THESIS

IMPACT OF CATTLE GRAZING ON BIGHORN SHEEP, TRICKLE MOUNTAIN, COLORADO

Submitted by

Scott A. McCollough

Department of Fishery and Wildlife Biology

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Spring, 1982

COLORADO STATE UNIVERSITY

Spring, 1982

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION

BY Scott A. McCollough

ENTITLED Impact of Cattle Grazing on Bighorn Sheep, Trickle Mountain, Colorado

BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF

Master of Science

Committee on Graduate Work

Richard M. Hansen

Allen L. Carpenter

Adviser

Head of Department

ABSTRACT OF THESIS

IMPACT OF CATTLE GRAZING ON BIGHORN SHEEP TRICKLE MOUNTAIN, COLORADO

Distribution and food habits of bighorn sheep during winter and spring (December-June) and cattle during summer (May-October) were investigated and compared on the Trickle Mountain study area, Colorado during 1978-1979. Effects of summer cattle grazing on bighorn forages and on carrying capacity of critical bighorn range were estimated. Observations of marked sheep suggested the existence of 2 sub-herds of bighorn. One sub-herd winters south of Trickle Mountain and uses lambing grounds near Buffalo Pass. The other sub-herd winters in the Poison Gulch-Ford Creek area and uses newly-identified lambing grounds along Middle and Jack's Creeks. Within winter-spring range, 18 areas were identified as essential to bighorn welfare and termed critical areas. Cattle were observed during summer on 4% of bighorn winter-spring range on 3 Bureau of Land Management allotments and on 5% of the range defined as critical areas. Topography, availability of water, and aspect limited cattle use of bighorn range and critical areas. Cattle were reluctant to wander over 1.5 km from water, preferred slopes of less than 5°, and used northern aspects more often than did wintering bighorn. Bighorn preferred areas with south or west-facing slopes of at least 16° as winter-spring habitat. They also preferred meadows and avoided timbered areas, as did cattle. Bighorn rarely strayed more than 240 m

from escape terrain. Cliffs and rock outcrops used as escape terrain were at least 200 m long and 8 m tall. Twelve areas not presently used by bighorn were designated as potential winter-spring habitats. Cattle food habits during May-October and bighorn food habits during December-June were determined using microhistological analyses of feces. Muhlys, blue grama, wheatgrasses, fescues, sedges, and rushes were the predominant cattle foods. However, browse, especially saltbush and winterfat, was an important diet constituent during fall. Important bighorn foods during winter-spring were fringed sagebrush, sedges, muhlys, fescues, blue grama, saltbush, winterfat, and yucca. Fringed sagebrush accounted for 36% of the 1978 winter-spring diet. Between-years variation in bighorn diets was due to effects of differences in snowfall on forage availabilities. Kulcyznski's index of similarity revealed a moderate (73%) overlap between the 1978 summer cattle diet and the 1978-79 winter-spring bighorn diet. Soil-Vegetation Inventory Methods (SVIM) were used to estimate production of bighorn forage on critical areas. Data from range cages indicated that percent utilization of critical winter-spring bighorn forage by cattle during summer was greatest on the Cross Creek allotment. However, more kg of critical bighorn forage were removed from the Trickle Mountain allotment. Utilization of critical bighorn forage on the Poison Gulch allotment was relatively low. Estimates of cattle utilization of bighorn forage on critical areas had wide confidence intervals. Winter (December 1-April 15) forage intake of an average Trickle Mountain bighorn was estimated from existing herd data and from information in the literature. Estimated impacts of cattle

grazing on bighorn carrying capacities reflected the wide confidence intervals for utilization values. Despite this limitation, this study suggests that the Trickle Mountain, Cross Creek, and Poison Gulch allotments could support an additional 117 bighorn in the absence of cattle grazing. Management recommendations and research needs are discussed.

Scott A. McCollough
Department of Fishery and
Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523
Spring, 1982

ACKNOWLEDGEMENTS

I wish to thank my major professor, Dr. James A. Bailey, for his advice and perseverance throughout my graduate studies. My research project was made possible by funding from the U.S. Bureau of Land Management. Dr. Allen Cooperrider, BLM Wildlife Biologist, offered valuable suggestions and became a trusted friend. J. Steve Hannan, BLM Range Conservationist, provided useful information regarding the study area. Food habits were analyzed at the Composition Analysis Laboratory under the supervision of Dr. R. M. Hansen. I was ably assisted during 2 summers of field work by Scott "Hondo" Hoover. Several undergraduate students helped me gather and compile data. Discussions with fellow graduate students, especially Gary Skiba and Ken Risenhoover, were an important part of my education. I am grateful to Kathy Everett, Evelyn Weddel, and Phyllis Turner for typing and assisting with administrative matters. Marian Hershcopf was most helpful during my visits to the Colorado Division of Wildlife library. My father, Richard McCollough, deserves thanks for the support he has given me throughout my life. Friends from Pingree Park (summer 1981) provided encouragement during the final stages of thesis preparation. Finally, thanks to Connie O'Brien for sending inspiration across the many miles.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

INTRODUCTION

Wildlife ecologists generally view competition as the common use of limiting resources by 2 or more animals or animal populations. The ultimate demonstration of competition is a population effect. Should competition occur, the numbers, distributions, or productivity of one or more of the associated populations will change.

Measurement of competition among ungulates has proven difficult. Most investigations have been based upon the extent to which 2 species graze the same area and prefer the same forage (Julander 1958). Results of these studies are of limited value because they have failed to demonstrate that mutually-used resources were limiting to one or both populations.

Mackey (1978) questioned the suitability of the term competition to describe interaction between livestock and wild ungulates. Through centuries of domestication, husbandry, and selective breeding, domestic herbivores have become little more than machines for converting vegetation to animal protein. Grazing patterns and behavior of livestock are often highly specialized, as well as controlled by man, such that they tend to be little influenced by the presence of wild ungulates. Stockmen have been partially successful in protecting livestock from predation, diseases, and nutritional ailments. Also, high stocking rates may provide livestock with an advantageous numerical superiority over wild ungulates (Oldemeyer 1966, Mackey 1978). Although forage consumption

and possible disease transmission concern stockmen, there are few documented cases of wild ungulates adversely affecting the numbers, distribution, or general well-being of domestic herbivores. From this perspective, livestock grazing may be viewed more as an impact rather than a setting for competition; at least where competition connotes a mutual or reciprocal relationship.

Livestock grazing may impact wild ungulates only during certain seasons. For example, forage removal during summer may affect wildlife only during the stressful winter period. The most valuable investigations of impacts of cattle grazing have therefore been conducted and analyzed on a seasonal basis.

Bighorn sheep (*Ovis canadensis*) appear to be more severely affected by livestock grazing than are other wild ungulates. Geist (1971), Morgan (1970), and Wagner (1976) stated that bighorn are dependent upon climax grassland. Cattle grazing has been responsible for converting some of these grasslands to shrublands (Buechner 1960, Morgan 1970). While mule deer (*Odocoileus hemionus*) populations apparently benefited from these conversions, bighorn populations decreased. Elk (*Cervus canadensis*) can succeed in a variety of vegetation types and remained relatively unaffected (Wagner 1976). The dispersal strategy of bighorn sheep does not favor rapid colonization of nearby suitable habitat (Geist 1971). Habitat loss is therefore especially harmful to bighorn populations. McCann (1956) suggested that while other herbivores are able to range widely in search of forage, bighorns are restricted to areas near escape terrain. Thus, forage removed from these areas by competing animals is particularly significant to bighorn.

The literature contains many references to competition between bighorn sheep and livestock. Often conclusions reached were speculative or based on circumstantial evidence. The few studies designed to investigate competition have been limited to determinations of spatial and dietary overlap. Blood (1961) and Lauer and Peek (1976) were among the few authors to assess forage availabilities as well as dietary and spatial overlap.

The major objectives of this study were to evaluate the impacts of cattle grazing on the habitat and population of the Trickle Mountain bighorn sheep herd. Winter (December 1-April 15) forage was assumed to be the limiting resource to the bighorn population. Amount and percentage of bighorn forage removed by cattle during summer from bighorn winter-spring (December 21-June 21) range were estimated. Numbers of bighorn that could have been carried through winter by the forage removed by cattle was estimated. This provided a measure of the impact of cattle grazing. Sub-objectives of the study were to:

1) identify winter-spring (December 21-June 21) ranges of bighorn;
2) characterize habitats used by bighorn within these ranges;
3) measure winter-spring food habits of bighorn;
4) describe summer (May-October) distribution of cattle, especially use of winter-spring ranges of bighorn;
5) characterize habitats used by cattle during summer; and
6) measure summer food habits of cattle.

This study was performed in conjunction with the Trickle Mountain Forage Allocation Research Project. Funding was provided by the U.S. Bureau of Land Management under contract YA-512-CT8-22.

REVIEW OF LITERATURE

BIGHORN-LIVESTOCK CONFLICTS

The decline of the bighorn in the United States has been described by Buechner (1960). Scattered populations exist on small portions of their once vast former range. Overhunting, diseases, and competition from livestock have been suggested as reasons for this decline (Smith 1954, Buechner 1960, Geist 1971, Trefethen 1975).

The appearance of livestock on western range has often coincided with declines of bighorn herds (Honess and Frost 1942, Packard 1946, Jones 1950, McColm 1963). Major reductions in populations of desert bighorn in Arizona and Nevada occurred at the same time cattle numbers reached their peak (Gallizioli 1977, McQuivey 1978). For over 50 years, the Rock Creek, Montana bighorn range was grazed at various intensities. Periodic fluctuations in bighorn numbers suggested a competitive relationship with domestic stock (Berwick and Aderhold 1968). Early observers in Wyoming noted the correlation between bighorn losses and increased livestock grazing (McCann 1956).

Cattle grazing has damaged much of the desert bighorn range (Russo 1956, Gordon 1957, McColm 1963, Rigelhuth 1956, Gallizioli 1977). Although some desert areas are presently protected from grazing, low precipitation levels insure that their recovery will take many years (Jones 1950, Russo 1956). Livestock grazing has also adversely affected less arid bighorn habitat (Jones 1950, Buechner 1960, Crump 1971,

Geist 1971, Brown 1974). It may have been responsible for converting some bighorn habitat from grassland to shrubland (Berwick 1968, Morgan 1970). Demarchi (1970) found weights and densities of bunchgrass on bighorn range decreasing due to cattle grazing.

Lauer and Peek (1976) investigated cattle-bighorn relationships near the East Fork of the Salmon River in Idaho. Bluebunch wheatgrass (*Agropyron spicatum*) was the major food for both species. Most overlap in habitat use was on slopes under 17° in big sagebrush (*Artemisia tridentata*)-bluebunch wheatgrass vegetation types. The limited amount of wheatgrass, exacerbated by mule deer use in spring, led the authors to conclude that competition was occurring.

Blood (1961) evaluated competitive interactions between cattle and a British Columbia bighorn herd. Almost 70% of bighorn winter range was occupied to some extent by cattle. Grasses, especially bluebunch wheatgrass, were common in both diets. Cattle removed up to 35% of vegetation from bighorn range. After considering other limiting factors, Blood speculated that cattle grazing was preventing a bighorn herd increase.

Several studies performed on areas shared by bighorn and cattle have failed to discover evidence of competition (Spencer 1943, Halloran 1949, Couey 1950, Jones 1950, Mathews 1960, Arellano 1961). Bighorn and cattle exhibit different habitat preferences that often prevent range overlap. Bighorn have inhabited areas of rugged topography while cattle were limited to valleys and gentle slopes (McCann 1956, Ferrier and Bradley 1970, Pallister 1974). However, some authors suggest that cattle have reduced bighorn forages in areas of gentle topography; thus

decreasing their use by bighorn (Sugden 1961, Barmore 1962). In contrast, other authors have noted that preference for escape terrain and nearby areas is part of the evolved predator evasion strategy of bighorns (Risenhoover and Bailey 1980).

Several researchers have noted that bighorn avoid areas occupied by cattle (McCullough and Schneegas 1966, Follows 1969, Albrechtsen and Reese 1970, Dean 1975, Horejsi 1975). Other authors, however, have found bighorn to be unresponsive to nearby livestock (Barmore 1962, Berwick 1968). Halloran and Blanchard (1950) observed a bighorn traveling with range cattle.

In arid regions, competition may be for water. Livestock may deplete or foul water. Critical forage supplies near watering points are often reduced by livestock grazing (Halloran 1949, Russo 1956, Kelly 1960, Van den Akker 1960, Wilson 1968, Ferrier and Bradley 1970).

BIGHORN HABITAT

Bighorn habitat consists of open, mountainous terrain with an interspersion of foraging areas and nearby cliffs. Plant communities usually include few tall shrubs and trees but an abundance of low-growing shrubs, forbs, and grasses (Geist 1971, Risenhoover and Bailey 1980).

Escape terrain is the most consistent feature of bighorn habitat. Any steep, broken terrain may serve as escape cover (Simmons 1961, Flook 1964). The terms cliffs, crags, rimrocks, and rock outcrops are used most often to describe escape terrain (Honess and Frost 1942, McCann 1956, McCullough and Schneegas 1966, Woolf 1968, Brown 1974). With the exception of Tilton (1977), who defined a cliff as a rock face

at least 4.5 m tall, authors have not quantified escape terrain. Occasionally, bighorn enter timber when disturbed (Streeter 1969, Frisina 1974).

Bighorn are reluctant to stray far from escape terrain. McCann (1956) observed "nervous" behavior in bighorn when they were away from cliffs. Both he and Oldemeyer (1966) sighted most bighorn within 90 m of escape terrain. In other studies, most observations were made within 137 m of escape terrain (Erickson 1972, Frisina 1974, Pallister 1974). Over half the observations made by Tilton (1977) were within 160 m of cliffs. Although bighorn in Rocky Mountain National Park ranged up to 240 m from escape terrain, the mean distance was 31 m (Harrington 1978). Risenhoover (1981) found bighorn were especially reluctant to travel far from escape terrain when in small, rather than large groups.

Morgan (1970) stated that climax grassland is essential to bighorn survival and others have described bighorn habitat as grassland (Smith 1954, Sugden 1961, Flook 1964, Schallenberger 1965, Oldemeyer 1966, Frisina 1974). However, Lauer and Peek (1976) and Tilton (1977) found shrub-grass mixtures most often used by bighorn. Bighorn are also often observed in "open timber" (Cooperrider 1969, Tilton 1977). Pallister (1974) made 43% of his observations of bighorn in a Douglas-fir-snowberry (*Symphoricarpos* spp.) type. Although bighorn may occasionally use timber as a travel route (Streeter 1969) or to avoid inclement weather (Honess and Frost 1942, Woolf 1968), dense timber accounts for only a small percentage of bighorn observations (McCann 1956, Simmons 1961, Frisina 1974, Schallenberger 1975, Tilton 1977, Harrington 1978).

Bighorn are not limited to foraging only on steep slopes. Bauman and Stevens (1978) recorded almost 90% of their observations on slopes of at least 40°. Tilton (1977) stated that bighorn preferred slopes over 39° and selected against slopes of 6 to 19°. Lauer and Peek (1976) found that slopes over 17° were preferred. Frisina (1974) and Pallister (1974) gave mean slopes used as 23° and 19°, respectively. Bighorns also frequently forage on level terrain (McCann 1956, Harrington 1978). Differences in slope use may be related to associated features, such as snow depth (Shannon et al. 1975) and distance from escape terrain.

Although Shannon et al. (1975) found that aspect did not strongly influence bighorn distribution, most winter observations of Rocky Mountain bighorn (*O. c. canadensis*) have been on southern aspects (McCullough and Schneegas 1966, Brown 1974, Tilton 1977, Baumann and Stevens 1978). West facing slopes also receive winter use (McCann 1956, Oldemeyer 1966, Lauer and Peek 1976). Frisina (1974) added that southern aspects are heavily used throughout the spring. Bighorn probably respond to reduced snow depths and forage characteristics on south and west aspects.

BIGHORN FOOD HABITS

Many publications contain information on food habits of the Rocky Mountain bighorn. However, these data have often been collected incidentally to other research objectives. Study designs and sample sizes tend to be inadequate. Techniques used in food habits studies include: direct observation of foraging bighorn, examination of feeding

sites, rumen analysis, and fecal analysis. Fecal analysis is discussed below.

Although bighorn are adapted for grazing (Geist 1971), they utilize a wide variety of foods (McCann 1956, Moser 1962, Todd 1972). Forage availability apparently influences diet composition. Availability of graminoids in desert environments is low, hence desert bighorn consume considerable browse and cacti (Yoakum 1964). Pallister (1974) found food habits differed between 2 locations within the same study area. Geographic variation in diets, probably related to forage availability, has also been noted by Cooperrider et al. (1980).

Bighorn populations exhibit seasonal variation in food habits. Berwick (1968) reported increased forb consumption during fall. In contrast, other researchers (Honess and Frost 1942, Smith 1954, Cooperrider et al. 1980) found forb utilization highest in spring and summer. When winter snows cover smaller plants, taller browse species should become more important in the diet. This phenomenon was reported by Smith (1954), Brown (1974), and Cooperrider et al. (1980). However, Keiss and Schoonveld (1977) and Pallister (1974) found decreased browse consumption in winter.

Todd (1972) reviewed literature on bighorn food habits. After detailing the works of Smith (1954) and Moser (1962), he concluded that grasses and grasslike plants are the staples of the Rocky Mountain bighorn diet. Wheatgrasses (*Agropyron* spp.), bluegrasses (*Poa* spp.), fescues (*Festuca* spp.), and muhlys (*Muhlenbergia* spp.) were the most important grass species. Sedges (*Carex* spp.) were important in some diets. Fringed sagebrush (*Artemisia frigida*) was often a critical browse

species. Other browse utilized included cinquefoil (*Potentilla* spp.), big sagebrush, willow (*Salix* spp.), and curl-leaf mountain mahogany (*Cercocarpus ledifolius*). Dwarf clover (*Trifolium nanum*), daisy (*Erigeron divergens*), and arrowleaved balsamroot (*Balsamorhiza sagittata*) were noted forbs in the diet.

Subsequent research has supplemented our knowledge of bighorn food habits. The Sun River, Montana bighorn herd's spring diet consisted of 94% grass, 3% forbs, and 2% browse (Frisina 1974). Pallister (1974) considered bluebunch wheatgrass and fringed sagebrush important foods. Lauer and Peek (1976) also reported bluebunch wheatgrass as heavily utilized. Biscuitroot (*Lomatium* spp.) was sought out by bighorn. Consumption by forage class was: grass 82%, forbs 11%, and browse 7%. Tilton (1977) found an unexpectedly high amount of browse (51%) in the winter diet. He listed grass at 38% and forbs at 11%. Again, bluebunch wheatgrass was the species taken in greatest amounts.

Fecal analysis has been used twice to evaluate food habits of the Trickle Mountain bighorn herd. Keiss and Schoonveld (1977) estimated summer consumption of browse at over 60%. This declined to 50% in fall and 25% in winter. Grass constituted the remainder of the diet. Fescues, muhlys, and fringed sagebrush were important forages. Todd (1975) quantified the annual diet as 46% grasses and sedges, 45% browse, and 9% forbs. Food habits varied among seasons. Browse, mostly fringed sagebrush, formed 67% of the winter diet. Grass and sedge consumption increased throughout spring; by summer they comprised 65% of the diet. Grass and sedge consumption declined to 54% in fall. Yucca (*Yucca glauca*) was classified as a forb and made up about 10% of the winter-

spring diet. Only trace amounts of other forbs were consumed. Todd designated fringed sagebrush, sedges, muhlys, fescues, and blue grama (*Bouteloua gracilis*) as major foods of the Trickle Mountain herd.

FORAGE INTAKE RATE

Review of literature revealed a paucity of data on forage intake rates of wild bighorn. Consumption rates of mule deer, Dall sheep (*Ovis dalli*), domestic sheep, captive bighorn, and a "generalized ruminant" have therefore been used to estimate intake rates of wild bighorn. Daily intake rates (Table 1) are given per kg of metabolic body weight. This allows comparisons among studies and calculation of a mean daily intake rate of 0.076 kg/kg of metabolic body weight. Metabolic body weight is the animal's body weight raised to an exponent of 0.75 (Moen 1973).

WATER REQUIREMENTS

Most researchers do not emphasize the importance of free water in the habitat of Rocky Mountain bighorns. Snow is present for a major portion of the year on much bighorn range and provides an alternative source of water (Honess and Frost 1942, Smith 1954, McCann 1956, Woolf 1968). When water is unavailable, bighorn are apparently able to survive for longer periods than other North American ungulates (Simmons 1961, Turner 1978). Studies in Colorado suggested that water had a minimal influence on bighorn movements (Simmons 1961, Barmore 1962). Pallister (1974) found bighorn summer distribution correlated with availability of water. However, he speculated that succulent forage growing near water affected distribution more than did water itself.

Table 1. Daily consumption of dry matter by ruminants.

Species	Estimated kg consumed per kg metabolic body weight	Reference	Comments
Bighorn	0.059	Chappel and Hudson 1978	Penned sheep, pelleted feed
Dall sheep	0.094	Palmer 1944	Estimated from other species
Mule deer	0.051	Alldredge et al. 1974	On winter range
Domestic sheep	0.086	Drew 1971	
Domestic sheep	0.055	Van Soest 1968	Legumes and grass diet
Domestic sheep	0.074	Natl. Res. Counc. 1964	Pregnant ewes on intermountain winter range
Generalized ruminant	0.110	Van Dyne et al. 1980	A "rule of thumb" for ruminants

Water becomes a more critical habitat component on the most arid bighorn ranges. It is the limiting factor for some desert bighorn herds (Welles and Welles 1961, Wilson 1968). The River Mountains of Nevada would be uninhabited by bighorn if it were not for the presence of developed springs and tanks. Percent of River Mountain bighorn observations within 3.2 km of water ranged from 47 in spring to 84 in summer (Leslie and Douglass 1979). Most observations made by Wilson (1968) were between 0.8 km and 1.6 km from water. Ferrier and Bradley (1970) discovered all bighorn bedding grounds within 6.4 km of water.

FECAL ANALYSIS

Fecal analysis is the quantification of forage remains in feces, usually under magnification ("microhistological analysis"). Advantages over other methods of food habits study include a practically unlimited sample size and minimal disturbance of animal populations. It is especially useful in studies of endangered or secretive species where stomach analyses are not always feasible (Todd 1972, Anthony and Smith 1974). Sacrifice of valuable animals is not required. Fecal analysis requires no bags, fistulas, or cages which may interfere with normal habits of animals and it can be used on any type of animal in any habitat type (Hercus 1960). Hansen et al. (1977, unpublished) believe a major advantage is that evidence is preserved on slides and can be used to settle disputes that may arise.

Fecal analysis was first used to determine diets of cottontails (*Sylvilagus* spp.) (Dusi 1949). North American ungulates whose diets have been examined using the microhistological technique include: deer (*Odocoileus* spp.) (Cooperrider 1969, Zyznar and Urness 1969, Free et al.

1970, Anthony and Smith 1974, Hansen and Dearden 1975), elk (Hansen and Reid 1975, Hansen and Clark 1977, Pulliam 1978), pronghorn (*Antilocapra americana*) (Jacobs 1973, Messenger 1978), bison (*Bison bison*) (Hansen et al. 1973), reindeer (*Rangifer tarandus*) (Dearden et al. 1975), wild horses and burros (Hubbard and Hansen 1976, Woodward and Ohmart 1976, Hansen et al. 1977), and bighorn sheep (Todd 1975, Keiss and Schoonveld 1977, Tilton 1977, Johnson 1980). Microhistological analyses have been used to study food habits of African ungulates (Kiley 1966, Stewart 1967, Casebeer and Koss 1970, Owaga 1977). Examination of livestock fecal material has supplemented knowledge of their food habits (Hercus 1960, Free et al. 1970, Hansen et al. 1973, Hubbard and Hansen 1976, Hansen et al. 1977, Hansen and Reid 1978, Vavra et al. 1978).

Description of Technique

1) Collection and preservation of samples

Collection should be limited to fresh fecal materials. This will reduce destruction of plant fragments in the feces by insects, bacteria, and fungi. It is desirable to collect samples from observed animals to eliminate mistakes in identification of the feces (Ward 1970). Field workers need not collect the entire group of pellets from animals such as deer or elk, or a complete defecation from animals such as cattle or bison. Approximately 2 g of material should be taken from each cattle defecation and 1-2 pellets from each elk or deer pellet group. A sample representing a population's seasonal diet on a given area can be obtained from 10 - 50 defecations per study area (Hansen et al. 1977, unpublished).

Fecal samples should be preserved after collection to prevent microbial and fungal action which can dissolve cutin, lignin, and cellulose. Ward (1970) recommended refrigeration of collected feces. Addition of table salt, freezing, oven or air drying, or preservation in formalin or alcohol also reduces microbial action (Hansen et al. 1977, unpublished).

2) Reference collection and sample processing

There is no substitute for a good reference collection. Its size depends on the scope of the study. All materials in the reference collection should bear authentic identification. Besides herbarium plant specimens, the reference collection should also contain seeds, buds, and underground parts such as bulbs and tubers. Some investigations may also require collection of plants in various phenological stages (Bear 1969, Ward 1970).

Many animals grind their food into very small fragments. Reference material should be prepared so it illustrates the microscopic characteristics of plants (Ward 1970). Most of the plant fragments in a ruminant's feces are less than 1 mm in size and those of monogastric herbivores are usually larger. Therefore, in studies of ruminants, grinding of plants in a Wiley Mill through a 20 mesh (1 mm) screen will simulate the condition of fecal plant fragments (Hansen et al. 1977, unpublished).

Prior to drying and grinding, fecal samples may be washed in a fine mesh nylon bag or over a screen to remove endogenous materials (Hansen et al. 1977, unpublished). Fecal samples from small mammals, such as rabbits and rodents, that masticate their food finely may not require grinding (Bear 1969).

3) Slide preparation

Although Storr (1961), Williams (1969), and Dusi (1949) found staining plant fragments to aid in identification, Hansen et al. (1977, unpublished) of the Composition Analysis Laboratory at Colorado State University obtain satisfactory results without staining.

The ground reference material must be cleared to remove pigments and soluble material. Baumgartner and Martin (1939) used Hertwig's solution as a clearing and mounting medium. Hertwig's solution consists of 270 g chloral hydrate crystals combined with 19 cc of 1 normal HCl and 60 cc of glycerine. Hansen et al. (1977, unpublished) use ordinary household bleach as a clearing solution. However, they advise that Hertwig's solution be used on samples that may contain lichens because bleach dissolves and destroys lichen characteristics.

After the clearing solution is washed out, the materials are transferred to slides. Templates insure that equal amounts of material are transferred to each slide. Hoyer's mounting medium is applied to each slide, thoroughly mixed with the sample, and spread evenly over the slide. Hoyer's solution consists of 200 g chloral hydrate combined with 20 cc of glycerine to which 30 g photopurified gum arabic and 50 cc water are added. A cover slip is placed over the sample and slides are heated and dried. Five slides are usually made for each kind of plant or plant part (Bear 1969, Ward 1970, Hansen et al. 1977, unpublished).

4) Identification of plant material

The principles forming the basis for plant fragment identification are: (1) When plant cell growth ceases, the cuticle hardens to a solid film molded to the contours of the underlying epidermal cells. Cuticles

will bear in imprint or sometimes part of the cells of the epidermis. (2) The arrangement of epidermal cells is characteristic of the plant group and family and often the species. (3) The cuticle is impermeable to water and resistant to the action of microbes in the digestive tract. It passes through the animal unchanged except for a reduction in size (Hercus 1960).

A compound microscope of 35 - 125 power is used to examine slides of fecal samples (Meyers 1962, Sparks and Malechek 1968). Each slide is examined at 20 systematically located fields (Free et al. 1970). Plant fragments are identified by histological comparisons with plant tissues referenced to slides of known plants.

Histological characters helpful in identification are: (1) size and shape of stomata, (2) pattern of cells, (3) structural peculiarities in cell walls, (4) distinctive characters of conductive tissues, and (5) specialized forms of pubescence (Bear 1969). If samples are stained, variation in stain intensity and color aids identification (Storr 1961).

Identifying some food items is difficult. Experience and frequent consultation of a reference collection reduce technician errors. Food items may be placed in either general or specific categories (Ward 1970). The Composition Analysis Laboratory at Colorado State University usually identifies plant fragments to genus.

5) Quantification of items in diet

Amount of an item in the diet is usually represented by a percentage. "Percent density" of an item is found by dividing the number of fragments counted for an item by the total number of fragments identified and multiplying by 100 (Hansen et al. 1977, unpublished). Sparks

and Malechek (1968) developed a time-saving "frequency conversion" procedure in which only presence or absence of a food item is recorded for each microscope field. Quantification by measurement of fragment area is of limited value (Storr 1961, Stewart 1967).

Evaluation of Technique

Ward (1970) evaluated the fecal analysis technique. He wrote: "The use of fecal analysis certainly has value. Studies to date have found only a few species of plants that lost their identity when passed through an animal. Qualitative data on a frequency basis was possible. The possibilities of making quantitative measurements is somewhat questionable. More studies are needed to evaluate the use of fecal analysis, particularly with different animals on different ranges."

Results of fecal analysis have been compared to results of analyzing stomach contents. Anthony and Smith (1974), using both techniques, obtained comparable estimates for the abundance of various browse species in mule deer diets. Estimates of herbs, fruits, and flower stalks were significantly higher from rumen samples. Fecal matter gave higher estimates for grass. Cooperrider (1969) found a significant correlation between fecal and rumen analyses for monocots in mule deer diets. Amounts of dicots and conifers in the rumens were not significantly correlated with amounts in the feces. Plant fragments in fecal pellets of 4 bighorn were compared with fragments in the rumens of these animals. Statistical analyses produced no significant differences between frequencies of occurrence (Todd and Hansen 1973). Microscopic analyses of both feces and stomach contents of several grass-

eating African ungulates have shown only minor differences between the 2 techniques (Casebeer and Koss 1970, Owaga 1977).

Vavra et al. (1978) determined cattle diets using esophageal fistulas and fecal analysis. Total grasses occurred significantly less in esophageal samples, while total forbs were significantly lower in fecal samples. For grass species, some were more abundant in fecal samples while others were more abundant in fistula samples. Most forb species appeared in greater percentages in fistula samples. Johnson (1980) studied bighorn food habits by direct observation and by fecal analysis. Forbs were underestimated and grasses were overestimated by fecal analysis when results were compared to observations. Minor species observed to be consumed were not identified in the feces.

Most criticisms of quantifying diets by fecal analysis arise from concern that the differential digestibility of various plants may cause incorrect estimation of relative food intake. In general, plant species with higher digestibility tend to be underestimated in diet composition while those with lower digestibility would be overestimated (Pulliam 1978). Forbs tend to be highly digestible. Most grasses, and some shrubs, are more resistant to digestion (Cooperrider 1969, Neal et al. 1973, Anthony and Smith 1974, Vavra et al. 1978). Methods to correct for differential digestibility among plants have been used on a limited basis (Voth and Black 1970, Neal et al. 1973, Dearden et al. 1975). Unfortunately, development of the large number of correction factors necessary for extensive investigations is impractical.

Despite criticisms, fecal analysis is a valuable method of food habits study. Its advantages over other techniques are considerable. The utility of fecal analysis depends upon: (1) the species of herbivore

in question, (2) the nature of its diet, and (3) characteristics of its habitat. Highly diverse diets would make the technique time-consuming and subject to more errors. Diets high in grasses are more accurately estimated than are diets dominated by forbs. Therefore, fecal analysis is best suited for use in grasslands. Diets of desert herbivores are difficult to accurately assess (Casebeer and Koss 1970, Anthony and Smith 1974, Westoby et al. 1976).

Some researchers have addressed the problem of differential digestibility among plants. Todd (1972) stated that even highly digestible forbs are detectable in bighorn feces. Digestion probably reduces the mean weight of fragments rather than eliminating whole fragments for plants common in the bighorn diet (Todd and Hansen 1973). Fecal analysis is useful in studies of dietary overlap among herbivores. Hansen et al. (1973) assume that if discernibility of different plants in fecal matter is similar among ungulates, dietary overlap can be measured. More research into effects of differential digestion on results of fecal analysis is necessary. Although fecal analysis appears not to be entirely accurate, the information it provides concerning the most important diet constituents is valuable in studies of dietary overlap (Vavra et al. 1978).

STUDY AREA

LOCATION AND OWNERSHIP

The Trickle Mountain study area is located at the northern end of the San Luis Valley in south-central Colorado. Saguache, about 6 km east, is the nearest town (Figure 1). The 56,540 ha area is bounded on the north and west by the Continental Divide and on the south by Colorado State Highway 114. The indefinite eastern boundary runs generally north along the ridge west of Findley Gulch to the Continental Divide. Approximately 90% of the study area is federally owned. The BLM administers 7 grazing allotments totaling 27,316 ha. Land to the north is in Rio Grande National Forest. Major riparian areas and meadows are privately owned (Figure 2). Although data were gathered from the entire study area, work was concentrated on the Poison Gulch, Trickle Mountain, and Cross Creek allotments. Vegetation was measured exclusively on these allotments which contain most of the bighorn winter-spring range on the study area.

CLIMATE

Weather records from Saguache, for 1951-1973, indicate the climate of the study area. January is the coldest month, with a mean temperature of -6 C. The warmest month is July, having a mean temperature of 19 C. Average temperature in winter (December-February) is -5 C. Average spring (March-May) temperature is 6 C (National Oceanic and Atmospheric Administration 1977).

Figure 1. Location of Trickle Mountain study area (crosshatch), Colorado.

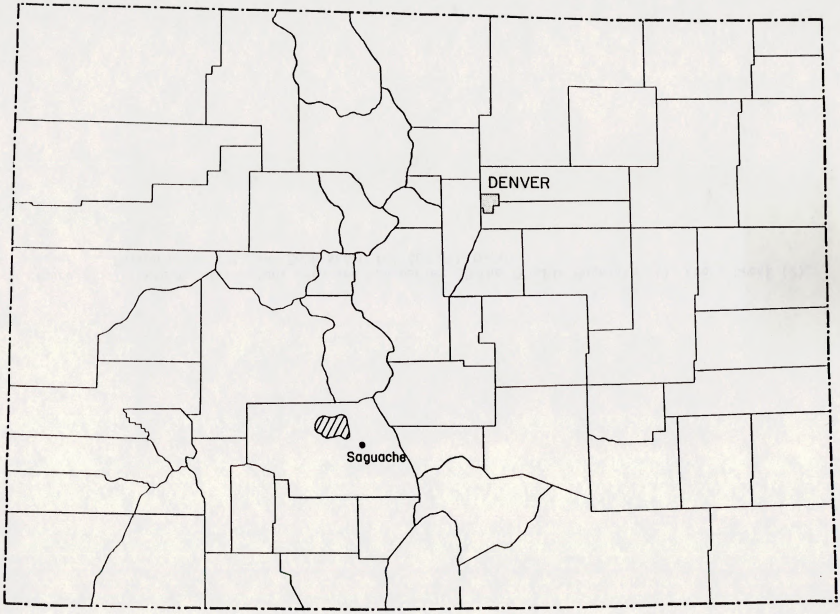
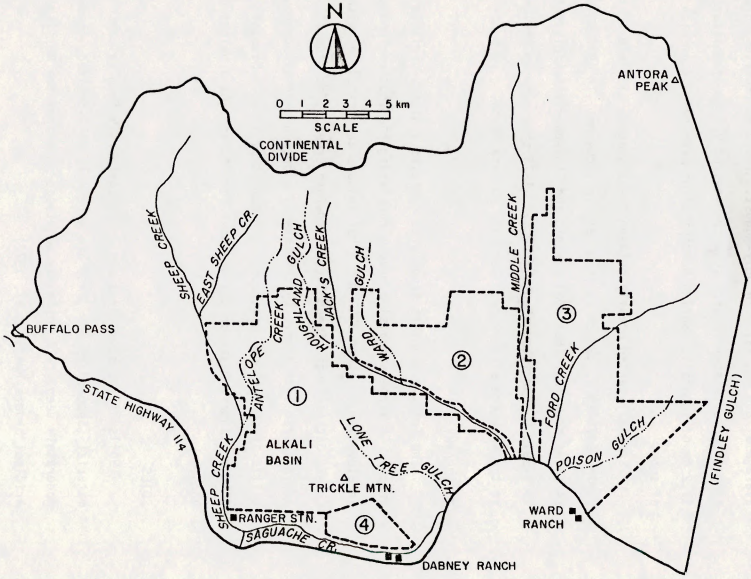

DENVER
Saguache

Figure 2. Trickle Mountain study area and boundaries of the Trickle Mountain (1), Cross Creek (2), Poison Gulch (3), and Robb Ranch (4) BLM allotments.


N
0 1 2 3 4 5 km
SCALE
CONTINENTAL DIVIDE
ANTORA PEAK
BUFFALO PASS
STATE HIGHWAY 114
SHEEP CREEK
EAST SHEEP CR.
ANTELOPE CREEK
HIGHLAND GULCH
JACK'S CREEK
WARD GULCH
MIDDLE CREEK
FORD CREEK
POISON GULCH
(FINDLEY GULCH)
LONE TREE GULCH
ALKALI BASIN
TRICKLE MTN.
RANGER STN.
SAGUACHE CR.
DABNEY RANCH
WARD RANCH
1
2
3
4

Precipitation averages 22 cm per year. Most precipitation, an average of 8.9 cm, falls in July-August. February receives only 0.23 cm of moisture. Winter records show averages of 0.7 cm of moisture and 11.2 cm of snowfall. Spring precipitation averages 1.6 cm with 5.8 cm of snow.

Snowfall varied greatly between the 2 seasons of field work. During 1978-1979, 128 cm of snow fell in Saguache. In 1977-1978, only 24 cm of snow fell (National Oceanic and Atmospheric Administration 1977-1979). Our measurements from 1978-1979 show snow on the ground at the Saguache airport from December to late March.

TOPOGRAPHY

The Trickle Mountain study area contains a highly variable topography. A large streamside meadow runs along the southern boundary at an elevation of about 2500 m. Other meadows are associated with Cross Creek, Jack's Creek, Sheep Creek, and Ford Creek. The federally administered land generally consists of slopes broken by numerous cliffs and occasional plateaus. The summit of Trickle Mountain is at 3088 m. Antora Peak, on the National Forest, attains a height of 4043 m.

SOILS

Soils of the study area are formed primarily from volcanic parent material (Shepard 1975). They are generally well-drained, loamy, and moderately deep. All soils may be placed in either the Mollisol or Aridisol orders (Heil et al. 1977).

VEGETATION

A vegetation map of BLM lands on the study area was developed from aerial photos by J. S. Hannan (Range Conservationist, BLM, Alamosa, CO). This map was modified, based on field observations. The following vegetation types were recognized:

1) Shortgrass; primarily blue grama and slimstem muhly (*Muhlenbergia filiculmis*) with scattered patches of sedges. Fringed sagebrush and winterfat (*Ceratoides lanata*) were the major browse species.
2) Shortgrass-pingue; similar to the shortgrass type except pingue (*Hymenoxys richardsonii*) constituted a major portion of the ground cover.
3) Midgrass; principally muhlys and fescues with scattered browse and forbs.
4) Mixed grass; the interface of shortgrass and midgrass types where it was impractical to distinguish between the 2 types.
5) Meadow; areas near water dominated by grasses and grasslike plants such as bluegrass, rushes (*Juncus* spp.), and sedges.
6) Rabbitbrush; shrublands found in gulches and depressions dominated by rabbitbrush (*Chrysothamnus* spp.) and currants (*Ribes* spp.].
7) Mountain shrub; hillsides with various grasses and forbs and an overstory of true mountainmahogany (*Cercocarpus montanus*).
8) Douglas-fir-Ponderosa pine; a fairly dense canopy of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) with fescues, muhlys, and forbs below.

9) Spruce-fir; a fairly dense canopy of Douglas-fir and blue spruce (*Picea pungens*) often interspersed with aspen (*Populus tremuloides*). Midgrasses, forbs, and frequent protrusions of bedrock were found beneath the trees.

10) Pinyon-juniper; primarily species found in the shortgrass type with an overstory of pinyon (*Pinus edulis*) and juniper (*Juniperus* sup.).

11) Sparse pinyon-juniper; essentially a shortgrass type with scattered pinyons and junipers. The designation of a vegetation unit as this type was subjective. Animals were expected to respond differently to this type than to the previous type.

12) Cliffs; very steep slopes of bedrock or boulders with little or no vegetation.

FAUNA

Bighorn Sheep

The Trickle Mountain herd began with a transplant of Rocky Mountain bighorn from the Tarryall herd onto the rim above Saguache Creek on February 15, 1951. The release consisted of 8 ewes, 4 lambs, and 3 rams. Ten years later, 36 bighorn were counted. Herd size was estimated at 125 in 1965. By 1971, the population was an estimated 165-175 individuals (Bear and Jones 1973, George Jones, pers. comm., 1981). The Colorado Division of Wildlife currently estimates the population at 350 (James Olterman, Colorado Division of Wildlife, pers. comm., 1980). Herd structure remains relatively unclear due to the difficulty of identifying yearling-class animals without intensive effort.

The herd was first hunted in 1953, after which the area was closed until 1960; annual seasons have been held from 1960 to the present. With the exception of 4 seasons, when the three-quarter-curl limitation was in effect, regulations have permitted harvest of half-curl rams (Bear and Jones 1973). From 1969 to 1979 an average of 8.6 rams was removed annually. The seasons of 1978 and 1979 had relatively high harvests, with 20 and 15 rams taken, respectively (Colorado Division of Wildlife 1969-1979).

The Colorado Division of Wildlife operated 2 bighorn feeding stations during the winters of 1978 and 1979. These stations were near Saguache Creek just north of the Dabney Ranch. Bighorns were regularly fed apple mash mixed with anti-helminthics. Small amounts of hay were used as an attractant. In April 1977, 20 bighorns were captured, marked, and released near the Trickle Mountain Ranger Station (Colorado Division of Wildlife, unpublished). These animals have provided information on herd movements.

Other Fauna

In addition to bighorn, substantial populations of other wild ungulates are found on the study area. The pronghorn population was estimated at 134 animals (Olterman, pers. comm.,1980). About 500 elk and 500 mule deer winter on the study area (U.S. Bureau of Land Management 1977).

Coyotes (*Canis latrans*) are the most numerous potential bighorn predators on the area. Bobcats (*Lynx rufus*) and mountain lions (*Felix concolor*) have been sighted. Golden eagles (*Aguila chrysaetos*) are frequently observed.

Appendix 1 lists all vertebrate fauna observed during this study.

LAND USE - PAST AND PRESENT

Settlement of the Saguache region occurred in the 1860s. Cattle grazing was unregulated until the Taylor Grazing Act of 1934. The BLM has records of licensed grazing levels for selected years from 1935 to the present.

The Trickle Mountain allotment was heavily grazed by 3000 to 5000 domestic sheep from 1935 to around 1950. Cattle use followed; 300 animal units (a.u.) were licensed for use in 1963. Although current licensed use is unchanged, the permittee grazes only 200 a.u.'s from mid-June to October. The Cross Creek allotment was grazed by an estimated 100 a.u.'s in 1959. Currently, the allotment is grazed by 255 a.u.'s from late June to mid-July and again from mid-August until October. Cattle grazing on the Poison Gulch allotment began with 90 a.u.'s in 1937. The a.u.'s peaked in 1955 at 270. The pattern of reductions in use since 1956 is not clear. Present licensed use is 172 cattle a.u.'s until mid-June after which only 50 a.u.'s are grazed until October. Small numbers of horses have also grazed this allotment. Licensed use for the other 4 allotments totals about 720 a.u.'s from May to December. The approximately 200 ha of bighorn range within the National Forest is extremely rugged and probably is not grazed by cattle.

Mineral exploration pits are common on the study area. Most were excavated in the 1950s in search of uranium (Shepard 1975). Although active claims are present on the Trickle Mountain allotment, no mining activity was observed during this study.

The BLM periodically conducts small timber sales on the Trickle Mountain allotment. In 1978, 228,000 board feet were harvested in 3 sales (J. S. Hannan, pers. com.). Although timber sales by the Forest Service were not investigated, any impact on bighorn was probably minimal.

Most recreational use of the area involves big game hunters. Hikers and fishermen were rarely observed. The presence of Indian artifacts attracts a few users each summer. Winter recreational use is limited to trapping and snowmobiling by local residents.

METHODS

DISTRIBUTION AND HABITAT USE

The winter-spring distribution of bighorn was determined from observations made while driving, walking, or skiing fixed routes through the study area during December 21-June 21, 1978-1979. These routes provided a representative view of the various habitats within the study area available to bighorn. As the study progressed, it became evident that more bighorn could be observed on certain routes. These routes were traveled about 5 days per week. Observations made by Allen Cooperrider (Wildlife Biologist, BLM, Denver, CO) during January 1-June 21, 1978 supplemented the 1978-1979 data.

Similar routes were driven during May-October, 1979 to determine cattle distribution. Again, most observation time was spent in areas of cattle concentrations. Cattle observed on private land were not included in determination of distribution and habitat use.

For each observation of bighorn or cattle, the following data were recorded: vegetation type, slope (in degrees), aspect, and distance from water. Weather conditions, especially snow depths, were recorded for bighorn observations. When possible, the distance of bighorn bands to escape terrain was estimated by pacing or from topographic maps. Escape terrain was defined as that terrain to which bighorn fled after being disturbed or subjectively as the nearest steep, rocky slope. Escape terrain which bighorn were observed to use was described as to height, length, slope, and vegetation.

Observations were plotted on topographic maps to determine bighorn winter-spring range and summer cattle range. The percentage of bighorn range used by cattle was then measured. Data on habitat use were converted to percentages. Preference indices were calculated for vegetative types by the formula:

$$\frac{\text{\% of observations in a vegetation type}}{\text{\% of study area (observable from routes) in the vegetation type}}$$

Preferences for slope and aspect categories were calculated similarly. The terrain observable from routes was classified into slope and aspect categories using topographic maps. Areas of at least 7 ha were considered in this classification.

FOOD HABITS

Microhistological analysis of feces was used to determine food habits of bighorn and cattle. Fifteen cattle fecal samples were collected from each allotment every 2 weeks during May-October 1978 and 1979. During January 1-June 21, 1978 and December 21-June 21, 1978-1979, 10 bighorn fecal samples were collected every 2 weeks. All samples were analyzed by the Composition Analysis Laboratory at Colorado State University. The percent density of undigested plant fragments in the fecal matter was presumed to accurately reflect the percent of each species in each herbivore's diet.

Summer diets of cattle and winter-spring diets of bighorn were compared using Kulcyznski's index of similarity (Oosting 1956): Similarity index = $[2w/(a+b)] \times 100$, where w is the lesser percentage of a food item in the 2 diets and a+b is the sum of the percentages of

food items in the 2 diets that is shared between 2 herbivores. Indices were calculated only for those forage species constituting at least 1% of either the cattle or bighorn diets.

VEGETATION MEASUREMENTS

Based upon observed consistent and frequent concentrations of bighorn, 18 areas were identified as critical to bighorn welfare during winter and spring. Seven areas were on the Trickle Mountain allotment, 7 were on the Cross Creek allotment, and 4 were on the Poison Gulch allotment. Bighorn forages for which production and cattle use were measured were those plants (1) constituting at least 1% of the 1978-79 bighorn diet, and (2) occurring in plots used to measure summer forage utilization (described below). These forages constituted 67% of the winter-spring diet of bighorn.

Production

Densities of bighorn forage on critical areas were determined using Soil-Vegetation Inventory Methods (SVIM) (U.S. Bureau of Land Management 1978) for each vegetation type within each allotment. Using these densities, production of bighorn forage used by cattle on each critical area was estimated from vegetation type composition of the area. Production figures were summed for each stratum (see below) within each allotment.

Utilization

Prior to the 1979 cattle grazing season, a pair of circular $0.46m^2$ plots were located in each of 3 strata on each of the 18 critical areas.

These strata represented expected differences in cattle grazing pressure based on distance from water or position on slope. The general location (within 25 m) of each pair of plots was determined at random. At each general location, a pair of plots with vegetation similar in composition and quantity was selected. A wire cage protected 1 randomly selected plot of each pair from grazing. In October, after all cattle had been removed from BLM land on the study area, herbaceous vegetation was clipped from each plot, air-dried, and weighed by species. Identical procedures were followed for current annual growth on shrubs. Differences between weights of winter-spring forages of bighorn in the caged plots versus the uncaged plots were used to estimate percent utilization of forage during summer. Production of bighorn forage within each stratum was multiplied by percent utilization to determine weight of forage removed in summer. Forage removal was averaged for each stratum across critical areas in each allotment.

Observations of cattle and wild ungulates on the critical areas indicated the species responsible for most of the grazing. To supplement these data, a 133 m^2 plot was centered on each range cage before the grazing season and cleared of fecal material. The plots were re-examined for wild ungulate or cattle feces concurrently with vegetation clipping.

IMPACT OF CATTLE GRAZING ON BIGHORN CARRYING CAPACITY

Literature review provided an estimate of daily forage intake by bighorn per kg of metabolic body weight. Information from the Colorado Division of Wildlife on body weights of Colorado bighorn and sex-age

composition of the Trickle Mountain herd was combined to estimate the average body weight for the Trickle Mountain bighorn herd. Daily forage intake of this average bighorn was calculated. The December 1-April 15 winter period assumed limiting to the bighorn population is 135 days. Daily forage intake of an average bighorn was therefore multiplied by 135 to estimate forage requirements per bighorn each winter. Amount of bighorn forage removed by cattle during summer was divided by this requirement. The quotient represents additional bighorn that could be supported by winter forage resources if cattle grazing did not occur.

RESULTS

DISTRIBUTIONS

Bighorn Distribution

Most bighorn winter-spring range was located on the Trickle Mountain, Cross Creek, Poison Gulch, and Robb Ranch allotments. A large segment of the herd, however, used lambing grounds on the National Forest. Bighorn also foraged on private land (Figure 3). Within winter-spring ranges on the Trickle Mountain, Cross Creek, and Poison Gulch allotments, 18 areas were identified as critical areas (Figure 4).

The area south of Trickle Mountain was an important winter range. However, feeding operations of the Colorado Division of Wildlife attracted bighorn to this area. From January 1 until March 15, 1979, 20 bighorn groups were observed at the feeders. Groups of 50-75 individuals were occasionally sighted. Bighorn also used snow-free canyons and cliffs in sections 24, 25, and 26, T45N R5E. In mid-February, these bighorn began expanding their range to include Lone Tree Gulch.

Dispersal from winter ranges in the vicinity of Trickle Mountain began in late March. In late April ewes, yearlings, and lambs arrived at traditional lambing grounds near Buffalo Pass where the earliest lamb was observed on May 28. Cliffs bordering East Sheep Creek probably were also used for lambing.

Figure 3. Distribution of bighorn during January-June 1978 and December-June, 1978-79 (crosshatch), Trickle Mountain study area.

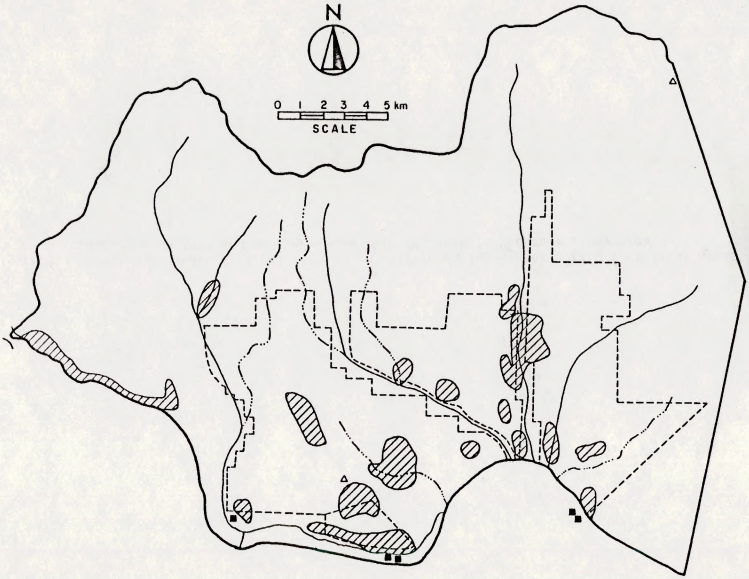
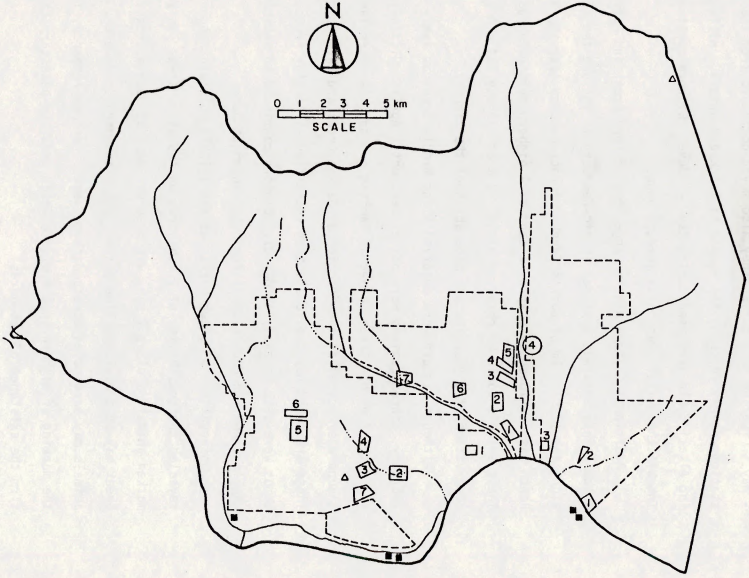

N
0 1 2 3 4 5 km
SCALE

Figure 4. Location of areas critical to bighorn welfare during winter-spring ("critical areas"), January-June 1978 and December-June 1978-79, Trickle Mountain study area.


N
0 1 2 3 4 5 km
SCALE

Bighorn foraged in private meadows along Saguache Creek in April - May. During this period they also moved northward from the feeding stations, nearly reaching the summit of Trickle Mountain. Hills surrounding Alkali Basin were used during May - June. Bighorn continued to inhabit the Buffalo Pass area through June.

Additional bighorn winter range is near Ford Creek and Poison Gulch. This area was expanded in mid-February to include the area along the first 2 km of Jack's Creek. A rock outcrop near the Ward Ranch was continuously used by a band of 4 bighorn during February-June. These animals could be observed within 50 m of Highway 114. A single observation of a yearling was made south of the highway.

Although bighorn were observed along Middle Creek as early as February, concentrations were not evident until April. Cliffs in the vicinity of Middle Creek served as lambing grounds. Another lambing ground was located at the junction of Jack's Creek and Ward Gulch. These areas had not previously been identified as lambing areas. Lambs were seen as early as May 31. Bighorn continued to inhabit the Jack's Creek and Middle Creek regions throughout June.

Observations of sheep marked at the Trickle Mountain ranger station revealed the possibility of 2 sub-herds on the study area. Only 1 marked animal, a class I ram, was observed east of Jack's Creek. Jack's Creek may be a dividing line between the 2 sub-herds. However, unmarked animals may have moved across Jack's Creek. Further research, including the marking of bighorn in the Middle Creek area, is necessary to confirm the existence of sub-herds.

Cattle Distribution

Cattle used only limited portions of available BLM land (Figure 5). Distribution for allotments containing bighorn winter-spring range is summarized below:

Trickle Mountain: The Houghland Gulch and Antelope Creek areas were heavily used for all but the last month of the grazing season. Rains in August filled reservoirs at the entrance to Lone Tree Gulch and allowed temporary use of that area. Scattered observations of cattle occurred on the plateaus north of Trickle Mountain.

Cross Creek: Cattle concentrated along accessible portions of Jack's Creek and Cross Creek. Concentrations were also noted near stock tanks in section 4, T45N R6E and section 33, T46N R6E.

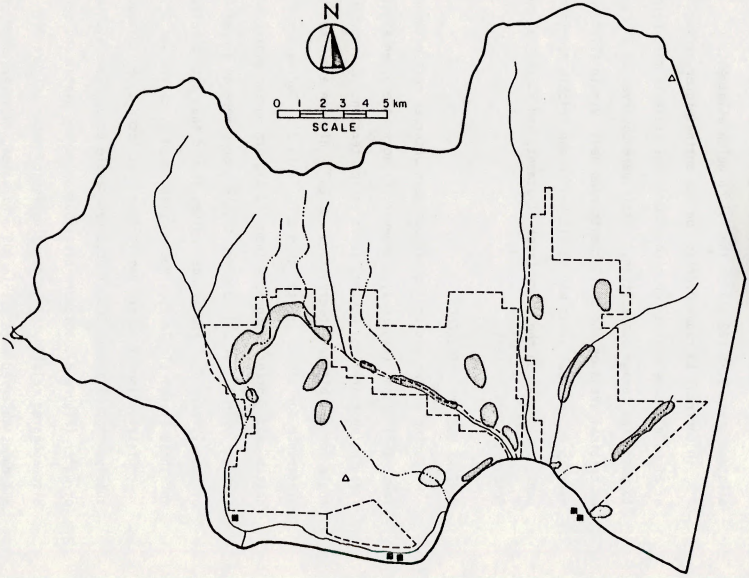
Poison Gulch: During June, cattle were sighted in Poison Gulch and along Middle Creek in sections 22 and 27, T46N R6E. They moved to Ford Creek in July and remained there the rest of the grazing season.

Robb Ranch: Cattle are permitted to range between this allotment and adjacent privately owned meadows during November - December. However, cattle were not observed on federal land during 1979.

Range Overlap

Cattle were observed in summer on 4% (64 ha) of bighorn winter-spring range on the Trickle Mountain, Cross Creek, and Poison Gulch

Figure 5. Distribution of cattle during May-October, 1979 on the Trickle Mountain, Cross Creek, and Poison Gulch allotments, Trickle Mountain study area.


N
0 1 2 3 4 5 km
SCALE

allotments (Figure 6). Within allotments, this overlap was 0.3% (3 ha) on the Trickle Mountain allotment, 8.8% (39 ha) on the Cross Creek allotment, and 9.2% (22 ha) on the Poison Gulch allotment.

In contrast to range overlap on the entire winter-spring range of bighorn, range overlap on bighorn critical areas is more relevant to potential forage competition. Cattle were observed on 5% (39 ha) of critical areas on the 3 allotments combined. Within allotments, overlap on critical areas was 3% (11 ha) on the Trickle Mountain allotment, 6% (14 ha) on the Cross Creek allotment, and 7% (13 ha) on the Poison Gulch allotment.

HABITAT USE AND PREFERENCE

During winter and spring bighorn were observed most often on steep (over 15°) slopes (Figure 7). However, bighorn were often sighted foraging on near-level benches above escape terrain. Median slope angle for all bighorn observations was 20°. Bighorn exhibited highest preference for slopes greater than 20° (Table 2). During summer, cattle used gentler topography than did bighorn during winter and spring. Over 75% of all observed cattle groups were on slopes of 5° or less (Figure 7). Preference indices showed that cattle selected for those slopes (Table 2). Median slope used by cattle was 2°.

Distribution of cattle was further restricted by a limited water supply. Approximately 50% of observed cattle groups were within 240 m of water (Figure 8). Bighorn distribution during winter and spring also appeared related to the distribution of water (Figure 9). Half of all bands observed were within 300 m of water. However, much of the escape terrain used by bighorn borders streams. These areas provided

Figure 6. Distribution of bighorn during January-June, 1978 and December-June 1978-79 (crosshatch) compared to distribution of cattle during May-October, 1979 (shading), Trickle Mountain study area.

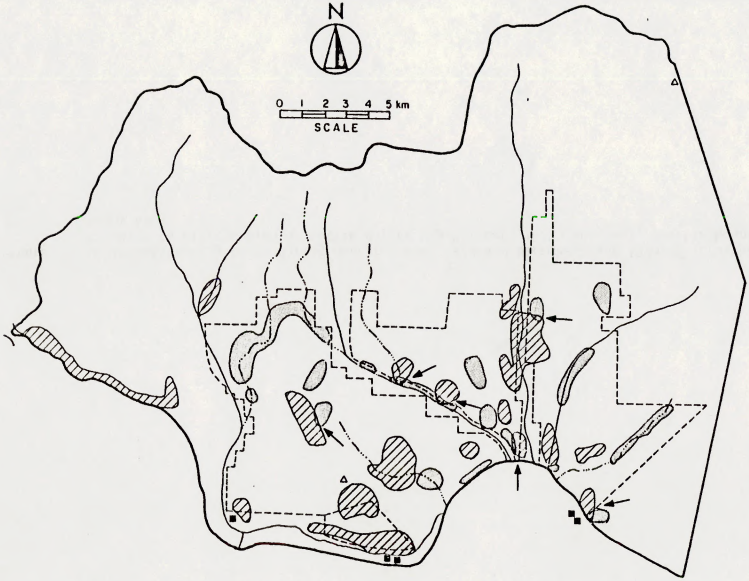

N
0 1 2 3 4 5 km
SCALE

Figure 7. Slopes used by cattle during summer and by bighorn during winter-spring, December, 1978-October, 1979, Trickle Mountain study area.

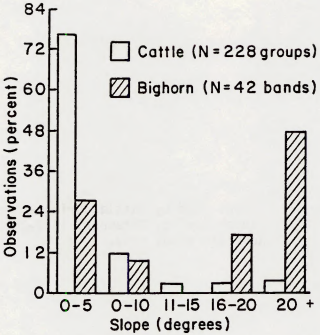

84
72
60
48
36
24
12
0
Observations (percent)
Cattle (N = 228 groups)
Bighorn (N = 42 bands)
0-5
0-10
11-15
16-20
20 +
Slope (degrees)

Table 2. Slope preference indices for 42 bighorn bands observed during winter-spring and 228 groups of cattle observed during summer on Trickle Mountain study area, December, 1978 - October 1979.

Slope (degrees)	Bighorn			Cattle		
	% of Obs.	% of Area in Class[1]	Preference Index[3]	% of Obs.	% of Area in Class[2]	Preference Index[3]
0-5	27.2	36.9	0.74	75.8	32.5	2.33
6-10	8.4	25.0	0.34	11.4	26.2	0.44
11-15	0.0	18.4	0.00	3.9	19.9	0.20
16-20	17.9	10.9	1.64	5.3	11.6	0.46
over 20	46.5	8.9	5.22	3.0	9.8	0.31

[1]Bighorn observations were recorded for both private and BLM lands, therefore all of these lands north of Highway 114 observable from routes are included in this column.

[2]Cattle observations were recorded only for BLM land. This column includes only BLM land north of Highway 114 observable from routes.

[3]Preference index = $\frac{\text{\% of Obs.}}{\text{\% of Area in Class}}$.

Figure 8. Distance of 230 observed cattle groups from water during May-October, 1979, Trickle Mountain study area.

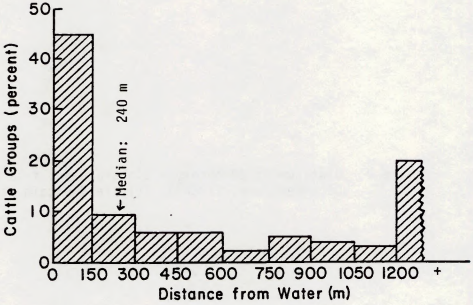
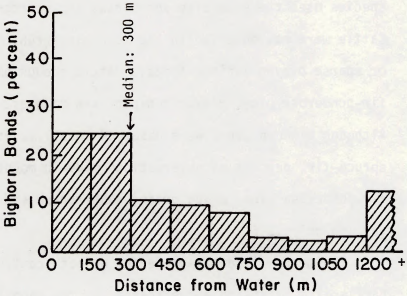

50
40
30
20
10
0
Cattle Groups (percent)
← Median: 240 m
0
150
300
450
600
750
900
1050
1200
+
Distance from Water (m)

Figure 9. Distance of 89 observed bighorn bands from water during December-June, 1978-79, Trickle Mountain study area.


Bighorn Bands (percent)
50
40
30
20
10
0
Median: 300 m
0 150 300 450 600 750 900 1050 1200 +
Distance from Water (m)

not only escape terrain but abundant streamside forage as well as water. The relative values of these 3 factors to bighorn of Trickle Mountain are not clear.

Both cattle and bighorn used the more open vegetation types (Figure 10). The limited amount of meadow type with its abundant forage accounted for about 9% of both bighorn and cattle observations. Both species used the extensive shortgrass and shortgrass-pingue types. Cattle were not observed in the mountain shrub, mixed grass, spruce-fir, or sparse pinyon-juniper types. Cattle groups observed in the Douglas fir-ponderosa pine, pinyon-juniper, and midgrass types totaled only 7.1%. Although bighorn bands were observed in all vegetation types except spruce-fir, percent of observations made in mountain shrub, Douglas-fir-ponderosa pine, mixed grass, rabbitbrush and pinyon-juniper types totaled only 12.5.

The meadow type was preferred by both cattle and bighorn (Table 3). Cattle also exhibited a preference for the rabbitbrush type. Low preference indices and an absence of observations in some forested types, revealed that cattle avoided timbered areas. Although the shortgrass and shortgrass-pingue types accounted for almost half the cattle observations, cattle did not show a preference for either type. In addition to meadows, bighorn preferred the midgrass, shortgrass and sparse pinyon-juniper types. The high preference index for the mountain shrub type may be fallacious because only 1 observation was made in this comparatively rare type. Bighorn seemed to avoid the shortgrass-pingue and rabbitbrush types. Like cattle, bighorn selected against densely timbered areas.

Figure 10. Vegetation types used by cattle during summer and by bighorn during winter-spring, December, 1978-October, 1979, Trickle Mountain study area.

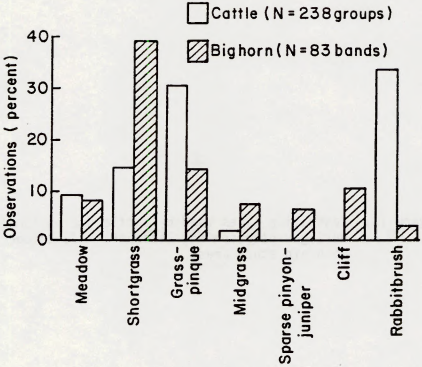

Cattle (N = 238 groups)
Bighorn (N = 83 bands)
Observations (percent)
40
30
20
10
0
Meadow
Shortgrass
Grass-pinque
Midgrass
Sparse pinyon-juniper
Cliff
Rabbitbrush

Table 3. Vegetation type preference indices for 83 bighorn bands observed during winter-spring and 238 cattle groups observed during summer, on Trickle Mountain study area, December 21, 1978 - October, 1979.

Vegetation Type	Bighorn			Cattle		
	% of Obs.	% of Area in Type[1]	Preference Index[3]	% of Obs.	% of Area in Type[2]	Preference Index[3]
Meadow	8.5	5.4	1.55	9.3	1.8	5.17
Shortgrass	38.7	20.1	1.92	14.2	20.8	0.68
Shortgrass-pingue	14.6	42.2	0.34	32.4	43.8	0.74
Midgrass	7.3	2.6	2.77	1.8	2.7	0.67
Rabbitbrush	3.7	9.3	0.38	36.0	9.6	3.75
Mountain shrub	1.3	0.3	4.00	0.0	0.3	0.00
Sparse pinyon-juniper	7.3	5.0	1.44	0.0	5.2	0.00
Pinyon-juniper	2.5	6.2	0.39	0.9	6.5	0.14
Douglas fir-pine	2.5	8.5	0.28	4.4	8.9	0.49
Spruce-fir	0.0	0.5	0.00	0.0	0.9	0.00
Mixed grass	2.5	--	--	0.0	--	--
Cliff	10.9	--	--	0.0	--	--

[1]Bighorn observations were recorded for both private and BLM lands, therefore all of these lands north of Highway 114 observable from routes are included in this column.

[2]Cattle observations were recorded only for BLM land. This column includes only BLM land north of Highway 114 observable from routes.

[3]Preference index = $\frac{\text{\% of Obs.}}{\text{\% of Area in Type}}$. Indices were not calculated for mixed grass and cliff types due to the difficulty of estimating their areas.

There were no major differences between cattle and bighorn in their uses of aspects available on the study area (Figure 11). Bighorn preferred southerly aspects which were snow-free in winter (Table 4). Cattle showed a slightly higher use of northerly aspects and a greater tendency to use level areas (Figure 11). They showed preferences for northeast aspects and especially for level areas (Table 4).

Bighorn Escape Terrain

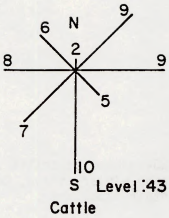
Bighorn fled to large, steep cliffs or rock outcrops when disturbed. They rarely ventured far from such terrain (Table 5). Of all bands observed, 90% were within 240 m of escape terrain. Bighorn usually used areas with southerly aspects for escape (Figure 12). Use of these aspects was probably related to bighorn preference for southerly aspects for foraging. After disturbance, bighorn would flee uphill. The first escape terrain encountered usually had an aspect similar to the foraging area. Of 58 bighorn bands observed, 84% fled into areas of little or no vegetation. Sparse pinyon-juniper was used by 10% of the bands, mountain shrub by 4%, and Douglas fir-ponderosa pine by 2%.

FOOD HABITS

Bighorn

Analysis of fecal samples collected during January 1-June 21, 1978 throughout the entire study area shows *Artemisia* spp. to be the predominant bighorn winter-spring forage (Table 6). Fringed sagebrush, the most common sage on the study area, probably constituted most of the *Artemisia* consumed. Amount of fringed sagebrush in the winter (January 1-March 21) diet was 55%. Concentration of fringed sagebrush

Figure 11. Aspects used (percent) by 234 groups of cattle during summer and by 88 bighorn bands during winter-spring, December, 1978-October, 1979, Trickle Mountain study area.


N
6
9
2
8
9
5
7
10
S
Level: 43
Cattle

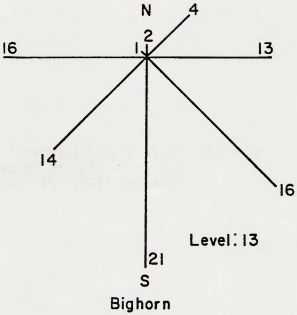

N
4
2
16
1
13
14
16
Level: 13
21
S
Bighorn

Table 4. Aspect preference indices for 83 bighorn bands observed during winter-spring and 234 groups of cattle observed during summer on Trickle Mountain study area, December 1978 - October 1979.

Aspect	Bighorn			Cattle		
	% of Obs.	% of Area in Class[1]	Preference Index[3]	% of Obs.	% of Area in Class[2]	Preference Index[3]
N	2.4	4.1	0.59	2.1	4.1	0.51
NE	3.6	6.5	0.55	9.4	7.0	1.32
E	13.3	15.6	0.85	9.4	16.8	0.56
SE	16.9	12.7	1.33	5.1	13.7	0.37
S	20.5	18.6	1.10	9.8	20.2	0.49
SW	13.9	10.9	1.22	7.3	11.9	0.61
W	15.6	13.0	1.20	8.1	14.0	0.58
NW	1.2	7.2	0.17	5.6	7.9	0.71
Level	13:3	11.3	1.18	43.2	4.3	10.05

[1]Bighorn observations were recorded for both private and BLM lands, therefore all of these lands north of Highway 114 observable from routes are included in this column.

[2]Cattle observations were recorded only for BLM land. This column includes only BLM land north of Highway 114 observable from routes.

[3]Preference index = $\frac{\text{\% of Obs.}}{\text{\% of Area in Class}}$.

Table 5. Physical characteristics of bighorn escape terrain and distances of bighorn bands from escape terrains, December 21, 1978 - June 21, 1979, Trickle Mountain study area.

Parameter	No. measured or observed	Mean	Range
Physical Characteristics[1]			
Height	19 escape terrains	16 m	8-25 m
Length	19 escape terrains	790 m	200-2100 m
Slope	25 escape terrains	72°	10-90°
Distance from Escape Terrains[2]	76 bands	103 m	0-1065 m

[1]Only those terrains to which bighorn fled after disturbance were measured.

[2]For these data, escape terrains were defined as (1) terrains to which bighorn fled after disturbance or (2) the nearest steep, rocky slopes if there was no disturbance.

Figure 12. Aspects of escape terrain used (percent) by 55 bighorn bands, December, 1978-June, 1979, Trickle Mountain study area.

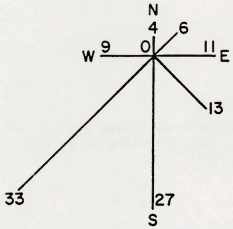

N
4
6
W
9
0
11
E
13
33
27
S

Table 6. Food items in winter-spring bighorn diet, as determined by microhistological analysis of feces, Trickle Mountain study area.

Food Item[1]	% in Diet	
	1978	1978-79
Total grass and grass-like plants	36.9	54.0
Muhlenbergia spp.	10.4	11.3
Bouteloua gracilis	--	11.4
Agropyron spp.	--	2.5
Festuca spp.	7.5	3.0
Sporobolus cryptandrus	--	4.7
Oryzopsis spp.	--	2.4
Carex spp.	2.7	9.5
Juncus spp.	1.6	--
Total forbs	4.8	7.3
Descurainia obtusa	--	1.5
Sphaeralcea coccinea	--	1.5
Total browse	58.3	38.7
Atriplex spp.	3.1	7.0
Artemisia spp.[2]	36.3	9.9
Ceratoides lanata	2.1	7.8
Yucca spp.	2.0	4.0
Salix spp.	--	2.5
Symphoricarpos palmeri	1.7	1.8
Potentilla spp.[3]	--	1.0
Ribes spp.	1.8	--

[1]Only food items accounting for at least 1% of the diet are included.

[2]Mostly *A. frigida*.

[3]Herbaceous *Potentilla* species occur on the study area but most of this genus is considered to be *P. fruticosa*.

in the diet declined sharply in mid-May. Bighorn consumed 20 % fringed sagebrush during spring (March 21-June 21). Other browses taken by bighorn included saltbush, winterfat, and yucca (*Yucca* spp.). Muhlys and fescues were the predominant grasses in the diet. Few forbs were utilized.

Winter-spring food habits of bighorns varied considerably between 1978 and 1978-79. Overlap of diets between the 2 years, estimated by Kulcyznski's index of similarity, was only 58%. The decreased importance of fringed sagebrush in the 1978-79 winter-spring diet accounted for most of the between-years dissimilarity (Table 6). Correspondingly, amounts of grasses in the 1978-79 diet increased. Percent of muhly remained similar to that of 1978 but blue grama rose from below 1 to over 11% in the diet. Sedges comprised almost 10% of the diet. Bighorn also grazed on sand dropseed (*Sporobolus cryptandrus*) and Indian ricegrass (*Oryzopsis hymenoides*) during 1979. Bighorn ate over twice as much saltbush and winterfat in 1978-79 as in 1978. Forbs, tansy mustard (*Descurainia obtusa*) and scarlet globemallow (*Sphaeralcea coccinea*), were consumed in small amounts during spring of 1979.

Snowfall during 1978-79 was over 5 times greater than in 1977-78. Further, the spring of 1979 was characterized by more precipitation and warmer temperatures compared to 1978 (Table 7). These differences in weather affected availabilities of bighorn forages. Fringed sagebrush was probably often covered by snow during 1978-79. Also, forb and grass production was greater in spring 1978-79. Bighorn diets reflected these changing availabilities of forages.

Table 7. Comparison of winter and spring weather data for Saguache, Colorado between 1977-79 and 1978-79.

	1977-78	1978-79
Snowfall		
Total Snowfall (cm)	24	128
Maximum Snow on Ground (cm)	13	58
Precipitation		
Total Precipitation (Jan-June) (cm)	7.3	9.0
Departure from Normal	-0.5	+1.2
Temperature		
Average Temperature (°C) (April-June)	8.6	10.4

Cattle

Analysis of fecal samples collected during May-October 1978 and 1979 from all BLM allotments showed a predominance of grass and grass-like plants in the cattle diet (Table 8). Muhlys, blue grama, wheat-grasses, fescues, sedges, and rushes were important food items during both years. Cattle consumed considerably more browse in 1979 than in 1978. Browse was most often utilized during September - October. Scarlet globemallow, which appeared in the 1979 diet, was the most prevalent forb consumed. Calculation of Kulcyznski's index revealed a similarity of 76% between 1978 and 1979 diets.

Cattle diets varied among the allotments containing bighorn winter-spring ranges (Table 9). Fringed sagebrush was an important cattle forage on the Trickle Mountain allotment. Large amounts of rushes were taken by cattle only on the Poison Gulch allotment. Muhlys, wheatgrasses, and sedges were important forages on all 3 allotments.

Diet Comparisons

Although browse was an important constituent of the 1979 diet, cattle of the Trickle Mountain study area were primarily grazers. Browse, especially fringed sagebrush, was more critical in the diets of bighorn, making up over half of the 1978 winter-spring diet. Several comparisons, using Kulcyznski's index of similarity, were made between bighorn and cattle diets (Table 10). Indices vary with changes in food habits of either species. Comparison of 1978 cattle diets to 1978-1979 bighorn diets indicates the potential impact of summer cattle grazing on bighorn welfare during a subsequent winter-spring period with above-average snowfall. Dietary overlap was similar among

Table 8. Food items in May-October cattle diet, as determined by microhistological analysis of feces, Trickle Mountain study area.

Food Item[1]	% in Diet	
	1978	1979
Total grass and grass-like plants	82.1	57.1
Muhlenbergia spp.	21.7	9.4
Bouteloua gracilis	10.6	10.3
Agropyron spp.	7.7	7.9
Festuca spp.	7.3	3.0
Sporobolus cryptandrus	3.0	--
Poa spp.	--	1.5
Sitanion hystrix	--	1.4
Carex spp.	9.0	12.7
Eleocharis spp.	--	1.7
Juncus spp.	10.3	5.5
Total forbs	4.0	19.2
Sphaeralcea coccinea	--	2.0
Total browse	13.9	23.7
Atriplex spp.	4.6	5.8
Artemisia spp.[2]	2.8	--
Ceratoides lanata	2.6	5.7
Salix spp.	--	1.5
Potentilla spp.[3]	1.0	6.2
Cercocarpus montanus	--	1.5

[1]Only food items accounting for at least 1% of the diet are included.

[2]Mostly *A. frigida*.

[3]Herbaceous *Potentilla* species occur on the study area but most of this genus is considered to be *P. fruticosa*.

Table 9. Food items in diets of cattle on the Trickle Mountain, Cross Creek, and Poison Gulch allotments as determined by microhistological analysis of feces; June - October, 1978.

Food Item[1]	% in Diet		
	Trickle Mtn.	Cross Creek	Poison Gulch
Total grass and grass-like plants	82.7	81.6	83.4
Muhlenbergia spp.	26.0	23.8	13.3
Bouteloua gracilis	--	--	2.2
Agropyron spp.	13.4	9.8	11.6
Festuca spp.	17.8	8.6	3.6
Sporobolus cryptandrus	--	--	1.4
Carex spp.	8.4	10.5	15.2
Juncus spp.	3.5	--	19.6
Total forbs	4.9	4.6	5.9
Total browse	12.0	14.0	10.8
Atriplex spp.	--	2.6	1.0
Artemisia spp.[2]	9.3	--	--
Ceratoides lanata	--	1.4	--
Potentilla spp.[3]	--	--	2.3

[1]Only food items accounting for at least 1% of the diet are included.

[2]Mostly *A. frigida*.

[3]Herbaceous *Potentilla* species occur on the study area but most of this genus is considered to be *P. fruticosa*.

Table 10. Similarity indices[1] for comparing winter-spring bighorn and May-October cattle diets, Trickle Mountain study area.

	Bighorn 1978	Bighorn 1978-79
Cattle 1978	49	73
Cattle 1979	63	82
Cattle 1978 - Trickle Mtn. allotment	51	62
Cattle 1978 - Cross Creek allotment	67	62
Cattle 1978 - Poison Gulch allotment	35	63

[1]Calculated using Kulcyznski's index of similarity (Oosting 1956).

allotments when these data were compared. Kulcyznski's index, calculated for the entire study area, indicated that 1978 cattle diets and 1978-79 bighorn diets were 73% similar.

FORAGE PRODUCTION AND UTILIZATION

Four grasses, *Carex*, and 5 browses each accounted for at least 1% of the 1978-79 winter-spring bighorn diet and occurred in plots used to measure utilization of forage by cattle during summer (Table 11).

Trickle Mountain Allotment

Production of bighorn forages on 7 critical areas within the Trickle Mountain allotment varied from 139 kg/ha in the sparse pinyon-juniper type to 217 kg/ha in the Douglas fir-ponderosa pine type (Table 12). However, 61% of the 7 areas consisted of the shortgrass-pingue type and this type produced most of the bighorn forage on the areas.

Cattle were the most frequently observed ungulate on critical areas from mid-June-October (Table 13). Most cattle were sighted in stratum 2 where they used 7% of the area (Table 14). Of 34 cattle observed on critical areas, 20 were within critical area number 6 (Table 15, Figure 4). One cattle dropping and 8 wild ungulate pellet groups were found within the plots on the 7 critical areas. Observation data were considered more reliable indicators of animal use than were pellet group counts because pellet group plots sampled less than 1% of the area within critical areas. Based upon relative numbers of ungulates observed and considering that a cow consumes much more than any wild ungulate on the study area, it was concluded that most forage was utilized by cattle.

Table 11. Plants accounting for at least 1% of 1978-1979 winter-spring bighorn diet and occurring in plots used for measurement of summer forage utilization.

Common Name	Scientific Name
Grasses and sedges	
Blue grama	*Bouteloua gracilis*
Muhly	*Muhlenbergia* spp.
Fescue	*Festuca* spp.
Wheatgrass	*Agropyron* spp.
Sedge	*Carex* spp.
Browses	
Sagebrush	*Artemisia* spp.
Saltbush	*Atriplex canescens*
Winterfat	*Ceratoides lanata*
Yucca	*Yucca* spp.
Cinquefoil	*Potentilla* spp.

Table 12. Vegetative composition of 7 bighorn critical areas on the Trickle Mountain allotment.

Vegetation Type	Production of bighorn forage[1] (kg/ha)	Total ha of critical areas in each vegetation type			Proportion of total critical area (%)
		Stratum[2] 1	Stratum 2	Stratum 3	
Shortgrass	172	2.6	18.3	19.3	11
Shortgrass-pingue	196	44.1	72.5	100.5	61
Midgrass	149	12.1	0.0	0.0	3
Rabbitbrush	180	0.8	12.3	3.8	5
Sparse pinyon-juniper	139	1.3	3.0	13.8	5
Pinyon-juniper	211	6.3	21.9	17.4	13
Douglass-fir-ponderosa	217	0.0	0.9	3.8	1
Total ha		67.2	128.9	158.6	
Total kg of bighorn forage		12,530	24,805	30,116	

[1]Based on Soil-Vegetation Inventory Methods (SVIM) (U.S. Bureau of Land Management 1978). Data were obtained during June-August 1978 and 1979.

[2]Stratification was based on differences among expected levels of cattle grazing: 1=high, 2=medium, 3=least.

Table 13. Numbers of cattle and wild ungulates[1] observed on bighorn critical areas June-October 1979, Trickle Mountain study area.

Species	Allotment		
	Trickle Mountain	Cross Creek	Poison Gulch
Cattle	34	140	30
Bighorn	0	50	35
Pronghorn	6	0	0
Mule Deer	0	0	1

[1]Elk were not observed on bighorn critical areas from June-October, 1979.

Table 14. Utilization of bighorn forage by cattle on critical areas, June-October 1979, Trickle Mountain study area, Colorado.

Allotment	Stratum[1]	Area (ha)	No. of Cattle Observed	Observed density of cattle fecals[2]	% of stratum used by cattle	Production of bighorn forage (kg)[3]	Mean % utilization of bighorn forage[4] (kg)	Amount of bighorn forage utilized (kg) and 90% C.I.
Trickle Mountain	1	67.2	9	1	4	12,530	25 (±30)	3,132 (0-6,892)
	2	128.9	25	0	7	24,805	24 (±21)	5,953 (744-11,906)
	3	158.6	0	0	0	30,116	4 (±29)	1,205 (0-9,938)
Totals		354.7	34	1		67,451		10,290
Cross Creek	1	53.6	130	38	11	12,284	42 (±27)	5,159 (1,843-8,476)
	2	58.8	10	5	18	11,929	24 (±36)	2,863 (0-7,157)
	3	124.6	0	3	0	24,357	3 (±25)	731 (0-6,820)
Totals		237.1	140	46		48,570		8,753
Poison Gulch	1	59.6	18	0	7	17,672	0[5]	0[5]
	2	59.2	1	0	10	17,546	19 (±35)	3,334 (0-9,475)
	3	67.3	11	0	6	19,989	19 (±14)	3,798 (999-6,596)
Totals		186.1	30	0		55,207		7,132

[1]Stratification was based on differences among expected levels of cattle grazing: 1 = high, 2 = medium, 3 = least.

[2]Sample sizes: Trickle Mountain, 7 plots per stratum; Cross Creek, 7 plots per stratum; Poison Gulch, 4 plots per stratum. Each plot was 133 m^2.

[3]Production estimates were based on Soil-Vegetation Inventory Methods (SVIM) (U.S. Bureau of Land Management 1978). Data were obtained during June-August 1978 and 1979.

[4]Sample sizes: Trickle Mountain, 7 paired plots per stratum; Cross Creek, 7 paired plots per stratum; Poison Gulch, 4 paired plots in strata 1 and 3, 3 paired plots in stratum 2.

[5]A negative utilization (-17%± 80%) was indicated.

Table 15. Number of cattle observed on bighorn critical areas, June - October, 1979, Trickle Mountain study area.

Area No.	Allotment		
	Trickle Mountain	Cross Creek	Poison Gulch
1	0	22	29
2	5	12	0
3	0	9	0
4	0	0	1
5	9	2	--
6	20	10	--
7	0	85	--

Summer utilization of bighorn forages was estimated at 25% in stratum 1, 24% in stratum 2, and 4% in stratum 3 (Table 14). Means of percent utilization exhibited wide confidence intervals resulting from large variances and the small sample (n = 7). Estimated total forage removal was greatest in stratum 2, where cattle consumed 5,953 kg of bighorn forage.

Cross Creek Allotment

The limited amount of meadow type produced 579 kg/ha of bighorn forage (Table 16). The predominant shortgrass type produced 214 kg/ha of bighorn forage. Lowest density of bighorn forage was produced by the sparse pinyon-juniper type.

Cattle were the most frequently observed ungulate on critical areas (Table 13). Over 90% of cattle sighted on critical areas were within stratum 1 (Table 16). Cattle were not observed in stratum 3 but ranged over 11 and 18% of strata 1 and 2, respectively. Critical area number 7, containing a meadow and permanent stream, was used by the greatest number of cattle (Table 15, Figure 4). Of 47 droppings located on 21 plots, 46 were cattle droppings (Table 14). The relatively high number of cattle observations and fecals indicate that most forage was used by cattle.

Cattle grazing had the greatest impact in stratum 1 (Table 14). The expected pattern of grazing occurred as forage removal declined in strata 2 and 3. The small sample (n = 7) and large variances caused wide confidence intervals about the means of percent utilization. Cattle utilized an estimated 5,159 kg of bighorn forage in stratum 1.

Table 16. Vegetative composition of 7 bighorn critical areas on the Cross Creek allotment.

Vegetation Type	Production of bighorn forage[1] (kg/ha)	Total ha of critical areas in each vegetation type			Proportion of total critical area (%)
		Stratum[2] 1	Stratum 2	Stratum 3	
Shortgrass	214	38.8	36.5	63.7	59
Shortgrass-pingue	390	0.0	1.9	9.1	5
Rabbitbrush	221	6.3	6.0	1.5	6
Sparse pinyon-juniper	93	4.8	10.2	12.6	12
Pinyon juniper	150	0.0	3.1	34.2	16
Douglas-fir-ponderosa	155	0.0	0.0	3.5	1
Meadow	579	3.7	1.1	0.0	2
Total ha		53.6	58.8	124.6	
Total kg of bighorn forage		12,284	11,929	24,357	

[1]Based on Soil-Vegetation Inventory Methods (SVIM) (U.S. Bureau of Land Management 1978). Data were obtained during June-August 1978 and 1979.

[2]Stratification was based on differences among expected levels of cattle grazing: 1=high, 2=medium, 3=least.

Poison Gulch Allotment

Production of bighorn forage on 4 critical areas within the Poison Gulch allotment ranged from 239 kg/ha in the rabbitbrush type to 375 kg/ha in the sparse pinyon-juniper type (Table 17). However, over 80% of the critical areas consisted of the shortgrass type. This type produced the most kg of bighorn forage.

Observed numbers of wild ungulates, primarily bighorn, exceeded numbers of cattle observed (Table 13). Only 1 cow was observed in stratum 2 (Table 14). This animal was near the middle of critical area number 4 (Figure 4). Consequently a large proportion of stratum 2 in critical area number 4 was considered to have been used by cattle. This resulted in an estimate that 10% of stratum 2 on the Poison Gulch allotment was used by cattle (Table 14). This estimate, based on 1 observation, is questionable. All other cattle were observed in critical area number 1 (Table 15, Figure 4). Cattle droppings were not found within 11 pellet group plots (Table 14). Six wild ungulate pellet groups were counted. Animal species responsible for forage utilization is unclear. Low numbers of fecal groups counted do not supply an accurate indicator of animal use. Although similar numbers of cattle and bighorn were observed, the greater amounts of forage required by cattle suggests that cattle consumed most of the forage removed.

Cattle were not detected to utilize bighorn forage in stratum 1 (Table 14). Means of percent utilization were identical in strata 2 and 3. Stratum 2 exhibited the widest confidence interval. Amount of forage removed was greatest in stratum 3.

Table 17. Vegetative composition of 4 bighorn critical areas on the Poison Gulch allotment.

Vegetation Type	Production of bighorn forage[1] (kg/ha)	Total ha of critical areas in each vegetation type			Proportion of total critical area (%)
		Stratum[2] 1	Stratum 2	Stratum 3	
Shortgrass	297	59.1	43.8	52.2	83
Rabbitbrush	239	0.5	0.0	3.5	2
Sparse pinyon-juniper	375	0.0	1.8	3.9	3
Pinyon-juniper	284	0.0	13.6	7.7	11
Total ha		59.6	59.2	67.3	
Total kg of bighorn forage		17,672	17,546	19,989	

[1]Based on Soil-Vegetation Inventory Methods (SVIM) (U.S. Bureau of Land Management 1978). Data were obtained during June-August 1978-1979.

[2]Stratification was based on differences among expected levels of cattle grazing: 1=high, 2=medium, 3=least.

IMPACT OF CATTLE GRAZING ON BIGHORN CARRYING CAPACITY

Forage Requirements of Trickle Mountain Bighorn

Mean body weights of bighorn trapped at Trickle Mountain in 1977 were: lambs, 30 kg; yearlings, 58 kg; and ewes, 67 kg. No rams were trapped. Mean ram weight, 72 kg, was derived from weights of rams trapped from 3 other Colorado bighorn herds (G. A. Schoonveld, Colorado Division of Wildlife, unpubl.). The assumed population structure of: 50 lambs, 36 yearlings, 100 ewes, and 84 rams was based on a lamb:ewe ratio provided by James Olterman (Colorado Division of Wildlife, pers. comm.), and a ram:ewe ratio based upon the estimated size of the Trickle Mountain herd (J. Olterman, pers. comm.) and known rates of rams harvested from the herd (Colorado Division of Wildlife, 1969-1979).

Body weights for each sex-age class were raised to an exponent of 0.75 to calculate metabolic body weights of: lambs, 12.82 kg; yearlings, 21.02 kg; ewes, 23.42 kg; and rams, 24.72 kg. Metabolic body weights were multiplied by 0.076 kg (daily intake/kg metabolic body weight, page 10) to calculate daily intake for an individual in each sex-age class. Daily intakes were weighted by multiplying by the percent of each sex-age class in the population. These products were summed to obtain a daily intake of 1.64 kg for an average bighorn in the Trickle Mountain herd. This animal would consume approximately 221 kg of forage during the 135 days between December 1-April 15.

Cattle Impacts on Bighorn Carrying Capacity

If forage available to bighorn on critical areas during winter limits bighorn numbers, removal of forage from these areas by cattle

Table 17. Vegetative composition of 4 bighorn critical areas on the Poison Gulch allotment.

Vegetation Type	Production of bighorn forage[1] (kg/ha)	Total ha of critical areas in each vegetation type			Proportion of total critical area (%)
		Stratum[2] 1	Stratum 2	Stratum 3	
Shortgrass	297	59.1	43.8	52.2	83
Rabbitbrush	239	0.5	0.0	3.5	2
Sparse pinyon-juniper	375	0.0	1.8	3.9	3
Pinyon-juniper	284	0.0	13.6	7.7	11
Total ha		59.6	59.2	67.3	
Total kg of bighorn forage		17,672	17,546	19,989	

[1]Based on Soil-Vegetation Inventory Methods (SVIM) (U.S. Bureau of Land Management 1978). Data were obtained during June-August 1978-1979.

[2]Stratification was based on differences among expected levels of cattle grazing: 1=high, 2=medium, 3=least.

IMPACT OF CATTLE GRAZING ON BIGHORN CARRYING CAPACITY

Forage Requirements of Trickle Mountain Bighorn

Mean body weights of bighorn trapped at Trickle Mountain in 1977 were: lambs, 30 kg; yearlings, 58 kg; and ewes, 67 kg. No rams were trapped. Mean ram weight, 72 kg, was derived from weights of rams trapped from 3 other Colorado bighorn herds (G. A. Schoonveld, Colorado Division of Wildlife, unpubl.). The assumed population structure of: 50 lambs, 36 yearlings, 100 ewes, and 84 rams was based on a lamb:ewe ratio provided by James Olterman (Colorado Division of Wildlife, pers. comm.), and a ram:ewe ratio based upon the estimated size of the Trickle Mountain herd (J. Olterman, pers. comm.) and known rates of rams harvested from the herd (Colorado Division of Wildlife, 1969-1979).

Body weights for each sex-age class were raised to an exponent of 0.75 to calculate metabolic body weights of: lambs, 12.82 kg; yearlings, 21.02 kg; ewes, 23.42 kg; and rams, 24.72 kg. Metabolic body weights were multiplied by 0.076 kg (daily intake/kg metabolic body weight, page 10) to calculate daily intake for an individual in each sex-age class. Daily intakes were weighted by multiplying by the percent of each sex-age class in the population. These products were summed to obtain a daily intake of 1.64 kg for an average bighorn in the Trickle Mountain herd. This animal would consume approximately 221 kg of forage during the 135 days between December 1-April 15.

Cattle Impacts on Bighorn Carrying Capacity

If forage available to bighorn on critical areas during winter limits bighorn numbers, removal of forage from these areas by cattle

will reduce bighorn carrying capacity of the study area. The best assessment of impacts of cattle grazing on bighorn carrying capacity is based on estimates of mean forage utilization. However, 90% confidence limits for those means were quite wide (Table 14). Impacts of cattle grazing are therefore presented in 3 ways: (1) a best estimate based upon mean removal of bighorn forage, (2) a minimum estimate based upon the lower limit of the 90% confidence interval for the mean removal, and (3) a maximum estimate based upon the upper limit of the 90% confidence interval for the mean removal.

Impacts of cattle grazing on bighorn carrying capacities of the Trickle Mountain study area are greatest on the Trickle Mountain allotment, intermediate on the Cross Creek allotment, and least on the Poison Gulch allotment (Table 18). Although percent utilization of bighorn forage on the Trickle Mountain allotment was less than on the Cross Creek allotment, there were 118 more ha of critical area on the Trickle Mountain allotment (Table 12). Therefore, more bighorn forage was produced and, thus, utilized by cattle (Table 14) causing a greater impact on the Trickle Mountain allotment.

The estimated amount of bighorn forage removed by cattle from all 3 allotments could have supported 117 bighorn through the winter (Table 18). However, due to wide confidence limits for estimates of bighorn forage removed by cattle, minimum and maximum estimates of cattle impacts are 16 and 304 bighorn, respectively.

ADDITIONAL BIGHORN HABITAT

Information on habitat preferences and characteristics of bighorn escape terrain was used to identify 12 areas as potential bighorn

Table 18. Estimated impacts[1] of cattle grazing on winter (December 1-April 15) carrying capacities for bighorn on 3 allotments, Trickle Mountain study area, 1978-1979.

Allotment and stratum	Best estimate[2] of impact	Minimum estimate[3] of impact	Maximum estimate[4] of impact
Trickle Mountain			
1	14	0	31
2	27	3	54
3	5	0	45
Totals	46	3	130
Cross Creek			
1	23	8	38
2	13	0	32
3	3	0	31
Totals	39	8	101
Poison Gulch			
1	0	0	0
2	15	0	43
3	17	5	30
Totals	32	5	73

[1]Number of bighorn that could be supported by amount of bighorn forage removed by cattle.

[2]Best estimates are based upon mean kg of bighorn forage removed by cattle.

[3]Minimum estimates are based upon lower 90% confidence limit of mean kg of bighorn forage removed by cattle.

[4]Maximum estimates are based upon upper 90% confidence limit of mean kg of bighorn forage removed by cattle.

habitat (Figure 13). These areas were unused by bighorn but had the characteristics of preferred habitat[1] (Table 5, Figures 9, 12) and adequate escape terrain (Table 5). On these sites, areas with preferred habitat characteristics within 240 m (Table 5) of escape terrain were considered usable by bighorn.

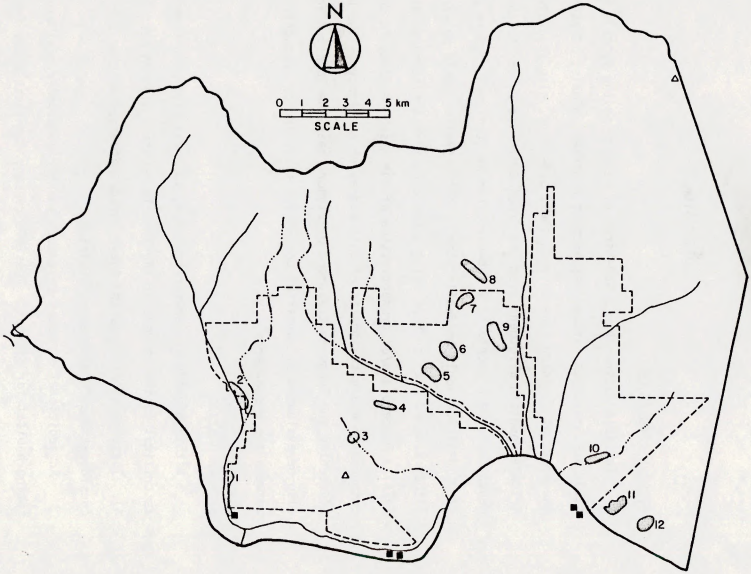
Should bighorn inhabit these areas in the future, either by colonization or transplants, carrying capacity of the study area would increase. Increases would be greatest on the Trickle Mountain and Cross Creek allotments which contain 166 and 168 ha, respectively, of potential habitat. Only 10 ha of potential habitat were located on the Poison Gulch allotment. Additional potential habitat was identified on the Laughlin Gulch allotment, adjoining the east side of the Poison Gulch allotment, and on the Rio Grande National Forest.

Present overlap of cattle range on potential areas is insignificant. However, should both bighorn and cattle distribution expand or change, forage production and utilization of potential areas will affect future carrying capacities.

---

[1]Habitat characteristics used as criteria for identification of potential habitat included: vegetation type, slope, aspect, and distance from water.

Figure 13. Location of potential bighorn habitat (shading), Trickle Mountain study area.


N
0 1 2 3 4 5 km
SCALE
1
2
3
4
5
6
7
8
9
10
11
12

DISCUSSION

BIGHORN POPULATION

Possible existence of 2 sub-herds of bighorn on the Trickle Mountain study area requires further research with marked animals. Jack's Creek, the apparent dividing line between the 2 sub-herds, also separates the Trickle Mountain allotment from the Cross Creek and Poison Gulch allotments. If the presence of 2 sub-herds can be confirmed, future studies of competition would be facilitated. Cattle grazing could be varied on either side of Jack's Creek using a switchback design (Cochran and Cox 1975). Numbers and/or productivities of the 2 sub-herds could then be compared to evaluate impacts of cattle grazing on bighorn. The utility of feeding and lungworm-treatment of bighorn near the Dabney Ranch could also be evaluated by comparing population sizes and/or productivities between the 2 sub-herds.

BIGHORN HABITAT

Within bighorn winter-spring range, 18 areas have been identified as critical to the welfare of the Trickle Mountain bighorn herd (Figure 4). These critical areas and their forage resources deserve special considerations in management planning.

An additional 12 areas have been identified as potential winter-spring habitat for bighorn. Possible reasons for these areas remaining unused include: (1) currently used winter-spring range (Figure 3) may

fulfill requirements of the bighorn population at its present size and (2) traditions for use of these areas have yet to be established. Geist (1971) explained the role of tradition in range use by bighorn. In a management program emphasizing bighorn, these 12 areas would be protected as future bighorn habitat.

Bighorn winter-spring range was determined by observing bighorn in both an average and a severe winter (Table 7). This suggests that important bighorn range was accurately identified. However, the Colorado Division of Wildlife's feeding and treatment operations may have exaggerated bighorn use of the Robb Ranch allotment (Figure 3).

Prior to McCollough et al. (1980), no publications had identified the areas along Middle Creek, Jack's Creek, and Ward Gulch as bighorn lambing grounds. A major portion of the Trickle Mountain herd's lamb crop is produced in these newly-identified areas. Included within these lambing grounds are critical areas 3-7 of the Cross Creek allotment and critical area 4 of the Poison Gulch allotment. As lambing grounds, these may be the most important critical areas for the Trickle Mountain herd.

Winter-spring habitats of bighorn on the Trickle Mountain study area generally consisted of areas of sparse or low-growing vegetation on south or west-facing slopes, within 240 m of escape terrain (Tables 3-5). Bighorn habitat has been similarly described in previous studies (Smith 1954, McCullough and Schneegas 1966, Geist 1971, Frisina 1974, Lauer and Peek 1976, Tilton 1977, Baumann and Stevens 1978). Areas used by bighorn shed snow in winter, contained adequate escape terrain, and allowed good visibility of surrounding environment. Risenhoover

and Bailey (1980) discussed the importance of visibility and escape terrain in the predator evasion strategy of bighorn.

Bighorn Escape Terrain

Qualitative descriptions of bighorn escape terrain are common in the literature (Honess and Frost 1942, McCann 1956, Simmons 1961, Flook 1964, McCullough and Schneegas 1966, Woolf 1968, Brown 1974). These descriptions are of limited value because they allow subjective interpretations. Selected bighorn escape terrain on the Trickle Mountain study area was quantified (Table 5, Figure 12). Slopes on escape terrain averaged 72° and were characterized by low-growing or sparse vegetation. Ninety percent of all bighorn bands were observed within 240 m of cliffs measuring at least 200 m long and 8 m tall. These descriptions can be used in identifying and managing bighorn habitat and potential bighorn habitat in other areas.

BIGHORN FOOD HABITS

Important winter-spring forages of bighorn on the Trickle Mountain study area are fringed sagebrush, sedges, muhlys, fescues, blue grama, saltbush, winterfat, and yucca (Table 6). Most other studies of Rocky Mountain bighorn have indicated a preponderance of grasses in the diet (Smith 1954, Moser 1962, Todd 1972, Frisina 1974, Lauer and Peek 1976). Bighorn of the Trickle Mountain study area consumed considerable browse, especially fringed sagebrush (Table 6). Increased utilization of blue grama, sedges, saltbush, and winterfat during the severe winter of 1978-79 suggests that these plants may be emergency forage.

IMPACT OF CATTLE GRAZING ON BIGHORN FORAGE RESOURCES

Two factors determining forage competition among ungulates are: (1) the extent to which 2 species graze the same area and (2) the extent to which they prefer the same plants (Julander 1958). Julander (1958) and Cole (1958) stated that forage plants being utilized by competing animals must be in limited supply. Spatial and dietary overlap, but not limitations of forage resources, have been considered in several attempts to evaluate ungulate competition (Honess and Frost 1942, McCann 1956, Gordon 1957, Flook 1964, Oldemeyer 1966, Wilson 1968, Pallister 1974, Hansen and Clark 1977).

Cattle diets varied between summer and fall, between years, and among allotments (Tables 8, 9). The 1978 cattle diet was compared to the 1978-79 bighorn diet and revealed a moderate dietary overlap. Both diets represented forage selection averaged over the entire study area. Principal forages mutually used by bighorn and cattle were muhlys, fescues, sedges, saltbush, and winterfat. Three events, in particular, could cause an increase in the degree of overlap between bighorn and cattle diets: (1) Increased stocking rates or delayed removal of cattle from range in the fall could result in greater browse consumption by cattle. (2) Greater use of upland sites by cattle, particularly on the Trickle Mountain allotment, could result in increased utilization of fringed sagebrush by cattle. (3) Heavy snows, covering low-growing fringed sagebrush, could cause greater grass consumption by bighorn.

Although summer diets of cattle and winter-spring diets of bighorn were moderately similar on the Trickle Mountain study area, overlap of

cattle and bighorn range was minimal (Figure 6). Separation of bighorn and cattle range has also been reported by McCullough and Schneegas (1966) and Dean (1975). Factors limiting cattle use of bighorn range were topography, availability of water, and aspect. Cattle were reluctant to wander over 1.5 km from water (Figure 8), avoided slopes greater than 5° (Table 2), and used northern aspects (Figure 7) more often than did wintering bighorn. Northern aspects may be relatively moist and thus have more forage to attract cattle during summer.

Overlap of bighorn and cattle ranges in the 1.3 ha of meadow vegetation type on critical area 7 within the Cross Creek allotment contributed significantly to cattle impacts on bighorn forage. Cattle were frequently observed in this area (Table 15) and were responsible for much forage utilization. Cattle range also overlapped critical area 6 in this allotment. Forage utilization was heavy in the 5.6 ha of shortgrass vegetation type on this critical area.

The meadow type was preferred by both bighorn and cattle (Table 3). This similar preference creates a setting for forage competition in meadows. However, due to the reliance of bighorn on nearby escape terrain, range overlap should be expected only on those meadows within 240 m of bighorn escape terrain.

Food habits and distributions are dynamic characteristics of any ungulate population. These characteristics can vary in response to change in population size or in response to habitat change. On the Trickle Mountain study area, overlap in food habits and distribution could increase if either cattle or bighorn numbers should increase. In addition, range improvements, especially water developments, that

would expand the distribution of cattle could cause greater overlap of ranges used by bighorn and cattle.

IMPACTS OF CATTLE GRAZING ON BIGHORN CARRYING CAPACITY

This study was based on the assumption that winter forage resources limit the size and/or productivity of the Trickle Mountain bighorn herd. Other possible limiting factors are water, summer forage, predation, disease, and intrinsic mechanisms. Intrinsic mechanisms, behavioral and/or physiological processes that reduce reproduction and survival as population density increases, have not been demonstrated for ungulates (Pimlott 1967, Keith 1974). Effects of disease on Trickle Mountain bighorn are unclear and effects of predators are unknown. Summer forage and water appear to be abundant and available to the Trickle Mountain herd.

Estimates of bighorn forage removed by cattle had wide confidence intervals (Table 14). Therefore, conclusions regarding the effects of cattle grazing on the bighorn population can only be tentative. The data indicated that cattle grazing had a relatively minor impact on bighorn carrying capacity of the Poison Gulch allotment (Table 14).

The Trickle Mountain allotment has the largest amount of bighorn critical area and produces the most bighorn forage (Table 12). Therefore, a moderate percent utilization of bighorn forage by cattle resulted in removal of large amounts of forage (Table 14) and indicated large impacts on bighorn carrying capacity (Table 18). These impacts are best substantiated on critical areas 5 and 6 where a total of 29 cattle were observed (Table 15).

Cattle used similar amounts of critical areas on the Trickle Mountain and Cross Creek allotments. However, percent utilization of bighorn forage by cattle was greater on the Cross Creek allotment (Table 14). Considering limitations of data obtained in this study, impacts of cattle grazing on bighorn carrying capacity of the Trickle Mountain study area were most clearly shown on the Cross Creek allotment. Within this allotment, critical areas 6 and 7 were overlapped by cattle range and showed heavy forage utilization. They most clearly demonstrated impacts of cattle grazing. Opportunities for manipulating cattle grazing to improve winter forage conditions for bighorn are greatest on these 2 areas.

Presently, there are no objective, data-based estimates of the number of bighorn on the Trickle Mountain study area. It is therefore difficult to put estimates of bighorn numbers that could be supported by the forage removed by cattle into perspective. Wide confidence intervals for estimates and the unproven assumption that winter forage resources limit the bighorn population further confound conclusions. Despite these limitations, this investigation suggests that the Trickle Mountain, Cross Creek, and Poison Gulch allotments could support an additional 117 bighorn in the absence of cattle grazing.

The Trickle Mountain study area is managed under a multiple-use policy (Federal Land Planning and Management Act 1976). Complete removal of cattle is therefore not likely. However, manipulation of cattle grazing holds some promise for reducing the impacts of cattle on bighorn. Bighorn critical areas comprise only a small portion of BLM allotments (Figure 4). Fences and water developments could be located to discourage cattle use of critical areas. This strategy

could be most effectively applied to critical areas 6 and 7 on the Cross Creek allotment and critical areas 5 and 6 on the Trickle Mountain allotment.

CONCLUSIONS

1. Observations of marked bighorn suggested the existence of 2 sub-herds on the Trickle Mountain study area. One apparent sub-herd winters south of Trickle Mountain and uses lambing grounds near Buffalo Pass. The other possible sub-herd winters in the Poison Gulch-Ford Creek area and uses newly-identified lambing grounds along Middle Creek and Jack's Creek.
2. Based upon observed consistent and frequent concentrations of bighorn, 18 areas were identified as critical to bighorn welfare during winter and spring. Seven areas were on the Trickle Mountain allotment, 7 were on the Cross Creek allotment, and 4 were on the Poison Gulch allotment.
3. In 1979, summer cattle range overlapped only 4% of the bighorn winter-spring range on the Trickle Mountain, Cross Creek, and Poison Gulch allotments. Within these allotments, cattle were observed during summer on 5% of the range identified as critical areas.
4. Factors limiting cattle use of bighorn range and critical areas were topography, availability of water, and aspect. Cattle were reluctant to wander over 1.5 km from water, avoided slopes greater than 5°, and used northern aspects more often than did wintering bighorn.

5. Winter-spring habitats of bighorn generally consisted of areas on south or west-facing slopes of at least 16°, within 240 m of escape terrain. Cliffs and rock outcrops used as escape terrain were characterized by steep slopes ($\bar{x}$ = 72°) and little or no vegetation. Escape terrain was at least 200 m long and 8 m tall.
6. The meadow vegetation type was preferred by both cattle and bighorn. This similar preference creates a setting for forage competition in meadows within 240 m of escape terrain. Both bighorn and cattle avoided timbered areas. Cattle may have difficulty maneuvering through dense timber. Timber restricts bighorn vision and thus interferes with their evolved predator evasion strategy.
7. Information on bighorn habitat preferences and on characteristics of escape terrain was used to identify 12 areas as potential bighorn winter-spring habitat. These areas were unused by bighorn but had the characteristics of preferred habitats and adequate escape terrain. In a management program emphasizing bighorn, they would be protected as future bighorn habitat.
8. Although the May-October cattle diet was dominated by grasses and grass-like plants, browse constituted about 24% of the 1979 diet, being most often utilized during September - October. Muhlys, blue grama, wheatgrasses, fescues, sedges, and rushes were important foods during both 1978 and 1979.
9. Important winter-spring forages of bighorn were fringed sagebrush, sedges, muhlys, fescues, blue grama, saltbush, winterfat, and yucca.

Fringed sagebrush, accounting for approximately 36% of the 1978 diet, was the predominant browse utilized. However, bighorn diets of 1978 and 1978-79 were only 58% similar. Between-years variation in diets was primarily due to differences in snowfall affecting forage availabilities.

10. The 1978 summer cattle diet and the 1978-79 winter-spring bighorn diet were 73% similar. Mutually utilized forages responsible for most of this moderate dietary overlap were: muhlys, fescues, sedges, saltbush, and winterfat.
11. Approximately 355 ha of critical area on the Trickle Mountain allotment produced an estimated 67,451 kg of bighorn forage. Approximate sizes of critical areas and associated estimates of bighorn forage production for the other allotments were: Cross Creek, 237 ha and 48,570 kg; Poison Gulch, 186 ha and 55,207 kg.
12. Percent utilization of bighorn winter-spring forage by cattle was greatest on critical areas within the Cross Creek allotment. However, cattle removed the most kg of critical bighorn winter-spring forage from the Trickle Mountain allotment. Utilization of bighorn forage by cattle on the Poison Gulch allotment was relatively low. Estimates for cattle utilization of bighorn winter-spring forage had wide confidence intervals.
13. Daily forage intake of an average Trickle Mountain bighorn was estimated at 1.64 kg. This animal would require 221 kg of forage during winter (December 1-April 15).

14. Estimated impacts of cattle grazing on bighorn carrying capacities reflected the wide confidence intervals for utilization values. Despite this limitation, this study suggests the following reductions in bighorn carrying capacities due to cattle grazing: Trickle Mountain allotment, 46 bighorn; Cross Creek allotment, 39 bighorn; and Poison Gulch allotment, 32 bighorn.
15. Distributions and food habits of bighorn and cattle may vary in response to changes in population sizes or in habitat conditions. Impacts of cattle grazing on bighorn may therefore change. Management opportunities for reducing cattle impacts on bighorn include: fencing of selected critical areas, locating water developments over 1.5 km from critical areas, and limiting cattle numbers during fall to reduce utilization of bighorn browse.

MANAGEMENT RECOMMENDATIONS

Specific goals for the size of the Trickle Mountain bighorn herd and for annual harvests from the herd have not been formally established. Development of such goals through mutual decisions by the Colorado Division of Wildlife and federal land management agencies, especially the BLM, is desirable. In developing these recommendations, it was presumed that goals will include maintaining the Trickle Mountain herd at least at current levels.

1. Monitor distributions of bighorn and cattle. Variations in animal numbers and habitat changes are the primary factors expected to influence distributions. Bighorn critical areas should be closely monitored to determine the amount of use by cattle. Factors which may increase cattle use of bighorn critical areas include: (1) water developments near bighorn critical areas, (2) changes in stocking rates, and (3) changes in seasons of cattle grazing.
2. Cattle distribution was restricted by water availability (Table 8). Cattle of the Trickle Mountain study area were not observed over 1.5 km from water. Therefore, developing water sources at least 1.5 km from bighorn critical areas will discourage use of these areas by cattle.
3. To assure adequate habitat for the Trickle Mountain bighorn herd, cattle use of bighorn critical areas (Figure 4) should not be

increased. Reducing cattle use of critical areas 6 and 7 on the Cross Creek allotment and critical areas 5 and 6 on the Trickle Mountain allotment should be considered. Cattle use of these areas may be reduced by (1) fencing, (2) moving cattle to other sites, especially those sites where water supplies can be developed, and (3) removing cattle in early September to reduce utilization of browse species that are important bighorn forage.

4. Evaluate the impacts of bighorn feeding and treatment operations. Areas requiring further investigation include: (1) influence on bighorn distribution, (2) effectiveness of treatment in reducing lungworm infestations, and (3) possibility that concentrating animals may increase transmission of lungworms and/or contagious ecthyma. Lamb:ewe and yearling:ewe ratios from the treated sub-herd should be compared to ratios from the untreated sub-herd.

5. Experienced personnel should periodically determine the conditions of cattle range (Figure 5) and bighorn critical areas (Figure 4). Trends in forage production can be correlated with changes in cattle and/or wild ungulate numbers and distributions.

FUTURE RESEARCH NEEDS

1. Test the assumption that winter forage limits the Trickle Mountain bighorn herd. This assumption can be tested in 2 ways:

   a. The habitat-population system can be analyzed in greater detail. Seasonal patterns of bighorn forage production, removal, and availability on bighorn winter ranges could be measured more precisely. This would require replicated plots, some with cages, to measure (1) forage removed by cattle during summer, (2) forage available to and removed by bighorn during winter, and (3) forage remaining before the growing season begins. If it can be demonstrated that quality forage is available to bighorn throughout the winter, the assumption that this forage is limiting to bighorn will be questionable.

   b. Lamb production and survival can be tested for correlation with variation in forage resources. Lamb:ewe ratios obtained periodically during summer and fall for several years would provide a measure of lamb production and survival. Variation in availability of forage could be measured at various times during winter over several years. These data could be analyzed to test if years with poor availability of winter forage on critical areas are also years with low lamb:ewe ratios. A positive correlation would support the assumption that winter forage limits the bighorn population. Due to natural variation

in forage availability caused by among-years weather variation, many years may be necessary for this test. However, the test may be accelerated by actively manipulating forage in order to provide extremes of forage availability within a relatively few years. Varying cattle numbers among years or restricting cattle from certain critical areas may be used to influence forage supplies.

2. Improve methodology for relating forage resources to bighorn numbers. Forage intake rates of free-ranging bighorn should be investigated. Also, incorporating food habits information into calculations would strengthen estimates of population responses to variations in forage availability.

3. Increase sample sizes in any future studies of forage utilization. This would reduce confidence intervals, thus increasing the precision of estimates of forage utilization. Number of range cages required can be calculated from existing standard deviations (Appendix 2) and standard statistical formulae (Mendenhall et al. 1971). If budgetary constraints limit the number of cages available, studies should be conducted only in those portions of bighorn range receiving heavy cattle use.

4. Investigate impacts of cattle on bighorn forage within the Robb Ranch allotment and on private lands. Estimated amounts of forage removed can then be related to forage requirements of bighorn. These findings, combined with existing results (Table 18), will indicate the impact of cattle on the entire Trickle Mountain bighorn herd.

5. Investigate the existence of 2 sub-herds of bighorn on the Trickle Mountain study area. Some of the suspected eastern sub-herd should be marked. If these animals are not observed west of Jack's Creek, the presence of 2 sub-herds will be confirmed.

LITERATURE CITED

Albrechtsen, B. R., and J. B. Reese. 1970. Problem analysis of habitat management for desert bighorn sheep. Trans. Desert Bighorn Counc. 14:63-65.

Alldredge, W. A., J. F. Lipscomb, and F. W. Whicker. 1974. Forage intake rates of mule deer estimated with fallout Cesium 137. J. Wildl. Manage. 38(3):508-516.

Anthony, R. G., and N. S. Smith. 1974. Ecological relationships between mule deer and white-tailed deer in southeastern Arizona. Ecol. Monogr. 47(3):255-277.

Arellano, L. M. 1961. Bighorn management in Mexico. Trans. Desert Bighorn Counc. 5:51-52.

Barmore, W. J., Jr. 1962. Bighorn sheep and their habitat in Dinosaur National Monument. M.S. Thesis. Utah State Univ., Logan. 134 pp.

Baumann, T. G., and D. R. Stevens. 1978. Winter habitat preferences of bighorn sheep in the Mummy Range, Colorado. Proc. Northern Wild Sheep and Goat Conf. 1978:320-330.

Baumgartner, L. L., and A. C. Martin. 1939. Plant histology as an aid in squirrel food habit studies. J. Wildl. Manage. 3:266-268.

Bear, G. D. 1969. The microscopic technique in food habit studies. Colorado Div. Game, Fish, and Parks, Game Inf. Leaflet No. 68. 3 pp.

_____, and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colorado Div. of Wildl. Publ. 232 pp.

Berwick, S. H. 1968. Observations on the decline of the Rock Creek, Montana population of bighorn sheep. M.S. Thesis. University of Montana. Missoula. 245 pp.

_____, and M. Aderhold. 1968. A history of land use and herd dynamics in a Montana population of bighorn sheep. N.W. Sci. 42(1): 30. (Abstr.)

Brown, G. W. 1974. Distribution and population characteristics of bighorn sheep near Thompson Falls in northwestern Montana. M.S. Thesis. University of Montana, Missoula. 134 pp.

Blood, D. A. 1961. An ecological study of California bighorn sheep in southern British Columbia. M. S. Thesis. University of British Columbia, Vancouver. 127 pp.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. No. 4. 174 pp.

Casebeer, R. L., and G. G. Koss. 1970. Food habits of wildebeast, zebra, hartebeast, and cattle in Kenya Masailand. E. African Wildl. J. 8:25-36.

Chappel, R. W., and R. J. Hudson. 1978. Winter bioenergetics of Rocky Mountain bighorn. Can. J. Zool. 56(11):2388-2393.

Cochran, W. G., and G. M. Cox. 1957. Experimental designs. John Wiley and Sons, Inc., New York. 611 pp.

Cole, G. F. 1958. Big game-livestock competition on Montana's mountain rangelands. Montana Wildl. April:24-30.

Colorado Division of Wildlife. 1969-1979. Colorado big game harvest. Colorado Div. of Wildl., Colorado Dep. of Nat. Resour., Denver.

Cooperrider, A. Y. 1969. Biology and management of the bighorn sheep of Rock Creek, Montana. Montana Game and Fish Dep., Job Completion Rep., Proj. No. W-98-R-8,9. 92 pp.

_____, S. A. McCollough, and J. A. Bailey. 1980. Variation in bighorn sheep food habits as measured by fecal analysis. Proc. Biennial Symp. Northern Wild Sheep and Goat Counc. 1980: 29-41.

Couey, F. M. 1950. Rocky Mountain bighorn sheep of Montana. Montana Fish and Game Comm. Bull. 2. 90 pp.

Crump, W. 1971. The Wind River bighorn herd - a new approach to sheep habitat management. Trans. First N. Am. Wild Sheep Conf. 1:174-181.

Dearden, B. L., R. E. Pegau, and R. M. Hansen. 1975. Precision of micro-histological estimates of ruminant food habits. J. Wildl. Manage. 39(2):402-407.

Dean, H. C. 1975. Bighorn investigation in Canyonlands National Park. Trans. Desert Bighorn Counc. 19:7-11.

Demarchi, D. A. 1970. Bighorn sheep and overgrazing in the lower Chilcotin River region, British Columbia. Trans. Northern Wild Sheep Counc. 1970:39-45.

Drew, K. R. 1971. Some effects of weight loss and compensatory growth on the whole body and carcass composition in sheep. Ph.D. Thesis. Cornell Univ., Ithaca. 150 pp.

Dusi, J. L. 1949. Methods for the determination of food habits by plant microtechniques and histology and their application to cottontail rabbit food habits. J. Wildl. Manage. 13(3):295-298.

Erickson, G. L. 1972. The ecology of Rocky Mountain bighorn sheep in the Sun River area mountains with special reference to summer food habits and range movements. Montana Game and Fish Dep., Proj. Rep. W-120-R-2w-R-3. 50 pp.

Federal Land Policy and Management Act. 1976. Public Law 94-579, 94th Congress of the United States.

Ferrier, G. J., and W. G. Bradley. 1970. Bighorn habitat evaluation in the Highland Range of Southern Nevada. Trans. Desert Bighorn Counc. 14:66-93.

Flook, D. R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119-128 in D. Crisp, ed. Grazing in terrestrial and marine environments. Blackwell's Sci. Publ., Oxford.

Follows, D. S. 1969. Desert bighorn in Canyonlands National Park, Utah. Trans. Desert Bighorn Council 13:33-42.

Free, J. C., R. M. Hansen, and P. L. Sims. 1970. Estimating dry weights of food plants in feces of herbivores. J. Range Manage. 23:300-302.

Frisina, M. R. 1974. Ecology of bighorn sheep in the Sun River area of Montana during fall and spring. Montana Game and Fish Dep., Job Final Rep., Proj. W-120-R-4-5. 67 pp.

Gallizioli, S. 1977. Overgrazing on desert bighorn ranges. Trans. Desert Bighorn Counc. 21:21-23.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. University of Chicago Press, Chicago and London. 383 pp.

Gordon, S. P. 1957. The status of the bighorn sheep in New Mexico. Trans. Desert Bighorn Counc. 1:3-4.

Halloran, A. F. 1949. Desert bighorn management. Trans. N. Am. Wildl. Conf. 14:527-536.

_____, and W. W. Blanchard. 1950. Bighorn ewe associates with cattle on Kofa Game Range, Arizona. J. Mammal. 31(4):463-464.

Hansen, R. M., D. G. Peden, and R. W. Rice. 1973. Discerned fragments in the feces indicates diet overlap. J. Range Manage. 26(2):102-105.

_____, and L. D. Reid. 1975. Diet overlap of deer, elk, and cattle in southern Colorado. J. Range Manage. 28(1):43-47.

_____, and B. L. Dearden. 1975. Winter foods of mule deer in the Piceance Basin, Colorado. J. Range Manage. 28(4):298-300.

_____, and R. C. Clark. 1977. Foods of elk and other ungulates at low elevations in northwestern Colorado. J. Wildl. Manage. 41(1): 76-80.

_____, R. C. Clark, and W. Lawhorn. 1977. Foods of wild horses, deer, and cattle in the Douglas Mountain Area, Colorado. J. Range Manage. 30(2):116-118.

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

Heil, R. D., D. S. Romine, D. C. Moreland, R. K. Dansdill, R. H. Montgomery, and J. E. Cipra. 1977. Soils of Colorado. Colorado State Univ. Exp. Stn. Bull. 5665. 39 pp.

Hercus, B. H. 1960. Plant cuticle as an aid to determine the diet of grazing animals. Proc. Int. Grassland Conf. 8:443-444.

Honess, R. F., and N. M. Frost. 1942. A Wyoming bighorn sheep study. Wyoming Game and Fish Comm., Bull. No. 1. 127 pp.

Horejsi, B. 1975. Discussion following Management of mountain sheep: theoretical considerations (V. Geist). 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.

Hubbard, R. E., and R. M. Hansen. 1976. Diets of wild horses, cattle, and mule deer in the Piceance Basin, Colorado. J. Range Manage. 29(5):389-392.

Jacobs, J. G. 1973. A microtechnique index to pronghorn diet and sagebrush digestion coefficients. M. S. Thesis. University of Wyoming, Laramie. 49 pp.

Johnson, B. K. 1980. Bighorn sheep food habits, forage preferences, and habitat selection in alpine and subalpine communities. Ph.D. Thesis. Colorado State Univ., Fort Collins. 170 pp.

Jones, F. L. 1950. A survey of the Sierra Nevada bighorn. Sierra Club Bull. 35:29-76.

Julander, O. 1958. Techniques in studying competition between big game and livestock. J. Range Manage. 11(1):18-21.

Keiss, R. E., and G. A. Schoonveld. 1977. Evaluation of the nutritional requirements of bighorn sheep. Colorado Div. of Wildl. Job Final Proj. Rep. W-41-R-26. 56 pp.

Keith, L. B. 1974. Some features of population dynamics in mammals. Int. Congr. Game Biologists 11:17-58.

Kelly, W. E. 1960. Bighorn sheep management recommendations for the state of Arizona. Trans. Desert Bighorn Counc. 4:41-44.

Kiley, M. 1966. A preliminary investigation into the feeding habits of the waterbuck by faecal analysis. E. African Wildl. J. 4(1):153-157.

Lauer, J. L., and J. M. Peek. 1976. Big-game livestock relationships on the bighorn sheep winter range, East Fork, Salmon River, Idaho, Coll. For., Wildl., and Range Sci. Bull. No. 12, University of Idaho, Moscow. 44 pp.

Leslie, D. M., Jr., and C. J. Douglas. 1979. Desert bighorn sheep of the River Mountains, Nevada. Wildl. Monogr. No. 66. 56 pp.

Mackie, R. J. 1978. Impacts of livestock grazing on wild ungulates. Trans. N. Am. Nat. Resour. Conf. 43:462-476.

Mathews, W. L. 1960. Management responsibilities and practices of the BLM as they relate to the desert bighorn sheep. Trans. Desert Bighorn Counc. 4:26-27.

McCann, L. J. 1956. Ecology of the mountain sheep. Am. Midl. Nat. 56:297-325.

McColm, M. A. 1963. A history of the bighorn sheep in central Nevada. Trans. Desert Bighorn Counc. 7:1-11.

McCollough, S. A., A. Y. Cooperrider, and J. A. Bailey. 1980. Impact of cattle grazing on bighorn sheep habitat at Trickle Mountain, Colorado. Proc. Biennial Northern Wild Sheep and Goat Counc. 1980: 42-58.

McCullough, D. R., and E. R. Schneegas. 1966. Winter observations on the Sierra Nevada bighorn sheep. California Fish and Game 52(2):68-84.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nevada Dep. of Fish and Game, Biol. Bull. No. 6. 81 pp.

Mendenhall, W., L. Ott, and R. L. Scheaffer. 1971. Elementary survey sampling. Duxbury Press, Belmont. 247 pp.

Messenger, N. C. 1978. Diet and nutrition of the pronghorn antelope. M. S. Thesis. S. Dakota State Univ., Brookings. 53 pp.

Moen, A. N. 1973. Wildlife ecology. W. H. Freeman and Co., San Francisco. 458 pp.

Morgan, J. K. 1970. Ecology of the Morgan Creek and East Fork of the Salmon River bighorn sheep herds and management of bighorn sheep in Idaho. Idaho Game and Fish Dep., Job Final Rep., Proj. W-142-R-1. 155 pp.

Moser, C. A. 1953. The bighorn sheep of Colorado. Colorado Dep. of Game and Fish, Tech. Publ. No. 10. 49 pp.

Myers, G. T. 1962. Food habits of the plains pocket gopher in the sandhills of eastern Colorado. M. S. Thesis. Colorado State Univ., Fort Collins. 73 pp.

National Oceanic and Atmospheric Administration. 1977. Climate of Colorado. Climatography of U.S. No. 60. 20 pp.

_____. 1977-1979. Climatological data, Colorado. Climatological Data. Vols. 82, 83, 85.

National Research Council. 1964. Nutrient requirements of domestic animals. Natl. Res. Counc. Publ. 1193. 90 pp.

Neal, B. R., D. A. Pulkinen, and B. D. Owen. 1973. Comparison of fecal and stomach contents analysis in meadow vole (*Microtus pennsylvanicus*). Can. J. Zool. 51(7):715-521.

Oldemeyer, J. L. 1966. Winter ecology of bighorn sheep in Yellowstone National Park. M. S. Thesis. Colorado State Univ., Fort Collins. 107 pp.

Olsen, F. W., and R. M. Hansen. 1977. Food relations of wild free-roaming horses to livestock and big game, Red Desert, Wyoming. J. Range Manage. 30(1):17-20.

Oosting, H. J. 1956. The study of plant communities. W. H. Freeman and Co., San Francisco. 440 pp.

Owaga, M. L. 1977. Comparison of analysis of stomach contents and fecal samples from zebra. E. African Wildl. J. 15:217-222.

Packard, F. 1946. An ecological study of the bighorn sheep in Rocky Mountain National Park. J. Mammal. 27(1):3-28.

Pallister, G. L. 1974. The seasonal distribution and range use of bighorn sheep in the Beartooth Mountains. Montana Fish and Game Dep., Job Final Rep., Proj. No. W-120-R-5. 67 pp.

Palmer, L. J. 1944. Food requirements of some Alaskan game mammals. J. Mammal. 25(1):49-54.

Pimlott, D. H. 1967. Wolf predation and ungulate populations. Am. Zool. 7:267-278.

Pulliam, D. E., Jr. 1978. Determination of digestibility coefficients for quantification of fecal analysis with elk. Symp. on Elk Ecology and Manage. in the Jackson-Yellowstone Region, Laramie. (Abstr.)

Riegelhuth, R. 1965. A reconnaissance of Sierra bighorn and bighorn ranges in Sierra Nevada. Trans. Desert Bighorn Counc. 9:35-39.

Risenhoover, K. L. 1981. Winter ecology and behavior of bighorn sheep, Waterton Canyon, Colorado. M.S. Thesis. Colorado 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. Proc. Biennial Northern Wild Sheep and Goat Counc. 1980: 18-27.

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

Schallenberger, A. D. 1965. Food habits, range use and interspecific relationships of bighorn sheep in the Sun River area, west-central Montana. M. S. Thesis. Montana State Univ., Bozeman. 44 pp.

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain Bighorn sheep. J. Wildl. Manage. 29(2):387-401.

Shepherd, H. R. 1975. Vegetation of two dissimilar bighorn sheep ranges in Colorado. Colorado Div. of Wildl., Rep. No. 4 223 pp.

Simmons, N. M. 1961. Daily and seasonal movements of Poudre River bighorn sheep. M. S. Thesis. Colorado State Univ., Fort Collins. 73 pp.

Smith, D. R. 1954. The bighorn sheep in Idaho: Its status, life history, and management. Idaho Game and Fish Dep., Wildl. Bull. No. 1. 154 pp.

Sparks, D. R., and J. C. Malechek. 1968. Estimating percentage dry weights in diets using a microscopic technique. J. Range Manage. 21(4):264-265.

Spencer, C. C. 1943. Notes on the life history of the Rocky Mountain bighorn sheep in the Tarryall Mountains of Colorado. J. Mammal. 24(1):1-11.

Stewart, D. R. M. 1967. Analysis of plant epidermis in faeces: a technique for studying the food preferences of grazing herbivores. J. Appl. Ecol. 4(1):82-111.

Storr, G. M. 1961. Microscopic analysis of feces, a technique for ascertaining the diet of herbivorous mammals. Aust. J. Biol. Sci. 14:157-164.

Streeter, R. G. 1969. Demography of two Rocky Mountain bighorn sheep populations in Colorado. Ph.D. Thesis. Colorado State Univ., Fort Collins. 96 pp.

Sugden, L. G. 1961. The California bighorn in British Columbia with particular reference to the Churn Creek herd. British Columbia Dep. of Recreation and Conserv. 58 pp.

Tilton, M. E. 1977. Habitat selection and use by bighorn sheep (*Ovis canadensis*) on a northwestern Montana winter range. M.S. Thesis. University of Montana, Missoula. 121 pp.

Todd, J. W. 1972. A literature review on bighorn sheep food habits. Colorado Div. of Game, Fish, and Parks, Spec. Rep. No. 27. 21 pp.

_____. 1975. Foods of Rocky Mountain bighorn sheep in southern Colorado. J. Wildl. Manage. 39:108-111.

_____, and R. M. Hansen. 1973. Plant fragments in the feces of bighorns as indicators of food habits. J. Wildl. Manage. 37:363-366.

Trefethen, J. B. 1975. The wild sheep in modern North America. Boone and Crockett Club and The Winchester Press, New York. 302 pp.

Turner, J. C. 1978. Osmotic fragility of desert bighorn sheep red blood cells. Comp. Biochem. Physiol. 64A:167-175.

U.S. Bureau of Land Management. 1977. Trickle Mountain wildlife habitat management plan. U.S. Dep. Interior, Bur. Land Manage. 87 pp.

_____. 1978. Soil-vegetation inventory methods. Manual No. 1731 [Draft]. U.S. Dep. Interior, Bur. Land. Manage. 119 pp.

Van den Akker, J. B. 1960. Human encroachment on bighorn habitat. Trans. Desert Bighorn Counc. 4:38-40.

Van Dyne, G. M., N. R. Brockington, Z. Szocs, J. Duek, and C. A. Ribic. 1980. Large herbivore subsystem. Pages 269-537 in A. I. Breymeyer and G. M. Van Dyne, eds. Grasslands, systems analysis and man. Int. Biol. Programme 19. Cambridge Univ. Press, Cambridge.

Van Soest, P. J. 1968. Chemical estimates of the nutritional value of feeds. Proc. Cornell Nutr. Conf. for Feed Manufacturers. 1968: 38-46.

Vavra, M., R. W. Rice, and R. M. Hansen. 1978. A comparison of esophageal fistula and fecal material to determine steer diets. J. Range Manage. 31(1):11-13.

Voth, E. H., and H. C. Black. 1973. A histologic technique for determining feeding habits of small herbivores. J. Wildl. Manage. 37(2):223-231.

Wagner, F. H. 1978. Livestock grazing and the livestock industry. Pages 121-145 in H. P. Brokaw, ed. Wildlife and America. Counc. on Environ. Quality, Washington, D.C.

Ward, A. L. 1970. Stomach content and fecal analysis: methods of forage identification. Pages 145-158. in Range and Wildl. Habitat Evaluation. U.S. For. Serv. Misc. Publ. No. 1147.

Welles, R. E., and F. B. Welles. 1961. The bighorn of Death Valley. Natl. Park Serv. Fauna Ser. No. 6. 242 pp.

Westoby, M., G. R. Rost, and J. A. Weis. 1976. Problems with estimating herbivore diets by microscopically identifying plant fragments from stomachs. J. Mammal. 57(1):167-172.

Williams, O. B. 1969. An improved technique for identification of plant fragments in herbivore feces. J. Range Manage. 22:51-52.

Wilson, L. O. 1968. Distribution and ecology of the desert bighorn sheep in southeastern Utah. Utah Fish and Game, Publ. No. 68-5. 220 pp.

Woodward, S. L., and R. D. Ohmart. 1976. Habitat use and fecal analysis of feral burros (*Equus asinus*), Chemehuevi Mountains, California, 1974. J. Range Manage. 29(6):482-485.

Woolf, A. 1968. Summer ecology of bighorn sheep in Yellowstone National Park. M. S. Thesis. Colorado State Univ., Fort Collins. 112 pp.

Yoakum, J. 1964. Bighorn food habit-range relationships in the Silver Peak Range, Nevada. Trans. Desert Bighorn Counc. 8:95-102.

Zyznar, E., and P. J. Urness. 1969. Quantitative identification of forage remnants in deer feces. J. Wildl. Manage. 33(3):506-510.

APPENDICES

Appendix 1. Vertebrate fauna observed on Trickle Mountain study area, Colorado, 1978-79.

Common Name	Scientific Name
MAMMALS	
Bighorn sheep	*Ovis canadensis*
Mule deer	*Odocoileus hemionus*
Elk	*Cervus canadensis*
Pronghorn	*Antilocapra americana*
Bobcat	*Lynx rufus*
Coyote	*Canis latrans*
Short-tailed weasel	*Mustela erminea*
Striped skunk	*Mephitis mephitis*
Spotted skunk	*Spilogale putorius*
Cottontail	*Sylvilagus audubonii*
White-tailed jackrabbit	*Lepus townsendii*
Porcupine	*Erethizon dorsatum*
Gunnisons prairie dog	*Cynomys gunnisoni*
Abert squirrel	*Sciurus aberti*
BIRDS	
Mallard	*Anas platyrhynchos*
Green-winged teal	*Anas carolinensis*
Ruddy duck	*Oxyura jamaicensis*
Goshawk	*Accipiter gentilis*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
Golden eagle	*Aquila chrysaetos*
Marsh hawk	*Circus cyaneus*
Great horned owl	*Bubo virginianus*
American kestrel	*Falco sparverius*
Prairie falcon	*Falco mexicanus*
Killdeer	*Oxyechus vociferus*
Common snipe	*Capella gallinago*
Sandhill crane	*Grus canadensis*
Snowy egret	*Leucophoyx thula*
Morning dove	*Zenaidura macroura*
Blue grouse	*Dendragapus obscurus*

Appendix 1. Continued.

Common Name	Scientific Name
Stellar's jay	*Cyanocitta stelleri*
Gray jay	*Perisoreus canadensis*
Clark's nutcracker	*Nucifraga columbiana*
Pinyon jay	*Gymnorhinus gymnorhinus*
Black-billed magpie	*Pica pica*
Common raven	*Corvus corax*
Common crow	*Corvus brachyrhynchos*
Common flicker	*Colaptes cafer*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Western meadowlark	*Sturnella neglecta*
Red-winged blackbird	*Apelatus phoeniceus*
Loggerhead shrike	*Lanius ludovicianus*
Horned lark	*Eremophila alpestris*
Robin	*Turdus migratorius*
Mountain bluebird	*Sialia currucoides*
Townsend's solitaire	*Myadestes townsendi*
Gray-crowned rosy finch	*Leucosticte tehrocotis*
Red crossbill	*Lokia curvirostra*
Oregon junco	*Junco oreganus*
Gray-headed junco	*Junco caniceps*
Tree sparrow	*Spizella arrorea*
White-breasted nuthatch	*Sitta carolinensis*
Pigmy nuthatch	*Sitta pigmaea*
Mountain chickadee	*Parus gambeli*
Ruby-crowned kinglet	*Regulus calendula*
REPTILES	
Prairie rattlesnake	*Crotalus viridis*
Garter snake	*Thamnophis* spp.

Appendix 2. Mean percent utilization of bighorn forage by cattle and associated standard deviations, Trickle Mountain study area, Colorado.

Allotment	Stratum	Sample Size[1]	% Utilization	Standard Deviation
Trickle Mountain	1	7	25	40
	2	7	24	28
	3	7	4	40
Cross Creek	1	7	42	37
	2	7	24	49
	3	7	3	34
Poison Gulch	1	4	0[2]	68
	2	3	19	30
	3	4	19	12

[1]Number of paired plots.

[2]A negative utilization (-17%) was indicated.

Typist:

Kathy Everett
2420 West Plum Street
Fort Collins, CO 80521
(303) 493-6764