Bienn. Symp. North. Wild Sheep
and Goat Counc. 3: 9-22

ECOLOGICAL RELATIONSHIPS

OF MOUNTAIN GOATS AND ROCKY MOUNTAIN BIGHORN SHEEP

Layne G. Adams [1], Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

Kenneth L. Risenhoover [2], Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

James A. Bailey, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

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.

---

[1]Present address: Bureau of Land Management, P.O. Box 1150, Fairbanks, AK 99707

[2]Present address: Department of Biological Sciences, Michigan Technological University, Houghton, MI 49931

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 cryptpogams 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.

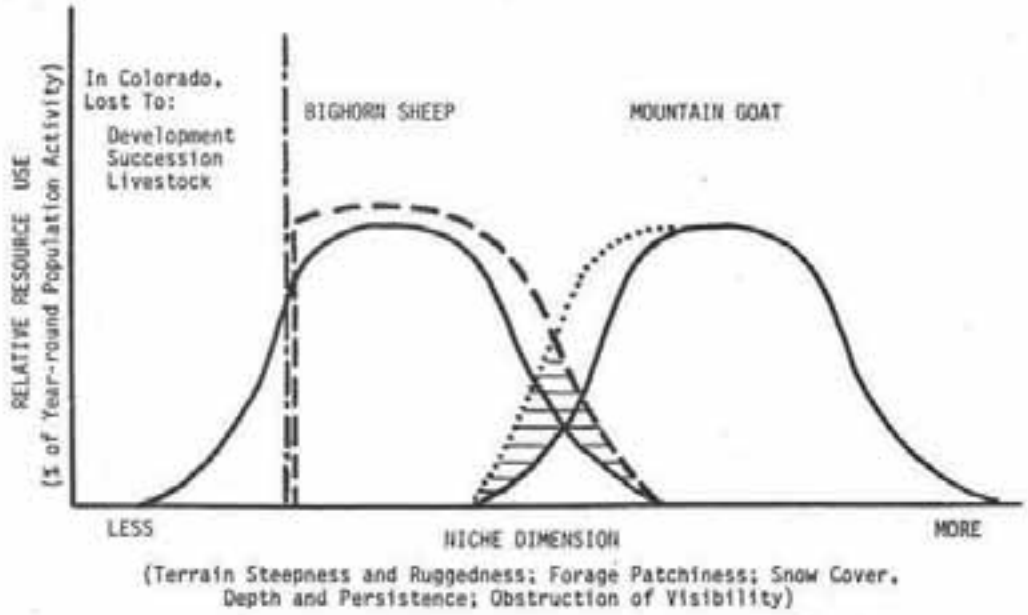

Fig. 1. Conceptual model of ecological relationships of bighorn sheep and mountain goats along some habitat-related niche dimensions. Solid lines represent niche breadths on native sympatric ranges. Dashed line represents observed altered pattern of habitat use by Colorado bighorns, due to habitat losses. 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 influences, 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.

LITERATURE CITED

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

_____ and J. A. Bailey. 1980. Winter habitat selection and group size of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. Pages 465-481 in W.O. Hickey, ed. Proc. Bienn. Symp. Northern Wild Sheep and Goat Counc. 668pp.

_____ and _____. 1982. Population dynamics of mountain goats, Sawatch Range, Colorado. J. Wildl. Manage. 46(4):1003-1009.

_____ and _____. 1983. Winter forages of mountain goats, Sheep Mountain-Gladstone Ridge, Colorado. J. Wildl. Manage. (in press).

_____, M. A. Masteller and J. A. Bailey. 1982. Movements and home ranges of mountain goats, Sheep Mountain-Gladstone Ridge, Colo. Proc. Bienn. Symp. Northern Wild Sheep and Goat Counc. 3:396-410.

Anderson, N. W. 1940. Mountain goat study. Wahsington Dept. Game, Biol. Bul. No. 2. 21pp.

Bailey, J. A. and B. K. Johnson. 1977. Status of introduced mountain goats in the Sawatch Range. Pages 54-63 in W. Samuel and W. G. MacGregor, eds. Proc. First Int. Mountain Goat Symp. 243pp.

Bear, C. D. and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colorado Division of Wildlife. P-R Job Prog. Rept. Proj. W-41-R-22. 232pp.

Blood, D. A. 1967. Food habits of the Ashnola bighorn sheep herd. Can. Field-Nat. 81:23-29.

Brandbord, S. M. 1955. Life history and management of the mountain goat of Idaho. Proj. Comp. Rept. P-R Proj. 98-R, Idaho Fish and Game Dept. Bull. No. 2. 142 pp.

Casebeer, R. L. 1948. A study of the food habits of the goat (Oreamnos americanus missoulae) in western Montana. M.S. Thesis. Univ. of Mont., Missoula. 84pp.

Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. Ecology 51(1):53-72.

Chadwick, D. H. 1973. Mountain goat ecology-logging relationships in the Bunker Creek drainage of western Montana. M.S. Thesis. Univ. of Mont., Missoula. 262pp.

_____. 1976. Ecological relationships of mountain goats, Oreamnos americanus, in Glacier National Park. Proc. First Conf. on Sci. Res. in Natl. Parks. 451-456.

_____. 1977. The influence of mountain goat social relationships on population size and distribution. Pages 78-91 in W. Samuel and W. O. MacGregor, eds. Proc. First Int. Mountain Goat Symp. 243pp.

Colorado Division of Wildlife. 1977. Today's strategy . . . tomorrow's wildlife. Colo. Div. of Wildl. 96pp.

Cooperridger, A. Y., S. A. McCollough and J. A. Bailey. 1980. Variation in bighorn sheep food habits as measured by fecal analysis. Pages 29-41 in W. O. Hickey, ed. Proc. Bienn. Symp. Northern Wild Sheep and Goat Counc. 668pp.

Cowan, I. McT. 1944. Report of wildife studies in Jasper, Banff, and Yoho National Parks in 1944. Wildl. Serv. Dept. of Mines and Res., Ottawa, Can. 83pp.

Demarchi, R. A. 1968. Chemical composition of bighorn winter forage. J. Range Manage. 21(6):385-388.

Denney, R. N. 1976. The status and management of bighorn sheep in Colorado. Trans. 2nd N. Am. Wild Sheep Conf. 69-77.

_____. 1977. Status and management of mountain goats in Colorado. Pages 25-36 in W. Samuel and W. O. MacGregor, eds. Proc. First Int. Mountain Goat Symp. 243pp.

Geist, V. 1967. A consequence of togetherness. Nat. Hist. 76(8):24-31.

_____. 1971. Mountain sheep: a study in behavior and evolution. Univ. of Chicago Press, Chicago, Ill. 383pp.

_____. 1975. On the management of mountain sheep: theoretical considerations. Pages 77-105 in J. B. Trefethen, ed. The wild sheep in modern North America. Boone and Crockett Club and the Winchester Press, New York. 302pp.

Gossow, H. and O. Hjeljord. 1978. Zur Nahrungsokulogie von gams und schneeziege und fragen ihrer soziobiologie. (On the feeding ecology of mountain goat and chamois and aspects of their sociobiology). Tag. ber, III Int. Gams-Symp. 39-53. (English summary only).

Hanson, W. M. 1950. The mountain goat in South Dakota. Ph.D. Thesis. Univ. of Mich., Ann Arbor, Mich. 99pp.

Harmon, W. 1944. Notes on mountain goats in the Black Hills. J. Mammal. (25(2):149-151.

Harrington, F. A. 1978. Ecological segregation of ungulates in alpine and subalpine communities. Ph.D. dissertation. Colo. State Univ., Fort Collins, Colo. 152pp.

Hebert, D. M., and W. G. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia. Pages 126-146 in W. Samuel and W. O. MacGregor, eds. Proc. First Int. Mountain Goat Symp. 243pp.

Hibbs, L. D. 1967. Food habits of the mountain goat in Colorado. J. Mammal. 48(2):242-248.

Hjeljord, O. G. 1973. Mountain goat forage and habitat preferences in Alaska. J. Wildl. Manage. 37(3):353-362.

Holroyd, J. C. 1967. Observations of Rocky Mountain goats on Mt. Wardle, Kootenay National Park, British Columbia. Can. Field-Nat. 8(1):1-22.

Johnson, B. K., R. D. Schultz and J. A. Bailey. 1978. Summer forages of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 42(3):636-639.

Klein, D. R. 1953. A reconnaissance study of the mountain goat in Alaska. M.S. Thesis. Univ. of Alaska, Fairbanks. 121pp.

_____. 1968. The introduction, increase, and crash of reindeer on St. Matthew Island. J. Wildl. Manage. 32:350-357.

Kuck, L. 1977. The impact of hunting on Idaho's Pahsimeroi mountain goat herd. Pages 114-125 in W. Samuel and W O. MacGregor, eds. Proc. First Int. Mountain Goat Symp. 243pp.

McCullough, D. R. 1979. The George Reserve deer herd. Univ. of Mich. Press, Ann Arbor. 271pp.

Odum, E. P. 1971. Fundamentals of ecology, third edition. W. B. Saunders Co., Philadelphia. 574pp.

Park, T. 1954. Experimental studies of interspecies competition: II. Temperature, humidity, and competition in two species of Tribolium. Phys. Zool. 27(3):177-238.

Peck, S. V. 1972. The ecology of the Rocky Mountain goat in the Spanish Peaks area of southwestern Montana. M.S. Thesis. Mont. State Univ., Bozeman. 54pp.

Pitt, M. D., and S. M. Wikeem. 1978. Diet preference of California bighorn sheep on native rangeland in south-central British Columbia. Pages 331-341 in D. M. Hebert and M. Nation, eds. Proc. 1978 Northern Wild Sheep and Goat Conf. 412pp.

Rideout, C. B. 1974. A radio telemetry study of the ecology and behavior of the mountain goat. Ph.D. Thesis. Univ. of Kans., Lawrence. 145pp.

_____. 1978. Mountain goat. Pages 149-159 in J. L. Schmidt and D. L. Gilbert, Eds. Big game of North America- ecology and management. Stackpole Books. Harrisburg, PA. 494pp.

Risenhoover, K. L. 1981. Winter ecology and behavior of bighorn sheep, Waterton Canyon, Colorado. M.S. Thesis. Colo. State Univ., Fort Collins. 111 pp.

_____ and J. A. Bailey. 1980. Visibility: an important habitat factor for an indigenous, low-elevation, bighorn herd in Colorado. Pages 18-28 in W. O. Hickey, ed. Proc. Bienn. Symp. Northern Wild Sheep and Goat Counc. 668pp.

Rominger, E. M. 1983. Waterton Canyon bighorn sheep: Food habits and habitat management. M.S. Thesis. Colo. State Univ., Fort Collins. (in prep.).

Russo, J. P. 1956. The desert bighorn sheep in Arizona. Ariz. Game and Fish Dept. Wildl. Bull. No. 1, 153 pp.

Rutherford, W. H. 1972. Status of mountain goats in Colorado. Colo. Game, Fish, and Parks Div. Game Inform. Leafl. No. 90. 4pp.

Saunders, J. K. 1955. Food habits and range use of the Rocky Mountain goat in the Crazy Mountains, Montana. J. Wildl. Manage. 19(4):429-437.

Schoener, T. W. 1971. Theory of feeding strategies. Ann. Rev. Ecol. Syst. 2:369-404.

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

Smith, K. G. 1982. Winter studies of the forest-dwelling mountain goats of Pinto Creek, Alberta. Proc. Bienn. Symp. Northern Wild Sheep and Goat Counc. (see elsewhere in these proceedings).

Stewart, S. T. 1975. Seasonal ecology of bighorn sheep in the Beartooth Mountains. Mont. Dept. Fish and Game, P-R Rep., Proj. W-120-R-6,7.

Todd, J. W. 1972. Foods of Rocky Mountain bighorn sheep in southern Colorado. J. Wildl. Manage. 39(1):108-111.

Wilson, L. O. 1968. Distribution and ecology of the desert bighorn sheep in southeastern Utah. Utah Div. Fish and Game Publ. 68-5. 220pp.

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

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.