al. 1976). Optimal foraging theory assumes natural selection has produced animals which efficiently exploit their food resources and that inefficient forages suffer a decrease in fitness. Animals maximize their efficiency in obtaining energy and nutrients through decisions concerning foraging behavior and diet selection. These decisions are made under constraints placed on each animal by its behavior, morphology, physiology, and environment. Thus, maximizing foraging efficiency is actually an optimization process. If animals forage optimally, and if costs and benefits of foraging are measured accurately, the observed cost-benefit ratio represents the most efficient exploitation of available food resources.

OPTIMAL FORAGING AND HERBIVORES

Most conceptual models of optimal foraging by herbivores have dealt with diet selection as the sole process for maximizing energy intake within constraints of meeting nutrient demands (Westoby 1974, Pulliam 1975, Ellis et al. 1976) or minimizing ingestion of toxins (Freeland and Janzen 1974). For the most part, these models assume all potential foods are equally harvestable.

Belovsky (1978) suggested that poor harvestability of aquatic plants that were necessary for meeting sodium requirements of moose (Alces alces) constrained the animal's ability to maximize its energy intake. His model for moose on Isle Royale assumed sodium from aquatic plants to be the limiting nutrient and terrestrial forbs and browse to be the most profitable sources of energy in a moose's summer diet.

In his study of the foraging efficiency of greater kudu (Tragelaphus strepsiceros), Owen-Smith (1979) recognized a difference between "potential" and "accepted" foods and suggested differences in phenology accounted for this discrepancy. More recently, Owen-Smith and Novellie (1982) suggested that not only nutritive quality, a function of phenology, but also food bite size affect herbivore foraging efficiency.

Trudell and White (1981) investigated the effect of plant structure and availability on reindeer (Rangifer tarandus) feeding and foraging behavior. They found both structure and availability influence reindeer biting rate, and bite size.

Based on observations of bighorn foraging behavior and diet selection in Waterton Canyon, Colorado, we believe the following factors influence foraging efficiency of the animals: (1) visibility and distance from escape terrain; (2) group size; (3) forage nutritional quality; (4) sizes of the available forage items; and (5) the spatial arrangement of forage items. We are currently measuring bighorn foraging efficiency in a variety of environments, using a method described below. We expect results will provide insight to how the above factors affect bighorn foraging efficiency.

STUDY AREA

Bighorn sheep in Waterton Canyon provide a unique opportunity to study foraging efficiency because they are habituated to humans, allowing relatively close observations, and they seasonally exhibit 2 distinct feeding strategies (browsing leaves of shrubs during summer-fall and grazing grasses and forbs during winter-spring). Waterton Canyon is a shrubland environment located approximately 40 km southwest of Denver in Colorado's front range (elevation - 1700-2345 m). The lower portion of the canyon is dominated by Gambel oak (Quercus gambelii) on north-facing slopes and true mountainmahogany (Cercocarpus montanus) on south-facing slopes. Grassy openings are interspersed throughout the lower canyon and are larger on the higher slopes. Prominent species in these openings are Indian ricegrass (Oryzopsis hymenoides), wheat grass (Agropyron spp.), bluegrass (Poa spp.), needlegrass (Stipa spp.), cheatgrass brome (Bromus tectorum), hairy goldenaster (Chrysopsis villosa), and numerous other forbs. These species are also found in lesser densities in the understories of mountainmahogany stands. Understories of oak stands are dominated by sedges (Carex spp.). In the upper portion of the canyon, coniferous species including ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii) replace Gambel oak on north-facing slopes and oak dominates the south-facing slopes. For a more complete description of the Canyon, see Risenhoover (1981) and Rominger (1983).

METHODS

For this study, 4 measures of bighorn foraging efficiency are being obtained.

1. Digestible dry matter intake/step while foraging;
2. Digestible dry matter intake/minute foraging;
3. Crude protein intake/step while foraging;
4. Crude protein intake/minute foraging.

These necessitate measuring 3 components of bighorn foraging efficiency:

1. Field observations of foraging behavior to measure bite-intake rates;
2. Estimation of bite sizes for each forage species eaten;
3. Nutritional analyses of bighorn forages.

OBSERVATIONS OF BEHAVIOR

Feeding bighorn ewes are observed through binoculars or a spotting scope. Their foraging behavior is described into a tape recorder during 2-10 minute observation periods for each sheep. Information recorded includes the number of bites of each species ingested, the number of steps taken while foraging (a step is defined as movement of a particular foot), and any interruptions of foraging and feeding behavior.

These data provide indices of foraging efficiency in terms of bites/step and bites/minute of foraging. A sheep is considered foraging only when feeding or searching for food. (Searching for food is defined here as whenever an animal is interpreted to be looking at food or moving toward food.) Additional information recorded with each observation includes date, time, and habitat characteristics.

ESTIMATION OF BITES

Immediately following an observation period, the feeding site is visited to verify the species consumed and obtain duplicate bites of each species by hand-plucking samples. Each sample represents 20 bites.

Samples are field weighed and frozen within 24 hours. Prior to nutritional analyses, samples are oven-dried at 50C for 48 hours and reweighed.

LABORATORY ANALYSES

Samples are analyzed for *in vitro* digestible dry matter and crude protein content (Kjeldahl N X 6.25). Upon completion of analyses, coefficients of nutritional value will be applied to bite/size estimates to obtain digestible dry matter/bite and crude protein/bite for each major forage. These estimates will then be applied to the observed intake rates to calculate the above measures of foraging efficiency.

EXAMPLE RESULTS

Since nutritional analyses of forages are pending, results presented here are preliminary and intended only to illustrate potential applications of the technique. Foraging efficiency is expressed at a cursory level in bites/step and bites/minute.

For this study, bighorns were considered "browsing" when 75% or more of their bites during an observation period were on shrubs, and "grazing" when 75% or more of their bites during an observation period were on forbs and/or grasses. Comparison of bighorn ewes browsing versus grazing was based on 261 observation periods for a total of 1400 minutes (mean obs. = 5.4 minutes, Table 1). Sheep browsed most during June through October 1981 and grazed most during November 1981 through February 1982. When foraging efficiency was measured as bites/step and as bites/minute, sheep were more efficient while browsing ($P < 0.001$). However, these results do not address differences in bite sizes between forage classes. Biomass intake/bite was lower when sheep were browsing true mountainmahogany than when grazing mature grasses and forbs. Ultimately, conclusions will be based on digestible dry matter and protein intake per step and per minute.

A comparison of bighorns browsing year-old regrowth on clearcut true mountainmahogany stands versus browsing on uncut stands of the same species is not confounded by variation in bite sizes (Table 2). This comparison was based on 92 observation periods for a total of 520 minutes (means obs. = 5.6 minutes). Sheep foraged more efficiently while browsing on clearcut shrubs, however, the difference may well have been due to sampling variation ($P < 0.12$ for bites/minute, Table 2). Resprouting on clearcut shrubs concentrated many harvestable leaves into a small volume. Also harvest of leaves on the resprouting shrubs was not impeded by large stems which occurred on uncut shrubs.

Bites/minute appears to be about 3 times as precise a measure of foraging efficiency as its bites/step. When foraging efficiency was measured as bites/step, coefficients of variation (St. Dev./mean) for browsing and for grazing were 0.94 and 0.93, respectively (Table 1). In contrast, when foraging efficiency was measured as bites/minute, coefficients of variation were 0.26 and 0.32, respectively. A similar trend occurs in Table 2. Although measurements of bites/minute appear to be more sensitive to changes in foraging efficiency, measurements for bites/step may provide a better indication of energy or nutrient intake per energy expended for harvesting food.

Table 1. Foraging efficiencies of ewes browsing leaves of shrubs versus grazing grasses and forbs in Waterton Canyon, Colorado.

		Foraging Efficiency					
		Bites/Step			Bites/Minute		
Feeding Strategy	Observations (No.)	Mean	St.Dev.	Coef. Var.	Mean	St.Dev.	Coef. Var.
Browsing[1/]	98	10.4*	9.8	0.94	18.0*	4.7	0.26
Grazing[2]	163	6.0*	5.6	0.93	14.9*	4.8	0.32

1/ Sheep were considered browsing when 75% or more of their bites were of browse species during an observation period. Sheep browsed most during June-October 1981.

2/ Sheep were considered grazing when 75% or more of their bites were of grasses and forbs during an observation period. Sheep grazed most during November 1981 - February 1982.

* Difference between browsing and grazing significant at P 0.001.

Table 2. Foraging efficiencies of ewes browsing clearcut versus uncut true mountainmahogany (<u>Cercocarpus montanus</u>) in Waterton Canyon, Colorado, June-November 1981.

		Foraging Efficiency					
		Bites/Step			Bites/Minutes		
Forage Type	Observations (No.)	Mean	St.Dev.	Coef. Var.	Mean	St.Dev.	Coef. Var.
Clearcut	12	14.1	15.3	1.08	20.2*	4.8	0.24
Uncut	80	9.9	8.8	0.88	17.7*	4.5	0.25

*Difference significant at P 0.12

CONCLUSION

The value of a forage resource to bighorns is determined by its nutritional composition, palatability, the habitats in which it occurs, and its availability for efficient harvest by bighorns. This 4th characteristic, harvestability, is dependent upon the sizes and spatial arrangement of potential bites. Harvestability of forages is often overlooked in range evaluations.

Optimal foraging theory assumes animals have evolved foraging behaviors and diets which maximize their efficiencies in exploiting their food resouces. Most applications of the theory to ungulates have dealt with predicting optimal diets from an array of potential forages. The potential effects of differing forage harvestabilities on diet selection have been largely neglected.

A method for measuring foraging efficiency of bighorns has been described. The method has promise for providing insight into the effects of the sizes and spatial arrangements of potential bites on bighorn foraging efficiencies. Such knowledge should help identify valuable bighorn forage resources and increase our understanding of bighorn habitat requirements.

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FORAGE SELECTION BY BIGHORN SHEEP EWES AND LAMBS IN SOUTHCENTRAL COLORADO

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ABSTRACT

Summer food habits of Rocky Mountain bighorn (Ovis canadensis canadensis) ewes and lambs on 2 lambing ranges in southcentral Colorado were estimated and compared. Diets were also compared to the botanical composition and herbage production of each area. Food habits were estimated using fecal analysis, and vegetation was quantified using a double-sampling method. The grasses, mountain muhly (Muhlenbergia montana), blue grama (Bouteloua gracilis), Arizona fescue (Festuca arizonica), and sedges (Carex), made up 50% or more of the ewe and lamb diets, with true mountain mehaogany (Cercocarpus montanus) and other browse making up the other half. Ewe and lamb diets were similar on each lambing area but differed significantly between areas. Kulczinski's Similarity Index was greater than 75% for the diets of ewes and lambs on each lambing area but averaged less than 50% between areas. Ewes and lambs are selective and adaptive feeders, choosing different forage plants on different areas. The sheep did not select forage plants in proportion to their availability on the range.

INTRODUCTION

Rocky Mountain bighorn sheep occupy a variety of habitats from New Mexico to the Canadian Rockies. Many bighorn sheep herds have been declining in numbers and distribution since the late 1800s. Reasons for the decline are not fully understood. Man's encroachment upon bighorn sheep ranges, and especially upon winter ranges is thought to have been partly responsible for the decline (Buechner 1960). Poor lamb survival has contributed to declines in bighorns populations (Bear and Jones 1973) and could be related to loss of forages with loss of winter range. However little has been published in Colorado on lamb food habits and on the nutritional plane of lambs during summer before they enter the stressful winter period when forage quality and quantity are greatly reduced (Mautz 1978). Lambs grow rapidly during summer and fall and must store enough energy and nutrients to carry them through winter. Lactating ewes also have additional energy needs. The summer diets of ewes and lambs thus are key factors influencing how well animals survive the winter in cold climates with a substantial snowcover.

Objectives of this study were to determine if lambs choose a diet similar to that of thier mothers, and to determine if ewes and lambs select forage plants or choose diets proportional to the vegetation on lambing areas.

STUDY AREA

The study area is in southcentral Colorado in Saguache County, approximately 15 to 48 km west of the town of Saguache. The area contains 2 lambing ranges differing greatly in botanical composition as well as elevation. Commonly called Trickle Mountain, the area has been studied by Shephard (1975), and Todd (1975). However nothing has been published on herbage production related to food habits of bighorn ewes and lambs in the area.

Bighorns were indigenous to the Trickle Mountain area but the herd died out in the late 1800s. Bighorns were reintroduced from the Tarryall range in 1951.

BUFFALO ROCKS LAMBING AREA

The Buffalo Rocks lambing area is 48 km west of the town of Saguache north of highway 114. The area used by bighorn ewes for lambing is approximately 625 ha and ranges in elevation from 2682 m to 3238 m. East Pass Creek flows below the south-facing cliffs of the lambing area.

Most of the Buffalo Rocks lambing area is climax montane forest dominated by ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and lodgepole pine (*Pinus contorta*). Extensive grasslands occur on steep, xeric, south-facing slopes especially along the south edge of the lambing area.

Ewes make frequent use of a lava outcrop on the west boundary of the area. It consists of precipitous rocky cliffs which are south-facing and sparsely covered with rock spirea (*Holodiscus dumosus*), wax currant (*Ribes cereum*), and mountain muhly (*Muhlenbergia montana*). The dominant grass on the eastern 2/3 of the lambing area is Arizona fescue (*Festuca arizonica*). The entire Buffalo Rocks lambing area is located on U.S. Forest Service Land.

MIDDLE CREEK LAMBING AREA

The Middle Creek lambing area is 15 km west of Saguache just north of highway 114. The area covers approximately 1400 ha between 2418 and 2821 m elevation. The area is bordered by Jack's Creek on the west. Middle Creek and Cross Creek traverse the area. The area is dominated by blue grama (Bouteloua gracilis). It is located on BLM land with the exception of a riparian zone which is privately owned and harvested for hay.

METHODS

VEGETATION

Fresh ewe fecal pellets were collected at 2-week intervals from 8 May to 28 August 1978, and from 11 May to 24 August 1979 on the Buffalo Rocks lambing area. Lamb fecal pellets were collected concurrently from 1 July to 28 August 1978, and 30 June to 24 August 1979. Ewe fecal pellets were collected at 2-week intervals on the Middle Creek lambing area from 22 May to 11 August 1978, and 11 May to 14 August 1979. Lamb pellets were collected concurrently with ewe pellets from 1 July to 11 August 1978 and 15 June to 14 August 1979. Collections were made only when ewes and lambs were seen on a site to insure freshness and avoid collecting fecal pellets of mule deer (Odocoileus hemionus) or pronghorns (Antilocapra americana). Only as many pellet groups as there were sheep observed were collected on each site. Whenever possible, 15 pellet groups consisting of at least 15 pellets each were collected for ewes and for lambs. Very wet fecal pellets were sprinkled with table salt to prevent decomposition. The maximum time span for a collection period was 10 days.

Fecal pellets were taken to the Composition Analysis Laboratory at Colorado State University, Fort Collins, Colorado, within 14 days of collection. The fecal material was oven dried at 50C for at least 72 hours. Each fecal sample was ground separately and collected over a 1 mm screen. Plan fragments were then treated with household bleach for several minutes and washed with tap water over a 0.1 mm screen. Microscope slides were prepared according to Sparks and Malcheck (1968). One slide was prepared for each pellet group and was treated as one sample. The frequency of each plant taxa occurring in 20 fields for each slide using a 100X microscope was recorded. The frequency of plant fragments was converted to % relative density. Spearman's Rank-Order Correlation Coefficients were calculated for the estimated ewe and lamb diets for each lambing area (Snedecor and Cochran 1976). The % overlap in the diets was calculated using Kulczinski's Similarity Index for each collection period for both years. All plant taxa found in the diets were used for this test. Spearman's Rank-Order test was used to compare the relative abundance of each plant taxa found in th diets with the relative abundance of those taxa on the range. Only plant species comprising at least 2% of the diet were used for this test.

RESULTS

VEGETATION

The Buffalo Rocks lambing area is dominated by mountain muhly and Arizona fescue. The dominant forb is pinque (Hymenoxys richardsonii) and the most abundant shrub is common juniper (Juniperus communis). Herbaceous standing crop (Table 1) varied among vegetation types. Estimated heraceous standing crop for the Buffalo Rocks lambing area was 561 kg/ha in July 1978, and 266 kg/ha in 1979.

Botanical composition of the Middle Creek lambing area is dominated by blue grama in the dry areas and by sedges in the riparian areas. The most abundant for is annual goosefoot (Chenopodium sp.) and the most common shrub is fringed sagewort (Artemisia frigida). Estimated herbaceous standing crop was 829 kg/ha in 1978.

FOOD HABITS

Diets of ewes and lambs on the Buffalo Rocks lambing area was dominated by mountain muhly, Arizona fescue, true mountain mahogany, and cinquefoil (Potentilla sp.) (Tables 2 & 3) during the summers of 1978 and 1979. Grasses predominated in the early summer diets, whereas browse species increased in the late summer diets.

Diets of ewes and lambs on the Middle Creek lambing area in the summers of 1978 and 1979 were dominated by blue grama and mountain muhly in early summer, and blue grama and sedges in mid-summer. In late summer mountain mahogany and wax currant increased in their diets (Tables 4 & 5).

Table 1. Herbaceous standing crops on the Buffalo Rocks and Middle Creek lambing areas during July of 1978 and 1979.

Lambing Area	Vegetation Type	ha/type	kg/ha	
			1978 x ± se	1979 x ± se
Buffalo	Mountain shrub	23	455 ± 192	213 ± 109
	Ponderosa pine bunchgrass	446	535 ± 255	233 ± 56
	Aspen	56	749 ± 359	343 ± 96
	Douglas fir[a]	26	345 ± 217	
	Bunchgrass	77	654 ± 149	221 ± 49
	Blue grama	7	864 ± 273	331 ± 100
	Riparian[b]	17		1197 ± 164
Middle Creek[c]	Blue grama ridges	537		1036 ± 412
	Blue grama slopes	775		222 ± 48
	Riparian	100		4424 ± 459

[a] The Douglas fir stand was old growth in which no sheep use was observed, and was not sampled again in 1979.

[b] The riparian type was sampled only in 1979.

[c] The Middle Creek lambing range vegetation was sampled only in 1979.

Table 2. Mean percentages of plant taxa in the diets of bighorn sheep ewes and lambs on the Buffalo Rocks study area in southcentral Colorado, 1978.

Forage Taxa	May	June		July		August	
	Ewe	Ewe	Lamb	Ewe	Lamb	Ewe	Lamb
Grasses and Grasslike Plants							
Agropyron	6	2	4	4	2	2	2
Bouteloua	1	1	2	4	2	9	7
Carex	5	6	7	5	7	3	2
Festuca	17	7	2	3	1	3	2
Juncus	6	1	1	1	0	2	1
Muhlenbergia	16	20	29	39	21	18	19
Poa	7	3	1	2	1	3	1
Forbs and Browse							
Artemisia[a]	18	2	2	1	8	3	4
Cercocarpus	3	24	24	17	18	26	28
Potentilla	4	11	12	7	10	6	5
Rhus	1	8	7	4	5	5	5
Ribes	3	1	2	2	7	2	8
Number of Samples	24	29	10	30	30	30	34

[a] *Artemisia tridentata* made up most of the sages in the Buffalo Rocks bighorn diets whereas *Artemisia frigida* made up most of the Middle Creek bighorn sage portion of the diets.

Table 3. Mean percentages of plant taxa in the diets of bighorn sheep ewes and lambs on the Buffalo Rocks study area in southcentral Colorado, 1978.

	May	June		July		August	
Forage Taxa	Ewe	Ewe	Lamb	Ewe	Lamb	Ewe	Lamb
Grasses and Grasslike Plants							
Agropyron	4	1	1	3	1	1	1
Bouteloua	1	1	1	1	1	3	2
Carex	20	9	8	12	7	4	3
Festuca	27	14	1	9	1	3	1
Juncus	4	1	1	4	1	2	2
Muhlenbergia	7	20	8	11	10	11	10
Poa	5	1	1	1	1	1	1
Forbs and Browse							
Artemisia[a]	6	1	1	1	2	1	1
Cercocarpus	1	16	22	28	30	50	54
Potentilla	10	20	30	9	20	3	6
Rhus	1	7	18	3	7	2	4
Ribes	1	1	1	3	2	2	2
Number of Samples	30	30	15	30	30	30	30

[a] *Artemisia tridentata* made up most of the sages in the Buffalo Rocks bighorn diets whereas *Artemisia frigida* made up most of the Middle Creek bighorn sage portion of the diets.

Table 4. Mean percentages of plant taxa in the diets of bighorn sheep ewes and lambs on the Buffalo Rocks study area in southcentral Colorado, 1978.

Forage Taxa	June		July		August	
	Ewe	Lamb	Ewe	Lamb	Ewe	Lamb
Grasses and Grasslike Plants						
Agropyron	3	7	8	2	1	1
Bouteloua	6	9	10	11	6	4
Carex	14	12	17	14	4	2
Eleocharis	11	1	3	1	1	1
Festuca	8	5	7	2	1	1
Juncus	4	1	7	2	1	1
Muhlenbergia	8	9	4	5	3	3
Oryzopsis	3	2	2	1	1	1
Poa	2	3	3	1	1	1
Forbs and Browse						
Artemisia[a]	3	8	2	8	1	5
Atriplex	2	1	5	6	4	3
Ceratoides	1	5	3	8	1	1
Cercocarpus	4	1	6	3	61	61
Potentilla	7	8	1	2	5	3
Rhus	4	1	7	6	2	3
Ribes	2	5	2	5	1	4
Number of Samples	19	15	30	30	15	15

[a] *Artemisia tridentata* made up most of the sages in the Buffalo Rocks bighorn diets whereas *Artemisia frigida* made up most of the Middle Creek bighorn sage portion of the diets.

Table 5. Mean percentages of plant taxa in the diets of bighorn sheep ewes and lambs on the Buffalo Rocks study area in southcentral Colorado, 1978.

Forage Taxa	May	June		July		August	
	Ewe	Ewe	Lamb	Ewe	Lamb	Ewe	Lamb
Grasses and Grasslike Plants							
Agropyron	1	2	2	1	2	1	1
Bouteloua	7	7	10	23	14	26	29
Carex	26	13	31	16	29	33	27
Festuca	6	4	3	8	5	1	1
Juncus	1	1	1	1	1	1	1
Muhlenbergia	1	1	2	1	1	1	1
Poa	1	1	1	1	1	1	1
Forbs and Browse							
Artemisia[a]	6	1	7	2	5	1	3
Ceratoides	1	24	3	2	1	2	1
Cercocarpus	13	4	6	6	4	1	1
Potentilla	2	4	9	1	2	1	2
Rhus	1	3	3	1	1	1	1
Ribes	9	2	7	9	12	10	14
Number of Samples	30	30	30	30	30	15	15

[a] *Artemisia tridentata* made up most of the sages in the Buffalo Rocks bighorn diets whereas *Artemisia frigida* made up most of the Middle Creek bighorn sage portion of the diets.

DISCUSSION

VEGETATION

The Buffalo Rocks and the Middle Creek lambing areas differ significantly in species composition and herbage production. Herbage production at Middle Creek is higher primarily because of its larger riparian area. Comparison of the areas using Spearman's Rank-Order Correlation Coefficients for plant taxa making up 1% of the standing crops yields a negative value (-0.02) indicating discordance. (Table 6)

COMPARISON OF VEGETATION AND DIETS

Ewe diets were not significantly correlated with forage availability at either lambing area (Table 6). The ewe diet was more similar to the available vegetation at the Middle Creek lambing area than was the case at the Buffalo Rocks lambing area.

FOOD HABITS COMPARISONS

Ewes occupying the Buffalo Rocks lambing area chose similar summer diets in 1978 and 1979. Spearman's Rank-Order Correlation test applied to plant taxa making up 2% in the mean diets gave a coefficient of +0.79 (P 0.01, Table 6). Ewes of the Buffalo Rocks area ate the same forage plants in nearly the same order both years. At Middle Creek, ewe diets in the summers of 1978 and 1979 were less similar (RHO +0.45) and were not significantly correlated. One explanation for the dissimilarity is that moisture condition in the winters of 1978 and 1979 were different, and the summer of 1979 was much drier in the Middle Creek area than in the previous year.

Lambs on the Buffalo Rocks area ate a diet similar to that of their mothers. Diet overlap exceeded 80% during the summers of 1978 and 1979 (Table 7). Similarities between ewe and lamb diets became stronger as the summers progressed. Several factors may explain this trend. Lambs do not travel with the ewes to feed away from escape terrain for the first weeks after they are born, but rather lambs are confined to the lambing rocks with 1-2 ewes who watch them. Consequently, lambs do not have the same choices of forage plants that ewes have. Furthermore, this period coincides with the time that lambs obtain the greater part of their energy needs and nutritive requirements from ewes' milk.

Summer diets on the Middle Creek area also showed similarities between ewes and lambs (Table 8). Diet overlap exceeded 75% in each year. Ewe and lamb diets generally became more similar as the summer progressed, probably for the same reasons cited above.

Dietary overlap betwen Buffalo Rocks and Middle Creek ewes was only 47% for the summer of 1979 (Table 9). Dietary overlap between lambs of the 2 lambing areas was only 30%.

Table 6. Spearman's Rank Order Correlation Coefficients for plant taxa making up 1% or greater of the botanical composition by weight, and for forage taxa 2% or greater in the summer diets of the Buffalo and Middle Creek ewes and lambs.

Comparison	Number of Pairs	RHO Value	Significance
Buffalo R. vs. Middle C. Vegetation of 1979	12	-0.02	none
Buffalo R. ewes 1978 vs. 1979	12	+0.79	$P < 0.01$
Buffalo R. ewes vs. lambs, 1979	23	+0.78	$P < 0.01$
Buffalo R. ewes vs. vegetation, 1979	6	-0.20	none
Middle C. ewes 1978 vs. 1979	16	+0.45	none
Middle C. ewes vs. lambs, 1979	26	+0.78	$P < 0.01$
Middle C. ewes vs. vegetation, 1979	8	+0.57	none

Table 7. Kulczinski's Similarity Indices showing the percentages of dietary overlap between ewes and lambs on the Buffalo Rocks study area, summers 1978 and 1979.

Time Period	% Overlap	
	1978	1979
June 17 - June 30	76.0	71.0
July 1 - July 14	76.7	63.6
July 15 - July 28	57.2	70.4
July 29 - Aug. 11	71.2	88.0
Aug. 12 - Aug. 25	78.6	82.4
Summer (June 17 - Aug. 25)	84.2	81.9

Table 8. Kulczinski's Similarity Indices showing the percentages of dietary overlap between ewes and lambs on the Middle Creek study area, summer 1978 and 1979.

Time Period	% Overlap	
	1978	1979
June 17 - June 30	52.9	31.9
July 1 - July 14	60.1	68.5
July 15 - July 28	63.6	61.5
July 29 - Aug. 11	83.7	85.2
Summer (June 17 - Aug. 25)	75.3	76.3

Table 9. Comparison of Buffalo Rocks vs. Middle Creek ewe and lamb diets of the summer of 1979.

Time Period	Percent Overlap Kulczinski's Index	
	Ewes	Lambs[a]
May 6 - May 19	47.4	
May 20 - June 2	32.9	
June 3 - June 16	36.4	
June 17 - June 30	55.4	28.4
July 1 - July 14	38.0	28.8
July 15 - July 28	34.1	35.1
July 29 - Aug. 11	25.9	22.3
Summer (May 6 - Aug. 11)	47.6	30.0

[a] Lamb fecal pellets were not collected until the second half of June.

Table 10. Preference indices for the Buffalo Rocks and Middle Creek bighorn sheep ewes for the summer of 1979.

Lambing Area	Forage Species[a]	Preference Index (% in diet) (% on range)
Buffalo Rocks	*Cercocarpus montanus*	100
	Carex sp.	1.7
	Muhlenbergia sp.	0.85
	Festuca arizonica	0.65
Middle Creek	*Cercocarpus montanus*	100
	Festuca arizonica	1.7
	Bouteloua gracilis	0.93
	Carex sp.	0.88

[a] These 4 species were the most important in the ewe diets and accounted for at least 60% of the total diets.

These data suggest the bighorn ewes and lambs are selective feeders and are more opportunistic than were previously assumed (Capp 1968). Bighorn ewes and lambs do not require a specific vegetation type or specific forage plants in order to thrive. The Buffalo Rocks and Middle Creek areas are quite different in vegetation, herbage production, and elevation, yet they have increased in numbers in both areas.

Even though ewe and lamb diets were similar in composition the qualitative intakes may have been quite different. Langlands (1969) reported that younger domestic sheep tended to select diets higher in protein than did older sheep. The smaller mouth sizes of the lambs may enable them to be more selective of plant parts. Walker, et al. (1981) found the botanical compositions of cow and calf diets to be quite similar, but reported the nutritional quality differences were probably due to plant parts being selected.

FORAGE PREFERENCE

The most preferred forage plant of both ewe groups was true mountain-mahogany (Table 10). Little mountain-mahogany was present on the lambing ranges, and shrubs present on the escape terrains were either decadent or dying form heavy use. Other preferred forages of the ewes and lambs were sedges, mountain muhly, Arizona fescue, and blue grama (Table 10). Most of these forages were consumed especially during early phenological stages. Cook (1977) reported digestible protein values for these plants ranging from 5.8 to 12.3% in the vegetative stage and suggested that digestible protein may be the best single factor determining nutrient quality of range forage. An adequate level of digestable protein for domestic lactating ewes and nursing lambs ranges from 4.7 to 6.8% (Cook 1977). Although lambs are nursed throughout the summer they do learn to select the same forage plants that sustain the ewes.

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FORAGE PREFERENCE INDICES:

ADJUSTING FORAGE AVAILABILITY DATA

FOR HABITAT SELECTION

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ABSTRACT

Forage preference indices for Waterton Canyon bighorn sheep were calculated 2 ways by adjusting the forage availability data. Availability data from field measurements were (1) weighted by the proportional area of each habitat type in which each forage species occurred, to yield estimates of availability throughout the canyon (single-weighted); and (2) this availability figure was further adjusted for the proportions of times foraging bighorns were observed in each habitat type (double-weighted). With the latter adjustment, preferences for forage species occurring in "preferred" habitats decreased and preferences for species in "avoided" habitats increased. Adjusting availability data for foraging-site selection may give a more realistic measure of forage availablility.

INTRODUCTION

Many factors influence forage selection and forage preference by wild animals. Consequently, several methods for calculating and analyzing data on animal forage preference have been proposed (Krueger 1972, Neu et al. 1974, Petrides 1975, Ellis et al. 1976, Johnson 1980, Hobbs and Bowden 1982). The simplest preference index is a measure of the percent use of an item in proportion to the percent availability of the item. In food habits studies this is percent of a plant species in the total diet divided by percent of the plant species in the total available forage. A preference index greater than 1 indicates the forage species is more frequent in the diet than in the habitat and hence "preferred" (Petrides 1975). A preference index less than 1 indicates the forage species is less frequent in the diet than in the habitat and hence "avoided," or at least not sought after. More complex ratios (Krueger 1972) or ranking methods (Johnson 1980) may be used to develop preference indices and single data sets can yield different results with different methods.

For most forage preference indices, it is assumed that all vegetation is "available" forage to the herbivore, when in fact behavioral adaptations and other factors may preclude use of much "available" forage. This may be particularly true of wild sheep, which are seldom observed far from escape terrain (Flook 1962, Oldemeyer 1966, Capp 1967).

Selection of foraging sites by wildlife may be influenced by community structure as much as by availability of forage resources. Wikeem and Pitt (1979) felt that a high utilization of rough fescue (*Festuca scabrella*) by California bighorns (*Ovis canadensis californiana*) in August was due to the presence of rough fescue only in the understory of ponderosa pine (*Pinus ponderosa*) where bighorns sought shade. Thompson (1965) found the most preferred food of captive wild voles (*Microtus pennsylvanicus*) was white clover (*Trifolium repens*). However, in the wild, voles made very little use of white clover sites because these areas were characterized by very little surface litter and hence subjected voles to increased risks of predation and adverse temperatures. Habitat selection by Rocky Mountain bighorns (*O. c. canadensis*) in Waterton Canyon, Colorado was affected by visibility as bighorns selected habitats with more open vegetation (Risenhoover 1981).

If herbivores select foraging habitats for characteristics other than their forage resources, forage in nonselected habitats is unavailable to the animals. Consequently, only forages in habitats used as foraging sites should be considered as "available" when calculating forage preference indices. Furthermore, some foraging habitats may be used relatively more frequently than other habitats. Forages in the more frequently used habitats are therefore more available to the animals than are forages in the less frequently used habitats. If data on relative use of foraging habitats are obtained, data on forage resources in those habitats may be adjusted to reflect habitat selection when estimating forage availability for use in calculating forage preference indices. This paper describes a method for using data on habitat selection to adjust data on forage abundance to reflect relative forage availability.

METHODS

Data were collected in Waterton Canyon, Colorado during 16 April - 15 October 1980-81, hereafter referred to as "summer". Bighorn sheep pellet groups were collected bimonthly during 15 June - 15 October 1980 and during 15 April - 30 August 1981. Two pellets from each group were pooled into each bimonthly sample. Food habits data were obtained by microhistological analyses of feces at the Composition Analysis Laboratory, Colorado State University (Sparks and Malechek 1968).

Forage availability data were collected during July-August 1981. Availability was measured as plant canopy-coverage using a modification of the technique described by Daubenmire (1959). Transects were placed in 5 habitat types (Table 1). Forty 0.1-m^2 (20x50 cm) frames were established at 1 m intervals on alternating sides of a stretched 40 m tape in each transect.

Relative use of foraging habitats by bighorns was determined during summer of 1980-81. All observations of foraging bighorns were extracted from habitat preference data of Risenhoover (1981), Simmons (1982), Rominger (1983) and Dale (pers. comm.).

Summer forage preference indices were calculated by 2 methods for comparison (Figure 1). Percent canopy-cover for each forage species was first weighted (single-weighted) by the proportion of study area (Table 1) for each habitat type in which a forage species occurred. This provided an estimate of percent composition by forage species for the entire bighorn range. For the second method (Figure 1) the above estimate was weighted again (double-weighted) by the proportion of time foraging bighorns were observed in each habitat type in which the plant species occurred. (Table 2).

RESULTS

Forty-eight plant species or genera (identification to species is not always possible with microhistological analyses of feces) occurred in the summer diet of Waterton bighorns. Eighty-five plant species occurred in the 920 established Daubenmire frames and 339 observations of foraging bighorns occurred in the 5 habitat types measured for forage availability.

Only 6 species comprised 1 percent or more of the summer diet (Table 3). These 6 species represented 94 percent of the bighorn summer diet. Only 9 species comprised 1 percent or more of the total plant canopy-cover in Waterton Canyon. These 9 species represented 90 percent of the available summer foliage.

Forage preference indices are presented in Table 5 for the 6 species that comprised at least 1 percent of the summer diet. Species occurring in "preferred" habitat types, true mountainmahogany (Cercocarpus montanus), needle-and-thread (Stipa comata), and sand dropseed (Sporobolus cryptandrus), all had high preference indices when their availabilities were single-weighted by habitat-type availability (Table 5). Species occurring in the "avoided" habitats, Gambel oak (Quercus gambelii), and most sedges (Carex spp.), had low preference indices when availabilities were single-weighted. Adjustment of forage availabilities for observations of foraging bighorn habitat selection altered the forage availability figures (Table 4) and therefore the preference indices (Table 5). The preference index for true mountainmahogany declined from 14 to 3, for needle-and-thread it declined from 3 to 0.7, and for sand dropseed it declined from 6 to 2. Preference indices for Gambel oak and sedges increased: from 0.4 to 0.7 and from 0.1 to 0.3, respectively. Flannel mullein (Verbascum thapsus) had a preference index of 25, based on single-weighted availability, and a preference index of 5, based on double-weighted availability. Flannel mullein occurred on only 1 transect in mountain shrub habitat. Flannel mullein is a biennial that tends to grow on disturbed sites that were not measured in Waterton Canyon. This probably caused the high preference indices in both weightings and flannel mullein may not be as actively selected as the data suggest.

Table 1. Normalized[a] percent-availability of habitat types and numbers of transects sampled for available forage in Waterton Canyon.

Habitat Type	Available Area (%)	No. Transects Sampled
Grassy Opening	2	5
Open Mt. Shrub	4	4
Mountain Shrub	11	9
Conifer	41	2
Oak	42	3
Total	100	23

[a]These habitat types comprised 94.7% of the Waterton Canyon study area.

Table 2. Relative use of foraging habitats by Waterton Canyon bighorn sheep, 16 April - 15 October, 1980-81.

Habitat Type	Foraging Observations (%)
Grassy Opening	2
Open Mt. Shrub	23
Mountain Shrub	60
Conifer	8
Oak	6

Table 3. Plant species comprising at least 1% of the summer diet and their relative availabilities on Waterton Canyon bighorn summer range, 16 April - 15 October, 1980-81.

Species	Diet (%)	Availability (%)
Mountainmahogany	70	5
Gambel oak	17	41
Sedges	3	23
Sand dropseed	2	tr[a]
Needle-and-thread	1	tr
Great mullein	1	tr

[a]tr = <1%

Table 4. Availabilities of selected forage species in Waterton Canyon: a comparison of availabilities weighted by habitat composition (single-weighted) vs. availabilities weighted by habitat composition and by bighorn foraging site selection during summer (double-weighted).

Species	Relative Forage Availability (%)	
	Single-weighted	Double-weighted
Gambel Oak	41	25
Sedges	23	12
Mountainmahogany	5	23
Needle-and-thread	0.5	2
Sand dropseed	0.3	0.8
Great mullein	tr[a]	tr

[a] tr= < 1%

Table 5. Preference indices for selected forage species in Waterton Canyon: a comparison of preferences when forage availabilities are weighted by habitat composition (single-weighted) vs. when forage availabilities are weighted by habitat composition and by bighorn foraging site selection during summer (double-weighted).

Species	Preference Index	
	Single-weighted Availabilities	Double-weighted Availabilities
Gambel Oak	0.4	0.7
Sedges	0.1	0.3
Mountainmahogany	14	3
Needle-and-thread	3	0.7
Sand dropseed	6	2
Great mullein	25	5

DISCUSSION

In the above example, forage preference indices were altered by adjusting availability data for foraging-habitat selection by bighorns. Although the rankings of preference values did not change (Table 5), such rankings could change in other situations. Furthermore, for some purposes such as computer-simulating of grazing systems (Cooperrider and Bailey 1981), it may be desirable to separate habitat selection from forage selection. This may be accomplished using forage preference indices based on double-weighted estimates of forage availabilities.

Single-weighted by habitat availability, true mountainmahogany represented only 5 percent of the total available forage in Waterton Canyon. Using this availability figure produced a preference index of 14 for mountainmahogany. However, during summer 60 percent of observations of foraging bighorns occurred in the mountain shrub type wherein mountainmahogany comprised 46 percent of the available forage. This habitat type offered good escape terrain and was near the only source of water available to Waterton bighorns in summer. If selection of the mountain shrub type was not entirely because it contained mountainmahogany forage, but partly because of escape terrain and availability of water, the preference factor of 14 overrates the attractiveness of mountainmahogany. Double-weighting the forage availability figure to account for habitat selection reduced the preference index for mountainmahogany to 3. We suspect this is more realistic when compared to other preference indices based on double-weighting in Table 5.

By contrast, single-weighted by habitat availability, Gambel oak represented 41 percent of the total forage in Waterton Canyon. Use of this figure produced a preference index of 0.4. Much of the oak forage in Waterton Canyon occurs in vegetation avoided by bighorns because it is physically impenetrable and also because visibility is poor in the oak type. Thus its availability as forage was overrated in single-weighted calculations. For a short period in spring, when Gambel oak leaves were young, oak comprised 73 percent of the bighorn diet. Consequently the larger preference index of 0.7, obtained when availability of oak is calculated using bighorn foraging site selection (double-weighting) seems more realistic than does the lower index of 0.4.

Selection of foraging habitat by a herbivore may be largely a function of the abundance of preferred forages in the habitat. When evidence suggests this is true, the double-weighting of forage availability data, as suggested here, will be unnecessary for calculating forage-preference indices. However, if evidence suggests that selection of foraging habitat is based on factors other than the abundance of preferred forages, biologists should consider adjusting forage availability data to account for habitat selection.

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Fig. 1. Formulae for (1) forage preference index (FPI) with forage availability data weighted by habitat composition (single-weighted) and for (2) FPI with forage availability weighted by both habitat composition and herbivore foraging-site selection (double-weighted). Examples using true mountainmahogany (Cemo), which occurs in 2 habitat types in Waterton Canyon. i=forage species, j=habitat types, Di=proportion of species i in diet, Fij=proportion of species i in all forage of habitat type j, Aj=proportion of total study area comprised of habitat type j, Uj=proportion of foraging observations within habitat type j. In the examples, P. represents "proportion;" and will usually be expressed as a decimal.

FORMULA	EXAMPLE
(1) With single-weighted availability	(1) With single-weighted availability
$\text{FPI} = \frac{\text{Di}}{\sum_j \text{Fij Aj} / \sum_i \sum_j \text{Fij Aj}}$	$\frac{\text{P. Cemo in diet}}{\frac{\begin{pmatrix}\text{P.Cemo in}\\ \text{Habitat A}\end{pmatrix}\begin{pmatrix}\text{P.Avail.of}\\ \text{Habitat A}\end{pmatrix}+\begin{pmatrix}\text{P.Cemo in}\\ \text{Habitat B}\end{pmatrix}\begin{pmatrix}\text{P.Avail.of}\\ \text{Habitat B}\end{pmatrix}}{\Sigma\begin{pmatrix}\text{P.Forage in}\\ \text{Each Habitat}\\ \text{Type}\end{pmatrix}\begin{pmatrix}\text{P.Avail.of}\\ \text{Each Habitat}\\ \text{Type}\end{pmatrix}}}$
(2) With double-weighted availability	(2) With double-weighted availability
$\text{FPI} = \frac{\text{Di}}{\sum_j \text{Fij Aj Uj} / \sum_i \sum_j \text{Fij Aj Uj}}$	$\frac{\text{P. Cemo in diet}}{\frac{\begin{pmatrix}\text{P.Cemo in}\\ \text{Habitat A}\end{pmatrix}\begin{pmatrix}\text{P.Avail.of}\\ \text{Habitat A}\end{pmatrix}\begin{pmatrix}\text{P.Foraging Obs.}\\ \text{In Habitat A}\end{pmatrix}+\begin{pmatrix}\text{P.Cemo in}\\ \text{Habitat B}\end{pmatrix}\begin{pmatrix}\text{P.Avail.of}\\ \text{Habitat B}\end{pmatrix}\begin{pmatrix}\text{P.Foraging Obs.}\\ \text{In Habitat B}\end{pmatrix}}{\Sigma\begin{pmatrix}\text{P.Forage in}\\ \text{Each Habitat}\\ \text{Type}\end{pmatrix}\begin{pmatrix}\text{P.Avail.of}\\ \text{Each Habitat}\\ \text{Type}\end{pmatrix}\begin{pmatrix}\text{P.Foraging Obs.}\\ \text{in Each Habitat}\\ \text{Type}\end{pmatrix}}}$

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EFFECTS OF DOMESTIC SHEEP GRAZING ON BIGHORN SHEEP POPULATIONS: A REVIEW

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ABSTRACT

The Gates of the Mountains area in west-central Montana exemplifies areas where potential effects of domestic sheep grazing on bighorn sheep populations must be assessed. Based on review of published and unpublished reports and observations, effects of domestic sheep grazing on bighorn sheep can be classified into three categories: 1. Competition for forage; 2. Competition for space (social competition); and 3. Transmission of diseases. The ability of domestic sheep to utilize steep slopes and arid ranges permits a high degree of overlap in habitat use between bighorn and domestic sheep on shared ranges. Similar food preferences increase the potential for direct competition for forage. While individual bighorn have been observed to associate with domestic sheep, social avoidance is the rule on shared ranges. This avoidance can lead to bighorn occupying only part of the available habitat. The close genetic relationship of bighorn sheep to domestic sheep is reflected in hybridization and susceptibility of bighorn to many diseases which affect domestic sheep. However, observations indicate bighorn lack resistance to pneumophilic bacteria which domestic sheep can carry without ill effects. Co-use of ranges by domestic and bighorn sheep has been consistently linked with declines, die-offs, and extinctions of bighorn populations from historical to recent times. While much of the evidence for competition between domestic sheep and bighorn is circumstantial, it is sufficiently strong to have prompted management decisions against co-use of ranges by bighorn and domestic sheep by federal land management agencies and state wildlife departments.

The Gates of the Mountain area is located in the Big Belt Mountains of west-central Montana. Rocky Mountain bighorn sheep (Ovis canadenis canadensis) were originally numerous in the Big Belt Mountains and in the hills to the north of the range (Couey 1950). In the early 1880's, following introduction of domestic stock into the area, great losses of bighorn sheep occurred which were attributed to scabies and bighorn sheep disappeared from the area soon afterward (Couey 1950).

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In the early 1900's, domestic sheep were grazed in the Gates of the Mountains area in the Candle Mountain and Moors Mountain Allotments (Helena National Forest Allotment Files) (Figure 1). The Beartooth Game Management Area was privately owned and grazed by domestic stock (pers. comm. Hubert Ellwein).[2]

In 1942 and 1943, unsuccessful transplants of bighorn sheep were made into the Gates of the Mountains. In 1966, the Candle Mountain Allotment became vacant. In 1970, the Beartooth Game Management Area was purchased by the Montana Department of Fish, Wildlife and Parks (MDFWP) and livestock grazing was eliminated (pers. comm. Hubert Ellwein). Grazing of domestic sheep was limited to the eastern part of the Moors Mountain allotment and the allotment became inactive in 1973.

Bighorn sheep from the Sun River herd were transplanted onto the Beartooth Game Management Area in 1971, 1973 and 1975 (MDFWP 1975). One hundred and fourteen bighorn were transplanted in these reintroductions compared with only 14 bighorn in the unsuccessful transplants in 1942 and 1943. A bighorn herd which is currently estimated at 200 head (pers. comm. Jim McLucas[3]) and is expanding in both distribution and numbers (pers. comm. Frank Fiest[4]) was successfully established in the Beartooth Game Management Area and the Gates of the Mountains Wilderness. (Figure 2). The bighorn sheep in the Gates of the Mountains provide sport hunting as well as nonconsumptive use, including viewing by hikers in the Gates of the Mountains Wilderness and by pleasure boat from the Missouri River.

The current non-use agreement on the Moors Mountain Allotment ends in 1982. The permittee is interested in restocking the allotment with domestic sheep. Cochran Fields and Favorite Gulch are cattle allotments located south of the Gates of the Mountains Wilderness (Figure 3). They have been vacant since 1973 (Cochran Fields) and 1975 (Favorite Gulch). The Helena National Forest, Montana Department of Fish, Wildlife and Parks and the permittee are considering grazing management options on the three allotments. Alternatives under consideration include stocking them with domestic sheep or cattle and leaving them vacant.

This paper explores the question: What effect would stocking of domestic sheep on these allotments have on the bighorn sheep of the Gates of the Mountains?

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[2] MDFWP, Wildlife Area Manager, Beartooth Management Area, Wolf Creek, Montana.

[3] MDFWP (retired), 890 Granite, Helena, Montana.

[4] MDFWP, Great Falls, Montana.

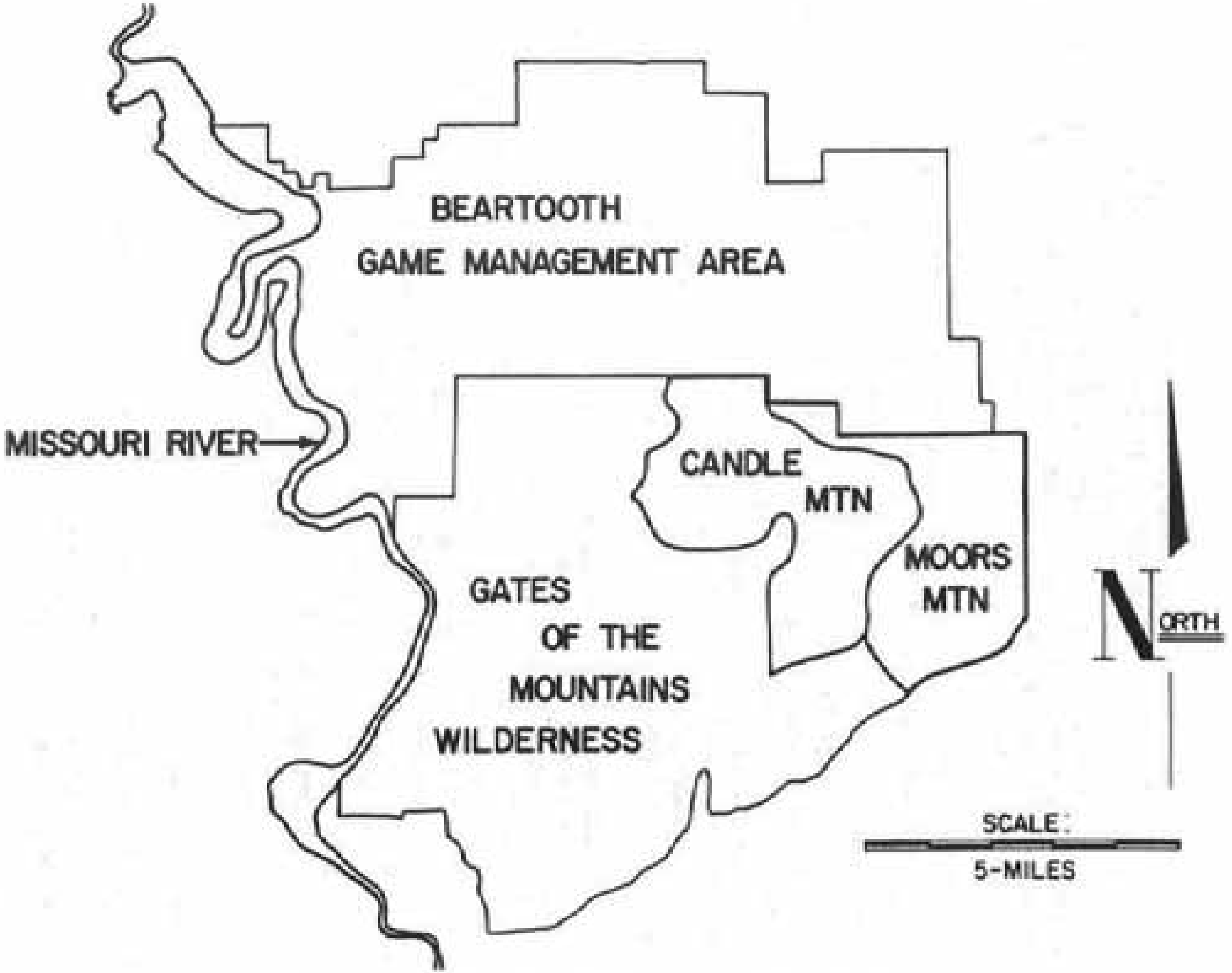

Figure 1. Domestic sheep allotments which were active in the early 1900's located in the Gates of the Mountains Wilderness (established in 1964). The Beartooth Game Management Area (established in 1970) was privately owned and grazed by domestic stock in the early 1900's.

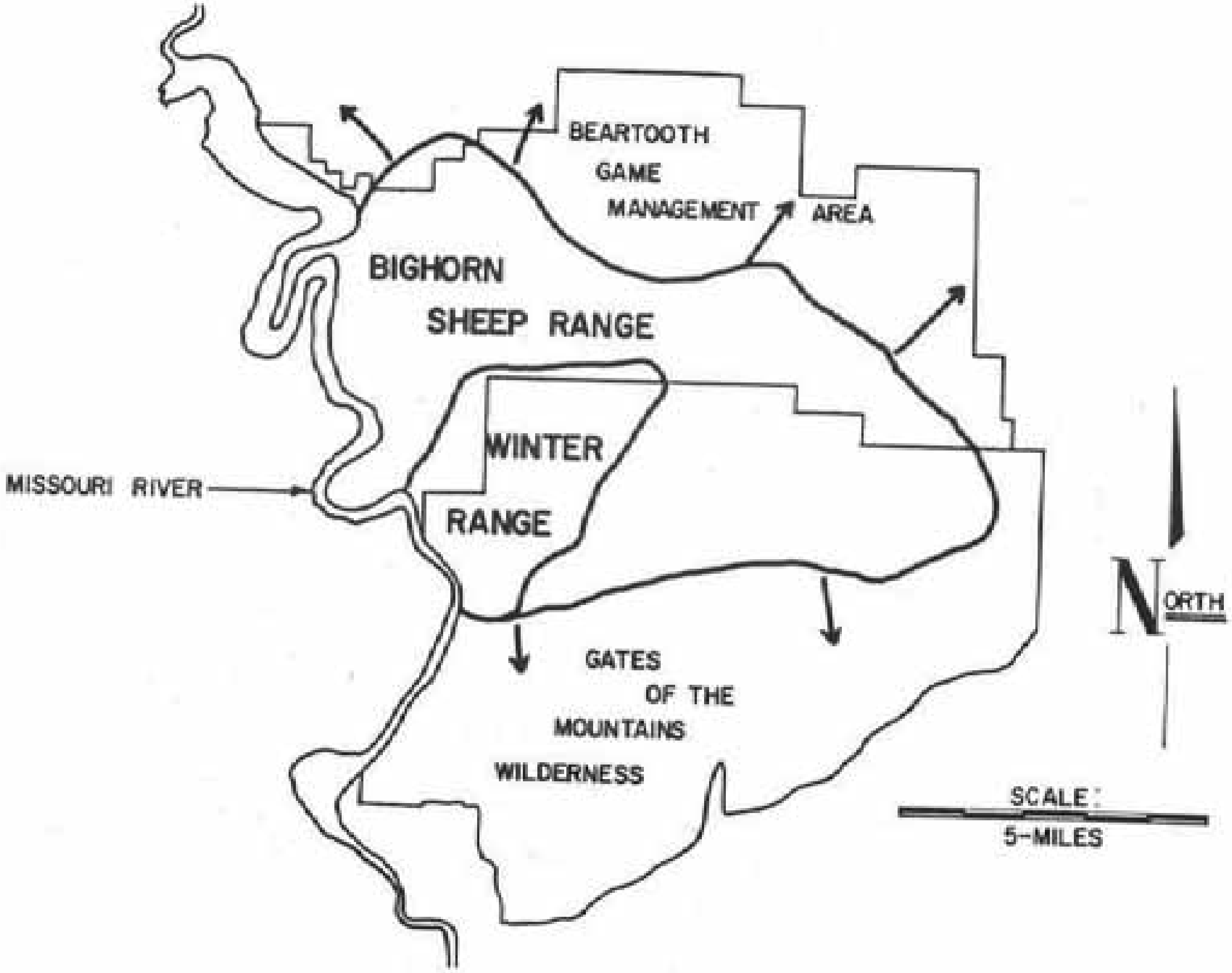

Figure 2. Currently occupied bighorn sheep range in the Beartooth Game Management Area and the Gates of the Mountains Wilderness. The arrows indicate directions of active range expansion.

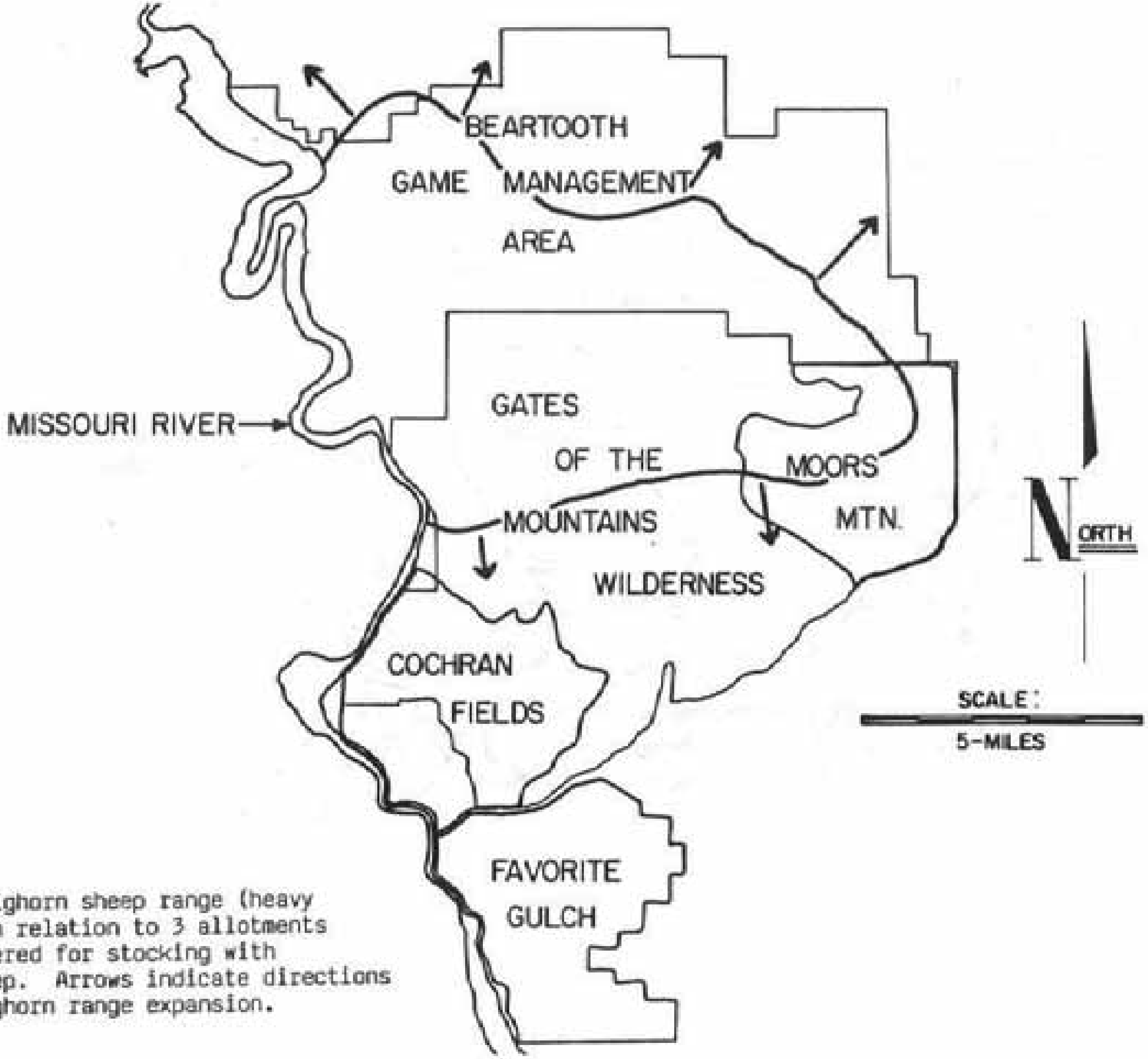

Figure 3. Bighorn sheep range (heavy dark line) in relation to 3 allotments being considered for stocking with domestic sheep. Arrows indicate directions of active bighorn range expansion.

I am indebted to a number of biologists who generously provided me with personal observations and/or unpublished reports. They are individually acknowledged throughout the paper. The United States Forest Service (USFS), Helena National Forest, provided support during preparation of this paper.

METHODS

This paper is based on review of published and unpublished findings and personal communications with wildlife biologists and range conservationists.

RESULTS

HISTORICAL DECLINES

The introduction of domestic livestock onto bighorn sheep ranges in the late 1800's and early 1900's was followed by severe and widespread die-offs of bighorn sheep attributed to scabies, caused by Psoroptes spp. mites (Honess and Frost 1942, Couey 1950, Buechner 1960, Bear and Jones 1973, Jones 1980, Lange 1980) (Table 1). Die-offs coincided with dates of introductions of domestic sheep (Packard 1939, Couey 1950, Buechner 1960, Lange 1980). In northern Colorado, Wyoming and parts of Montana domestic sheep were introduced in the mid-late 1800's and scabies epidemics followed in the 1860's to 1880's. In Canyonlands, where domestic sheep were introduced in 1910, scabies induced die-offs of bighorn followed during 1916-1922 (Dean 1977). The disease was not observed in bighorn prior to the introduction of domestic sheep (Buechner 1960).

Early observers were convinced that bighorn sheep contracted scabies from domestic flocks (Packard 1939, Couey 1950, Buechner 1960, Bear and Jones 1973), however, recent attempts to transfer Psoroptes sp. mites from desert bighorn (O.C. nelsoni), to domestic sheep, elk (Cervus elaphus), mule deer (Odocoileus hemionus) and Rocky Mountain bighorn have been inconclusive (pers. comm. Charles Hibler)[5]. Transient infestations were achieved on domestic sheep, elk, and mule deer. Infestation did not occur on Rocky Mountain bighorn (pers. comm. Charles Hibler).

Uncontrolled hunting for sport and market also impacted bighorn sheep populations during 1860-1900 (Packard 1939, Buechner 1960). Additionally, an encroaching civilization, with its associated roads, fences, and settlements influenced bighorn herds (Packard 1939, Buechner 1960).

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[5] Wild Animal Disease Center, Colorado State University, Fort Collins, Colorado.

Declines of bighorn sheep prior to 1900 probably resulted from several factors, however competition with domestic stock for range and losses due to scabies, believed to be contracted from domestic sheep, were considered of major importance by reviewers (Packard 1939, Honess and Frost 1942, Couey 1950, Buechner 1960, Sugden 1961, Bear and Jones 1973).

Table 1. Die-offs of bighorn sheep attributed to scabies during 1859-1939.

Location	Dates of Die-offs	References
Colorado	1859 - 1931	Lange 1980, Buechner 1960
Utah	1916 - 1922	Dean 1977
Wyoming	1881, 1885	Lange 1980, Buechner 1960
Montana	1880 - 1890	Lange 1980, Buechner 1960
Idaho	1870 - 1880	Smith 1954
California	1870 - 1879,1898	Lange 1980, Buechner 1960
Oregon	1936	Lange 1980, Buechner 1960

The number of domestic sheep grazed on rangelands in the 11 western states increased to a peak about 1920 and remained high through 1945 (Figure 4) (Wagner 1978). Grazing of domestic sheep on bighorn ranges was widespread. Concurrent with the peak was a pronounced die-off throughout most Rocky Mountain bighorn sheep range in the United States, while similar declines occurred in Rocky Mountain and California bighorn (O.C. californiana) in British Columbia (Stelfox 1974). The severe declines of bighorn sheep led to widespread concern among biologists. Some beleived bighorn were in danger of extinction (Couey and Schallenberger 1971, Dixon 1940). In 1939, biologists from Colorado, Idaho, Montana and Wyoming formed the Rocky Mountain Cooperative Bighorn Sheep Conference to study the decline of bighorn populations throughout the Rocky Mountains (Capp 1968).

A few examples illustrate declines occurring throughout bighorn range in the western United States (Table 2). In each case grazing by domestic sheep alone or in combination with cattle coincided with a decline or die-off of bighorn sheep.

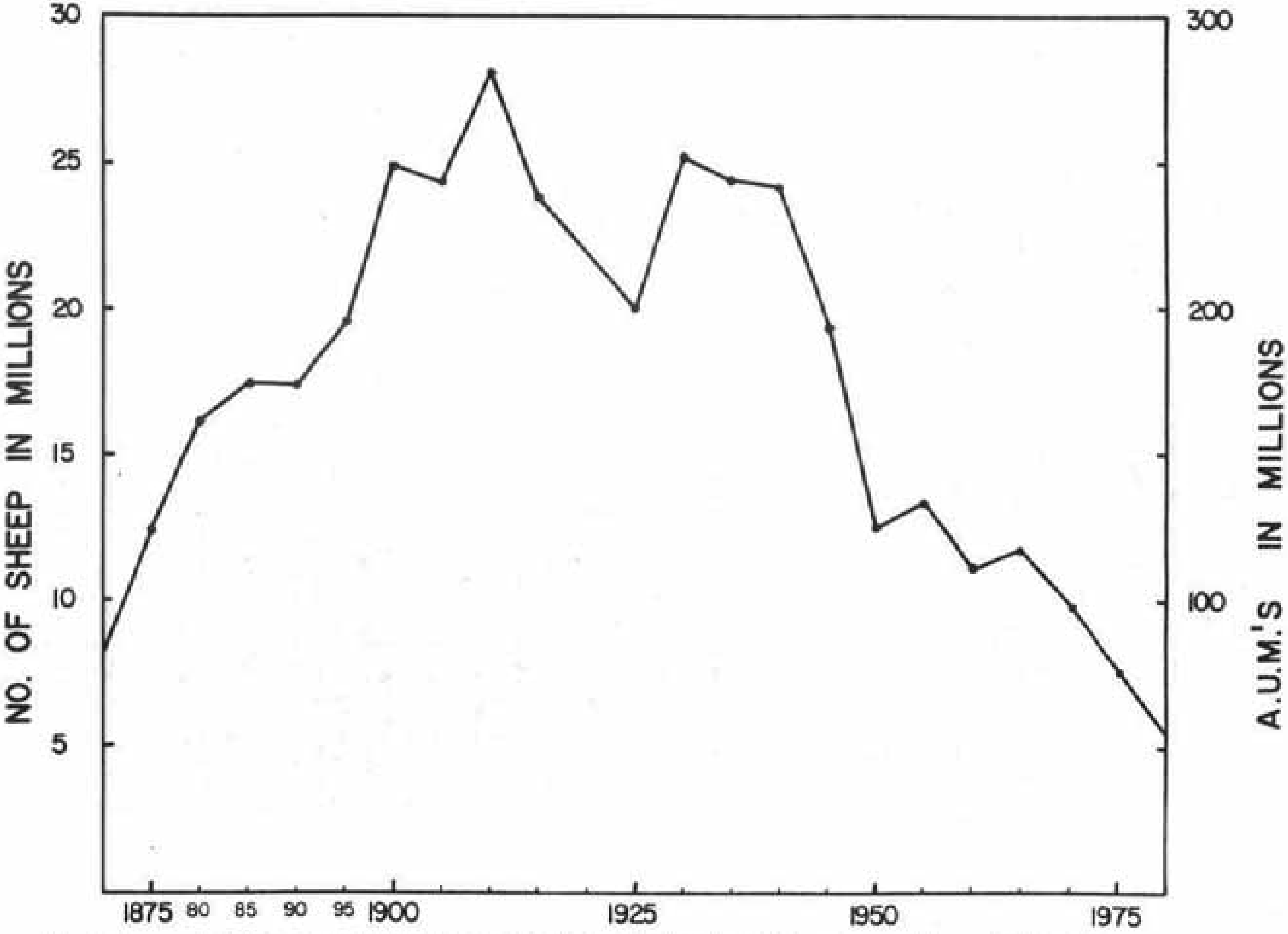

Figure 4. Numbers of domestic sheep grazed on rangelands of 11 western states, 1875-1975 (Wagner 1978).

Table 2. Historical examples of bighorn declines during periods of grazing by domestic sheep.

Location	Dates of Domestic Sheep Grazing	Status of Bighorn Sheep	References
Rocky Mountain National Park Colorado	1917 - 1930	All-age die-off pneuomonia	Packard 1939a, Packard 1939b, Shepherd 1976
Rock Creek Montana	1900 - 1920	Bighorn declined to low of 8	Berwick 1968 Aderhold 1972
Dinosaur National Monument, Colorado	1920 - 1950	Severe declines in early 1930's died out completed by 1950	Barmore 1962
Sun River, Montana	1910 - 1925	All-age die-off of 70% of herd	Picton and Picton 1975

RECENT REPORTS

Since 1945, declines in native herds have slowed or stopped and bighorn sheep numbers have increased in several states due to transplants onto historical ranges (Rutherford 1972, Couey and Schallenberger 1971). In many cases, bighorn sheep disappeared from these ranges during periods of heavy grazing by domestic livestock (Buechner 1960, Brown 1974, Goodson 1980, Butts 1980) and were successfully reintroduced after reductions in livestock use, often including removals of domestic sheep.

Declines in grazing of domestic sheep on western rangelands between 1945 and 1978 have been due largely to economic factors including rising costs of transporting and herding sheep and lower prices for wool and mutton (USFS 1976). Most sheep allotments on public lands were not closed but remain vacant if the permittee has relinquished his permit or in a non-use status. Some have been converted to cattle use (Allotment Files, Arapaho and Roosevelt National Forests, Helena National Forest.) Since 1978, improvements in the economics of sheep-raising have resulted in efforts to restock sheep allotments or convert cattle allotments to sheep allotments on public lands in California (USFS 1979), Wyoming (pers. comm. Bruce Johnson)[6], Colorado (pers. comm. Fritz Foutz)[7], New Mexico (pers. comm. Kurt Nelson)[8], Montana, and Oregon (pers. comm. Guy Sheeter)[9].

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[6] Wyoming Department of Fish and Game, Big Piney, Wyoming.
[7] USFS, Pine RD, San Juan NF Bayfield, Colorado.
[8] USFS, Seward RD, Chugach NF, Seward, Alaska.
[9] BLM, Burns District, Burns, Oregon.

Studies of interspecific competition often involve monitoring the response of one species to the introduction or removal of a second. Changes in public and private land management have provided examples of the reduction, removal and introduction of domestic sheep on bighorn ranges and the responses of bighorn herds. These were not experiments, however, and it is important to note that other variables were not controlled.

Montana

The Upper Rock Creek herd in western Montana was estimated at 150 bighorn in winter 1964-1965, based on an actual count of 103 (Aderhold 1972). The herd had been steadily increasing since the early 1950's with moderate use by cattle and horses on its fall-spring range. On June 1, 1965, 300 domestic ewe-lamb pairs were introduced onto the bighorn fall-spring range and remained until late October (Aderhold 1972). Contact between bighorn sheep and domestic sheep was possible during June. Fall counts indicated a decline to 71 bighorn during the summer. Losses continued through the winter, and by May 61 bighorn remained. An unusually cool and wet summer and fall may have been a factor in the decline (Aderhold 1972). Domestic sheep grazing was reduced in following years, however, the bighorn continued to decline, dying out completely in the early 1970's (pers. comm. Tom Butts)[10].

In 1975, 31 bighorn sheep were transplanted from the Sun River, Montana herd to the Upper Rock Creek range. The transplanted sheep increased to an estimated 150 bighorn by 1981. Factors believed contributing to the success of the transplant were elimination of domestic sheep, establishment of a rest-rotation grazing system for cattle, establishment of a livestock exclosure and control of human disturbance (Butts 1980).

The Thompson Falls bighorn herd in northwestern Montana was estimated at 50 head in 1942 (Brown 1974). From 1940 through 1955, 200 to 500 domestic sheep grazed the bighorn range. Bighorn sheep disappeared from the area during the early 1950's (Brown 1974). In 1959, bighorn were reintroduced (after removal of domestic sheep) and increased rapidly to an estimated 240 in 1974 (Brown 1974).

Shawn Stewart of the Montana Department of Fish, Wildlife and Parks counted 11 bighorn sheep on the Monument Peaks winter range in 1975, after many years of grazing of domestic sheep. Following a management decision (USFS 1976) domestic sheep grazing was eliminated from 95 percent of the bighorn winter range. Domestic sheep were grazed on the remaining 5 percent during 2 years (1977, 1981) since 1975. In 1981, the count on the winter range had increased to 36 bighorn sheep (pers. comm. Shawn Stewart)[11].

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[10] MDFWP, Roundup, Montana.

[11] MDFWP, Red Lodge, Montana

Utah

In 1974, 4000 domestic sheep were grazed on the White Rim of Canyonlands National Park (pers. comm. Bill Bates). Clay Dean, a graduate student at Utah State University found no use by bighorn sheep on the White Rim or west of the White River Road during his studies (1974-76)(Dean 1977). Dean estimated the bighorn herd in Canyonlands at 80-130 head in 1975 when domestic sheep use was terminated. Bill Bates, who is currently completing a graduate study on bighorn in Canyonlands, found bighorn now utilize the White Rim and areas west of the White Rim Road within .8 kilometer (.5 mile) of escape terrain. Since 1975, the population has increased rapidly and is currently estimated to number over 500 (pers. comm. Bill Bates [12], Mike King [13], Gar Workman [14]). Other factors which may have contributed to depressed bighorn sheep populations during the 1950's and 1960's were disturbance due to uranium mining and poaching by miners (Dean 1977).

Nevada

Jessup (1981) reported an all-age die-off of bighorn sheep in the Mormon Mountains of Nevada. Although domestic sheep normally are grazed only at the base of the Mormon Mountains, prior to the die-off two domestic sheep were observed running with a band of bighorn. Bronchopneumonia was identified in 4 hunter-killed bighorn examined. Counts indicated a 50 percent decline from approximately 600 to 300 bighorn sheep.

New Mexico

The bighorn herd in the Latir Peaks Wilderness of northern New Mexico was the result of a transplant of 20 bighorn in fall of 1978. In spring 1981, 36 bighorn sheep were counted and the herd was estimated at 50 head (pers. comm. Kurt Nelson, Stephen Henry[15]). In mid-July 1981, 115 domestic sheep were allowed to graze the allotment, which had been vacant for 10 years. The area grazed included parts of the summer range used regularly by bighorn sheep. By the end of July coughing bighorn were observed. During August-October coughing, rough, dry hair coat, lethargy and weak condition were noted in the bighorn, and only 10-12 individuals could be located. Four carcasses were found before winter weather ended field investigations. Necropsies indicated bronchopneumonia was the cause of death of all 4 sheep (pers. comm. Stephen Henry, Kurt Nelson, Charles Hibler). All radio-collared sheep were found dead during field

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[12] Department of Fisheries and Wildlife, Utah State University, Logan, Utah

[13] Department of Fisheries and Wildlife, Utah State University, Logan, Utah

[14] Department of Fisheries and Wildlife, Utah State University, Logan, Utah

[15] New Mexico Department of Game and Fish, Santa Fe, New Mexico

Hibler). All radio-collared sheep were found dead during field investigations in 1982, and no live sheep were observed indicating a complete die-off (pers. comm. Stephen Henry).

Colorado

Bear and Jones (1973) reported 12 bighorn sheep herds in Colorado with domestic sheep grazing on their ranges prior to 1970. In the late 1960's and early 1970's, nine of these herds experienced significant reductions or complete removals of domestic sheep from their ranges (Table 3). Six of the herds (67 percent) experiencing reductions have increased. For the Dinosaur National Park herd no counts are available; however, there is some evidence that the herd may be expanding its range into areas used by domestic sheep and cattle prior to 1975 (pers. comm. Gary Skiba)[16]. On the ranges of three herds (25 percent) domestic sheep grazing has remained the same and bighorn numbers have remained fairly constant. Only two of these herds have been treated for lungworms (Hibler et al. 1976), Georgetown and Ouray, and neither of these herds increased significantly (Table 3). Of 14 herds in 1970 without domestic sheep grazing, seven have increased; however, five of these have been treated for lungworm (Table 4). Overall six of nine herds treated for lungworm have increased and six of the nine herds experiencing reductions or removals of domestic sheep have increased (Tables 3,4).

Canada - British Columbia

In British Columbia, three die-offs of bighorn sheep have occurred since 1939, following contact between bighorn sheep and domestic sheep on their ranges. The 8 herds involved in one or more of the die-offs winter on contiguous ranges spanning over 130 map kilometers (80 map miles) on the Rocky Mountain Trench (pers. comm. Ray Demarchi[17], Peter Davidson[17], Bandy 1968).

In 1939, approximately 100 domestic sheep were introduced onto the range of the Radium-Stoddard bighorn herd near Kootenay National Park. In the fall of 1939, bighorn rams were observed breeding domestic ewes. A die-off of bighorn began the following winter. Hemorrhagic septicemia (pneumonia) was diagnosed as the proximate cause of death. Over the next several years the die-off spread through adjacent bighorn herds (pers. comm. Ray Demarchi, Peter Davidson).

A second die-off began in the Bull River bighorn herd in January 1965 (Bandy 1968, Demarchi 1980). Domestic sheep had not been grazed on this range except for a period in 1955 (Smith 1955, Demarchi 1980). In 1961, or 1962, a sheep rancher began grazing about 150 head of domestic sheep on the bighorn range. In January 1965, bighorn sheep were observed feeding on haystacks in the rancher's field with his domestic sheep. Several bighorn died, apparently from rumen compaction (Demarchi 1980). A die-off in the bighorn followed which reduced the herd from about 250 to 8 head.

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[16] Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado.

[17] Fish and Wildlife Branch, Cranbrook, British Columbia.

Table 3. Trends of Bighorn Sheep Herds in Colorado with Domestic Sheep Grazing in 1970.

Bighorn Range	Domestic Sheep Grazing 1960-1970[1]	Domestic Sheep Grazing Pressure 1970/1980			Population Estimates Bighorn Sheep	
		Trend %	% Reduced	Trend	1970[1]	1980[2]
Cimarron Peak	Heavy	Down	100[3]	Up	40	75
Gore Range	Moderate	Stable	0[4]	Stable	40	75
Lake City	Heavy	Down	25[5]	Up	70	90
Ouray	Moderate	Stable	10[5]	Stable	90	100
Pole Mountain	Moderate	Stable	0[6]	Stable	14	14
Redstone	Moderate	Down	100[4]	Up	25	60
San Luis Peak	Heavy	Down	50[5]	Up	150	200
Sheep Mountain	Moderate	Down	100[3]	Stable	40	40
Snowmass	Moderate	Down	100[3]	Up	25	75
Vallecito	Heavy	Down	100[3]	Up	12	30
Dinosaur National Monument	Moderate	Down	100[7]	?[7]	?[7]	?[7]
Georgetown	Moderate	Down	100[8]	Down	75	40

[1] Bear and Jones 1973.

[2] Schmidt and Rutherford 1980.

[3] pers. comm. Dave Cook, Fritz Foutz, San Juan, NF, Durango, Colorado.

[4] pers. comm. Bernie Rios, White River NF, Glenwood Springs, Colorado.

[5] pers. comm. Fred Wilde, Duane Harp, Grand Mesa, Uncompahgre and Gunnison National Forests, Delta, Colorado.

[6] pers. comm. John Verner, Rio Grande NF, Monte Vista, Colorado.

[7] pers. comm. Gary Skiba, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado

[8] Allotment Files, Roosevelt and Arapahoe National Forests, Fort Collins, Colorado

Table 4. Trends of bighorn sheep herds in Colorado without domestic sheep grazing.

	Population Estimates Bighorn Sheep			Dates of Lungworm Treatment[2]
	Trend	1970[1]	1980[2]	
Collegiate Range	Up	100	200	1976-79
Battlement Mesa	Stable	35	35	
Buffalo Peaks	Up	50	110	
Clinetop Mesa	Stable	15	15	
Mt. Evans	Up	160	250	1976-77
Poudre Canyon	Up	75	250	1976-79
*Pikes Peak	Down/Up	300	200	1976-79
Rocky Mountain National Park	Stable	200	200	
Tarryall	Up	100	250	1976-79
Taylor River	Down	40	30	1977-78
Trickle Mountain	Up	175	500	1976-79
Waterton	Stable	80	80	
Arkansas River	Stable	20	30	
Sangre de Cristos	Up	70	100	

[1] Bear and Jones 1973.

[2] Schmidt and Rutherford 1980.

*This herd underwent a decline and subsequent increase during 1970-1980.

The die-off spread north through 6 contiguous bighorn ranges covering a 130 kilometer (80 mile) span during the next 2 years. About 70 percent of the bighorn in 6 herds died (Bandy 1968). The Radium-Stoddard, Wigwam and Kootenay Park herds were affected. Bighorn died from acute pneumonia. Pasteurella multocida bacteria were isolated from bighorn during the die-off. Heavy lungworm (Protostrongylus spp.) burdens were also found in the bighorn (Bandy 1968). The die-off was sudden and unexpected since the bighorn herds had maintained stable population densities for over 10 years. Most of the herds involved in the die-off recovered to pre-die-off levels within the next 10-20 years, however, the Bull River herd has recovered very slowly and is currently estimated at 50 head.

A third die-off began during the winter of 1981-82 on the Maquire Creek-Red Canyon bighorn range (Davidson 1982a,b). This traditional year-round range supported about 50 bighorn prior to the die-off. Domestic sheep grazing began about 1978. Generally, domestic sheep were grazed for 3 weeks to 2 months during the summer, however, in October 1981, the bighorn herd was known to be in direct contact with about 60 domestic sheep (Davidson 1982a, b). The die-off began in December with at least 26 bighorn dying during December-January. Necropsies of 2 bighorn indicated acute pneumonia was the cause of death. Pasteurella spp. bacteria were isolated from 1 ram. Both bighorn had heavy lungworm burdens. (Davidson 1982a, b).

Bighorn on the Wigwam winter range about 1.6 kilometers (1 mile) north of the Maquire Creek-Red Canyon range began dying in late March 1982. During the next 3 weeks about 150 bighorn (50 percent of the herd) died. An acute bronchial pneumonia was the cause of mortality. Pasteurella multocida was found in necropsied sheep. Little lungworm damage was discovered in bighorn which died during the first 10 days of the die-off.

Seventeen bighorn were transplanted from the Wigwam range to the Bull River range to augment the native herd in mid-March about a week prior to the beginning of the die-off. The transplanted sheep remained in excellent condition for 6 weeks. During the seventh week, 7 of them developed acute pneumonia. Pasteurella multocida was isolated from 2 ewes which were necropsied. The ewes carried moderate-heavy lungworm burdens. The transplanted sheep had been foraging on green vegetation for about 5 weeks prior to the die-off (Davidson 1982a, b). The native Bull River sheep remained healthy.

The die-off continued to spread during the summer and by fall 1983, 8 herds were affected including most of the herds involved in the first 2 die-offs. Bighorn were dying on summer ranges where densities were low. Lungworm burdens in most of the herds were low. While the ranges of most of these herds were contiguous, one affected herd was over 60 kilometers (40 miles) from the nearest die-off and two herds between appeared unaffected (as of fall 1982) (pers. comm. Peter Davidson). Total mortality from this die-off will probably equal or exceed the losses of the 1939-42 and 1965-67 die-offs (pers. comm. Peter Davidson).

POTENTIAL COMPETITION MECHANISMS

Competitive interactions between bighorn and domestic sheep can involve direct competition for forage and more subtle interference including social intolerance and disease transmission.

Competion for Forage

Evidence for direct forage competition includes food habits overlap, habitat use overlap and the relative importance of shared foods in the diets of bighorn and domestic sheep. Domestic sheep may utilized the same habitats as bighorn sheep. Steepness is no barrier and they are capable of grazing arid and high elevation ranges (Bowns 1971, McDaniel and Tiedman 1981). These characteristics have frequently made them the preferred livestock on bighorn sheep ranges too high in elevation, rugged or dry for cattle (Allotment files, Arapaho-Roosevelt National Forests and Helena National Forest).

Food habitats of domestic sheep are similar to those of bighorn sheep. On spring and summer ranges, both prefer grasses and forbs (Todd 1972, Johnson and Smith 1980, MacCracken and Hansen 1981). On arid and winter ranges both consume greater proportions of browse (Todd 1972, Browning and Monson 1980, Cook et al. 1962, Olsen and Hansen 1977). Both domestic sheep and bighorn sheep feed selectively on more nutritious forage. Few data are available on food habits of domestic sheep and bighorn sheep on shared ranges. Stewart (1975) found domestic sheep preferred and heavily utilized sedges and bluegrass which were extremely important in the diet of bighorn sheep on shared summer ranges in southern Montana.

Social Intolerance

Typically, domestic sheep on mountain ranges are grazed in large bands, often of 1000 or more managed by a herder using several dogs (Allotment files, Arapaho and Roosevelt National Forests, Helena National Forest). After passage of such a band little forage may remain. It is impossible, based on casual observation, to separate the effects of domestic sheep, dogs, human herders and forage removal. Bighorn sheep avoid domestic bands on their ranges; in Colorado, in the Never Summer Range, on San Luis Peak, on Pole Mountain, and in the Gore Range (Bear and Jones 1973), and in Dinosaur National Park (Barmore 1962); in Utah, in Canyonlands National Parks (Dean 1975, Dean and Spillet 1976, Dean 1977), in Wyoming, on the Carter Mountain Alpine Research Area (Thilenius 1975), and in Montana on Monument Peak (USFS 1976). Removals of domestic sheep from bighorn ranges in the Never Summer Range, on San Luis Peak and in Canyonlands National Park were followed by expansion of bighorn sheep distribution into areas formerly used by domestic sheep (Bear and Jones 1973, pers. comm. Bill Bates). Duane Harp (pers. comm.)[18] mentioned bighorn on the Lake City range maintain a "buffer zone" between themselves and domestic sheep and

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[18] Duane Harp, USFS.

that the zone is greater during the lambing period. David Reeder (pers. comm.)[19] mentioned bighorn used areas domestic sheep "could not get to" and considered such areas important to the survivial of bighorn, Tom Thorne (pers. comm.)[20] noted domestic sheep tended to use the more level and mesic meadows while bighorn remained on steeper slopes on shared ranges. Thilenius (1975) noted bighorn used alpine ranges in Wyoming mainly before and after domestic sheep were present. In Canyonlands, bighorn expanded their distribution onto areas of gentle terrain up to .8 kilometer (.5 mile) from escape cover after domestic sheep were removed (pers. comm. Bill Bates.

These observations suggest that social intolerance may limit bighorn distribution and habitat use on shared ranges before forage competition. In Canyonlands, although surplus forage existed on some areas used by domestic sheep, bighorn did not use these areas until domestic sheep were removed (Dean 1977, pers. comm. Bill Bates).

Disease Transmission

Bighorn sheep are closely related to domestic sheep. They readily hybridize to produce fertile offspring (Monson and Sumner 1980). They are susceptible to virus-caused diseases (bluetongue, contagious ecthyma), bacteria-caused diseases (pasteurellosis, paratuberculosis), parasites (nasal botfly-induced chronic sinusitis, psoroptic scabies), and other pathogens (Chlamydia spp. induced pinkeye) that also affect domestic sheep (Jessup 1979, Hibler in press, pers. comm. Charles Hibler). While some of these diseases are currently controlled in domestic sheep (scabies), other are still common (pasteurellosis, contagious ecthyma, chronic sinusitis) or difficult to diagnose and control (paratuberculosis) (pers. comm. Charles Hibler, Williams and Hibler this volume). Of these diseases, contagious ecthyma, pasteurellosis, pinkeye, chronic sinusitis, and scabies have caused debilitation and/or death in free-ranging bighorn herds (Samuel et al. 1975, Spraker and Hibler this volume, Bunch in press, Meagher this volume, Lange 1980).

Chronic Sinusitis. Chronic sinusitis is currently considered to be an important cause of mortality in desert bighorn. According to a recent review (Bunch in press) chronic sinusitis has been found in bighorn populations throughout the warmer and drier parts of their range including Arizona, California, Nevada, New Mexico, and Utah. Prevalences as high as 45 percent in ewes and 27 percent in rams have been found in free-ranging herds. Severity is greater in desert regions where environmental conditions favor the nasal bot fly and where bighorn sheep concentrate at limited water sources which increase their vulnerability to fly strike. The disease is considered to be terminal in bighorn sheep and has

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[19] USFS, Lander Ranger District, Shoshone NF, Lander, Wyoming.

[20] Wyoming Game and Fish Department, Game and Fish Research Laboratory, Laramie, Wyoming.

contributed to the decimation of some herds and limits productivity of others (Bunch in press). Chronic sinusitis was introduced with domestic sheep and its occurrences in bighorn is the result of association with domestic sheep (Hibler in press). Currently, management recommendations are to maintain at least a 2-mile buffer between densities and bighorn sheep (Bunch 1978, USFS 1978).

Pasteurellosis. Two recent die-offs of bighorn sheep from acute branchopneumonia following association with domestic sheep were reported by Foreyt and Jessup (1982). Both incidents involved healthy bighorn herds which were in enclosures for 10 months or more before the deaths occurred suggesting that capture stress or acclimatization to the new habitat was not a problem. In each case, nose to nose contact with domestic sheep was followed within weeks by a die-off. In Lava Beds National Monument, California, all 43 bighorn died. In Washington, at the Methow Game Range, one ewe of 14 bighorn survived. No sickness or mortality was reported in the domestic sheep. Circumstantial evidence suggests that apparently healthy bighorn sheep transmitted pneumophilic bacteria (Pasteurella multocida was isolated in the California outbreak) to the bighorn sheep resulting in mortality (Foreyt and Jessup 1982).

These incidents are similar to others experienced by researchers attempting to maintain bighorn sheep in captivity in association with domestic sheep. While bighorn sheep are generally prone to pneumonia in captivity (Spraker 1977) association with domestic sheep seems to significantly increase the probability of developing pneumonia. Incidents of apparently healthy adult bighorn in captivity dying from pneumonia shortly after exposure to domestic sheep have occurred at Utah State University (pers. comm. J. Juan Spillet)[21], University of British Columbia (pers. comm. Daryll Hebert)[22] and Colorado State University (pers. comm. Charles Hibler). Workers at the Sybille Wildlife Research Unit of the Wyoming Department of Fish and Game have spent years developing a cross-bred bighorn-domestic sheep herd for research purposes. They found bighorn sheep and the hybrid offspring of bighorn-domestic crosses to be more susceptible to pneumonia than domestic sheep maintained under the same conditions (pers. comm. Tom Thorne). Hybrid lambs developed pneumonia within the first 3 weeks of life, and prompt treatment was necessary to prevent mortality. Second hand reports related by ranchers in Wyoming indicated the same process occurred in the free-ranging situation (pers. comm. Tom Thorne). When bighorn rams joined their domestic flocks and bred the ewes, the resulting hybrid lambs experienced a remarkably high mortality during the first few weeks of life. These observations are consistant with Foreyt and Jessup's (1982) hypothesis that domestic sheep are more resistant to pneumophilic bacteria than bighorn and are able to carry strains of bacteria capable of causing acute pneumonia in bighorn.

Circumstances of the Rock Creek, Mormon Mountains and Latir Peaks die-offs in the United States and the Radium-Stoddard, Bull River and

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[21] USFS, Caribou NF, Pocatello, Idaho.
[22] Fish and Wildlife Branch, Williams Lake, British Columbia.

Maquire Creek-Wigwam die-offs in British Columbia are consistent with the hypothesis that a pathogen transmitted from domestic sheep to bighorn sheep was the cause. In each of these cases, association of bighorn with domestic sheep was followed by an all-age die-off due to acute pneumonia, and significant mortality occurred in summer-fall rather than in winter when a malnutrition problem would be expected. In the Canadian die-offs, the spread of the die-off to adjacent populations suggests contagious spread of a disease. The delayed response of bighorn which were transplanted from the Wigwam range prior to the die-off is consistant with the hypothesis that a pathogen with a variable incubation period rather than a range-related factor triggered the die-off.

MANAGEMENT RESPONSES

Some land and wildlife management agencies have responded to the available information on interactions between domestic sheep and bighorn sheep by developing direction or guidelines or by specific management decisions. In 1954, the Colorado Division of Wildlife purchased 630 acres on the Pikes Peak bighorn range to prevent grazing of domestic sheep (Bear and Jones 1973). The San Bernardino and Angeles National Forests in California have a policy against domestic livestock on occupied bighorn range, which has been in force since 1967 (Light et al. 1967, pers. comm. Steve Loe)[23]. The Inyo National Forest, also in California, completed an Environmental Analysis Report in 1979, in which the preferred Forest Service Alternative was not to convert an allotment partially on bighorn sheep range from cattle to domestic sheep. This decision was based largely on concern about the potential for disease transmission between domestic and bighorn sheep (USFS 1979). The San Bernardino National Forest also recently documented a decision not to convert a cattle allotment to domestic sheep use because of its proximity to bighorn range and the potential for disease transmission (USFS 1981). The Bureau of Land Management in Idaho has a policy against grazing domestic sheep within 3.3 kilometers (2 miles) of occupied bighorn range in its Land Management Plan for 1 resource area (pers. comm. Alan Sands)[24].

In April 1981, Dale Jones, Director of Wildlife and Fisheries, U.S. Forest Service, sent a memo to Regional Foresters in 6 western regions drawing their attention to a note in "The Sheepherder" (Newsletter of the Society for Conservation of Bighorn Sheep) which referred to the die-offs at Lava Beds National Monument in California and at the Methow Game Range in Washington reported by Foreyt and Jessup (1982). Jones stated, "Although this is not conclusive evidence, it indicates that domestic sheep are a probable source of infection of bighorns and underscores the need to assess carefully the probability of disease transmission where domestic sheep are permitted to graze on bighorn sheep range or where domestic

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[23] USFS, San Bernardino National Forest, San Bernardino, California.
[24] BLM, Boise District, Boise, Idaho.

sheep may come into contact with bighorn held within enclosures, etc. Appropriate caution should be exercised to prevent contact between the species" (Jones 1981).

SUMMARY AND DISCUSSION

A review of published and unpublished information provides evidence of incompatibility between bighorn sheep and domestic sheep on shared ranges. Introductions of domestic livestock onto bighorn ranges in the late 1800's were followed by massive die-offs attributed to scabies, believed by contemporaneous observers to have been contracted from domestic sheep. Widespread grazing of domestic sheep on bighorn sheep ranges in the early 1900's was associated with severe declines in bighorn populations throughout bighorn sheep ranges in the western United States and British Columbia. While other factors such as uncontrolled hunting and construction of roads and settlements contributed to declines, competition with domestic livestock for forage and space and diseases, possibly contracted from domestic sheep, were considered the most important factors. In general, bighorn sheep have survived in their most remote and rugged habitats where the impacts of civilization, including competition with domestic livestock have been least (Buechner 1960, McQuivey 1978, Goodson 1980), They have been successfully reintroduced into many historical ranges after reduction in livestock grazing, often including removals of domestic sheep.

Since 1940, declines or die-offs in 7 free-ranging and 2 captive bighorn herds in the U.S. and Canada have been reported following introductions of domestic sheep onto bighorn ranges. Eight bighorn herds have increased significantly following reduction or removal of domestic sheep from their ranges. Interpretation of these observations is complicated by the facts that some bighorn herds have not increased following domestic sheep removal and that some herds have survived for many years with domestic sheep on their ranges. However, no herds I researched with domestic sheep on their ranges are increasing except those on ranges where use by domestic sheep has been significantly reduced. The rest are typically small and static or declining in numbers (Bear and Jones 1973, pers. comm. Dave Reeder, Shawn Stewart). The ranges of large, productive bighorn herds are conspicuously free from domestic sheep grazing, though most experience conservative cattle or horse use on parts of their range. Examples include the Sun River herd in Montana, the Whiskey Mountain herd in Wyoming, the Trickle Mountain and Poudre Canyon herds in Colorado, the Salmon River herd in Idaho, and desert bighorn herds in Nevada (Bear and Jones 1973, Picton and Picton 1975, McQuivey 1978, Thorne et al. 1979, Schmidt and Rutherford 1980. pers. comm. Bill Hickey)[25].

Declines and die-offs have occurred in bighorn populations without any known association with domestic sheep (Marsh 1938, Bear and Jones 1973, Feuerstein et al. 1980, Wishart et al. 1980, Simmons this volume). The

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[25] Idaho Department of Fish and Game, Salmon, Idaho.

proximate cause of mortality in these die-offs as well as those following association with domestic sheep was bacterial pneumonia. Bacteria of the genus *Pasteurella*, most frequently *P. multocida* and *P. haemolytica*, were invariably found when sought (Buechner 1960, Post 1962, Spraker and Hibler in press). However, *Pasteurella* are also found in the upper respiratory tract of healthy, normal bighorn (Spraker 1977). Several mechanisms have been proposed through which bighorn resistance to infection can be reduced allowing development of pneumonia.

Mortality from stress-induced pneumonia is well-documented in captive bighorn sheep (Spraker 1977). Long term chronic stress due to captivity results in increased output of adrenal hormones which depress the immune responses of bighorn. Lowered defences permit bacteria such as *Pasteurella* to invade the lungs (Spraker 1977). A similar mechanism may be operative in die-offs of free-ranging sheep under conditions of stress due to disturbance (Simmons this volume), or poor nutrition and crowding (Feuerstein et al. 1980).

Stress-induced immune deficiency can also allow lungworm burdens to increase. Heavy lungworm burdens induced by stress, crowding and/or poor nutrition may compromise lung tissue creating favorable conditions for bacterial attack (Spraker in press). Respiratory irritation, caused by inhaling dust under severely dry conditions may similarly increase the vulnerability of lung tissue (Simmons this volume).

Alternatively, pneumonia may be induced through introduction of virulent strains of *Pasteurella* (Foreyt and Jessup 1982). *Pasteurella* spp. occur as antigenically different strains, which differ so much that vaccines effective for one or several strains may be totally ineffective against others. Although bighorn may be capable of carrying some strains without ill effects, others may induce acute pneumonia.

Circumstantial evidence reviewed in this paper indicates grazing of domestic sheep on bighorn ranges can precipitate bighorn declines or die-offs. Domestic sheep can negatively affect bighorn sheep through direct forage competition and restriction of bighorn distribution and habitat use through social avoidance, thereby causing crowding and/or poor nutrition of bighorn. Bighorn resistance to infection may be lowered due to stress caused by crowding, poor nutrition and/or harassment caused by the presence of domestic sheep and their associated dogs and herders. Additionally, domestic sheep may carry virulent strains of *Pasteurella* capable of inducing severe pneumonia in healthy bighorn. In addition to *Pasteurella*, domestic sheep may carry a number of other diseases which can continually challenge the bighorn population causing subtle or dramatic increases in mortality.

Current bighorn populations in the western United States are estimated to be 1 percent of pre-settlement numbers (Wagner 1978). Following enormous losses in the 1800's and early 1900's, bighorn populations have remained low, in contrast to the remarkable recoveries of elk and mule deer. Bighorn have shown less tolerance of poor range conditions and interspecific competition than other wild ungulates and greater susceptibility to disease. They are less able to adapt to rapid habitat changes and increased harassment resulting from the development of their ranges for man's use (Buechner 1960, Goodson 1980). Conservation of bighorn herds requires careful management which minimizes the potential for interspecific competition and disease. On ranges where bighorn sheep are considered an important resource, domestic sheep should not be introduced. Where domestic sheep are currently grazed on bighorn ranges, reduction or elimination of such use is recommended if enhancement of bighorn status is a management goal.

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HEART RATE RESPONSES OF BIGHORN SHEEP TO SOME ENVIRONMENTAL FACTORS[1]

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ABSTRACT ONLY

Responses of free-ranging bighorn sheep to their environment were examined via heart rate telemetry. Heart rate is a well-established correlate of arousal and anxiety. Thus, it is a good indicator, though not an exact physiological equivalent of the stress experienced by an individual. Equally important, heart rates could be determined in the field.

Cardiac electropotential changes were monitored by two sub-cutaneous electrodes inserted over the sternum to minimize noise from muscle artifact. The EKG's were transmitted by a 1 milliwatt FM transmitter designed by the University of Calgary and mounted externally in a leather "backpack" harness. EKG signals were recorded as audio tones on one channel of a stereo cassette recorder with simultaneous verbal accounts of visual observations on the other. Observations were usually made from 400 to 500 m away and rarely from within 20 m of the sheep.

The study population was located on Ram Mountain, Alberta. This is a healthy, isolated, non-migratory herd in almost daily contact with one or two researchers through each summer since 1971. Five sheep were studied from 3 1/2 to more than 9 weeks each during June, July and August, 1979. Three were ewes with lambs, one a ewe without a lamb and the fifth study sheep was a two year old ram. Effects of environmental factors on heart rate were examined by multivariate analysis using the ANOVA program of the SPSS computing package. This allowed the results to be adjusted for interactions among the factors and to be simultaneously adjusted for the effects of activity, metabolic weight and individual differences. Additionally the results were adjusted for time of day since the study sheep were found to display circadian heart rate rhythms. The results of this analysis were extremely significant. The summary equation generated was further tested by separate analysis for each sheep, each habitat type, each major activity and with detailed control for circadian rhythms. Though these results were not all identical, the few exceptions were essentially consistent with the relationships shown by the summary equation.

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Variables known to affect heart rate caused it to change as expected. Heart rate decreased with increasing metabolic weight [HR (bpm) $\propto -2.67$ $(\text{kgm})^{0.75}$] and increased with increasing activity level. For example, heart rates averaged 13.2 bpm higher when feeding than when bedded. Individual differences in baseline heart rate were present and appeared to reflect in part the rate of growth, lactation and age of the sheep.

Thermal conditions were evaluated by means of black-bulb temperature, a measure integrating the effects of ambient temperature, solar radiation and convective cooling. Heart rates decreased quadratically as temperature increased [HR $\propto - 0.006\text{BBT}^2$ (C°)] reflecting decreased heat production in the thermoneutral zone. Evidence of heat stress was also seen in some sub-samples with heart rate increasing with tempeature. Occurrence of heat stress was contingent upon the baseline heart rate of the sheep which, in turn, depended upon time of day and activity. Although the upper limit of the thermoneutral zone clearly depended upon a number of factors it is felt to have been in the range of 25 to 30°C, black bulb. This is equivalent to ambient temperatures of 18-20°C, sunny with up to 4/8 cloud cover and light breezes. The sheep responded to heat stress by postural changes, by using favourable microclimates, particularly higher elevations, and by decreasing time spent foraging.

Results also showed that the heart rates of sheep responded to security features. Expotential increase in heart rate with increase in distance from escape terrain [HR $\propto 0.594\ (\text{DESC}(m)/100)^{1.5}$] was one of the most significant effects observed, physical or environmental. Once adjusted for distance from escape terrain heart rates were also low when the sheep were on talus slopes, higher on meadows, and more so, in shrubbery (+4.5 and +6.2 bpm relative to cliffs, respectively). It is hypothesized that these increases were the result of loss of advantage with respect to potential predators due to changes in footing and visibility. Though footing on talus slopes is poor for bighorns, it is worse for predators, as seen during the study in the uncomfortable, noisy and ineffectual approaches of the sheep executed by two dogs. Meadows do not provide this advantage to the sheep. Areas of shrubbery further disdvanntage them by severely restricting their ability to detect predators. Responses to tree cover were mixed. When in secure habitat (cliffs and talus) the sheep perceived tree cover as a noxious feature, as seen in increased heart rate with proximity to trees. However, in unsecure habitat heart rates were lower near tree cover. Within cover there also appeared to have been both secure and unsecure situations depending upon undetermined factors. Minimal predation on the herd probably allowed cover to be conditionally secure - except for its distance from escape terrain.

Heart rate increases in response to security features could be considerable. A change in location from cliffs into shrubbery 300 m away was accompanied by a heart rate increase of 11.8%. This shows that the situation of the sheep with respect to key environmemtal features was important enough to produce sustained physiological changes indicative of chronic stress. In spite of this, the sheep were still found in the unsecure habitats (meadows, shrubbery and cover) over half of the time recorded because of the forage found there. Here, they attempted to minimize anxiety by staying close to escape terrain. Seldom were they further than 300 m away and continuations of good feeding sites extending more than 500 m from cliffs were never utilized by the study sheep.

CONFERENCE DISCUSSION

Q. Did you say the predation rate in the area was low?

Ans. Yes, the predation rate was low. There are apparently some cougar up there and some black bears. I've heard coyotes around the mountain a number of miles to the east, when I was driving in. But there were no scats or tracks on the upper parts of the mountain. I think there may have been predation, but not a large amount.

Q. Is it possible that the unusually nervous ewe had seen a predator and others had not?

Ans. Yes, it's possible. Also the low growth rate of her lamb occurred prior to my using her in the study. It was not a response to the study; to wearing that backpack harness. On the 3rd of June, her lamb was 3-4 Kg. heavier than any other lamb measured around that time. But, by the 17th of August, her lamb had only gained 3 Kg. Other lambs were much heavier than that 2 weeks earlier. I think this was largely the result of her staying close to the cliffs and not using the best meadows. Although there will be some physiological stress effects, I think one of the most important costs of anxiety due to habitat changes that bother sheep, or due to harassment, may be functional loss of habitat.

Q. Two questions. First, did you ever have an opportunity to record heart rates in denser cover types, say with greater than 25% tree coverage?

Ans. Some of the data were from such types. But I had to group the data just to get reasonable sample sizes so one category was not swamped by others. In this type of analysis, if you divide a variable into categories and you have one category that has a very small sample, its effect may be exaggerated. I had to group the cover category to include everything greater than 10% tree cover for that reason. Part of the mixed response to cover may well have been due to differences in density of cover included in one category. Normally, when they bedded in cover, they were in the less-dense margin. But still, a lot of time spent standing in cover--when they were noticeably not secure, having high heart rates,--not like when bedded--was still in that less dense margin.

Q. And finally did you have any chance to measure any group-size effects on heart rate.

<u>Ans</u>. Group size was untestable. I really wanted to test it, but I found that group size responded similarly to heart rate, when tested against a number of the other variables. Partly this was coincidence and partly, I think, because of behavioral response. For example, when the sheep were distant from escape terrain, you tended to get large groups and high heart rates. What happened in the analysis was that group size stepped in as a proxy for all the other variables and so was the first in the equation versus heart rate. So it produced a high positive relationship with heart rate. I was able to test the effect of group size in my harassment trials. When I looked at my, something like 47 approaches or overpasses, I found a significant shortening of the relaxation time with increases in group size. It only explained about 11% of the variance but it was significant. That's the best I could come up with on group size.

<u>Q</u>. Shortening of the length of the response?

<u>Ans</u>. Of the period during which a significantly higher heart rate occurred. This was shorter, the larger the group was. It was significant at the 10% level, but it only explained 11% of the variance.

<u>Q</u>. Would you comment more on your harassment trials. What you did, what you found.

<u>Ans</u>. That would take a fair bit. There were only 21 completely separate trials, involving about 47 or 48 approaches or overpasses. I only considered them to be demonstrations of what can happen. What they do demonstrate is that physiological and behavioral responses are very different and they demonstrate that some of the relaxation times can be extremely long. Single approach by two individuals, unknown to the sheep required 960 seconds before heart rate returned to normal. That's something like 16 minutes. A single overpass by a helicopter, which caught them by surprise away from escape terrain--it came directly from behind them over cliffs, so it was 1400 feet above them, but only a few hundred feet above the cliff, and flew straight over them at 80 Km/hour and away--produced significantly higher heart rate for about 27 minutes. But the effect was not always that great. Another sheep, with a helicopter overpass, a number of overpasses, while she was at the base of the best cliff on the mountain, had relaxation times of less than 3 minutes.

Persistence, I'm convinced is an important factor. If an intruder continues to approach, or makes a second approach after the sheep has responded with increased heart rate or intent to break away, the heart rate is higher and the relaxation time is longer the second time. And that is not because the intruder is closer. Often the sheep has broken off, and if the individual comes towards it again it is at a much greater distance; yet you get a much longer relaxation time. So persistence is an important factor.

I can give perhaps a little bit of information on the difference between behavioral and heart rate responses. After excluding the helicopter data, which tended to be intense, I was able to partition the responses into two characteristic patterns, based on period of interrupted maintenance activity. This is when the animal is no longer bedding or feeding, but either standing, walking or running. With interrupted maintenance acitivity of a minute or less, heart rate relaxation times were always as long or longer than activity interruption. The heart rate response was always as long or longer than the behavioral response. With periods of interrupted maintenance activity of longer than a minute, maintenance activity interruption tended to be longer than the heart rate responses. But the exceptions were profound. Exceptions were extremely long heart rate responses, 2715 seconds, when the behavioral estimate was no more than 1400 seconds. You are under-estimating by 1300 seconds. If you looked at interrupted maintenance activity periods of less than 60 seconds, the average was 8.6 seconds. For more than 60 seconds, the average interrupted maintenance time was on the order of 7 minutes. But for both of those categories, more or less than a minute in terms of interrupted maintenance activity, the heart rate relaxation was on average 6 minutes. So just by looking at the sheep you can't tell how much it is responding.

Bob MacArthur, using Sheep River sheep, (one of his articles is in Canadian Journal of Zoology in 1979) found much shorter responses of sheep to helicopters. Perhaps 65 seconds longest relaxation time. That's right, 20 to 65 seconds relaxation time. Those sheep were probably more used to helicopters than were mine. It would seem that habituation can occur but it does not always. On the other hand, I often found sensitization occurring, and Bob has found this with approaches of a person over a ridge or of a person with a dog. You cannot always assume habituation, but it seems that it does occur in some cases. The behavioral responses of my sheep to helicopters are more like Bob MacArthur's, although I had very long heart-rate relaxation times. Then there are to some that Brian Horesji has reported. He has noted some panic runs of up to a mile. How, behavioral and physiological responses may not be equivalent, but if you see an animal in a panic run for a mile due to an object a half mile away, then I think you can pretty safely predict there's a profound physiological response too. So the Ram Mountain sheep seem to be intermediate insensitivity.

Oh, and one other thing, a very short sharp stress response is very adaptive. Individuals that are particularly healthy, particularly well adapted, and coping well tend to have short sharp responses. If you should approach an animal and it finally gets to the point where it doesn't like you and bolts and then stops, if the heart pattern is doing the same thing, you may very well have a minimum response compared to an individual who did not move. One sheep remained bedded through the whole trial, yet heart-rate relaxation time was 1980 seconds. Yet I was positive that there was no response. I was positive I would have nothing out of that trial, just showing that this sheep could not be bothered. There was one time that I threw a rock at her, I was convinced that she was stuffed. But she was responding all of the time.

<u>Q</u>. Was your ram more comfortable away from the escape terrain than the ewes?

<u>Ans</u>. Did not appear to be. He was a 2-year old ram.

<u>Q</u>. Was he with the ewe-lamb groups then?

<u>Ans</u>. He was. His heart rate fluctuated a lot.

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RESPONSES OF DALL SHEEP POPULATIONS TO WOLF CONTROL IN INTERIOR ALASKA

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ABSTRACT

Severe winters in the early 1970's and overharvest of moose by humans coupled with very high wolf populations necessitated a wolf control program in the Tanana Flats south of Fairbanks. This area is adjacent to a low quality sheep population which has been extensively studied for 12 years. The sheep populations had been declining since a high was reached in 1970. Wolf control began in 1976, the population of sheep stabilized at that time, and numbers began a gradual upswing. Aerial surveys in 1980 indicated that sheep populations closest to the foci of wolf reductions benefited most. Expansion of these local population responses to the entire area affected by wolf control indicates wolf predation may have been largely responsible for declines in sheep numbers observed in the early 1970's.

INTRODUCTION

Severe winters in the late 1960's and the early 1970's initiated a moose (Alces alces) decline in the Tanana Flats south of Fairbanks. Excessive sport hunting and wolf (Canis lupus) predation sustained the moose population decline. Other ungulate species, particularly caribou (Rangifer tarandus), were also declining. The gravity of moose and caribou population declines prompted the Alaska Department of Fish and Game to initiate a wolf control, program to reduce mortalities on the ungulate species involved. This program had immediate beneficial effects on moose and caribou numbers which have increased to levels that can safely support reasonable levels of both human harvest and predation. Wolf numbers are also increasing again (Gasaway et al., submitted 1982).

Sheep numbers also responded to reduced wolf numbers but to a smaller degree than moose or caribou populations. The purpose of this paper is to describe changes in the sheep population prior to and following wolf control and to discuss, in general, the effects wolves may have on Dall sheep abundance in Interior Alaska.

METHODS

Wolves

The abundance and distribution of wolves in the study area were determined primarily by extensive aerial surveys (Stephenson 1978). Population estimates for the 17,060-km^2 area were made annually between 1972 and 1979 with the most accurate estimate resulting from 324 hours of fixed-wing flying prior to and during initial wolf control efforts in winter 1975-76. Wolves were removed by shooting from a helicopter after tracking and locating wolf packs with fixed-wing aircraft. A mandatory sealing program provided accurate harvest data on wolves taken by the public. The carcasses of 162 wolves killed in the study area from 1976 through 1979 were necropsied in the laboratory. Data on sex and age, nutritional and reproductive condition, and food habits were collected.

Sheep Population Size

Lamb production and yearling recruitment were determined from composition counts at the major mineral lick in the study area. Sheep were classified using spotting scopes at distances of less than 200 m. The mineral lick was observed daily from 19 June through 30 June from 1972 through 1981 from 0430 to 1200 hours.

Population estimates were made from collared sheep resighting data, aerial censuses and intensity of mineral lick use recorded for the observation period. Aerial censuses of 1970, 1975 and 1980 were used to determine population sizes for those years. The number of incoming sheep during the observation period in those years was then plotted as a function of population size. This plot revealed a linear relationship, and population sizes were then estimated from data on mineral lick use going back to 1970. One further data point where intensity of mineral lick use and population size were known was derived from collared sheep return frequency observed in 1972.

During 1972 the mineral lick was observed for 24 hours/day for 6 weeks. The return frequency for 200 collared sheep of all age and sex classes was then used to estimate the total sheep population size. The estimate of 1,473 sheep total minus the lambs present (which were not collared) based on a collared sheep number of 200 indicated about one sheep in eight was marked when this estimate was made. All 4 known population sizes and mineral lick use intensities fell on the same straight line, and subsequent population estimates are thought to have an accuracy of about plus or minus 3%. Obviously these estimates are of insufficient validity to place much confidence in any individual value, but we believe they are adequate for determining population trend in the range of population sizes observed.

During aerial counts, data were divided into census units which correspond to the home ranges of ewes determined from movement studies (Heimer 1973). A map detailing census blocks is shown in Fig. 1.

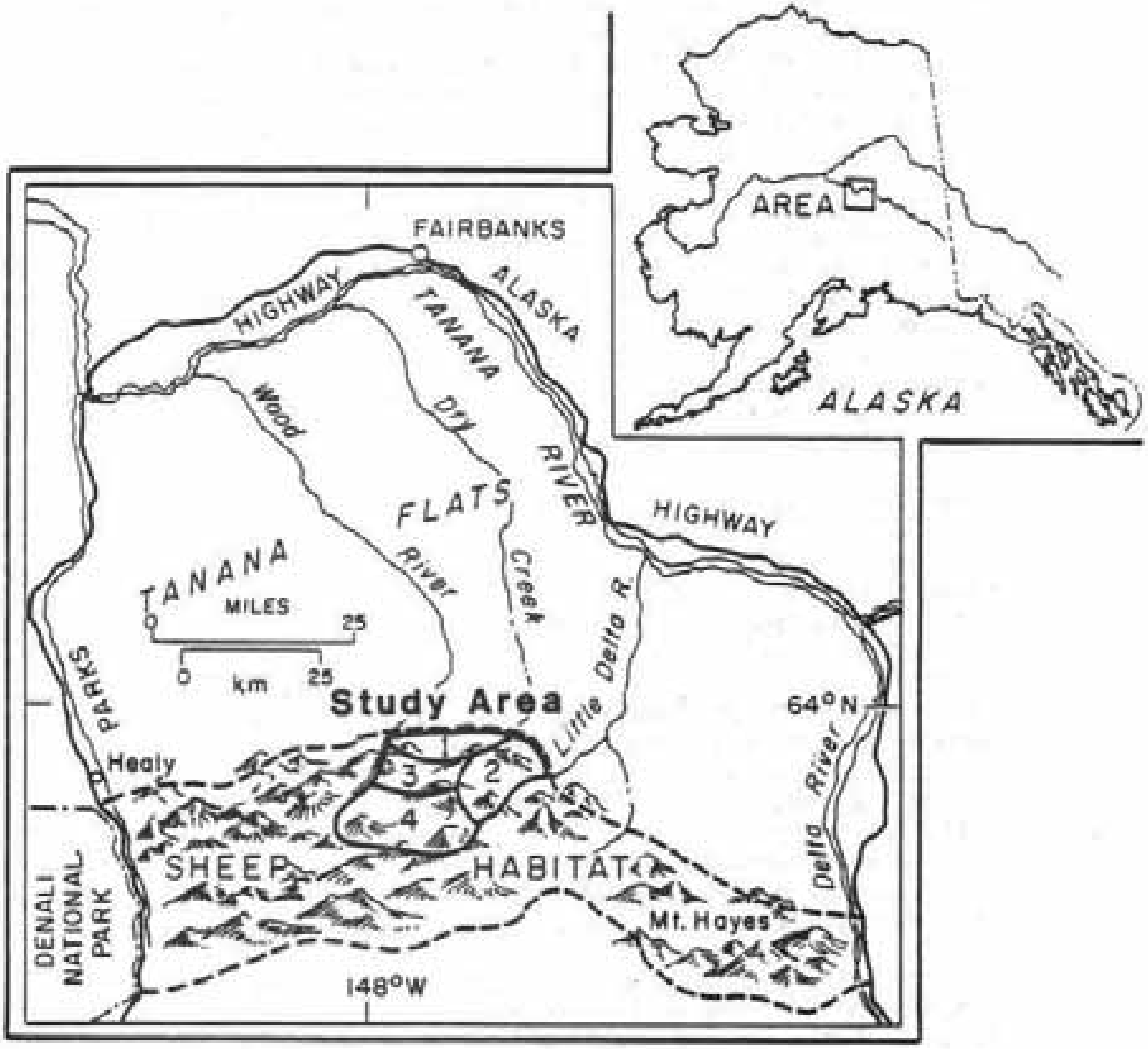

Fig. 1. Map of the Tanana Flats and the sheep habitat lying along the southern edge. The count blocks in the Dry Creek study area are numbered 1-4.

RESULTS

Wolves

The Tanana Flats wolf population was estimated at 239 prior to the initiation of control efforts in winter 1975-76. Less extensive surveys indicated at least 200 wolves were present during early winter from 1972 through 1974. The 1975 population included 23 packs with an average size of 9.3 wolves, distributed fairly uniformly on the Tanana Flats. This population was reduced by about 60% during winter 1975-76 when 145 wolves were taken. Wolf numbers were maintained near this level through 1979. This program was primarily designed to benefit moose and caribou populations, and control efforts were emphasized in areas used by these species. Moose and caribou habitat overlapped considerably with sheep between 1976 and 1979.

Data reflecting winter food habits were obtained from the stomachs of 156 wolves killed between 1976 and 1979. Fifty-five percent of the stomachs contained moose remains, 12% contained caribou, 2% sheep, 3% snowshoe hares, and 26% were empty. Of the 99 wolves killed near sheep habitat, only 3% had sheep remains in their stomachs. Although both successful and unsuccessful attempts by wolves to prey on sheep have been observed during summer and winter fieldwork, neither of these observations nor the occurrence of food remains in stomachs suggests that wolves preyed on sheep as regularly as on moose and caribou.

Sheep Population Size and Trend

Sheep populations adjacent to the wolf control area showed immediate trend reversals. Those that were in decline began increasing when wolves were removed from their home ranges. Where wolves were not removed, sheep populations continued to decline at the same rate observed before wolf control. Fig. 1 shows the sheep study area divided into count blocks corresponding to discrete ewe subpopulations (Heimer 1973). These subpopulations were used for comparative analyses of the aerial censuses in 1970, 1975, and 1980. Table 1 gives flight times and total sheep seen during the census flights in these years. Since lamb production is variable from year to year, it is best to use the number of adults for year-to-year comparisons. We have gone further, using only adult "ewes" from censuses of 1975 and 1980, those years immediately prior to and following sustained wolf control (Table 2).

Postlambing sheep population size estimates and sex and age compositions for the entire study area before and after wolf control are given in Table 3. The 4 estimates of prelambing population size prior to initiation of wolf control show a downward trend. This trend is described by the equation $y = 1{,}254 - 85X$. After wolf control, the population trend is described by the equation $y = 1{,}010 + 0.5X$. It should be noted that these slope coefficients have units of "sheep lost or gained" per year in the prelambing population. Before wolf control, the overall population trend was downward at a rate of 85 sheep/year. Following wolf control, the population trend changed, indicating a gain of about 1 sheep annually.

That is, the number of sheep lost/year was reduced by 86 sheep/year following wolf control. However, during the pre-wolf control period, research-associated mortalities (Heimer 1982) accounted for an average of 6 sheep/year. These mortalities were not wolf related and should be subtracted. Hence, differences in population trend indicate about 80 sheep/year were not lost to the prelambing population of sheep following wolf reduction. The total overall prelambing population size has stabilizied near the 1975 level with count blocks 1 and 2 15.5% higher and blocks 3 and 4 17.5% lower than 1975 levels.

DISCUSSION

Impact of Wolf Reduction on Dry Creek Population

It is clear that sheep numbers and population trend in blocks 1 and 2 changed noticeably at the time wolf control began. Shepherd, Lentsch, and Haggland (pers. commun.), continuous participants in wolf reductions since 1975, report wolves continue to frequent count blocks 3 and 4 but are virtually absent from blocks 1 and 2. This suggests that wolves were, in large measure, responsible for the decline in sheep numbers seen in the 1st half of the 1970's. These findings tend to corroborate Murie's (1944) conclusion that wolf predation was the primary force controlling sheep numbers in Mt. McKinley National Park, adjacent to the Tanana Flats. Data given in Tables 2 and 3 suggest the various sheep subpopulations in the study area did not respond uniformly to wolf control. Populations in areas 1 and 2 increased to 1970 levels after declining by about 20% by 1975, while populations in areas 3 and 4 have apparently continued to decline from 1975 levels. These differences could be due to survey irregularities but may indicate that subpopulations closest to the focus of wolf removal (the Tanana Flats) showed the greatest response in terms of population trajectory. However, the low frequency of sheep hair in wolf stomachs during late winter suggests sheep were not a major food source for wolves during this time. This raises the question of how wolves could have depressed sheep numbers.

Changes in lamb production, survival, and yearling recruitment in the Dry Creek study area are strikingly similar to those in Denali National Park, about 70 km to the west, where no wolf control occurred and where moose and caribou populations are still low or declining. Therefore, the pattern of lamb survival does not appear to be related to wolf density. That is, wolves do not appear to exert their primary influence on Dall sheep populations through selective predation on lambs and yearlings. Because wolves did not appear to take large numbers of sheep in the study area during winter when caribou and moose are most vulnerable, 1 remaining hypothesis is that most wolf predation selects the various sex and age classes of sheep in the same proportions in which they occur in the populations during summer. It is also possible that no packs specializing in sheep hunting were collected during the wolf control effort on the alpine fringe of the Tanana Flats, and that some wolves relied more on sheep during winter than our food habits data indicate.

Table 1. Total Dall sheep counts from 1970, 1975, and 1980 for Dry Creek, Alaska Range.

Area surveyed	1970		1975		1980	
	Count	Time	Count	Time	Count	Time
1	315	*	250	3.0hrs	407	3.5hrs
2	485	*	347	2.4hrs	454	4.0hrs
3	332	*	341	3.0hrs	327	4.0hrs
4			294	5.9hrs	220	7.8hrs

*Specific time not available by area; total times 11 hrs.

Table 2. "Ewe"[1] numbers for survey areas within the Dry Creek vicinity in 1975 and 1980.

Area	1975	1980	Direction and magnitude of change
1	183	197	+8%
2	240[2]	294	+23%
3	186[2]	166	-11%
4	152[2]	116	-24%

[1] Definition of "ewe": sheep not identifiable as lambs or rams during aerial surveys. This class includes yearlings and young rams which can't be reliably distinguished from adult ewes in July.

[2] Number of lambs not classified in these areas for 1975. The number of ewes is back-calculated using aerial counts, mineral lick data for 1975 for lambs and yearlings, and lick data from 1974 to give a number of 2-year-old rams likely to be present with ewes and classified as such from the air.

Impact of Wolf Reduction on the Entire Game Management Unit (GMU) 20A Sheep Population

During an aerial survey in July 1970, 4,142 sheep were observed in GMU 20A; 25% were lambs. Assuming a sightability factor of 0.8 (Heimer 1982), the total population would have included 5,178. Subtracting the estimated number of lambs results in an adult population estimate of 3,882. Prior to wolf control, the prelambing population (Table 3) in the Dry Creek study area averaged 1,150 sheep and was declining by about 80 sheep/year. Use of data from Dry Creek to estimate prewolf control losses for the entire sheep population influenced by wolf control indicates the total population declined by about 280 sheep annually. This decline ceased following wolf control, suggesting the annual loss of sheep to wolves had exceeded recruitment by about 280.

During winter 1975-76, 39 wolves were taken in or near sheep habitat. During the 3 subsequent winters, an additional 11, 39, and 10 wolves, respectively, were taken. Because sheep numbers responded immediately following the reduction in wolf numbers in 1976-76 and because subsequent removal of wolves probably maintained the population near the level initially reached, it appears the removal of about 39 wolves resulted in 280 additional sheep surviving annually. Although this does not tell us the total number of sheep killed by wolves annually, it does indicate the amount by which the loss of sheep (to net wolves removed) exceeded recruitment.

These figures appear to be reasonable when the following calculations are considered. The composition of the sheep population averaged 22% lambs and yearlings with a mean weight of 16 kg, 58% ewes with a mean weight of 50 kg, and 20% rams with a mean weight of 77 kg. Assuming the average weight for sheep in this area is 48 kg (Heimer 1973) and that wolves preyed on the various sex and age classes of sheep in the proportion at which they occur in the population the total weight of sheep taken annually by wolves (above recruitment) would have been 13,440 kg. Since wolves consume about 80% of a sheep carcass, the total weight of sheep actually consumed was nearly 11,000 kg. Based on a study of radiocesium concentrations in wolves and their prey in the Tanana Flats, Holleman and Stephenson (1981) calculated that wolves preying primarily on moose consumed at least 2.8 kg/day/wolf. This estimate compares favorably with estimates of the amount of prey consumed in various field studies of free-ranging wolves (Mech and Frenzel 1971, Kolenosky 1972, Mech 1977, Peterson 1977, Fuller and Keith 1980) which range from 1.7 to 10 kg/day/wolf. If wolves occupying sheep habitat also consumed 2.8 kg daily, 11,000 kg of sheep would support about 11 wolves for 1 year.

These conservative calculations suggest the equivalent of 11 wolves relying on sheep for all of their diet would be sufficient to make the difference between stability and the observed decline in sheep numbers prior to wolf control. If wolves maintained a higher consumption rate, the number of wolves required to cause a decline of the magnitude observed would be even less.

Table 3. Estimated prelambing population, postlambing population, percent adult ewes observed, calculated number of ewes, lambs, percent survival to yearling age, and number of yearlings recruited in Dry Creek study population from 1972 through 1981.

Year	Estimated prelambing population	Estimated postlambing population	% breeding ewes	Number breeding ewes	Number lambs produced	Number yearlings produced	% survival
1972	1300	1473	55.9	823	123	132	--
1973	1110	1423	57.9	823	313	91	74
1974	1070	1280	58.6	750	210	187	60
1975	1031	1230	57.7	709	199	163	78
wolf control begun							
1976	1050	1310	55.2	723	260	116	58
1977	936	1350	52.9	714	414	121	47
1978	1094	1390	51.9	721	296	180	43
1979	942	1340	45.7	612	398	116	39
1980	1003	1425	44.2	630	422	227	57
1981	1044	1450	46.6	646	387	277	66

Other Factors

Lamb production and/or survival in the study area were variable between 1969 and 1981. The decline in dall sheep numbers from 1970 to 1975 coincided with low lamb production and yearling recruitment (Table 3). This was during a period of what are considered "normal" winter in interior Alaska except for winter 1971-72 which was particularly severe for sheep. Only 123 lambs were produced the following spring, and 91 survived to yearling age. Generally higher lamb production after wolf control probably resulted from milder winter weather after 1975. Winters have been noticeably mild since the mid-1970's. We believe factors other than weather must be included to produce different population responses in the differing count areas.

It is possible that overall increased lamb production and subsequent recruitment could be a result of decreased numbers of breeding ewes mediated by a density-dependent mechanism. However, Table 1 shows that in 1975, 709 ewes produced 199 lambs. In 1977, 714 ewes produced 414 lambs. This number of lambs in 1977 more than doubled the number produced by nearly the same number of ewes 2 years earlier. We think the increases in lamb production are more likely related to mild winters than to decreased density. It is interesting to note that survival to yearling age decreased following wolf control.

In summary, it appears reduced wolf numbers in the Tanana Flats had a noticeable effect on the area's sheep numbers. Our calculations of wolf numbers and the amount of wolf predation necessary to account for the observed response are approximate. However, they clearly show how relatively small increases or decreases in wolf predation can significantly influence sheep population dynamics.

In recent years, the varying effects of predation on moose and caribou populations in Alaska have been brought into perspective (Gasaway et al., submitted 1982). The data from our study indicate that in areas where large predators exist at normal levels of abundance in the presence of moose and caribou, predation may still have a significant controlling effect on sheep. However, there is little evidence suggesting that over large areas wolves rely on Dall sheep to the extent they do on moose or caribou since the decline we observed in sheep numbers during the early 1970's was less precipitous. Nevertheless, our data showing changes in sheep population trends where wolves are absent and continuing sheep declines where wolves are present suggest wolves may have depressed sheep numbers and were probably a major cause of mortality. The occurrence of wolves and other predators and other general ecological conditions in this area are to a large degree representative of most Dall sheep habitat in interior Alaska. These specific considerations suggest that increases in the human harvest of sheep must be approached cautiously in areas, such as Alaska, where large predators are still abundant. Furthermore, areas with less stable weather patterns should receive an even more cautious appraisal when increased human harvest is considered.

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DIFFERING REPRODUCTIVE PATTERNS IN DALL SHEEP: POPULATION STRATEGY OR MANAGEMENT ARTIFACT?

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ABSTRACT

Observed lamb:ewe ratios, collection prgrams, and studies of marked Dall sheep (Ovis dalli dalli) indicate differing reproductive patterns between ewes of two populations in Interior Alaska. The Dry Creek (low-quality) population has a high incidence of lambing at age 2 and a subsequent alternate-year production of lambs. In the Sheep Creek (high-quality) population, ewes have their first lambs a year later, at age 3, and then produce lambs annually. Nutrition and body composition data reveal no differences between ewes in the two populations and suggest no differences in energy availability on the two ranges. The major difference between the two groups is age composition of the breeding rams. In the Dry Creek population, maximal harvest at 3/4 curl has been practiced for more than a decade; consequently, young rams are able to take part in the rut. The Sheep Creek group has an essentially undisturbed ram age-structure as it has been managed for trophy production since 1974. We suggest that behaviorial differences due to the removal of dominant males before the rut may result in the breeding of 18-month-old ewes in the Dry Creek group. Early breeding in these populations is not a direct result of density-mediated nutritional conditions.

INTRODUCTION

In 1978, Heimer reported on alternate year lambing by ewes of a low-quality, declining population of Dall sheep in Dry Creek. Irregular reproduction has also been documented in bison (Bison americanus) (Fuller 1955), caribou (Rangifer tarandus) (Dauphine 1976) and red deer (Cervus Elaphus) (Lowe 1969, Mitchell and Brown 1974, Hamilton and Blaxter 1980). Explanations for irregular reproduction are often based on nutrition. Mitchell and Brown (1974), Dauphine (1976), and Hamilton and Blaxter (1980) found a strong correlation between body weight and fertility for a particular year in mature females. The existence of barren mature females in a population appears to be a symptom of nutritional stress reflecting environmental or physiological conditions. Lactation is especially thought to create nutritional stress, reduce body weight, and lower the probability of annual breeding (Fuller 1955, Lowe 1969, Mitchell and Brown 1974). Heimer (1978) proposed similar explanations for the Dall sheep population.

The age of first estrus is also thought to be influenced by nutrition. Daniel (1963) found that red deer on high-quality forage came into estrus as fawns while those on poorer range did not breed until age 3. Wegge (1974) and Hamilton and Blaxter (1980) attributed early fertility to high-quality summer forage, high body weight, and, possibly, genetics, while Stains (1978) concluded low population density was a main contributor to early fertility.

The purpose of this paper is to report on observed differences in the reproductive onset and frequency between two Dall sheep populations. We also propose a model which may explain these differing patterns on the basis of behavior during rut and offer methods by which the prime hypothesis generated by the model can be tested.

METHODS

Two sheep populations fron the Alaska Range were the focus of this study. The Sheep Creek population is located 30 km. from Tok, Alaska, between the Robertson and Tok Rivers. The area is characterized by steep hills and long drainages with glaciers. Vegetation is relatively sparse. THe Dry Creek area is 200 km east of Sheep Creek and located between the Wood River and the West Fork of the Little Delta River. It is characterized by comparatively gentle hills and short drainages without glaciers. Vegetation is relatively abundant. In the Sheep Creek population, sheep were trapped at a mineral lick as described by Heimer et al. (1980). The ages of ewes captured were determined, and individuals were marked with numbered neckbands and large eartags. Data on reproductive status were gathered at capture and upon resightings at the mineral lick from 1977 through 1981. Ewes were classified as reproductively active on the basis of suckling a lamb. Sheep at the mineral lick were observed from 0400 through 2000 hours throughout June 1980 (except for 6 days) and June 1981.

In Dry Creek, methods for determining age at first parturition and subsequent reproductive performance were similar to those used in Sheep Creek and are described by Heimer (1978). Field studies were conducted from 1972-77 and 1981.

Attempts to define the role of nutrition in both study groups were made by assessing nutrient quality of food plants on the range (Winters 1980), the nutritive content of plants selected (rumen contents), as well as body condition (Heimer 1982). The latter was determined by homogenizing ewe carcasses and analyzing for percent bone, fat, protein, and water.

RESULTS

In ewes from the Sheep Creek population, evidence indicates the age of first parturition is 3 years. Only 1 of 24 marked ewes aged 2 years and under was found to lead a lamb. Ten 3-year-old ewes were trapped; eight of them were lactating or had lambs. Eighty-three percent of the 24, 2-year-old ewes had lambs at age 3. These data show the dominant pattern is first lambing at 3 years of age.

Once a ewe from the Sheep Creek population has become reproductively active, it appears highly probable that she will produce a lamb annually. Of the 74 consecutive-year observations made where the earlier year's reproductive status was known, 49, or 66 percent, had lambs in consecutive years. Only 23 ewes, or 30 percent, of the marked individuals have missed reproducing each year. There have shown two consecutive failures to lamb.

In the Dry Creek population, ewes were found to breed at 18 months and give birth to lambs at 2 years as reported in Heimer (1978). Of the 88 consecutive-year observations where the earlier year's reproductive status was known, 5, or 6 percent, had lambs in consecutive years, while 44 ewes, or 50 percent, were without lambs one of the years. Thirty-nine ewes have shown two consecutive failures to lamb. Table 1 summarizes data on reproductive frequency for both populations.

Three 2-year-old ewes of the Dry Creek population were trapped on 9-11 June 1981. None of these were lactating when captured, but all three had swollen vulvae and enlarged, but unpigmented, udders. One died of internal hemorrhage resulting from capture. When necropsied in the field, she was found to be pregnant. The fetus was still covered with darkly pigmented hair, and its hooves were yellow and cartilaginous in texture. We believe the fetus was at least 4 weeks from term. One of the surviving 2-year-old ewes was seen at the end of June with a small lamb. The third ewe was not resighted. During the same trapping period, three 3-year-old ewes were captured. One was lactating and had a lamb, the other two were not lactating. Thirteen older ewes were caught, and eight were lactating. The total frequency of lactation in ewes, including the 2-year-olds which could have borne lambs in spring 1981, was 11 of 18. This small sample size indicated 61 percent of the marked females were reproductively active. The observed lamb:ewe ratio was 60 lambs/-100 ewes in the entire population. Table 1 summarizes data on reproductive frequency for both populations.

Winters (1980) and Whitten (1975) found no significant difference in the nutritive quality in the food plants on the two ranges. There was also no difference in nutritive quality of rumen contents analyzed for soluble cell components, protein, lignin, and other fiber. Neither was there any detectable difference in amount of fat, protein, or water in ewe carcasses from either group (Heimer 1982).

DISCUSSION

There is little doubt the reproductive patterns of these populations are strikingly different. Table 2 (from Heimer 1982) shows other contrasts in the two populations. These data, along with the finding that no detectable differences could be identified in nutritional and body condition components, suggest the difference in onset of reproduction is not range-related. Indeed, the earlier onset of reproductive activity for the Dry Creek (low-quality) population suggests range resources are better for that population group.

We think another mechanism may be responsible for the age differences at the onset of breeding in these two groups. The Dry Creek group, those with early breeding followed by alternate-year lambing, was managed as an open hunting area for rams with a 3/4-curl legal minimum horn size until 1979. After 1979, the legal definition for ram horns was raised to 7/8 curl. Ram harvest in this area has been heavy and equals recruitment to the legal age class. In a 1980 preharvest census, only 4.9 percent of the population (n = 1,417) were legal (7/8 curl) or older rams. This represents 27 percent of the ram population (69 rams) at or above 6 years of age. In contrast, the Sheep Creek population has been managed for trophy production since 1974. Hunting pressure there has been held at a low level by permit regulations, and ram harvest is limited to a number less than the full-curl recruitment. A 1980 preharvest census of this group showed 7.1 percent of the total population (n = 892) legal at or above full curl. This is 31 percent of the ram population (63 rams) at or above 8 years of age.

We hypothesize that the absence of behaviorally and sexually mature rams in the heavily hunted, Dry Creek population leads to active participation in the rut by young, inexperienced rams which would be virtually excluded from participation by the presence of mature (Class IV) rams in a population with a less distorted age distribution (Geist 1971, Nichols 1971). Data presented by Geist (1971) and Nichols (1971) indicate the younger rams participate more in chasing behavior, less in guarding, and more frequently in courtship of anestrous ewes. The cue given by an estrous ewe is running after being approached and front-kicked by a ram (Geist 1971). Anestrous ewes are thought to signal their condition and lack of receptiveness to breeding by urination. We hypothesize that young rams, in the absence of mature dominants, eventually pester the 18-month-old ewes into flight which results in breeding. We also suggest these ewes are physiologically capable of breeding, but behaviorally immature. Suche ewes would not be bred if breeding were restricted to mature rams that rut in accord with accepted social constraints. Courtship-induced estrus in 18-month-old ewes resulting from attention by immature rams could also explain early breeding.

We are unsure of the specific relationship between nutrition and biennial lamb production; however, this behavioral model more adequately explains the earlier onset of reproduction in the Dry Creek population. Our hypothesis predicts that an alternate-year lamb production pattern will change to annual lamb production once a ram age structure exists in which the very young rams do not actively participate in the rut. The mangement benefits of annual production are easily demonstrated. In a given life-span of 10 years, the number of lambs produced by an individual ewe beginning at age 2 and continuing with alternate-year lambing would be five lambs. For a ewe lambing the first time at 3 years of age, the lifetime production would be eight lambs. The increase in initial lamb production is 60 percent.

The hypothesis is testable by one of the following three methods. First, if young ewes from the Dry Creek population could be marked and prevented from breeding during their frst estrus at 18 months and their reproductive pattern followed, the hypothesis predicts futher annual production. Second, cultivation and establishment of a normal ram age structure by closure of ram hunting in the area of alternate-year lambing and continued studies of reproductive frequency should show whether the hypothesis predicts correctly. Finally, monitoring reproductive pattern and frequency in an unhunted population similar to the Dry Creek population should show a delayed breeding age and greater reprodutive frequency. Such a potential study exists in Denali National Park, about 70 km to the west of the low-quality group. We favor the third option in order to test the hypothesis and intend to pursue it as funding becomes available.

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Table 1. Annual resightings of collared ewes with or without lambs at the Dry Creek and Sheep Creek study sites.

	Dry Creek (n = 88)		Sheep Creek (n = 74)	
With/with	6%		66%	
With/without biennial	26%	= 50%	13%	= 30%
Without/with production	24%		17%	
Without/without	44%		4%	

Table 2. Dall sheep population characteristics at the Dry Creek and Sheep Creek, Alaska Range study sites.

Characteristic	Dry Creek (low-quality)	Sheep Creek (high-quality)
Ram horn growth quality index (Heimer and Smith 1975)	14th of 18	4th of 18
Mean lamb production	55 lambs/100 ewes	65 lambs/100 ewes
Percent lamb survival to yearling age	51 percent	54 percent
Mean yearling recruitment	26 yearlings/100 ewes	32 yearlings/100 ewes
Near-term fetal weight	2.2 kg (n = 7)	2.8 kg (n = 8)
Mean suckling duration	15 seconds (n = 139)	14 seconds (n = 60)
Mean age in collected sheep	91 months (n = 24)	66 months (n = 17)
Summer range density	3.5 sheep/km^2	1.5 sheep/km^2
Winter range density	5.3 sheep/km^2	2.0 sheep/km^2
Habitat character	gentle hills short drainages elevation relief = 830 m glaciers absent abundant vegetation	steep hills long drainages relief = 990 m glaciers present sparse vegetation

CONFERENCE DISCUSSION

Q. I think you are suggesting you could produce more sheep for harvest in the low quality population by having more mature rams present there. That is, going to harvest of older males such as you do in the Tok study area is the cure for alternate year breeding. Would you discuss the impact this has on hunter opportunity within these populations? Are you going to increase the sheep populations, but offer reduced hunting opportunity.

Ans. At the outset it appears hunting opportunity would be lessened under a system where harvest is limited to the take of rams above the age of 8 years. However, since we are dealing in hypothetical terms, here let's go just a bit further. A look at the survivorship curves published for unhunted mountain sheep populations suggests that mortality is greatly increased as rams mature socially and take a major role in the rut. If we apply the rate of mortality which is presumably rut-associated to the very young rams it appears we may be able to harvest more rams at full curl (maximally) than at younger ages. This presumably occurs because rut-associated mortality is transferred to younger rams which are not adapted to survive it. If this is true, we could harvest more rams by cropping maximally at full-curl age than by cropping maximally at 3/4 curl. Let me emphasize that we are working with a hypothesis here. This has yet to be tested, but we do have some data which indicate we can harvest as many or more sheep at full curl as we used to at 3/4 curl.

Q. Wayne, what you are saying is contrary to lots of traditional management theory, that the most productive herds have a young age structure. I believe you are saying that reestablishment of an older-age male segment in the population will make the herd "young" and productive again. This reminds me of the situation in our National Parks in Alberta where we see nice lamb crops with these "old" herds until winter and the followng spring. Then it seems that winter losses bring that survival way down. Do you have survival rates on lambs in your "old" herd, the high quality one, vs. your low quality herd, the one where rutting is run by younger rams?

Ans. Yes, survival in the low quality herd averages 51% and in the high quality herd it averages 54%. Of course, survival varies with winter severity which is not uniform for the 2 study areas. I don't believe there is any statistically significant difference in survival between the herds. We've seen an interesting relationship that we don't understand, or even have a hypothesis for; mortality seems higher (percentage-wise), the higher the lamb crop. Still, recruitment to yearling age is easily greater following a high initial lamb production (even with the increased percentage of mortality). Higher initial lamb production seems to result in greater yearling recruitment.

Q. In which herd?

Ans. Either one, or both. Even if there is a greater (percentage) mortality which seems associated with higher lamb producton, yearling recruitment doesn't seem to be low because of the higher mortality. We always come out ahead following years with great lamb production.

Q. Just a couple of points, Wayne, on the Kenai Peninsula study areas we've come through some difficult winters which caused significant adult mortality. The herd which had been heavily harvested, where there wasn't a ram older than 3/4 curl, produced the highest relative number of lambs last year, that is, had the greatest lamb:ewe ratio of all 3 populations studied. This includes a population where no hunting is practiced. This is just the opposite of what your hypothesis predicts. A question I have is: Have you made any comparisons of range conditions between your so-called high and low quality herds? Do you know that your low quality herd, for example, is actually a more dense population in terms of forage available per individual? You mentioned in one of your reports that vegetation was rather abundant in your low quality area and relatively sparse in the high quality area.

Ans. Concerning your first comment, I should stress that the hypothesis predicts generally, and I am not surprised nor alarmed that exceptions exist. This is particularly true for the Kenai study areas where you showed weather influences on the 3 sheep groups were quite variable among ranges. If we could be assured that weather influences were consistent among your 3 populations I'd be more prone to re-examine the hypothesis. The answer to your question is, no. We haven't done any classical range work, but we have looked at the quality of food plants between the 2 areas in summer. We have also looked at the quality of food plants during winter as reflected by the quality of washed rumen contents. This means we have examined the plants selected by sheep on winter range and compared them at the beginning and end of winter. There is no differnce in food quality of washed rumen contents. I think this suggests uniformly poor quality winter range is available to both populations to the extent that it isn't limiting in a classical, live or starve, sense. We suspect that it doesn't matter how much low quality food is available beyond what is necessary to keep the rumen full. As long as sheep can fill their rumens they will do as well as possible. Of course, winters of such severity that keeping the rumen full and active is not possible do occur. These winters result in death of unusually large numbers or percentages of adults. In the Interior of Alaska winters like this are rare, and a severe winter is usually indicated by low lamb production the following spring more than by death of large numbers of adults. Ewes apparently utilize the energy stored in the fetus before they expire.

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MOUNTAIN GOAT INVENTORY AND HARVEST STRATEGIES:

A RE-EVALUATION

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ABSTRACT

Growth of the Hoodoo Creek and Stanton Creek goat (Oreamnos americanus) herds were simulated based on field data. Unadjusted field values could not be used to simulate observed herd size trends. The implications of goat population growth responses to harvest are discussed.

INTRODUCTION

Mountain goat populations in many parts of North America and especially in British Columbia declined for a variety of reasons during the period from 1950 to 1970 (Hebert and Turnbull 1977). Inventory and monitoring were and continue to be inadequate for most goat populations in British Columbia.

Goat classification systems based on aerial surveys have been developed by Hebert (1978) and Nichols (1980); however, the population structure data have not been compared to estimates of population change and the relationship between survey results and subsequent management (harvest) strategies is unclear. These strategies should be based on the population characteristics of the ecotype or sub-ecotype (Hebert 1978). This paper examines the adequacy of present survey methods to provide needed harvest management information.

STUDY AREA

The study area encompassed the drainages of Hoodoo and Stanton Creeks both of which are part of the Knight Inlet watershed (Figure 1). These areas are characterized by precipitous slopes, recent and continuing glacial activity and open alpine habitats. They are part of the Coast Crystalline complex containing granitic, metamorphic and volcanic rock (Souther 1967). A more complete description is contained in Hebert and Turnbull (1977).

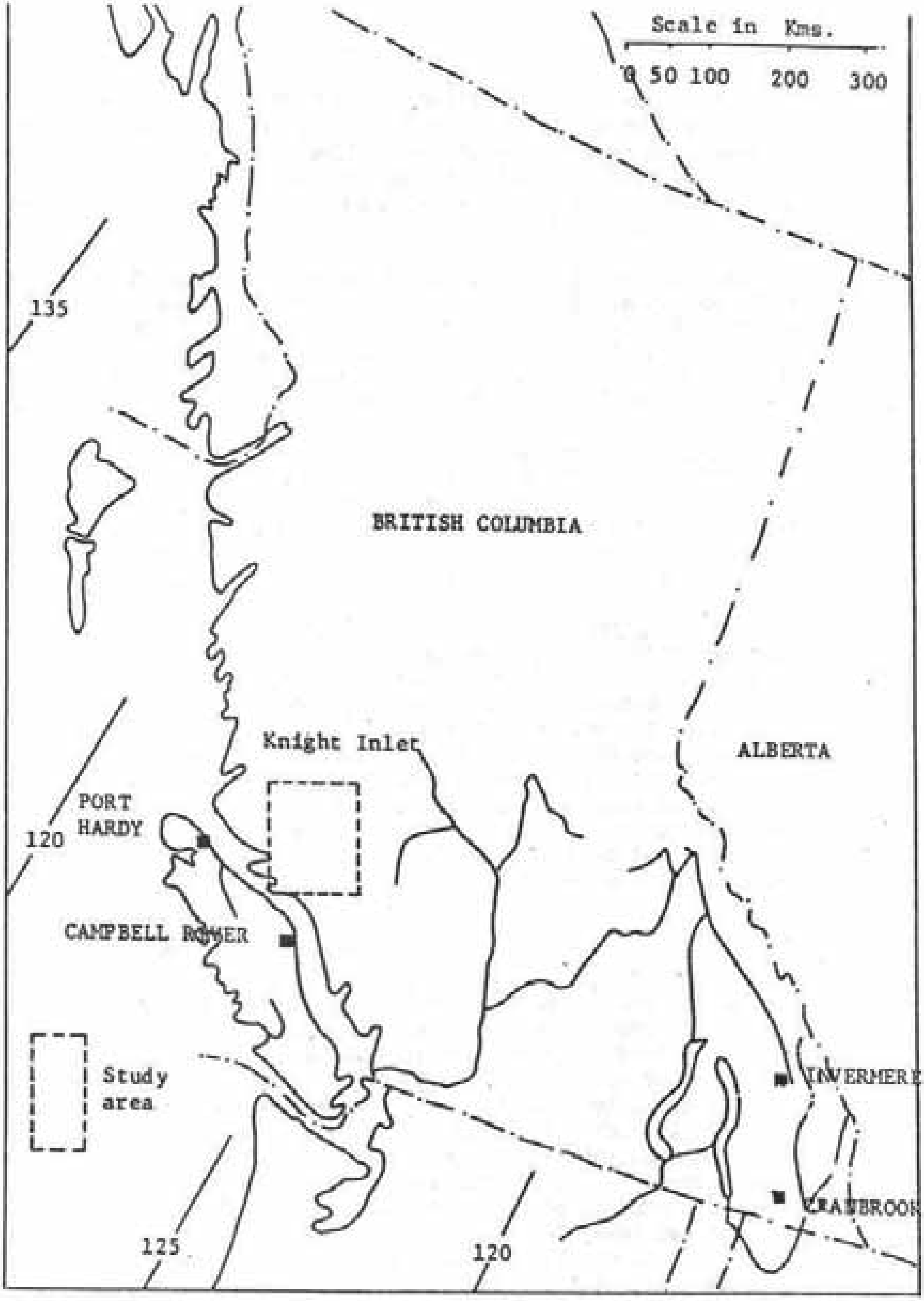

Figure 1 - Mountain Goat Study Area in Coastal British Columbia.

METHODS

The survey data were collected from helicopter transects flown at 150 m intervals from an elevation of 1200 m to the mountain tops (2800 m). Surveys were designed to produce estimates of sex and age ratios and population size and involved observing goats at close range (12-25 m) with 8x30 binoculars or a 200 mm telephoto lens. At least two observers were present for each survey.

All successful surveys were flown between July 18 and August 5 when goats were present on high elevation habitats. Surveys in September were unsuccessful in locating significant numbers of goats. Variability in the scheduling of the flights was caused by weather, helicopter availability and the work schedule of the participants. Attempts were made to fly the survey during clear weather, two to five days following inclement weather.

A population projection model was constructed which included productivity estimates (kids per 100 adult females), adult sex ratios and kid mortality estimates (based on ratios of yearlings per 100 adult females) derived from the survey data. Yearling and adult mortality were estimated (Youds et al. 1980). Harvest is not a factor for these populations and was not considered in the analysis.

For the purpose of analysis, values derived from the survey were considered to be an accurate estimate of the total population size. Survey data were tested for consistency by the model. Projections based on estimated productivity and mortality rates were compared to observed population trends. Parameters were altered based on literature and estimated values in an attempt to duplicate annual changes in the total goat population in order to compare simulated and observed population composition values for specific years. Subsequently, the underlying assumptions of goat harvest strategies were examined and the requirements for a revised inventory and harvest strategy for previously unhunted goat populations were examined.

RESULTS

During the period 1974-1980, fluctuations in weather produced population changes which allowed the dynamics of coastal goat populations to be examined. During a consecutive period of mild winters (1974-1977) the observed Hoodoo and Stanton Creek populations increased by 71.4 and 90.9 percent, respectively. These observed population changes were then compared to model predictions. Subsequently, a severe winter in 1978-1979 produced substantial decline of 82 and 92 percent in these respective populations. Although this was documented by a duplicate, systematic survey in Hoodoo Creek, a partial survey in Stanton Creek suggests that the decline was less than 92%. The resultant increase in the two populations, following the crash, allowed a wide range of dynamics to be compared, especially rates of increase.

Several years of data collection indicated that data quality varied among years. It was assumed that the data collected in 1977 by more experienced observers was of higher quality than that collected previously [compare identified animals in 1977 to those unidentified in 1974 (Table 1)]. Portions of the data were obviously incorrect and adjustments and assumptions had to be provided.

It was apparent from our data, and from the literature (Nichols 1980) that:

1. yearlings were underrepresented in the survey.
2. observed sex ratios could vary due to summer weather variability.

The survey results were examined through:

(a) a simulation of the original data

(b) a simulation which duplicated the observed change in population size and allowed a comparison of observed and simulated population structure for a specific year (1977).

(c) A simulation based on an adjusted set of data:
    i. selecting the year with the best quality data (most complete age and sex identification and greatest numbers counted)
    ii. adjusting data on yearling production and sex ratios.

Surveys conducted in July and August of 1974, 1976, 1977, 1979 and 1980 produced estimates of total population size and age and sex ratios (Table 1). Surveys conducted in September of 1975, 1978 and 1981 were unsuccessful in locating significant numbers of goats. It is believed that coastal goats migrate to lower elevations prior to the effects of early winter storms. The small numbers of goats recorded in these years were located below treeline (1200 m).

The model was used to simulate the observed trends in goat numbers for the Stanton Creek and Hoodoo Creek populations (Tables 2, 3) between 1974 and 1977. Mean values for productivity (kids per adult female) and kid mortality were used to define the model populations. Kid mortality was estimated from kid and yearling proportions in the populations. The initial population sizes were set at the number of goats recorded for the 1974 surveys.

Using these initial parameters, both simulations produced decreasing populations (simulation #1; Tables 2 and 3). The rate of decline (r) was -0.01 for the Stanton Creek population and -0.06 for Hoodoo Creek population.

In order to reproduce the recorded increase in numbers determined by the Stanton Creek surveys between 1974 and 1977, it was necessary to increase productivity (0.95 kids per adult female) and to decrease kid mortality (0.08) and yearling mortality (0.05) for the simulated Stanton Creek population (Simulation #2; Table 2). Similar adjustments were required for the Hoodoo Creek simulation in order to reproduce the observed increase in numbers (Simulation #2; Table 3). Rates of increase were 0.21 and 0.18 for the Stanton Creek and Hoodoo Creek simulations, respectively.

Table 1.

SUMMARY OF HOODOO AND STANTON CREEK

SURVEY RESULTS

Year	AD M	Males/100[1] Adult F's	AD F	UNID AD	Year-lings	Yearlings/[2] 100 AD F's	Kids	Kids/100[2] Adult F's	Total
HOODOO CREEK									
1974	-	-	-	26	-	-	2	15.4	28
1976	2	18.2	11	15	1	5.4	6	32.4	35
1977	8	34.8	23	1	1	4.3	15	63.8	48
1979	2	200.0	2	3	1	40.0	1	40.0	8
1980	2	50.0	4	1	2	44.4	3	66.6	12
STANTON CREEK									
1974	2	50.0	4	22	2	13.3	3	20.0	33
1976	17	121.4	14	5	2	12.1	5	30.3	43
1977	16	69.6	23	7	2	7.6	15	56.6	63
1979	4	-	-	1	-	-	-	-	5
1980	5	62.5	8	1	1	11.8	6	71.0	21

[1] Actual classification.

[2] Based on assumption that one-half of unidentified adults were females.

[3] Partial survey.

Table 2. Stanton Creek Simulation Results

	Estimated Mortality[1]					Sex and Age Composition					
Year	AD M	AD F	YR	K	Productivity K/ADF	AD M	AD F	YR	K	TOTAL	r
Simulation 1											
0	.05	.05	.20	.74	.42	13.0	13.0	1.4	5.5	33.0	
3						12.7	12.7	1.1	5.0	32.0	-0.01
Simulation 2											
0	.05	.05	.05	.08	.95	13.0	13.0	1.4	5.5	33.0	
3						19.2	19.2	10.8	13.2	62.6	0.21

Simulation 1 - Based on derived and estimated population parameters.
Simulation 2 - Based on observed population increase.

[1] See Youds et al. (1980)

Table 3. Hoodoo Creek Simulation Results

	Estimated Mortality[1]					Sex and Age Composition					
Year	AD M	AD F	YR	K	Productivity K/ADF	AD M	AD F	YR	K	TOTAL	r
Simulation 1											
0	.05	.05	.20	.91	.48	10.8	10.8	0.5	5.8	28.0	
3						9.8	9.8	0.4	4.6	23.9	-0.04
Simulation 2											
0	.05	.05	.10	.15	.90	10.8	10.8	0.5	5.8	28.0	
3						15.1	15.1	7.6	10.4	48.4	0.18
Simulation 3											
0	0	0	0	0	.79	4.8	11.3	3.0	8.9	28.0	
3						9.2	15.7	3.2	11.2	39.5	0.12

Simulation 1 - Based on derived and estimated population parameters.
Simulation 2 - Based on observed population increase.
Simulation 3 - Based on adjusted population parameters (see text).

[1] See Youds et al. (1980).

The Hoodoo Creek simulation was rerun using adjusted population parameters based on the assumption that the 1977 classification was more accurate than the 1974 classification. The classification was applied to the number of goats recorded in the 1974 survey (28). The number of yearlings was increased since it was likely that some were missed in 1977. It was also assumed that no mortality occurred between years for any age class. These adjustments produced an increasing population which totalled 39.5 animals in year 3 (Simulation #3; Table 3). The r value was 0.12, compared to 0.18 for the actual increase in goat numbers observed over the 1974 to 1977 period.

DISCUSSION

This exercise was not intended to estimate population parameters for the study area populations because a variety of productivity and mortality values would reproduce the observed increase in total numbers. In addition, the present survey counts do not provide good estimates of total population sizes. The results do, however, demonstrate that uncorrected productivity estimates and survival estimates for kids to yearling age (measured in July or August) were inconsistent with the apparent increase in herd size during the 1974 to 1977 period. Corrected classification data (Simulation #3; Table 2) fit the observed increase more closely for the Hoodoo Creek herd. Re-examination of inventory objectives and methodologies was undertaken on the basis of this analysis.

The study area populations are not subject to harvest at the present time due to their near inaccessibilty. In addition the entire area was closed to hunting in 1979 when the surveys showed a substantial decline in goat numbers. In the future, however, these and other coastal areas will become more accesible as logging progresses and road construction provides access for hunters. A means to inventory goat populations and effectively manage these previously unhunted populations is required.

Several models which simulate goat population growth (Kuck 1977, Hall and Bibaud 1978, Youds et al. 1980, Nichols 1980) have been described. These models represented goat populations as continually growing or declining, depending on the characteristics of the population (productivity and mortality). The chosen population variables produced increasing model populations from which a portion was available for harvest. Harvest slowed the rate of population increase but did not depress population numbers until the harvest rate exceeded the rate of increase. The need to estimate yearling and adult mortality rates introduces a major potential source of error to this method.

Additional complexity is introduced to goat management by their unknown density dependent response to harvest. At least two reports have indicated increased productivity did not occur when goat populations were harvested. Kuck (1977) monitored the harvest of an Idaho goat population and found that no increase in productivity (kids per adult female) occurred as the population size decreased. Hebert and Turnbull (1977) compared unhunted or lightly hunted and heavily hunted populations in a south-eastern British Columbia study area and found significantly lower kid proportions in the heavily hunted populations. This type of response may invalidate traditional harvest theory for some goat populations.

Rates of increase for harvested goat populations have not been adequately measured. Information on these rates is required if reasonably stable harvest regimes are to be established. Kuck (1977) describes a harvset experiment of the type necessary for calculation of the response of a population to harvest (see Caughley 1977). The harvest rate employed however, was greater than any goat poplation could reasonably be expected to sustain. Extension of this type of harvest experiment to other goat populations is required (Figure 2).

Careful monitoring of harvest and population size are required to establish the response of a goat population to harvest. The difficulties described in our study area in determining population variables make it unlikely that this method will provide sufficient sensitivity to adequately monitor any harvest of these populations. The need to establish total population estimates or at least population trends is evident. If we assume for example that the logistic growth model described by Caughley (1977) applies to goat populations then the allowable harvest is extremely low. Youds et al. (1980) calculated the maximum rate of increase for goats at 0.10. The expected response to harvest of a previously unhunted population which grows according to the logistic model at this maximum rate is shown in Figure 3. The maximum sustainable harvest is 2 - 3 animals per year; at this harvest level the population would be reduced to 50 animals.

The applicability of this model to the growth of goat populations is of course unknown. The value for $_m$ determined by Youds et al. (1980) is likely low since the theoretical maximum rate is .26 and this value was reached by one transplanted population (Thompson and Guenzel 1978). Conversely however, harvested goat populations may not show compensatory responses and therefore may not reach growth rates attained by unhunted transplanted populations.

Development of survey methods based on the establishment of population size estimates is required. Annual classification surveys in the study area produced inconsistent results which were of little value in establishing a harvest management program.

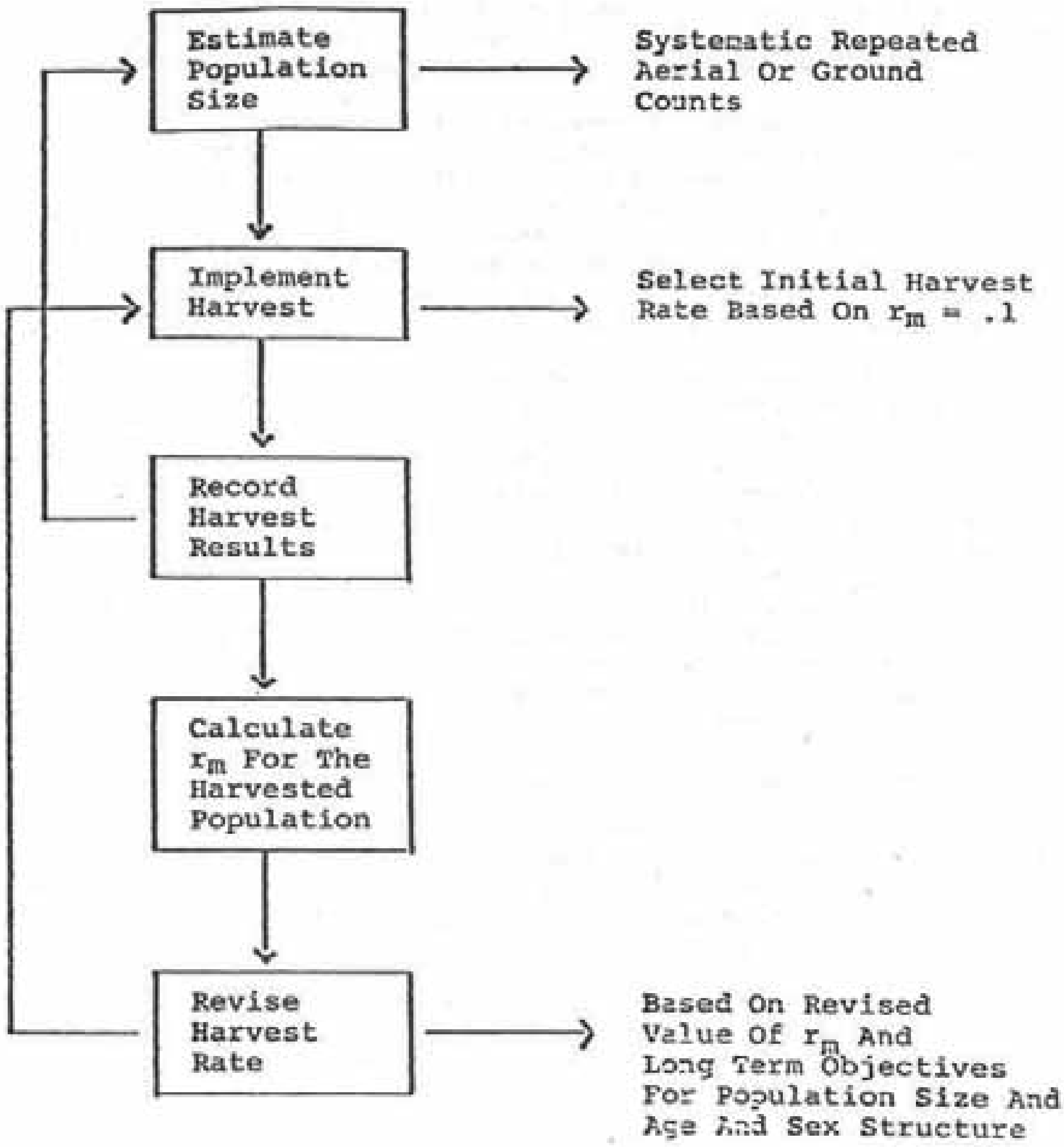

Figure 2. Flow diagram of a harvest management system for a previously unhunted goat population.

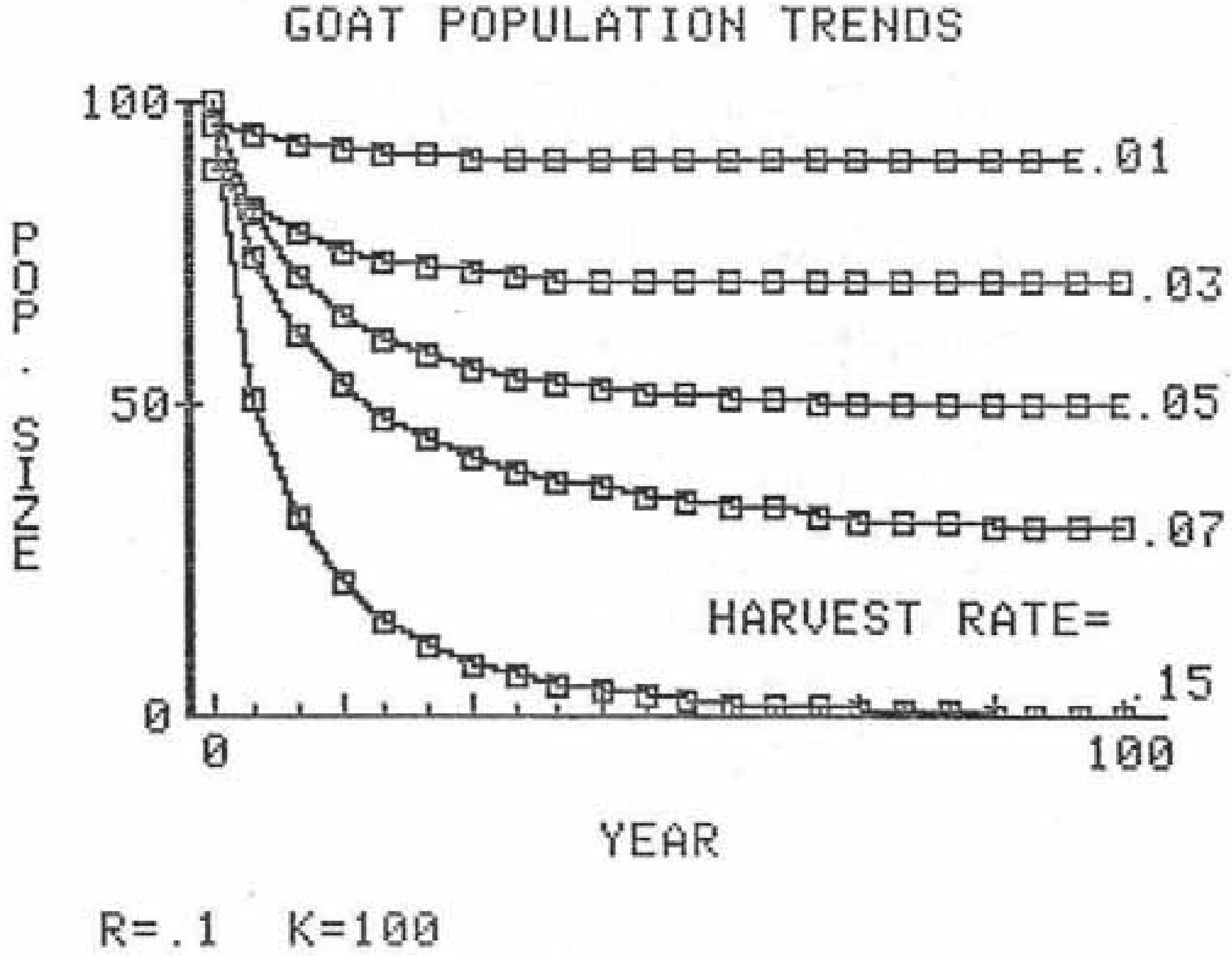

Figure 3. Hypothetical goat population under five harvest rates. The population is assumed to be at carrying capacity when harvest is imposed and to be showing a density dependent response according to the logistic model (after Caughley 1977).

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CONFERENCE DISCUSSION

Q At what age do coastal mountain goats reproduce?

Ans. We talked about that and as I said, I haven't really looked at the reproductive tracts of any of these animals. I just considered first reproduction at 2 1/2 years and considering the low productivity I get here, I think it could well be 3 1/2 before any nannies reproduce. But again, that's something that we haven't played with on the computer in terms of what effect the age of first reproduction might have on population growth.

Q. What are the effects of your helicopter surveys

Ans. All of our surveys were helicopter counts. They were done with a jet ranger. Those goats hadn't seen a human being before I got into there I'm sure. There had been a few helicopter passes over it. Its a totally remote part of coastal British Columbia. They were all done with systematic transects and they were all done with the same observers. When I first started flying in there, as Lyman showed, you could get to within a roter blade of those goats against the cliffs so all the sexing and aging was done from the helicopter. We did a bit of ground work but it wasn't really necessary. The goats are becoming a little harder to deal with now after 9 years of buzzing around but they have a year interval between each time we get there so they are still not that difficult to observe. Now I'm at the point where most of the sexing and aging is done with a camera with a 200 mm telephoto where I can zoom in on the animals and I'm still not having problems. I brought Tori Stevens up 2 years ago as an independent observer to do the age- and sex-classifying with me and we came up with almost identical results at the end of the survey. Every sort of check that I've tried to put on the system has worked very well. I really haven't hit any major stumbling blocks as yet.

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IMPLICATIONS OF MATERNAL SEPARATION ON OVERWINTER SURVIVAL OF MOUNTAIN GOAT KIDS

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ABSTRACT

It is calculated that, annually throughout North America, approximately 3000 mountain goat (Oreamnos americanus) kids enter their first winter without a mother. Only 20 percent of these kids are a result of female harvest practices; the remainder are a consequence of the breakdown in the nanny-young bond. A review of mountain goat literature generally reveals positive opinions pertaining to overwinter survival of these kids. Important components influencing winter kid survival are addressed; these include time of weaning, predation, intraspecific behaviour, winter distribution and food habits. Theoretical implications provide little evidence for differential rates of kid survival even though maternally-separated kids may become subordinate and subject to increased aggression from conspecifics.

INTRODUCTION

High levels of juvenile mortality occur in most big game ungulate species (Caughley 1966). Major components contributing to this mortality phenomenon are adverse climatic conditions (Moen 1973), disease (Spraker and Hibler 1982), abnormal maternal care and juvenile inexperience (Rheingold 1963).

The effect of premature mother-young separation (i.e. prior to behavioural weaning) has received increased attention by wildlife researchers. Systematic studies on survival of these offspring were previously expressed by Lent (1974) as an essential requirement of big game management.

To date, observations or studies of maternally-separated or orphaned young have been conducted on pronghorn antelope (Antilocapra americana) (Bromley and O'Gara 1967), mule deer (Odocoileus hemionus) Swenson 1972), white-tailed deer (*O. virginianus*) (Reed 1974), bighorn sheep (*Ovis canadensis*) (Wishart 1976, Smith and Wishart 1978), domestic sheep species (Zito et al. 1978, Arnold and Dudzinski 1978), moose (*Alces alces*) Altmann 1958, Johnson et al. 1973, Markgren 1975, Sigman 1977) and grizzly bears (*Ursus arctos*) (Jonkel et al. 1980). Interspecific differences in overwinter survival are apparent. For example, moose calves orphaned in the fall are highly vulnerable to winter mortality, whereas juvenile white-tailed deer, pronghorn and bighorn sheep are generally considered to survive.

The purpose of this paper is to review and compare relationships affecting overwinter survival of mountain goat kids separated from their nanny to those with a natural mother. The importance of maternal care is examined within the concepts of natural metabolic and behavioural weaning processes (Sadlier 1980), protection from predators and aggressive conspecifics, and identification of winter habitat and forage types.

LITERATURE REVIEW OF MOTHERLESS KID SURVIVAL

No systematic studies have been conducted on overwinter survival of maternally-separated mountain goat kids. Contradiction in findings and opinion are revealed in the scant information published or presented in theses. Brandborg (1955) stated that if motherless kids are left to their own devices, their survival is doubtful. He based his conclusion partly on one case of an emaciated 7 month old kid found dying from what appeared to be starvation. Other researchers (Chadwick 1973, Rideout 1974, Hebert and Turnbull 1977, Kuck pers. comm.) also speculated that chances of a motherless kid surviving are further reduced than if they were with a female. These beliefs were based on the premise that maternal leadership, alertness, aid and protection is essential to the survival of young through the first winter.

Consequently, conservative attitudes stress the importance of the nanny in rearing her young. Wright (1977) recommended that hunting nannies who are accompanied by kids or yearlings should be prohibited until subadult age classes comprise 35 percent of the herd. Several game management agencies have recently implemented strict harvest regulations or pleas to the hunter. For example, in a review of 1981 game regulations, Nevada emphatically discouraged and Washington recommended against the harvest of females accompanied by kids. The Yukon Territory made the harvest of maternal nannies illegal.

Conversely, a number of researchers have provided evidence for motherless kid survival. For example, Kerr (1965) reported 93 percent overwinter kid survival in Alberta after a fall hunting season in which 40 percent of the herd (n=35 goats) was removed. Some kids were undoubtedly orphaned, prior to the severe winter experienced in the area. Similarly, Foster (in prep) observed kid survival rates of 73 and 63 percent over two consecutive mild winters in British Columbia. Eight hunter-induced orphans and at least four kids naturally separated from their mothers, were known prior to the second winter, however the difference in survival rates between the two years (9.8%) accounted for a discrepancy of three or four kids only, suggesting that no significant differential rates of orphan and non-orphan and non-orphan kid mortality occurred.

In Montana, Chadwick (1973) noted that two orphaned kids survived a very mild winter in his study area and Rideout (1974) recaptured two of his marked kids which were separated from their nannies during marking procedures the previous your. One was emaciated and had trouble walking (a male), and the other (a female) was in good physical condition. Additionally, Thompson (1981) noted the apparent survival of a hunter-orphaned kid over a severe winter. He also cites a pair of orphaned twins (generally considered less fit than individual newborn) surviving their first two consecutive winters, both of which were considered severe.

DISCUSSION

OCCURRENCE AND FREQUENCY OF MOTHER YOUNG SEPARATION DURING BEHAVIOURAL WEANING

Four processes are involved in the loss of maternal care to mountain goat kids during their behavioural weaning period: (1) temporary, accidental separations (due to weaning conflict and juvenile independence) occur predominantly in June and July, (2) permanent (sometimes accidental) separations (due to higher levels of juvenile independence and further weakening of the maternal bond) generally occur in August and September, (3) hunter-induced orphaning (harvest of the nanny) usually takes place in October, and (4) natural orphaning (death of nanny from natural causes or predation) is most susceptible during critical periods, from November through March.

By measuring distance of the kid from its nanny, DeBock (1970) showed that kid independence steadily increased with time from birth. This results in accidental and temporary maternal-young separations being observed with increasing frequency as the period of weaning conflict (Berger 1979) progresses (Brandborg 1955, Chadwick 1973, Foster and Rahs unpubl. data). No information is available on the rate on maternal abandonment for mountain goats, however inexperienced mothers are a common source of this phenomenon (Rheingold 1963).

After the period of metabolic (or nutritional) weaning (about 4-5 weeks), separations continue to occur with increasing frequency, but on a more permanent basis, as kids are no longer dependent upon the nanny for milk. Foster and Rahs (unpubl. data) recorded nearly 10 percent of an annual kid cohort to have maternal ties permanently severed by early October (and prior to hunting). This corresponds to approximatley 1300 kids being naturally separated from their mothers by mid-October each year in British Columbia.

Hunter-induced orphaning is believed to be much less significant, based upon hunting restrictions discussed earlier and subsequent harvest statistics, and hunter morals. In British Columbia, where approximately 45 percent of North America's mountain goats reside and are harvested (Johnson 1977), it is estimated that approximately 2 percent of all goat kids (n=250) are orphaned by hunting. This figure is obviously dependent upon the proportion of hunters who would shoot a nanny accompanied by a kid, and therfore may be actually less[1].

The incidence of natural orphaning, or death of the nanny, is believed to be slight as numerous researchers have failed to document significant levels of adult goat mortality (Chadwick 1973, Vaughan 1975, McFetridge 1977). Nanny mortality would be expected to occur more so during late winter-early spring, when old females should be in a poorer nutritional state. Accidents, avalanches and old age are believed responsible for most adult deaths. Vaughan (1975) theorized that adult goat predation is low due to the ability of mature goats to defend themselves and the absence of a specialized predator.

In all of North America it is estimated that natural, permanent nanny-kid separations, in addition to hunter-induced orphans, account for approximately 3000 kids entering the winter without a mother each year. The kid figures were based upon: (1) population estimates from Johnson (1977) and the British Columbia Ministry of Environment (1979), (2) total annual British Columbia harvest figures gathered over a 12 year period (1965-1976) (Macgregor 1977), (3) total annual British Columbia harvest of males and females over an 11 year period (1965-1975) (Foster 1977), and (4) male:female and kid:female ratios from Anderson (1940), Cowan (1944), Hanson (1950), Brandborg (1955), Kerr (1965), Chadwick (1973), Rideout (1974), Hebert and Turnbull (1977), Foster and Rahs (1981) and Foster (in prep). A ratio of 65 males:100 females was used in the calculation.

FACTORS INFLUENCING MATERNALLY-SEPARATED KID SURVIVAL DURING BEHAVIOURAL WEANING

Weaning Conflict

Mountain goat kids fall into the category described by Lent (1974) as <u>followers</u>, and parental investment early in life is high (DeBock 1970, Chadwick 1973, Rideout 1974). However a rapid progression is observed in the breakdown of the mother-young bond prior to metabolic weaning. In fact, maternally terminated suckles start within 2-4 days subsequent to birth (DeBock 1970). The major immediate result is a decrease in milk supply to the offspring (Trivers 1972, 1974).

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[1] This estimate is based upon the fact that, on average, 55 out of every 100 adult females is accompanied by a kid and that females with and without kids are harvested equally.

Within one week, newborn are mouthing plants. By the age of 4 to 5 weeks, DeBock (1970) stated that kids are feeding extensively on solid foods. Casebeer et al. (1950) also noted that kids are weaned by their fourth week. After this period, milk appears to have only a behavioural significance, being merely a dietary supplement, with frequency and duration of nursing averaging approximately one suckle per eight hour period. Chadwick (1973) noted that nursing durations were sharply curtailed and that frequent rejections occurred at this age. By August, McFetridge (1977) found that it was often difficult to associate any kid with a particular nanny. At this time, DeBock (1970) stated that almost all nursing attempts are resisted by the nanny and that kids appear to be fully weaned (metabolically) by their fourth month. Sadlier (1980) found that black-tailed deer fawns (Odocoileus hemionus columbianus) were also weaned in a metobalic sense before they were behaviourally weaned.

Kids were observed by McFetridge (1977) to be largely independent by late September (when hunting season started in Alberta). Most of the naturally-separated mountain goat kids observed by Foster and Rahs (unpubl. data) were documented immediately after metabolic weaning (i.e. late August to early October). A marked increase in mother-young distance was noted by DeBock (1970) during the rutting season, suggesting a progressively normal breakdown of the mother-young bond prior to winter. Chadwick (1973) additionally noted that a lack of interest by nannies towards their own offspring increased through the winter. By late winter, he observed short yearling groups with increasing frequency.

Predation

The ability of adult goats to dispatch predators, as described by Guiget (1951), Cowan (1944), Kerr (1965) and Smith (1976), suggests that predation is most successful on subadult cohorts. Brandborg (1955) stated that wandering kids are extremely susceptible to predation and kids were found by Chadwick (1973) to be the least alert class of goats. However, our own observations, in conjunction with those of Holroyd (1967) and Wright (1977) infer that kids and yearlings are the most alert and the first to display alarm.

Goat researchers have witnessed successful predatory acts involving eagles, wolves and mountain lions only. Brandborg (1955) and Smith (1976) report in total, three cases of observed eagle predation, all of which were restricted to young kids. However, Anderson (1940) refers to the non-selective eagle predator strategy of striking an adult goat (a billy) and successfully knocking another (a yearling) off a ledge. Cowan (1947), Carbyn (1974) and Fox and Streveler (1979) each documented successful wolf attacks, but only on young goats. It could not be determined from the available literature whether or not mountain lions had selected for kids, as no successful predatory acts were documented in detail (Cowan 1944, Young and Goldman 1946, Holroyd 1967, Burleigh 1978).

Casebeer et al. (1950) and Chadwick (1977) described *predator confusion* during attacks on large goat groups. The authors have noted similar responses by goats, however we also documented that responses to other disturbances (primarily aircraft) were independent of group size (Foster and Rahs 1981). Therefore, if motherless kids are social, as suggested by Rideout (1974) there should be similar chances of survival for both kids with their true mother and kids without. In any event, predation appears to be so low that no significant population changes result (Klein 1953, Smith 1976).

Intraspecific Stress and Aggression

Stress may be placed upon kids through agonistic behaviour of conspecifics, however this is usually reduced by maternal aggression when other goats approach too close to young offspring (DeBock 1970, Chadwick 1973, Wright 1977). Consequently, kids with mothers become associated to some extent with the dominant status of nannies (Chadwick 1973). Disturbances usually induce nursing behaviour by kids (DeBock 1970, Chadwick 1973). Brandborg (1955) speculated that the high frequency of nursing he observed may have been due to his nearby presence and associated disturbance, implying traumatic relief from the nannies' presence. Liddell (1958, 1961 - in Geist 1971) found that physic trauma was fatal to domestic goats and sheep separated from their mothers, but not if it occurred in her presence. However, Dailey (1981) has shown that newborn mountain goat kids, taken away from their nanny, developed rapidly in captivity, and in good health, given a nutritionally balanced diet.

Mountain goat kids separated from their mothers become the least dominant members of all groups. Thus they receive increased levels of agonistic behaviour from most other cohorts (Chadwick 1977). These kids also create stress among conspecifics (primarily nannies with young) because of their selection towards *foster mothers* or *foster groups* (Rideout 1974). Craig (1981) described added stress within a group when a strange member joins, resulting in increased aggression and decreased forage consumption. Lost or orphaned kids generally do not leave their *foster groups* voluntarily, but may be driven off by intolerant group members. A means of reducing this aggression is demonstrated by the occasional pairing-up of motherless off-spring who winter for the most part by themselves (Thompson 1981, Foster and Rahs (unpubl. data).

Winter Distribution

Winter habitat use by goats is ultimately dictated by snow characteristics (Adams 1981, Dailey 1981), with secondary influences generally imposed by forage and other thermal conditions (Peck 1972, Rideout 1974, Bailey and Johnson 1977). Thick snow cover encourages goats to aggregate, thus reducing both the number of single animals and increasing the occurrence of mixed groups (Casebeer et al. 1950, Lentfer 1955, Petocz 1973, Rideout 1974).

It is conceived that during winter social aggregational tendencies direct motherless animals to traditional wintering areas where their own mothers might otherwise have led them. Of course this may not be possible if population densities are extremely sparse and long seasonal migrations are involved, or if excessively large snowfalls trap animals in unfavourable winter habitats. However, these situations are normally believed to be an exception rather than the rule.

During winters of heavy snow-fall, social integration may become advantageous to motherless kids in the sense that conspecifics develop well-trodden trails between scattered areas of available food and cover, thus reducing potentially high levels of physical exertion required for locomotion. Competition and range overuse may occur if winter range is limited, but not to the exclusion of motherless kids.

Food Habits

Chadwick (1973) stated that in winter, kids depend to a considerable degree upon their mothers to paw snow from forage. However, our observations over two winters showed high levels of independence among kids. Only rarely did we observe kids to utilize their mother's feeding crater (Foster and Rahs unpubl. data). Kids were mainly observed to dig their own snow craters and feed adjacent to their mother. Nannies were observed to occasionally become aggressive towards intruders, including their own offspring. Both studies were conducted during winters of light snow-fall. Petocz (1973) showed that during the deep snow period of winter, high levels of agonistic behavoiur resulted in competition for feeding craters. When snow depths increased, we also observed more crater parasitism, however a change to browsing habits generally occurs at such times (Dailey 1981).

By selecting similar habitat types of other goats (by following them), forage conditions should not significantly alter for motherless kids. Under rigidly controlled studies, Dailey (1981) found that not only did tame, motherless kids and yearlings selectively eat certain plant species, and also the most nutritious components (i.e. leaves and flowers), but the animals were capable of altering diet choices in an apparent response to differences in nutrient composition among forages. He concluded that the motherless goats choose diets largely similar in composition to diets of wild goats.

SUMMARY AND CONCLUSIONS

Incidents of natural separation of mother and young start during postpartum isolation and commonly occur with increasing frequency during the progressive breakdown of the nanny-kid (weaning). Many researchers do not distinguish between complete metabolic weaning (generally less than 120 days) and behavioural weaning (up to one year in goats).

Rideout (1974) concluded that separations do not invariably result in the motherless kid's death as suggested by Brandborg (1955). We support Rideout's conclusions that under these circumstances a kid typically follows a foster group or joins another motherless kid. Our general discussion of potentially influencing factors affecting overwinter survival of these kids suggests little reason for differential rates of mortality between the two kid categories. Although an absence of systematic studies is evident, the general concensus of the literature agrees with our observations. We conclude that: (1) milk requirements subsequent to late summer (September) are not essential for over-winter juvenile survival: (2) predators appear to select for young offspring, however no differential selection should occur between social orphans and non-orphans: (3) winter, in particular, induces goat aggregational tendencies and therefore a learning response for use of winter habitat: (4) kids generally paw snow to expose forage independently: (5) maternally-deprived kids have the ability to select both highly nutritious plant species, and their components, and exhibit seasonal alterations in their diets corresponding to plant nutritional values: and (6) kids taken from their mother at an early age develop rapidly and remain healthy in captivity. We must stress that maternally-deprived kids may fall into a lower position in the dominance hierarchy and consequently receive premature levels of increased aggression (predominantly from nannies) at an earlier age. An additive effect is that of increased agonistic behaviour and resultant energy cost to gestating adult females.

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CONFERENCE DISCUSSION

Q. In the northern half of British Columbia, our hunting seasons opened on August 1st for goats. Now some of them have shifted ahead to August 15th. Do you think that has any effect on the survivability of kids?

Ans. We found from our field work in the Terrace area that most resident hunting activity generally did not commence until mid-October, when stormy weather and new snow forced the animals down to lower elevations. Our resident hunters tend to be a little bit lazy. Many road-hunt goats, as people road-hunt deer and moose. Therefore goat hunters usually wait for the last possible chance. Generally the season ends October 31st in most areas. Non-resident hunters, on the other hand (contributing to about half of the provincial goat harvest), often hunt in August and September, but they are generally after male trophies.

Q. But females comprise a rather large component of the harvest in B.C. Don't you feel that the incidence of hunter-induced orphaning may be rather high and with significant effect?

Ans. No I do not. Firstly, because I've found that the resident hunter harvest averages about 40% females and non-residents about 30%. Only half of most female goats are accompanied by a (single) kid, and these animals are usually selected against by the hunter. Secondly, the incidence of hunter-induced orphans appears to be far outweighed by the number of orphans created via natural separation from their mother, say, by the end of September.

Q. I wonder about your comparison with Tom Dailey's goats to the ones that are orphaned in the wild. His goats got an awful lot of attention. I wonder about the human caretakers that are filling in the mother-role a little bit. Couldn't these goats also have been influenced in their free-ranging food habits by captive-rearing?

Ans. Although the social implications of a surrogate mother may eventually eliminate the social stress of a kid removed from its original mother, there also existed the likely event that abnormally high levels of trauma may have been induced to these motherless kids subsequent to capture in the wild. The effects of this have not been measured. To answer your second question, I would like to say that the highlight of Dailey's thesis was that the goats in captivity were initially fed a diet of milk (until September), and later, alfalfa hay. They weren't supplemented by natural foodstuffs from traditional goat ranges (or the study area). Also there was no learning between animals because all feeding trials were conducted with individuals. So it was apparent that innate behaviour was involved in their ability to select more nutritional forages.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:364-373

SOCIAL DYNAMICS OF MOUNTAIN GOATS IN SUMMER: IMPLICATIONS FOR AGE RATIOS

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ABSTRACT

Sex-age compositions of mountain goat (Oreamnos americanus) groups on Mount Evans, Colorado, were determined during late-summer, 1981. Eighty-four percent of observed groups contained kids and/or yearlings. Groups without kids or yearlings were composed exclusively of adult and/or 2-year-old males. Few adult males were observed using alpine tundra habitats during late-summer. Because adult males are less observable, kid:yearling:adult ratios are biased and tend to overestimate the proportions of kids and yearlings in populations. Implications of these findings for population estimation and modeling are discussed. Recommendations for standardizing methods of obtaining age ratios are given.

INTRODUCTION

Mountain goat age ratios have been used as indicators of reproductive success and kid survival, and to evaluate population trends. In addition, age ratios are used in setting harvest rates for some goat populations. However, because mountain goats are not sexually dimorphic, classification is often difficult. Consequently, goat age ratios are often reported as either kids per adult or kids per older animal instead of as kids per adult female, as with other ungulates. To our knowledge, the validity of mountain goat age ratios as indicators of reproductive success has not been examined.

Objectives of this paper are to: (1) present data on late-summer group composition of mountain goats on Mount Evans, and (2) examine the accuracy of age ratios as indicators of reproductive success of mountain goats.

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METHODS

Ground surveys, initiated from the Mount Evans road (Colorado Highway 5), were conducted on 9 days from 30 July to 19 August, 1981, to locate and classify mountain goats. Despite being a hunted population, goats on Mount Evans have become habituated to the presence of humans due to the amount of human activity on and near the Mount Evans road. This relative "tameness" provided an unusual opportunity to approach and observe goats at close range (often <15m). From such distances it was possible to determine the exact sex-age composition of all groups observed. Goats were classified as kids, yearlings by sex, 2-year-olds by sex, or as adults by sex using horn characteristics, urination postures, external genitalia, and nanny-kid associations (Brandborg 1955).

Group composition data were compared with sex-age ratios derived from a 1-day intensive gound survey of Mount Evans conducted by Colorado Division of Wildlife personnel on 21 July, 1981. For this survey, goats were classified as kids, yearlings, older animals (either yearlings or adults) or as adults (males, females, or unclassified).

When goats were observed, the date, time, location, group size and composition, group activity, and habitat type were recorded on standard observation forms. Goats were considered within the same group if they were in visual contact and <50 m apart.

RESULTS

A total of 118 goats was observed from 12 walking routes during an intensive 1-day ground survey of alpine tundra habitats on Mount Evans on 21 July, 1981 (Table 1). Assuming the age ratio in 11 "older" goats was the same as the ratio in 72 classified yearlings and adults, the observed kid:yearling:adult ratio was 57:36:100. The observed kid: older goat ratio was 42:100.

Of the 64 groups observed during the 9 days of ground surveys, 84% contained either kid and/or yearling goats (Figure 1). All adult and 2-year-old females observed were in groups containing either kid and/or yearling goats. Thirty-seven percent of observed nanny-juvenile groups contained mature males. Groups without kids or yearlings were composed exclusively of adult and/or 2-year-old males. Nine of 10 observed groups composed of adult and/or 2-year-old males contained 2 or fewer goats, and 74% of all adult and 2-year-old males observed using alpine tundra habitats were in groups of 5 or less individuals (Figure 2). Nanny-juvenile groups (averaging 6.4 individuals) were significantly ($P < 0.001$) larger than were male-only groups (averaging 1.6 individuals).

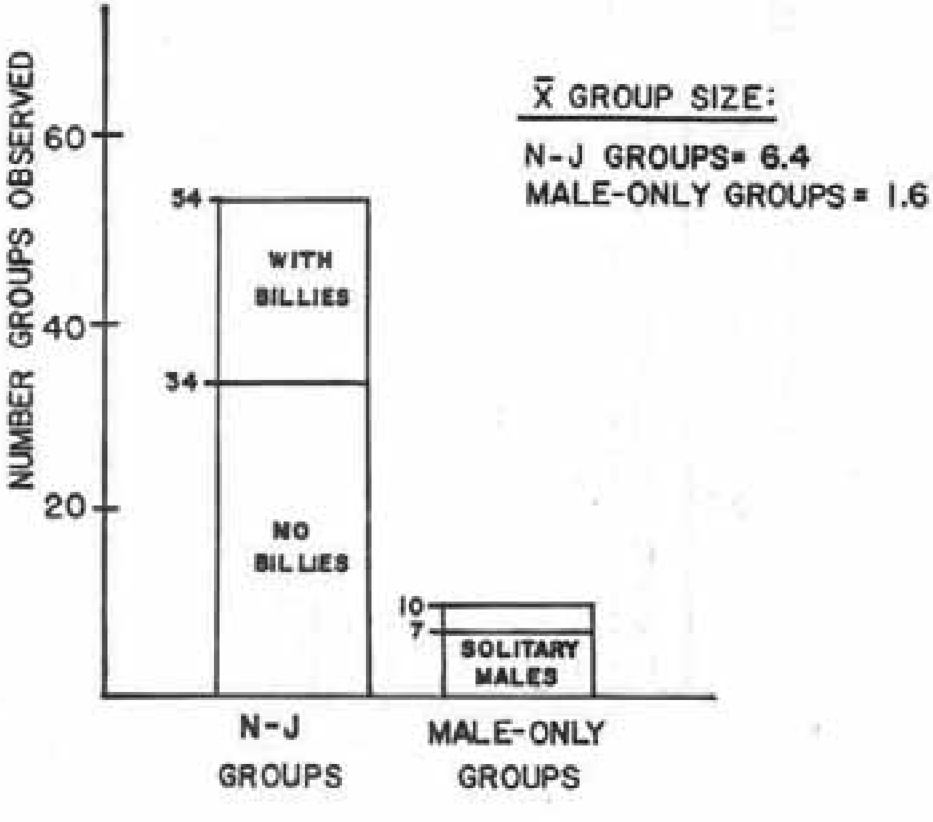

Figure 1. Composition of 64 mountain goat groups observed using alpine tundra habitats on Mount Evans during 30 July - 19 August, 1981.

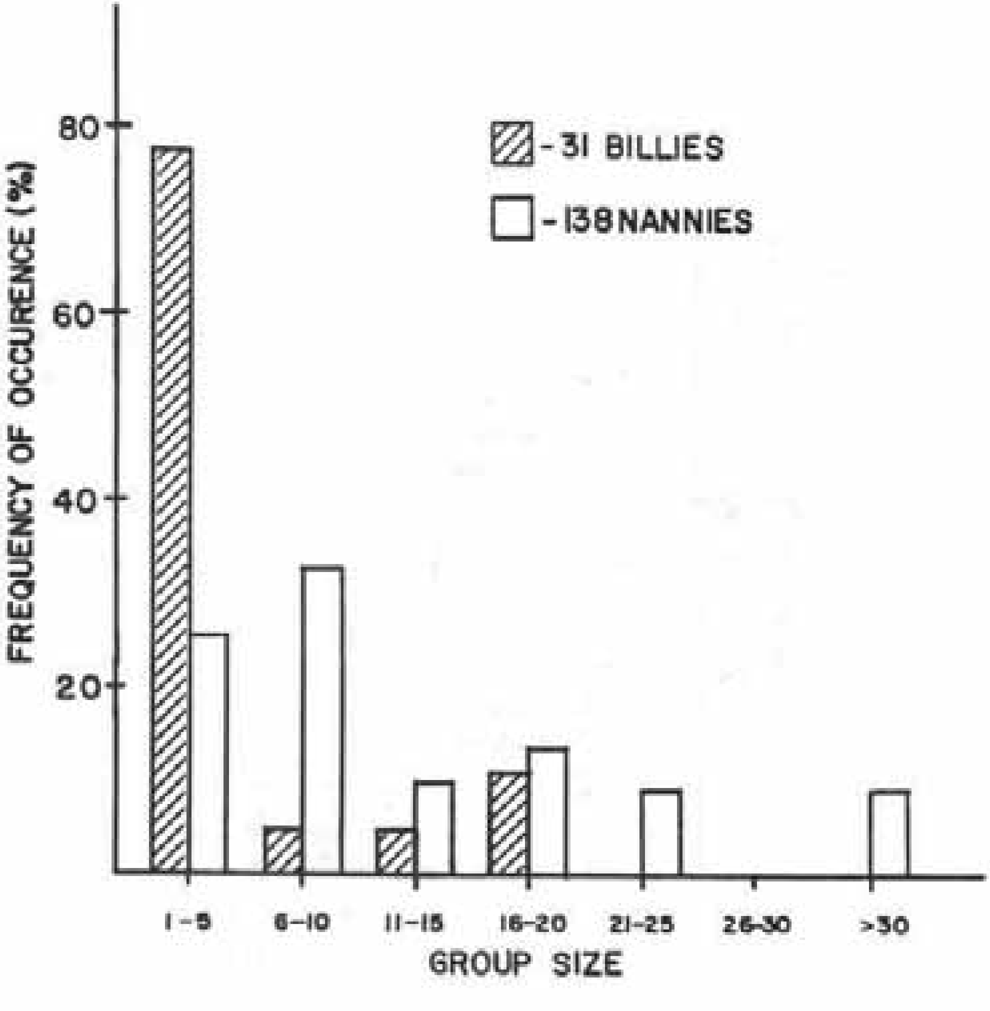

Figure 2. Frequency distribution of group size categories for adult and 2-year-old male, and female mountain goats observed using alpine tundra habitats on Mount Evans during 30 July - 19 August, 1981.

Table 1. Late-summer population structure of mountain goats using alpine tundra habitat on Mount Evans as determined from a 1-day intensive ground survey.

Goats Counted	Adult Males	Adult Females	Adult Uncl.[1]	Older[2]	Yearlings	Kids
118	7	35	11	11	19	35

[1] Unc. = Unclassified.

[2] Older goats are either yearlings or adults.

Group composition data from the 9 days of ground surveys were pooled using the minimum population method (Geist 1971, Table 2). Although the population estimate obtained from this method (71 goats) was smaller, the kid:yearling: adult ratio (59:32:100) and the kid:older ratio (45:100) were very similar to results of the 1-day intensive ground survey. This suggests that both surveys were equally representative of the goats using alpine tundra habitats during this period.

Table 2. Sex-age composition of the known minimum population of mountain goats using alpine tundra habitats on Mount Evans during 30 July-19 August, 1981.

Known Minimum Population Size	Adults		2-Year-Old		Yearling		
	Males	Females	Males	Females	Males	Females	Kids
71	7	22	5	3	6	6	22

DISCUSSION

SOCIAL DYNAMICS

Chadwick (1977) hypothesized that, beginning at 2 years of age, male mountain goats occupy ranges peripheral to or separate from those of females and subadults. Such spatial separation minimizes competition between adult males and females and their offspring, and reduces the potential for injury to kids through interactions with adult males (Geist 1974, Chadwick 1977, Dane 1977, Singer 1977). In addition, adult male goats tend to occur in smaller groups during summer than do nannies and juveniles, and inhabit more rugged terrain where they are less observable (Geist 1974, 1978; Rideout 1975, Chadwick 1977, Masteller 1980, Adams 1981, Adams et al. 1982).

By forming large groups in open tundra habitats, nanny-juvenile groups may be better able to avoid predators. Although goats possess formidable horns, nannies with kids could be surprised by predators in forested habitats. In contrast, goats in large groups in open tundra habitat can use mutual alertness and good visibility to detect predators at a distance and can move vulnerable offspring to secure terrain when necessary. Furthermore, preliminary analysis of data from Mount Evans (Risenhoover, in prep.) suggests that goats in larger groups were less antagonistic toward each other when compared to individual goats in smaller groups.

Gregariousness is a common mechanism in predator-evasion strategies of ungulates inhabiting open habitats (Walther 1969, Estes 1974, Bergerud 1974, Jarman 1974, Jarman and Jarman 1974, Bertram 1978, Risenhoover and Bailey 1980, Seigfried 1980). We hypothesize that nannies and juveniles become more gregarious on more open alpine tundra habitats during summer, when kids are small and vulnerable, at least partly to avoid predators. In contrast, mature billies avoid competition with nannies and juveniles by avoiding alpine tundra habitats and by occupying more rugged areas, often in more forested habitats. Billies which remain on alpine tundra ranges with nannies and juveniles are obliged to keep their distance from kids by frequent agonistic encounters with nannies (Risenhoover, in prep.) and as a result, tend to form small bachelor groups.

Assuming there is an 80:100 (male:female) sex ratio among adult goats on Mount Evans, approximately 62% of the adult males were unaccounted for during the 1-day intensive ground survey and during the other 9 field days. Such a sex ratio is not unreasonable since harvest data for Colorado (Adams 1981) indicate only a slight selection for male goats (58% of all harvested goats were males).

Geist (1964) also observed a low ratio of adult males to females in late September. However, the ratio of males to females increased from 10:100 in late September to 80:100 during the rut in November, supporting the premise that, during late summer, adult males occupy habitats other than those being utilized by nanny-juvenile groups.

IMPLICATIONS FOR AGE RATIOS

A variety of age ratios may be used as data on mountain goat populations depending upon opportunities for accurate sex-age classification. At one extreme, observers in fixed-wing aircraft may only classify goats as kids vs. older animals, especially in autumn when yearlings cannot be reliably distinguished from adults. With ground-based surveys in late summer, kid:yearling:adult ratios may be obtained from most Colorado populations. The opposite extreme is represented by this study in which habituated goats were observed from short distances and 7 sex-age classes were identified. However, few mountain goat populations are so accessible and habituated to people.

It is often tempting to survey populations in late summer because (1) yearlings can be distinguished from adults, even at a distance; and (2) because at least some populations exhibit large groups of goats on tundra during late summer, allowing large numbers of goats to be found and classified. However, this study supports Chadwick's (1977) hypothesis concerning differential habitat use between adult male and female goats in summer. In addition, it appears that adult males are less observable than are nannies and juveniles, probably because they use more rugged terrain and/or forested habitats and because they tend to be in smaller groups. Masteller (1980), using ground surveys, found marked adult male goats were reobserved 0.32 times as often as were marked female goats during summer. As a result, sex-age ratios based upon summer classification counts are biased because adult males are under-represented, and kid:yearling:adult ratios will overestimate rates of production and recruitment. Likewise, if numbers of kids and yearlings in a goat herd are estimated by combining age ratios obtained in summer with a population census, these numbers will be overestimated.

Based on data from Geist (1964), more accurate age ratios might be obtained during the rut. However, at this time yearlings may not be distinguished from adults under some survey conditions. (Distinguishing yearlings from adults in autumn will be especially difficult if yearlings grow especially large. Exceptional yearling growth might be common in Colorado's introduced goat herds if they exist at low densities in relation to forage resources that were exploited little before goat introductions.) If only the pre-winter kid crop is to be estimated, kid:older animal ratios obtained in the rut should be considered. If the yearling crop is also to be estimated, an unbiased prediction might result if a kid:yearling ratio is obtained in late summer and a kid:older animal ratio is obtained during the rut. If one assumes the ratio of kids:yearlings is stable during summer to the rutting period, the number of yearlings classed as older animals during the rutting season can be estimated from the late-summer ratio. These possibilities deserve additional research.

An alternative for estimating rates of production and recruitment is, of course, to classify adults as nannies or billies and use kid:yearling:nanny ratios. However, we have been unable to classify all adults by sex under most survey conditions in Colorado.

Age ratios may also be used as indices to trends in rates of reproduction or recruitment. In this procedure, biased age ratios will not produce inaccurate trends so long as biases are consistent over time. Consequently, age ratios obtained in summer may be used to detect trends over years or to detect differences among years with different weather conditions if the same proportion of the adult males in the population can be classified each year. Standardizing the survey method would support this goal. Surveys should be conducted during the same time of year and under the same weather conditions. Observer effort should remain constant among years, as extra effort in some years may result in the location and classification of extra adult male goats. Using fixed survey routes would be a way to control this source of bias.

CENSUS

Lincoln-Petersen censuses require either animals be marked at random or that a later random sample be obtained to estimate the proportion of marked animals in the population. If adult males are not properly represented in a marked sample of mountain goats, a late-summer sample of the population marked:unmarked ratio will be biased if, as suggested here, males are less observable than are females. Solutions to this problem are (1) mark males and females in proportion to their occurrence in the population, or (2) perhaps a random sample of the population marked:unmarked ratio can be obtained during the rutting season.

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CONFERENCE DISCUSSION

Comment - Just a couple of comments instead of questions. Because a previous paper involved detailed age ratios, I'm not sure that it was always clear that we're talking about implications for age ratios taken largely from aircraft. You're not able to identify males and females so that the biases you are talking about are biases when you are calulating kid ratios and the males are unrepresented. Secondly, with respect to the adaptive strategy of large groups on open tundra at that time of year, maybe something we've overlooked here is that during this season metabolic requirements are extremely high, especially for the reproducing segment of the herd. Kids have high metabolic requirements as do lactating nannies. It also may be important to put on a lot of tissue in order to get through the next winter, and what may be going on here is that the animals simply cannot find enough high quality forage in a high enough density if they stay in the cliffs. So, they have to get out where they can forage efficiently, out of the cliffs, and the only way, as you say, they can do this safely is to form these large groups.

Q. The survey of Mount Evans in 1981 produced an unbalanced sex ratio. How about the survey that was done in 1980? I know that surveys have been done on Mt. Evans in 1980 and maybe 1979. Are they also exhibiting this unbalanced male sex ratio?

Ans. In most cases, adult goats were not classified by sex during those surveys.

Comment - I think its entirely possible to sex goats out of aircraft, certainly out of a helicopter.

Comment - I have a comment on the problem of sexing goats from aircraft in Colorado. One of the problems we have is with large groups away from escape terrain. If you fly over, even if your are in a helicopter, you fly over 40 goats in open terrain. They run instead of stopping like they do on cliffs. And what they do on rough terrain is spread out all over, or run into trees.

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and Goat Counc. 3:374-390

WINTER STUDIES OF FOREST-DWELLING MOUNTAIN GOATS OF PINTO CREEK, ALBERTA

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ABSTRACT

As a result of increased interest in petroleum development within the Pinto Creek Mountain Goat Reservation, a study was initiated to assess the potential impacts on this atypical population of forest-dwelling mountain goats (Oreamnos americanus). Baseline data were collected on the habits, distribution and basic ecology of the population during the winter of 1981. Suspected population limiting factors and the possible effects of future petroleum development are discussed.

INTRODUCTION

Management studies were initiated in 1980 to examine the potential impact of a proposed natural gas well on the forest-dwelling mountain goats of Pinto Creek, Alberta. Pinto Creek, despite being biogeographically isolated from typical mountain goat range by many kilometers of dense forest, provides suitable habitat for mountain goats. Although solitary mountain goats have been observed in other areas within the foothills of west-central Alberta, Pinto Creek provides the longest term example of a goat herd known to reside in a forested area in Alberta. The known range of the Pinto Creek herd consists of a 13 kilometer section of Pinto Creek and the area surrounding its junction with Hightower and Wroe Creeks. This area offers the only known occupied habitat suitable for mountain goats in the study area.

Mountain goats have inhabited Pinto Creek at least since 1945 and may have used the area as early as 1931 (Kerr 1965). A series of cliffs are connected by regularly used trails through forested areas. The proposed wellsite would be located within 400 m of one of these trails (Figure 1).

Little data is available on the subject of harassment (as defined by Geist 1975) of mountain goats. However, some applicable information is available. Singer (1978) examined the influence of a highway on mountain goat movements to mineral licks and demonstrated a negative correlation of highway crossings towards vehicular and human activity. McFetridge (1977) suggested that where resource development overlaps goat range, the impact on the resident herd may be severe, particularly if a core refuge is disturbed. He indicated "that the total area used by goats, or the frequency of excursions, might be reduced by the presence of heavy

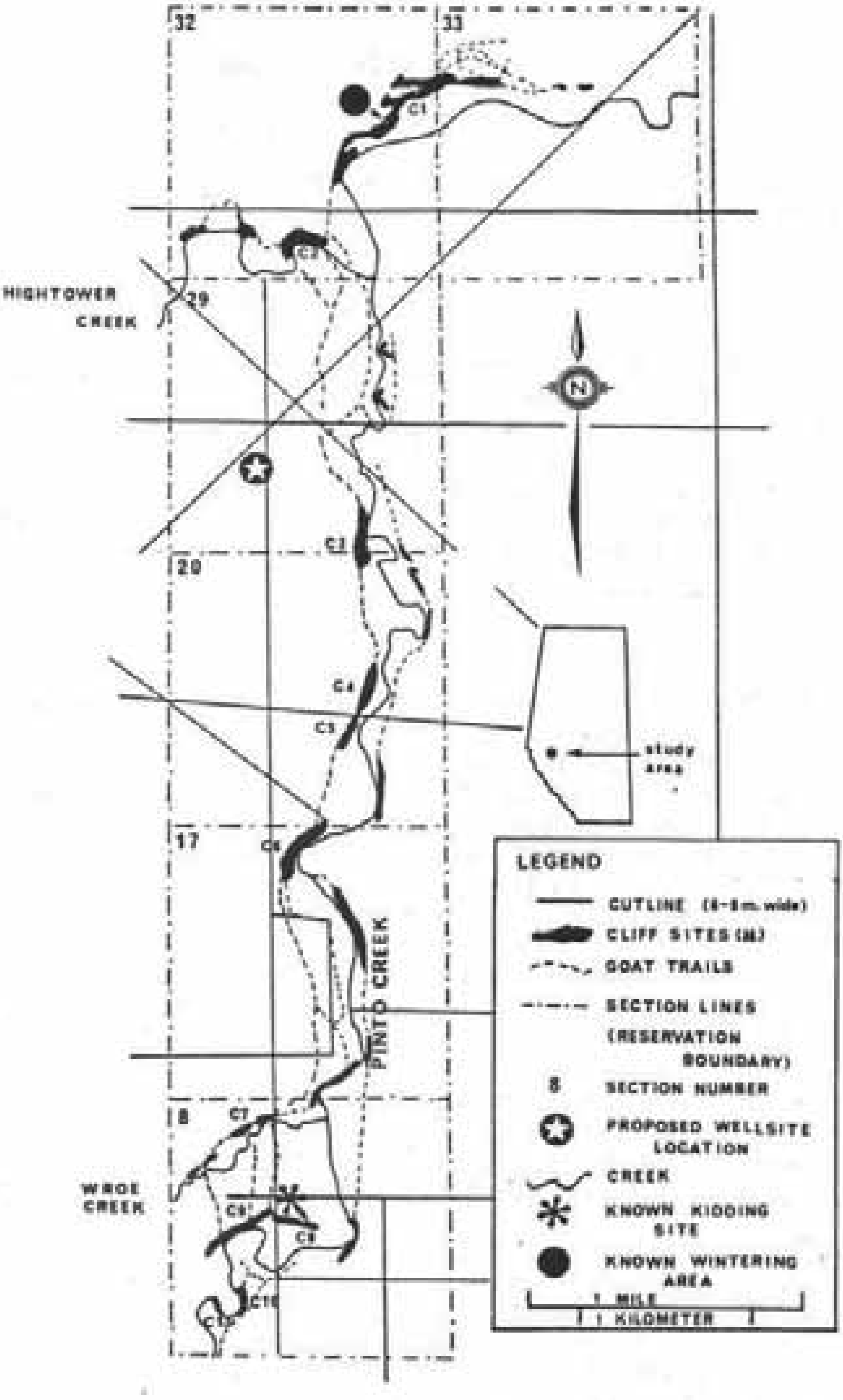

Figure 1. Pinto Creek mountain goat study area.

predation or regular interference by human activity" (p. 84). It was also suggested that the absolute amount of forage available to any herd of mountain goats is a function of the distance that they will travel from core areas of high security. Thus food is a key limiting factor for both the size and distribution of mountain goat herds. Furthermore, it appears that mountain goats are a species particularly vulnerable to disturbance and this high sensitivity should be reflected in management strategies. (Hunting has not been allowed in this area since 1964.)

Preliminary data from aerial surveys have indicated that mountain goats are more tolerant of activity located below them than from above (Bill Hall, Section Head - Wildlife management, Alberta Fish and Wildlife Division, Edmonton, Alberta, pers. comm.). This also has been documented for bighorn sheep (*Ovis canadensis*) (Geist 1971, Hicks and Elder 1979). Therefore wildlife managers have expressed particular concern that the location of a wellsite on the same contour or slightly above the goat trails will result in habitat alienation through direct disturbance. The ultimate impact would be disappearance of the herd.

Data was collected from 17 January - 13 April, 1981 to determine the habits, distribution and basic ecology of the population during winter and early spring. The purpose of the study was to ascertain whether or not development is compatible with management of these goats.

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STUDY AREA

The study area is located almost entirely within Township 55, Range 26, west of the 5th meridian approximately 38 km northeast of the nearest Rocky Mountain ranges. Total relief varies by less than 110 m throughout the study area (1112 - 1220 m elevation). Rowe (1972) has classified the area as Upper Foothills. The area largely consists of a gently rolling forested plateau dominated by lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*). The steeply dissected valley breaks are dominated by poplar (*Populus tremuloides*) in the forest canopy and rose (Rosa sp.), dogwood (*Cornus stolonifera*), willow (*Salix* sp.), silverberry (*Eleagnus commutata*), buffalo berry (*Shepherdia canadensis*), raspberry (*Rubus* sp.) and various graminoids in the understory. Pinto Creek is bordered by rock walls, characterized by eroded sandstone and bedrock formations. These cliffs are dominated by bearberry (*Arctostaphylos uva-ursi*) and several graminoids including hairy wild rye (*Elymus Innovatus*), bluegrass (*Poa* sp.), fescues (*Festuca* sp.), wheat grass (*Agropyron* sp.), and sedges (*Carex* sp.). Talus-like slopes often are found at the base of the cliffs. In some cases muskegs, dominated by black spruce (*Picea mariana*), separate the cliffs from Pinto Creek. Similar habitat types are found at the junctions of Wroe and Hightower Creeks.

METHODS

Observations were made with the aid of a 20-40X variable spotting scope and 8 X 40 binoculars. The mountain goats were located each day and observed from the other side of the valley at a distance of approximately 400 - 600 m.

Sex class was determined by horn curvature, urination posture, or both. Individuals were classified as kid, juvenile or adult based on body size (Debock 1970). As the observers became familiar with each individual by sex, horn size and configuration and body size a permanent identificaton number was assigned.

A system of track transects was established along known goat trails (identified by the presence of goat hair, pellets and tracks). These transects were checked periodically to determine daily movements between cliff complexes. Weather conditions and snow depths also were recorded at that time and old tracks erased.

Food habits and habitat selection were determined by direct observation and examination of bedding and feeding areas. In addition, pellet groups were collected and analyzed for lungworm levels using the Baerman technique as described by Samuel and Gray (1982). Fecal crude-protein levels were determined by the Kjeldahl method (Association of Official Analytical Chemists 1965). Wolf (Canus lupus) scats also were collected and analyzed for the presence of mountain goat hair.

Daily activity patterns were determined by recording the total time spent at each activity (bedding, standing, feeding and moving while not feeding) during daylight hours. (One observation hour is 1 mountain goat observed for 60 minutes or 6 goats observed for 10 minutes each). Total observation times varied from 1 to 9 hours per day.

Average hourly temperatures were calculated for each day mountain goat observations were made. The data were obtained from the nearest continually operating weather station at Edson, approximately 90 km southeast of Pinto Creek.

RESULTS AND DISCUSSION

During the study period, the herd was comprised of 3 adult females, a single 2 year old female, 2 adult males, 1 yearling male and 1 male kid for a total of 8 (Table 1). The size of the herd appears to have remained fairly constant in recent years and probably never consisted of more than 12 animals from 1942 - 1962 (Stelfox and Kerr 1962).

The nannies, kid and yearling male were first observed in the northern extent of the study area on 16 January 1981 (Figure 1, cliff #1). By 30 January the entire herd (including the 2 adult males) was observed on this cliff complex. They remained in that area until at least 17 March 1981.

Table 1. Historical mountain goat herd structures in Pinto Creek, Alberta.

Year	≥ Three years		Two years		Yearlings	Kids	Total
	males	females	males	females			
1962[1]	4[4]	5	1	2	3	2	17
1976[2]	7 adult goats				1	1	9
1977[3]	6 adult goats				1	2	9
1981	2	3		1	1 male	1	8

[1] (from Kerr 1965)

[2] (from Bibaud and Hall 1976)

[3] (from Bibaud 1977)

[4] (two adult males collected)

Examination of track transects on 25 March 1981 indicated that all of the goats with the exception of 1 adult male moved to the cliff complexes in the southern portion of the study area (cliffs 8 and 9, Figure 1). The goats remained in these same general areas until the termination of field work on 15 April 1981.

The cliff (#1) where the goats spent the majority of the winter is the largest of the south facing cliff complexes in the study area and provides the largest continuous snow free area. Bedding sites on all cliffs typically provided a clear view of the creek valley. However, some bedding sites were found up to 70 m from the cliff edge within the lodgepole pine forest (the majority was within 10 m).

Examination of the vegetation not covered by snow indicated that the majority of dominant shrubs, forbs and graminoids mentioned in the study area description was used as forage. In addition, the goats appeared to be pawing at bearberry in order to expose the roots. Most feeding took place within 50 m of escape terrain. However, on one occasion goats were observed feeding in a lodgepole pine forest as far as 400 m from the nearest cliffs. (Cranberry was the major plant species exposed in craters in the snow).

Daily activity patterns were characterized by bedding early in the day while feeding activity increased towards evening (Figures 2, 3). The lack of early morning activity corresponds with that reported by Geist (1971) and probably is a behavioral adaptation which minimizes energy expenditures during the colder periods of a winter day. A comparison of percentage of standing activity (includes standing, moving and feeding) with the average temperature on an hourly basis may partly explain this phenomenon (Figure 4). (Two linear regression formulas were calculated from the data presented in Figure 4: one formula incorporates all data points, the other formula does not include the outlying data point for the last hour of observation during the day. It is hypothesized that feeding might be overrepresented in the activity pattern at the end of the daylight period (regardless of ambient temperature) if the daily forage requirement had not been met by that time. When the data point for the last hour of observation during the day is ignored, the relationship becomes highly significant ($p < 0.01$). Reducing early morning activity would minimize heat loss by exposing the least amount of body surface area during the coldest period of the day. The resulting reduction of feeding periods would be consistent with the voluntary decrease in food consumption demonstrated by deer (Moen 1973) and moose (Heptner and Nasimovitsch 1968, cited by Geist 1971) in winter months. However, these data may be biased by the fact that direct animal observations were made only when goats were visible on the cliffs. If the majority of bedding activity was limited to cliffs, feeding would be underrepresented in the activity budget (goats were often observed feeding as they disappeared from view). This was particularly relevant to the observations of the adult males and for this reason the data comparing standing activity and average hourly temperature for adult males is not included. On numerous occasions they were not observed for the entire day

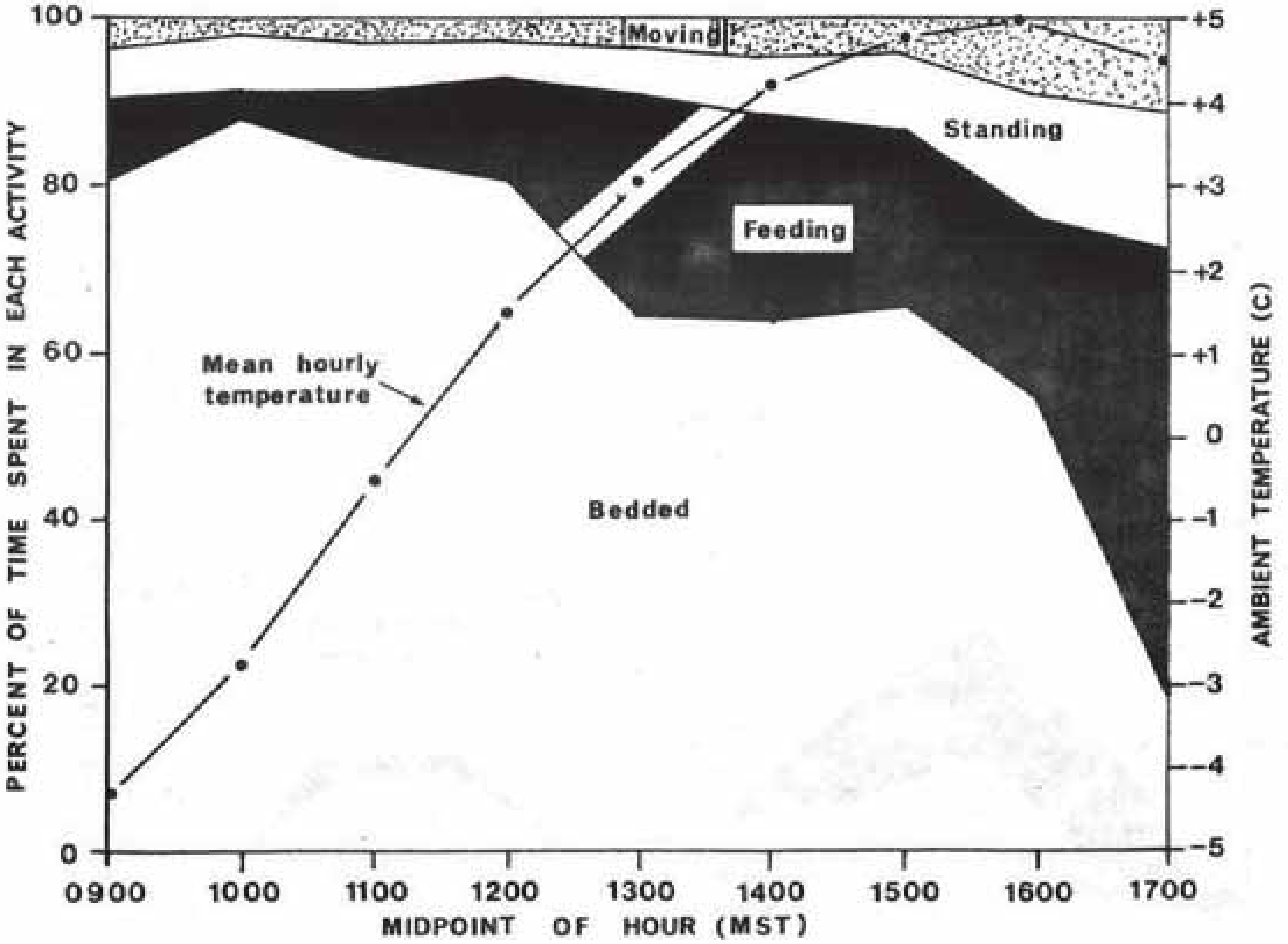

Figure 2. Percentage of time spent by nannies, kid and juvenile male in Pinto Creek, Alberta based on 498 observation hours during January 17 - April 13, 1981. Mean hourly temperature calculated from Edson, Alberta for those days mountain goat observations were made.

[a] Moving while not feeding.

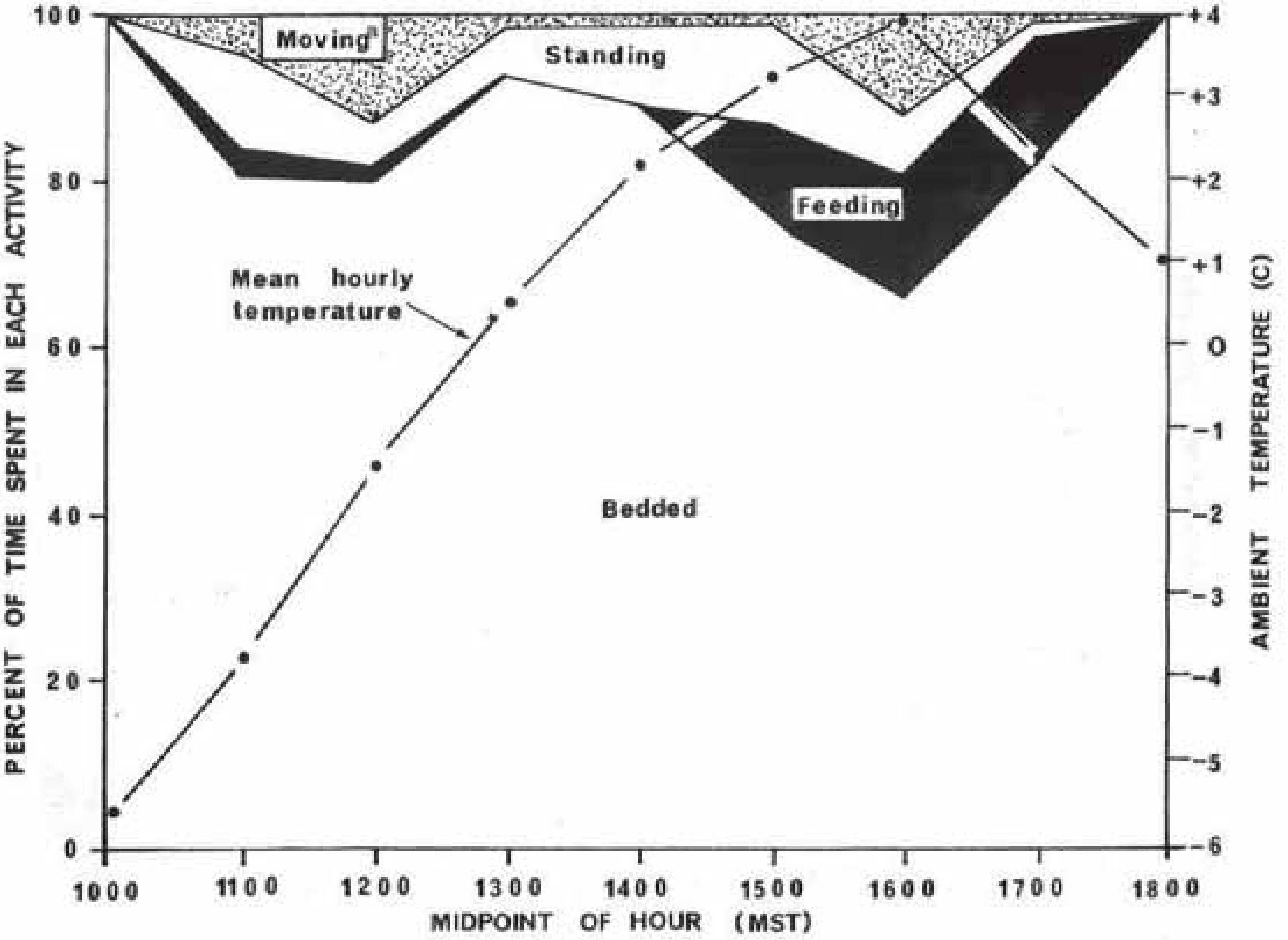

Figure 3. Percentage of time spent by adult billies in Pinto Creek, Alberta based on 52.3 observation hours during January 17 - April 13, 1981. Mean hourly temperature calculated from Edson, Alberta for those days mountain goat observations were made.

[a] Moving while not feeding.

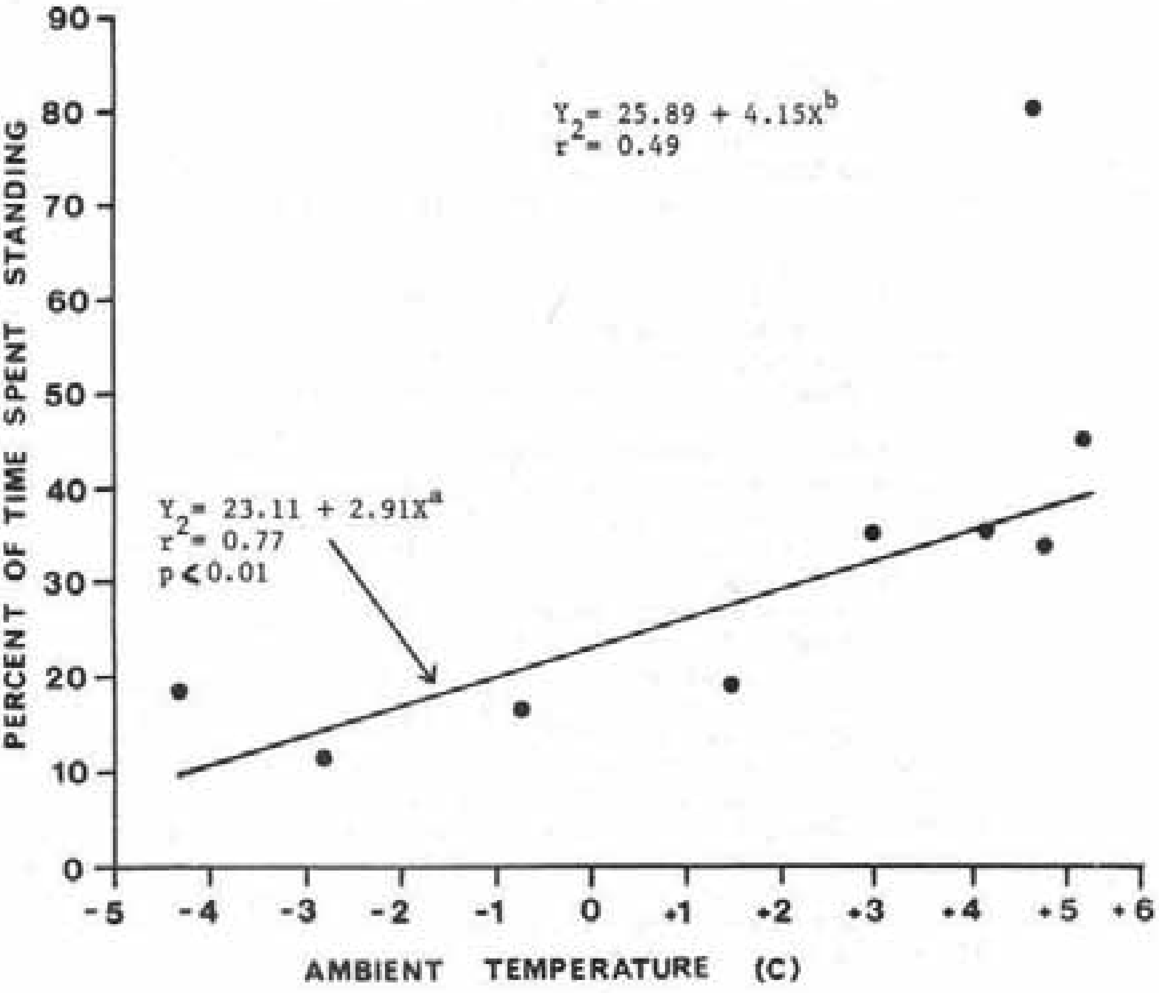

Figure 4. Relationship of percent of time nannies, juvenile male and kid spent standing (includes moving, feeding and standing) to varying ambient temperatures. Ambient temperature calculated as hourly means from Edson, Alberta for those days mountain goat observations were made.

[a] This linear regression formula does not include the outlying data point representing the last hour of observation during the day.

[b] This linear regression formula includes all data points.

even though track transects did not indicate that these animals had moved to adjoining cliff complexes. In these cases, all their activities occurred in, or near the forest. Geist and Petocz (1977), observed mature bighorn rams utilizing slopes significantly further from escape terrain than ewe-lamb groups and the same could hold true for mountain goats. In addition, the ability of male ruminants to limit food intake much more than female-young groups (Moen 1973) helps to explain the data presented in Figure 3. Continuous observations of the nanny-juvenile male-kid group indicates that the data more accurately reflects their actual activity patterns.

LIMITING FACTORS

Potential factors which might be individually or collectively limiting the Pinto Creek mountain goat herd include: illegal hunting, predation, emigration, interspecific competition, parasites, inbreeding and limited range.

Direct evidence does not exist which suggests that illegal hunting is limiting the herd, although access is readily available during winter months by snowmobile. However, this possibility can not be eliminated because poaching is very difficult to document.

Predation is another possible limiting factor. Wolf tracks were observed on the study area in late January and late March. Although evidence of mountain goat was not found in wolf scats collected during the summer of 1980 (N=7) it is possible that wolf predation could have a significant impact on the mountain goat population, particularly if wolves were to encounter goats between cliff complexes. (Mountain goats would be more vulnerable to wolf predation in these areas due to the lack of escape terrain). In addition, lynx (Lynx lynx) and black bear (Ursus americanus) tracks and golden eagles (Aquila chrysaetos) were observed on the study area. Furthermore, a significant grizzly bear (Ursus arctos) population (estimated at one bear per 70 sq. km) inhabits the general area (Nagy 1982). All of these species could prey upon mountain goats. If emigration is maintaining the band at a constant level, those animals have not been observed as established herds in similar areas. Predation may be limiting the opportunity for this to occur. Mountain goats have been observed on the Berland River (downstream destination of Pinto Creek via the Wildhay River) for short durations.

Elk (Cervus canadensis), moose (Alces alces) and mule deer (Odocoileus hemionus) are found in the study area. Although all 3 ungulates utilize forage species common in the diet of mountain goats, their preferred habitats differ; goats prefer areas close to the cliff faces, a zone the other species usually do not occupy.

Results of fecal analyses suggest high levels of "lungworm" infections (Figure 5). Levels of larvae of the nematode family Protostrongylidae in goat feces are higher than reported for other mountain goat populations (Cooley 1976, McFetridge 1977), however, these authors did not sample goats during the late winter-spring when the highest counts are usually recorded (Bill Samuel, Department of Zoology, University of Alberta, Edmonton, Alberta, pers. comm.). Although most larvae were straight-tailed and presumably are *Protostrongylus stilesi* or *P. rushi*, the usual lungworms of goats (Samuel *et al.* 1977), 85 percent of 15 samples examined under a compound microscope contained some spined larvae (not *Protostrongylus* sp.). Spined larvae were also found in 58 and 70 percent of the goats from the Skeena and Stikine Rivers, respectively, in British Columbia (Samuel and Foster, unpubl. data). The identity of this larvae has not been confirmed, however, several possibilities exist. *Parelaphostrongylus odocoilei* adults were recovered recently from a mountain goat from Washington State and one from Jasper National Park, Alberta (Margo Pybus, Bill Samuel, Department of Zoology, University of Alberta, Edmonton, Alberta and Bill Foreyt, Department of Veterinary Microbiology and Pathology, Washington State University, Pullman, Washington, unpubl. data). In addition, adult lungworms of the genus *Muellerius* were recovered from bighorn sheep lungs from the "Black Hills" of South Dakota and also could occur in mountain goats (Pybus and Samuel, unpubl. data). Their larvae are spined.

It was also found that 2 percent of the dorsal spined larvae also had a ventral spine on the tail. Double spined larvae have not been reported in feces of North American wild ruminants, but are known from *Chamois* (*Rupicapra*) in Europe and may be similar to those found in feces from mountain goats (also rupicaprids) in Pinto Creek (B. Samuel, pers. comm.). There also is a possibility that the nematode has not been described previously. In summary, more than the usually-recorded *Protostrongylus* spp. occur in the Pinto Creek goats. Whatever their identity, continuous use of restricted range throughout the year increases the possibility of reinfection by them.

Inbreeding could be a factor limiting population growth. "A review of the literature shows that even a small amount of inbreeding typically undermines fecundity and viability" (Soule 1980, p.168). Ralls et al. (1979) presented data "which suggests that increased juvenile mortality in inbred young is a general phenomenon in ungulates" (p.1102). Furthermore, based on a rule of thumb employed by animal breeders, the basic rule of conservation genetics is that the maximum allowable rate of inbreeding is 1 percent, which corresponds to a genetically effective population size of 50 (Soule 1980, p.168). (The Pinto Creek herd totalled 8 during the winter of 1981). However, limited observations suggest that immigration occassionally occurs and could contribute genetically to the population. (Two males collected by Kerr were physically comparable to mountain goats from populatins with much larger gene pools (Kerr 1965, Rideout 1978).

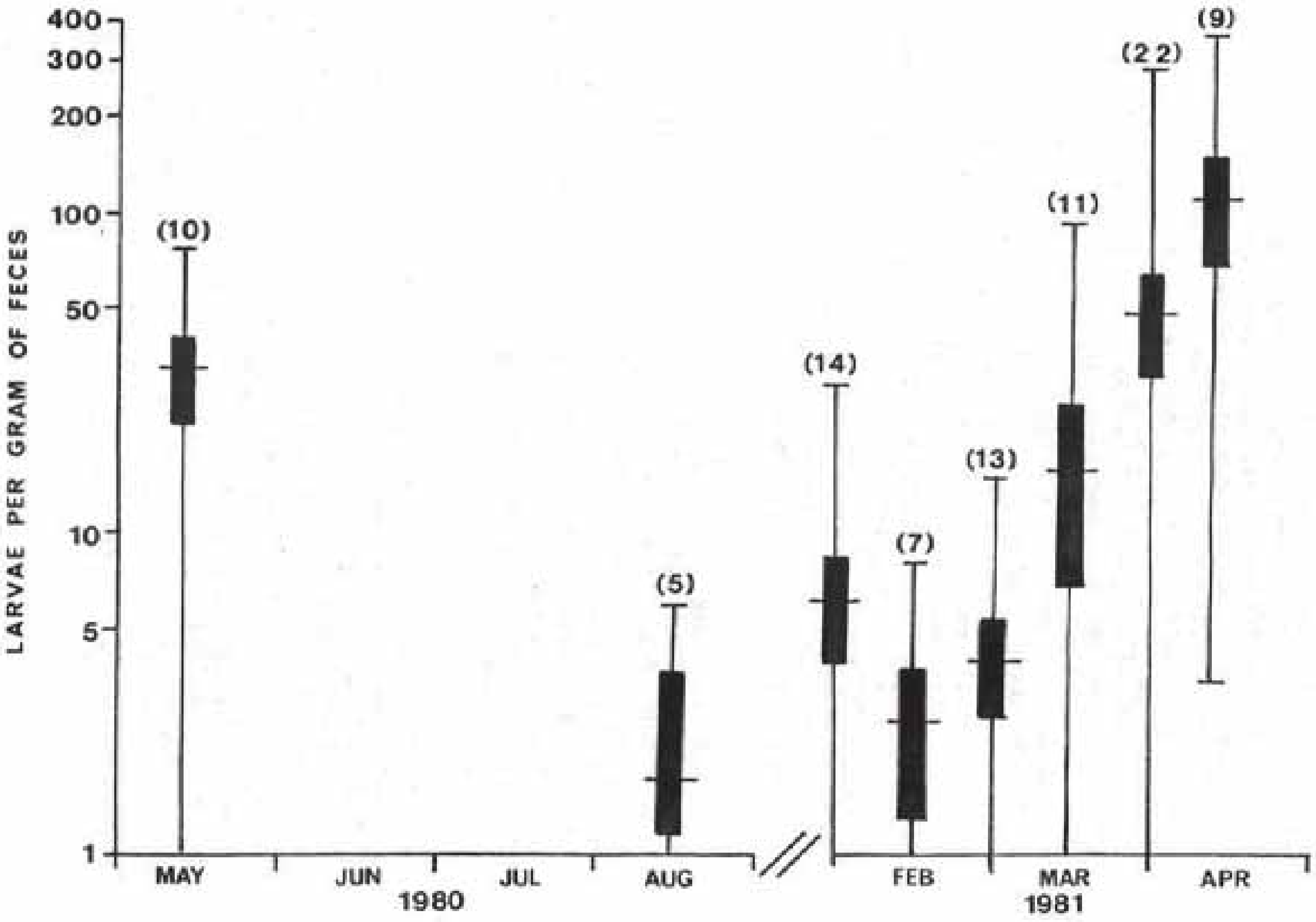

Figure 5. Seasonal changes of larvae of the nematode family Protostrongylidae in mountain goat feces from Pinto Creek, Alberta, 1980-1981. Means, ranges, ± one standard error and sample sizes (in parentheses) are presented.

Fecal crude-protein values (Figure 6) were comparable to those observed in other mountain goat populations (McFetridge 1977). The available forage appears to be of sufficient quality to provide a suitable plane of nutrition. However, the reliance of the herd on a single cliff complex for the majority of the winter suggests that a combination of range and availability of secure habitat might be a significant limiting factor on herd size.

All of the aforementioned factors, with the exception of interspecific competition, may be playing an active role in limiting the Pinto Creek goat herd.

POSSIBLE EFFECTS OF PETROLEUM DEVELOPMENT

The Pinto Creek goat herd has successfully colonized a very restricted range. Limited observations during the year indicate that continuous movement between cliff complexes is typical for all seasons, with the exception of winter, suggesting a rotational-like grazing system. Any disturbance of this routine could severely limit alternatives for the herd. Therein lies the most detrimental possible effect of drilling an exploratory natural gas well within the Pinto Creek study area. The herd could be forced to abandon all, or part of its core range of high security because of activities associated with petroleum development. This could result in the demise of the herd due to the lack of alternative and suitable habitat with escape terrain. Abandonment could be the result of visual, auditory and olfactory stimuli related to drilling activity or direct human harassment.

More subtle impacts might include disruption of daily activity patterns, habitat selection, and seasonal distribution. This would disrupt the herd's ability to use an already limited range and thus could affect the viability of the population by reducing productivity. Increased access would also increase opportunities for illegal hunting.

Habituation, similar to that documented for highway crossings by mountain goats (Singer 1978) might be the only possible behavioral alternative if the Pinto Creek goats are to survive with development. Evidence to date suggests that the disturbance must occur predictably and persistently to allow for habituation (Geist 1978); criteria somewhat foreign to petroleum development. Even if this can be accomplished, factors such as illegal hunting, and human harassment will be very hard to control after the initial access is provided and could severely affect the Pinto Creek herd.

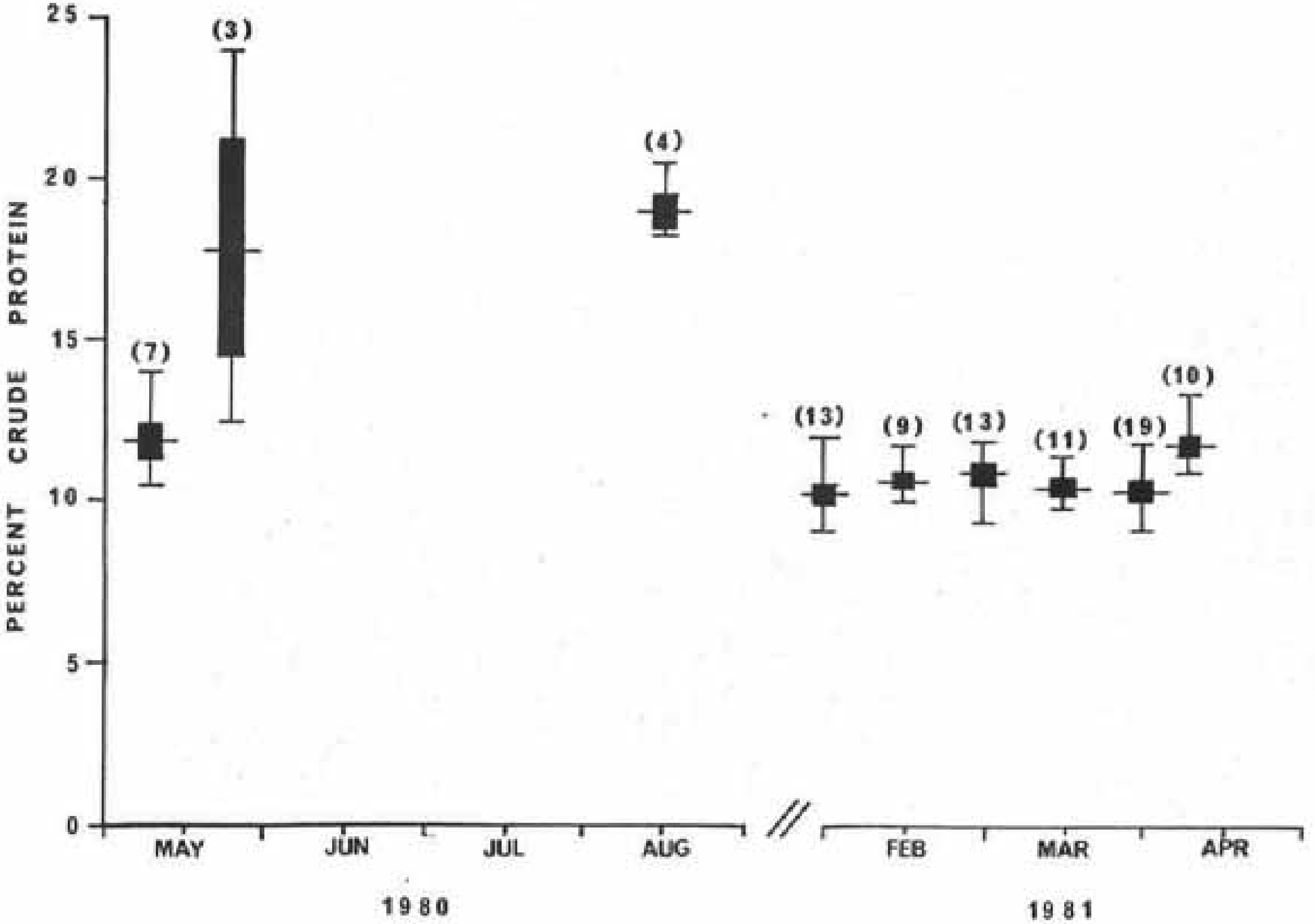

Figure 6. Seasonal changes in fecal crude protein content of mountain goats from Pinto Creek, Alberta 1980-1981. Means, ranges ± one standard error and sample sizes (in parentheses) are presented

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CONFERENCE DISCUSSION

Q. Was there any attempt by the oil company to move their wellsite further away from Pinto Creek by direction drilling?

Ans. The proposed location would require directional drilling. We were given the impressiong that the "gas pocket" is underneath Pinto Creek itself and the proposed location was the maximum distance the wellsite could be removed from the target area.

<u>Q</u>. Do you have any information regarding the impact of petroleum activity on other species in your region that you could apply in this situation?

<u>Ans</u>. Yes, we have limited data for elk, moose and deer, however, we felt that the forest-dwelling goat population was somewhat unique and therefore warranted special attention. We weren't prepared to extrapolate the information from the other species since we were concerned that goats would be more sensitive to distrubance, particularly in this situation.

<u>Q</u>. Do you realistically feel that you can control petroleum development because of 8 mountain goats?

<u>Ans</u>. I'm confident that if the research indicates that there is a very high probability of petroleum activity resulting in the demise of the goat herd, that we would be successful in avoiding it. Although we know of two other small herds in similar habitats which are equivalent distances from mountain ranges, they do not appear to be as successful. One could take the opposite approach and ask the question "Do you feel that this atypical mountain goat herd should be sacrificed at the expense of a natural gas well of which hundreds are currently capped in Alberta but not producing because of lack of market or low prices"? I admit an oil well would be a different situation. Perhaps an analogy in the U.S. would be the concern over 250 snail darters and the proposed dam which could adversely affect them, although I admit I'm not well informed on that situation.

<u>Q</u>. Have you looked at alternatives to cancelling the petroleum lease?

<u>Ans</u>. Perhaps one option would be to transplant the goats, however, as I mentioned previously, the herds in similar habitats have not been doing well. We have transplanted goats from one mountain complex to another in Alberta, but that herd is only maintaining itself at very low numbers and doesn't appear to be expanding.

Another option might be to exchange the drilling rights for adjoining lands or lands in other promising gas fields, however, the companies' argument would probably be that they are reasonably confident they would be successful at Pinto Creek based on considerable exploration (seismograph) effort and this could not be guaranteed in other areas. The Alberta government does not have a record of returning monies collected for mineral rights.

Bienn. Symp. North. Wild Sheep
and Goat Counc. 3:391-405

MOVEMENT AND HOME RANGE OF MOUNTAIN GOATS,

SHEEP MOUNTAIN-GLADSTONE RIDGE, COLORADO

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ABSTRACT

During summer 1979, 24 mountain goats (Oreamnos americanus) were marked with individually identifiable canvas collars and/or eartags to determine movements and home ranges of goats on Sheep Mountain and Gladstone Ridge, Colorado. Marked goats were observed June-August 1979, January-March 1980, and June-August 1980. Greatest linear distance between any 2 observations of an individual was used as an index of home range size for each goat. During the 2 summers, there was no significant difference in average home range size between sexes. Summer home ranges averaged 8 times the size of winter home ranges. During both summers, home ranges expanded as forage turned green and snow disappeared at higher elevations. Goats frequently moved back and forth between salt licks on and near Sheep Mountain and alpine tundra areas on Gladstone Ridge and associated peaks, a distance of at least 5 km. During winter, goats remained within relatively small home ranges, although they were not limited to these areas by deep snow. Small home ranges may be an energy-conservation strategy in winter. During both seasons, females were reobserved more often than were males. This may have been due to males being in smaller and therefore less detectable groups, or to males having a greater tendency to disperse. One male dispersed from the study area and was seen in 1980 and 1981 on Mount Shavano, a linear distance of 16 km from Sheep Mountain.

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INTRODUCTION

Movements and home ranges of Rocky Mountain goats, particularly in winter, are little known due to the remoteness and rugged character of areas they inhabit. This facet of mountain goat ecology is particularly important in Colorado where mountain goats have been introduced outside their natural range and may compete with native bighorn sheep (Adams et al. 1982). Knowledge of seasonal home range size, movement patterns, relation of mineral licks to such patterns, and dispersal capabilities of mountain goats will be useful in assessing the potential for expansion of mountain goat populations onto ranges of existing bighorn herds.

The literature offers little information on movements and home ranges of mountain goats. Rideout (1974) radiocollared 16 goats in Montana and recorded their movements mainly from May to November with limited data collected during winter. Smith (1976) determined seasonal home ranges of 6 goats in the Bitterroot Mountains of Montana. The radio telemetry studies being conducted by Schoen (Unpub. Alaska Fed. Aid Prog. Rep. W-17-11-12.4R, 1979), Nichols (1982), and Smith and Raedeke (1982) are the most intensive investigations to date, but have been initiated recently with few results reported. Some information can be gleaned from occasional comments scattered throughout mountain goat literature, but these 5 studies represent the bulk of existing information on movements and home ranges of mountain goats.

Objectives of this study (Adams 1981) included determining home ranges and monitoring movements of 24 marked mountain goats on Sheep Mountain-Gladstone Ridge, in the Sawatch Range of central Colorado. We gratefully acknowledge the financial support of the International Order of Rocky Mountain Goats, the National Wildlife Federation, Colorado State University (CSU), the Hill Memorial Foundation, and the Colorado Division of Wildlife (CDOW). T. Dailey, J. Howlett, T. Spezze, H. Hood (CDOW), B. Trentlage, S. McCollough (CSU), and R. Smith (US Forest Service) assisted with the trapping and marking operations. We also acknowledge support provided by S. Ogilvie, D. Reed (CDOW), B. Lyons (US Forest Service), and E. Maben.

DESCRIPTION OF STUDY AREA

The study area is located 11 km west of Buena Vista, Colorado in the Arkansas River drainage. Boundaries of the area are the continental divide, Middle Cottonwood Creek, and South Cottonwood Creek. Major geographic features included Sheep Mountain (3640 m), Gladstone Ridge (4027 m), Jones Mountain (4031 m), and Mount Kreutzer (4000 m). Elevation ranged from 2775 m at the confluence of South and Middle Cottonwood Creeks to 4031 m at the summit of Jones Mountain (Fig. 1).

Treeline occurs at about 3600 m depending on topography. Tundra vegetation consists mainly of grasses, sedges, and forbs with patches of Englemann spruce (*Picea englemanni*), bristlecone pine (*Pinus aristata*), and willow (Salix spp.). Common plants include Carex spp. Agropyron scribneri, Oreoxis alpina, Trifolium nanum, and Geum rossii. Below treeline is a forested zone dominated by Englemann spruce, Douglas fir (Pseudotsuga menziesii), limber pine (Pinus flexilis), and bristlecone pine. Other major plants below treeline include Muhlenbergia montana, Festuca arizonica, Artemisia frigida, Holodiscus dumosus, and Populus tremuloides. Previous research on this area has been reported by Bailey and Johnson (1977), Johnson et al. (1978), Adams (1981), and Adams and Bailey (1980, 1982, 1983).

METHODS

In August 1978, an adult female mountain goat was collared on the study area. From May to July 1979, an additional 23 goats (19 adults, 4 yearlings) were captured and marked (Adams 1981). All goats were captured in Clover traps (Clover 1956) over artificial mineral licks at Cottonwood Lake and Porphyry Gulch (Fig. 1). Both licks were established at least 2 years in advance and were used regularly by goats prior to constructon of traps on the sites.

Adults were collared with 10-cm wide colored and/or numbered vinyl-covered canvas collars and eartagged with numbered 5-cm Ritchey cattle eartags. Males were marked with green eartags and females with yellow eartags. Yearlings were eartagged by not collared. Kids were released unmarked.

Marked goats were observed June-August 1979, January-March 1980, and June-August 1980. Observations were recorded to the nearest ha using a gridded 15-min U.S.G.S. topographic map (Adams (1981).

The greatest linear distance between any 2, not necessarily consecutive, observations of an individual was used as an index of home range size for each goat. This was appropriate since the study area is linear in shape (Fig. 1).

RESULTS

SUMMER

During summer, marked mountain goats were observed ranging over large portions of the study area. Goats observed on Sheep Mountain during June stayed in that area until the end of the month, then moved on to other parts of the study area (Fig. 2). Marked goats moved erratically over much of the study area during the rest of the summer (Fig. 3). An adult female, R46, was observed to move 8.6 km, between Gladstone Ridge and a mineral lick on Sheep Mountain in 24 hours or less.

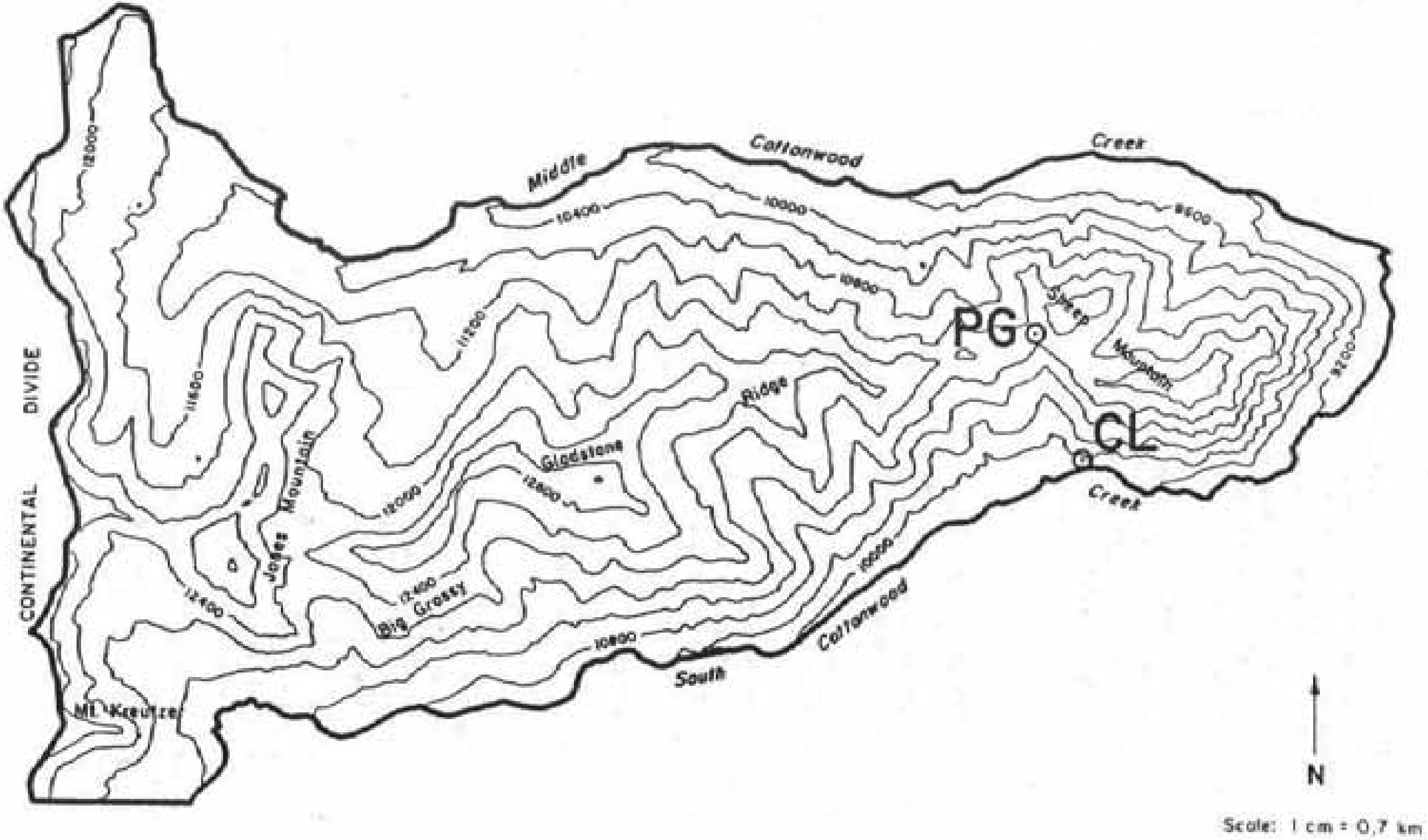

Fig. 1. Major geographic features and trapsites, Sheep Mountain-Gladstone Ridge, Sawatch Range, Colorado. PG=Porphyry Gulch trapsite, CL=Cottonwood Lake trapsite.

The greatest linear distances across the home ranges averaged 6.4 km for the 2 summers (Table 1). There was no significant difference in average home range size between sexes. Males were less apt to be reobserved than were females. Of 14 adult females collared by July 1979, 13 were reobserved an average of 1.8 times that summer (Table 2). Four of 6 collared adult males were reobserved an average of 1.3 times each that summer after release. Similar trends occurred in 1980 (Table 2).

One adult male, G2, was not observed during any of the 3 field seasons after he was collared. One unidentified green-collared male (presumably G2 but possibly G1 or G3) was observed during summer 1980 and 1981 on Mount Shavano, 16 km linear distance from Sheep Mountain. The probable dispersal route along the continental divide was over 30 km.

WINTER

Marked goats were more sedentary in winter than in summer. Typical winter movements were exemplified by 2 adult females (Fig. 4). Only 3 goats were observed to move more than 1.3 km. These goats were in a group observed on Mount Kreutzer during a helicopter survey on 22 January 1980. Goats were not observed in that area after the flight. It is possible that these long movements resulted from helicopter-related disturbance and are not characteristic of mountain goats in winter.

If the movements off Mount Kreutzer are ignored, the greatest linear distance covered by goats in winter averaged 0.7 km, based on 9 female goats (Table 3). However, if the movements off Mount Kreutzer are included, the average greatest linear distance covered was 1.7 km.

In winter as in summer, average number of reobservations for males was less than that for females (Table 2). Nine female goats were reobserved an average of 1.8 times, whereas of 3 males observed, only 1 was reobserved.

DISCUSSION

In summer, home ranges of mountain goats expanded as the season progressed and encompassed large areas. In June, goats observed on Sheep Mountain inhabited small areas (Fig. 2). During this time, forage was turning green at the lower elevations of the study area and these goats may have remained in the area to utilize succulent forage. These goats were also near mineral licks that may have attracted them. The rocky, broken terrain of southern Sheep Mountain is characteristic of kidding areas and goat G (Fig. 2) was observed with a small kid in the area on 25 June 1979. She was last observed on Sheep Mountain 3 days later, then was seen subsequently on Gladstone Ridge.

As summer progressed and vegetation turned green and snow dissipated at higher altitudes, mountain goat home ranges expanded (Fig. 3). Goats began utilizing alpine tundra summer range on Gladstone Ridge, but moved between

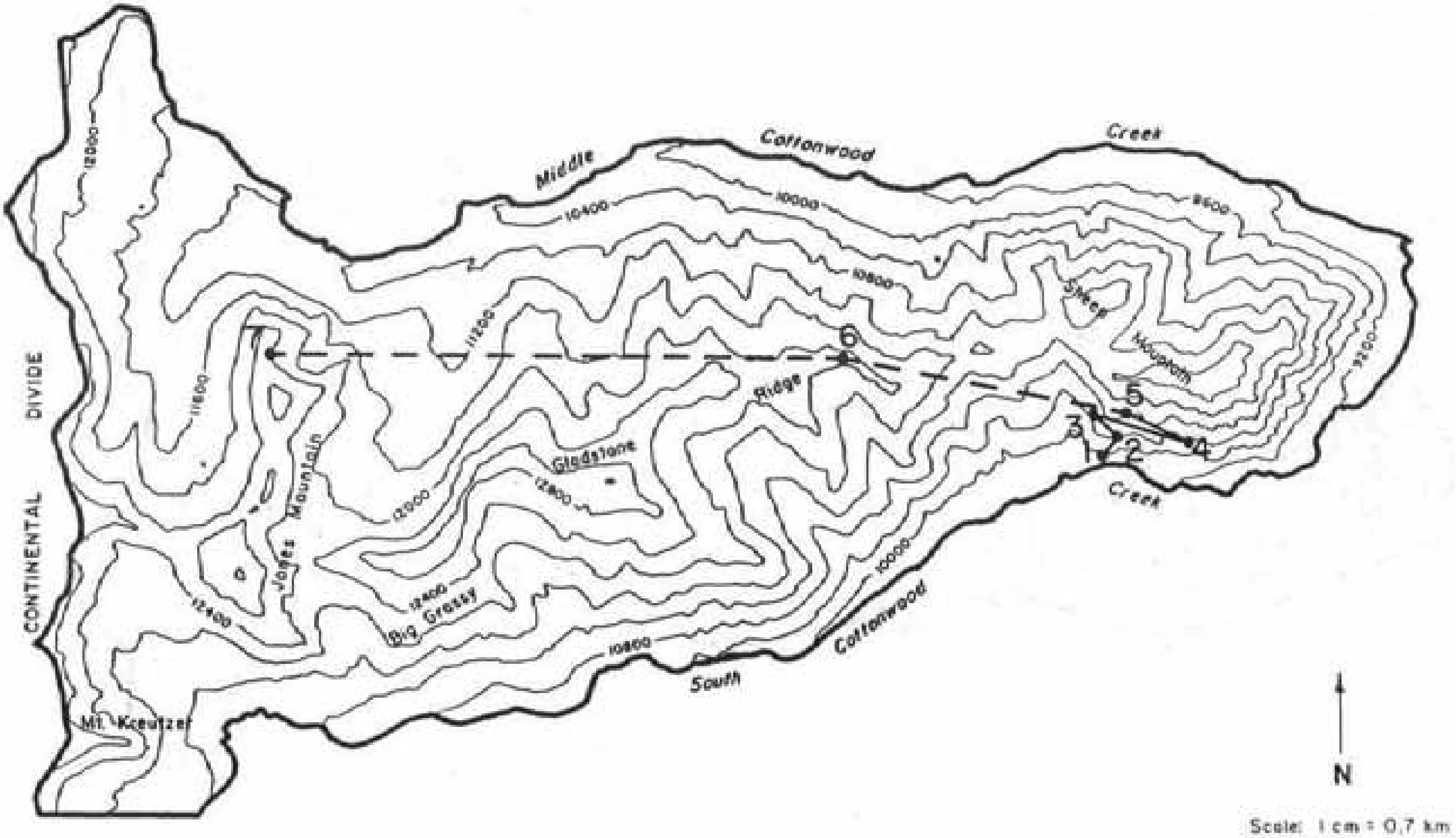

Fig. 2. Movements of adult female mountain goat, G, summer 1979. Sheep Mountain-Gladstone Ridge, Sawatch Range, Colorado. Solid line represents movements during June.

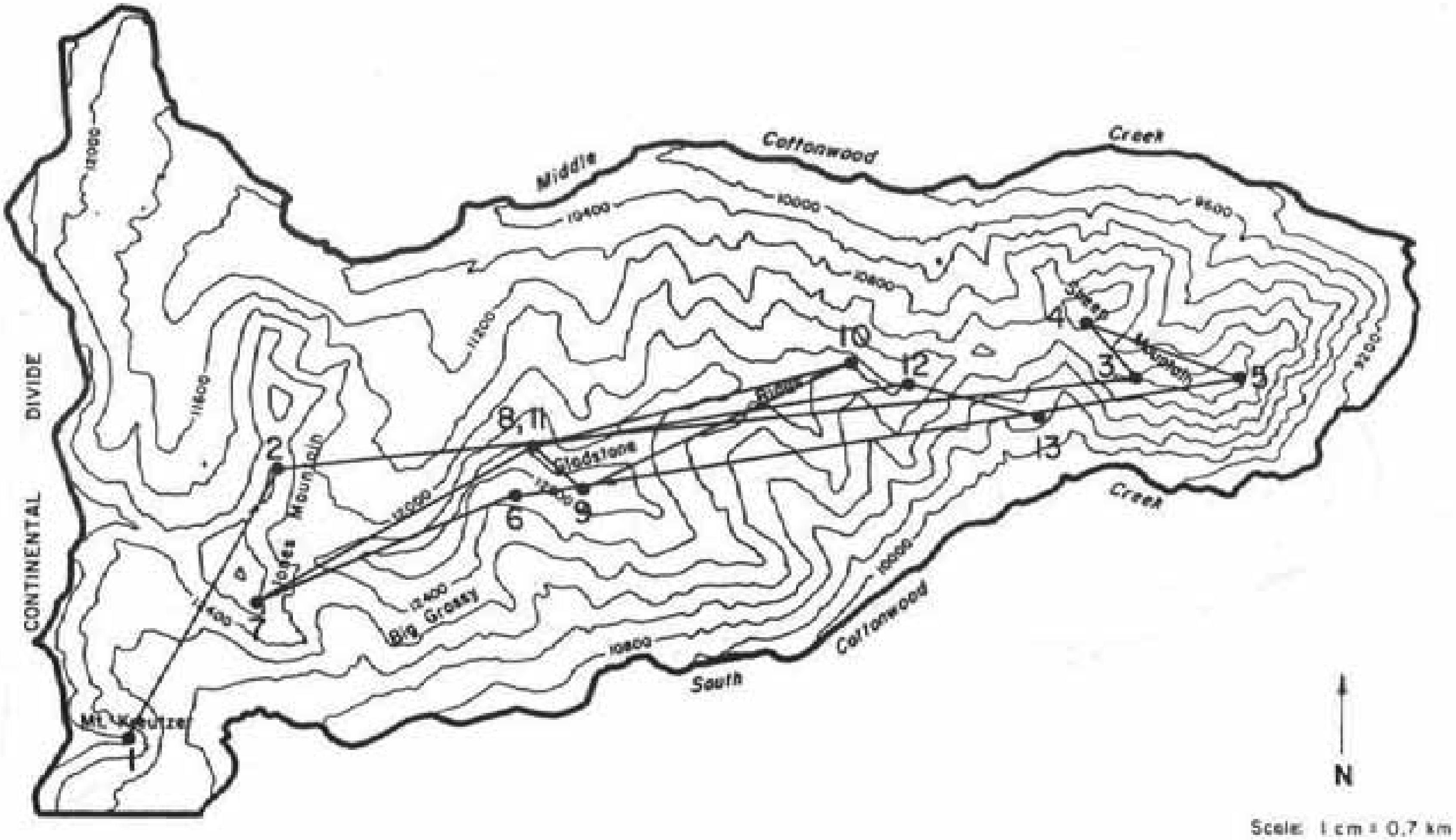

Fig. 3. Movements of adult female mountain goat, B59, summer 1980, Sheep Mountain-Gladstone Ridge, Sawatch Range, Colorado.

Table 1. Greatest linear distance between any 2 observations during summer for each goat, Sheep Mountain-Gladstone Ridge, Colorado.

		SUMMER 1979			SUMMER 1980		
MARKED GOAT	AGE (in 1979)	LENGTH OF OBSERVATION PERIOD[a] (days)	NUMBER OF OBSERVATIONS[b]	GREATEST LINEAR DISTANCE (km)	LENGTH OF OBSERVATION PERIOD[a] (days)	NUMBER OF OBSERVATIONS	GREATEST LINEAR DISTANCE (km)
FEMALES							
BR	3	69	4[c]	3.7	46	12	8.0
G	3	67	7	9.3	–	–	–
R92	2	26	6	1.6	47	6	6.1
YR	2	64	4	6.3	66	19	8.2
BW	2	42	5	7.2	62	13	9.4
R96	3	41	3	9.0	33	9	6.2
y6	1	34	3	3.1	55	7	2.1
R95	3	31	4	5.0	66	12	6.4
R97	3	17	2	3.4	46	7	8.3
B60	3+	34	5	6.2		HARVESTED IN 1979	
G4	3+	24	3	9.3	48	16	8.2
R46	2	22	3	8.6	66	12	6.7
y12	1	18	2	2.0	–	–	–
B55	3	–	1		44	11	11.0
B57	3+	12	2	0.7	48	11	8.3
B59	2	12	2	3.1	59	15	11.2
			mean=	5.2±1.5[d]		mean=	7.7±1.3[d]
				Overall Mean= 6.4±1.1[d]			
MALES							
WG	3+	47	4	7.4		HARVESTED IN 1979	
B56	2	15	2	9.2	63	8	6.6
g3	1	–	1		14	2	3.7
B58	3+	–	1		6	2	0.5
G2	2	–	1		–	–	–
g6	1	–	1		70	4	5.9
G1	3	6	2	9.2	–	–	–
G3	3+	32	5	9.2	–		–
			mean=	8.8±0.9[d]		mean=	4.2±2.7[d]
				Overall Mean= 6.5±2.2[d]			

[a] Period between first and last observation. [b] Includes trapping. [c] Trapped in 1978. [d] ±2S.E.

Table 2. **Reobservations of marked adult mountain goats, summer 1979-1980, and winter 1980, Sheep Mountain-Gladstone Ridge,** Colorado.

		SUMMER				WINTER	
		(9 June-21 August)		(3 June-19 August)		(17 January- 11 March)	
SEX	MARKED ADULT GOATS	NUMBER OBSERVED IN SEASON	REOBSERVATIONS PER GOAT	NUMBER OBSERVED IN SEASON	REOBSERVATIONS PER GOAT	NUMBER OBSERVED IN SEASON	REOBSERVATIONS PER GOAT
FEMALES	14	13	1.8	12	11.9	9	1.8
MALES	6	4	1.3	2	5.0	3	0.8

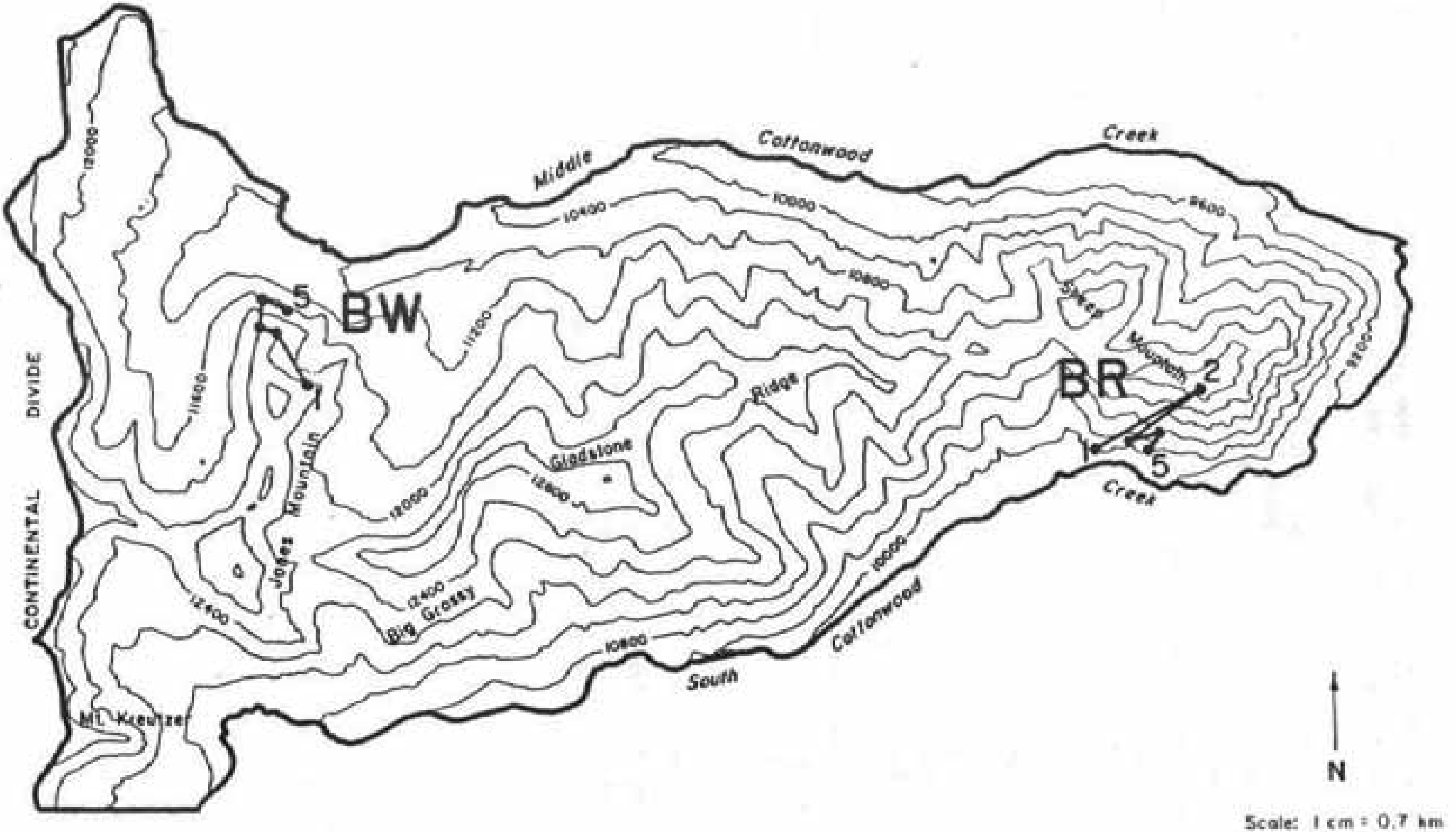

Fig. 4. Movements of 2 adult female mountain goats, BW and BR, winter 1980, Sheep Mountain–Gladstone Ridge, Sawatch Range, Colorado.

Table 3. Greatest linear distance between any 2 observations during winter 1980 for each goat, Sheep Mountain-Gladstone Ridge, Colorado.

MARKED GOAT	LENGTH OF OBSERVATION PERIOD[a,b] (days)	NUMBER OF OBSERVATIONS[b]	GREATEST LINEAR DISTANCE[b] (km)
FEMALES			
BR	34	5	1.3
R92	-	1	-
YR	9(50)	2(3)	0.2(4.7)
BW	50	5	1.1
y6	22	3	1.1
R97	2	3	0.4
G4	6	4	0.9
B55	9(50)	2(3)	0.2(4.7)
B57	10	2	0.4
B59	10	2	0.4
		mean=	0.7±0.3[c]
MALES			
B56	-	1	-
B58	-(16)	1(2)	(1.8)
G1	-	1	-

[a] Period between first and last observation.

[b] Numbers in parentheses include data from goats on Mt. Kreutzer disturbed by helicopter and not included in mean.

[c] ± 2 S.E.

these areas and the lower slopes of Sheep Mountain throughout the summer. These movements appear to be due to the attraction of mineral licks on and near Sheep Mountain. The longest movement by a goat within 24 hours, a distance of 8.6 km, was from alpine tundra on Gladstone Ridge to a salt lick on eastern Sheep Mountain. On 4 August 1979, an adult female, YR, was observed to travel from Dead Can Gulch to the lick at Porphyry Gulch trapsite, a distance of 4.5 km, in less than 2 hours. Such strong attractions to mineral licks have been reported elsewhere for mountain goats (Hebert and Cowan 1971, Singer 1977, Hutchins and Stevens 1981).

Greatest linear distance covered by goats from June to August averaged 6.4 km for goats on this area. Schoen (Unpubl. Alaska Fed. Aid Rep. W-17-11-12.4R, 1979) reported a comparable 6 km as the mean yearly home range length for goats in Alaska.

During winter, mountain goats restricted their movements to small areas within the boundaries of their summer home ranges. Winter home ranges averaged 11% the sizes of summer home ranges. Smith (1976) reported similar differences between summer and winter home ranges for goats in Montana. Brandborg (1955) mentioned 10 goats remaining on 81 ha for 3 months during winter in Idaho. Schoen (Unpubl. Alaska Fed. Aid Rep. W-17-11-12.4R, 1979) reported that a majority of 20 radio-collared goats near Juneau, Alaska occupied smaller areas in winter than in summer, but the opposite was true for some of the goats.

Such characteristically small home ranges may be due to snow conditions that do not allow animals to move far. However, this does not appear to have been the case on Sheep Mountain-Gladstone Ridge. Although deep snow in the forested portions of Gladstone Ridge did not permit travel between alpine ranges and subalpine ranges, the goats were not as restricted as their movements indicated. Much of the study area above treeline was relatively snow-free and available to goats wintering on the tundra, but only a small portion of it was used. Long movements of goats off of Mount Kreutzer following the 22 January helicopter survey illustrate the ability of mountain goats to travel long distances through snow if necessary.

Small winter home ranges may be an energy conservation strategy. If adequate forage was available in areas that provided escape terrain, resting cover, and the other required resources, there would be no reason to move from those areas. On Sheep Mountain-Gladstone Ridge, mountain goats appeared to select and remain in areas that offered a combination of foraging areas with plentiful vegetation, interspersed with cliffy terrain (Adams and Bailey 1980).

Male mountain goats were less apt to be observed than were females regardless of season. Males seem to have a greater tendency to disperse than females, which may account for this difference. Dispersal of an adult male to Mount Shavano supports this theory. Rideout (1974) reported that marked male goats were never observed on his study area the year following their capture. Four of 8 males trapped on this study area in summer 1979 were not observed again during that summer. Two more marked males were not observed on the area during the following winter or summer. In comparison, only 1 female of 16 collared was not observed during summer 1979, after her release, but she was seen during winter 1980.

Male goats may also aggregate into smaller, hence less detectable, groups than do females. This has been reported by several authors (Brandborg 1955, Holroyd 1967, Chadwick 1977) and may account for their reduced observability.

Information presented here has implications for management of goats. First, since goats are capable of moving long distances in relatively short periods, aggregating several daily ground surveys of different portions of the area would be questionable for estimating the minimum population size. Surveying the entire area in 1 day with several ground crews or by helicopter, is preferable.

Second, when using the Petersen estimate (Caughley 1977) with mountain goats, a survey of the population to estimate the marked:unmarked ratio will not be a random sample if adult males are less observable than are adult females, as suggested above. Consequently, adult males and females should be marked in proportion to their occurrence in the herd.

More information on home range fidelity in mountain goats would be useful in determining the potential for dispersing animals to establish new populations. Schoen (Unpul. Alaska Fed. Aid Rep. W-17-11-12.4R, 1979) suggested some fidelity to home ranges being expressed by females, albeit from limited data. If female goats usually return to the same winter ranges, establishment of new satellite populations would be slowed. Harvest data from Colorado (Denney 1977) suggest this may be true. On areas between the Mount Shavano population, introduced in 1948, and the Sheep Mountain-Gladstone Ridge population, introduced in 1950, only males were harvested until 1974. Determination of home range fidelity could affect the amount of concern over and management strategies for limiting expansion of existing mountain goat populations in Colorado. Additional information on movement patterns, home range dynamics and fidelity, dispersal rates, and factors that trigger dispersal will aid the Colorado Division of Wildlife in making timely decisions on management of the state's mountain goat populations.

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Dr. Spraker's paper was entitled "An Overview of the Pneumonia Complex in Bighorn Sheep." Dr. Williams' reported on a "Survey of Colorado and Wyoming Bighorn Sheep and Mountain Goats for Paratuberculosis."

IN MEMORIAM

Harold Mitchell and Wesley Prediger died together in a tragic helicopter crash in March, 1981 while working on a bighorn sheep project in British Columbia. These proceedings are dedicated to these individuals, their work and accomplishments in managing wild sheep.

Wesley Prediger Harold Mitchell

Harold Mitchell served as wildlife biologist for the Cariboo Region of the B.C. Fish and Wildlife Branch for 22 years. Wesley Prediger worked as his wildlife technician for 10 years during that period.

Harold hosted the first official Northern Wild Sheep Council meeting in Williams Lake, B.C. in 1970. Through his efforts, the Junction Bighorn Sheep Range, south of Williams Lake, British Columbia, has been preserved for future generations. Due to the conservation efforts of these men, all wildlife in the Cariboo Region has benefited.

Raymond W. Stemp, Faculty of Environmental Design, University of Calgary, received the Jonas Bighorn Trophy for the outstanding presentation at the conference. Jack H. Jonas of Denver Jonas Brothers Taxidermy presented the trophy to Mr. Stemp. His paper was entitled "Heart Rate Response of Bighorn Sheep to some Environmental Factors."