THESIS

THE BIGHORN SHEEP OF BATTLEMENT MESA - A LOW ELEVATION POPULATION

submitted by

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Fishery and Wildlife Biology

In partial fulfillment of the requirements

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY MARY LOUISE CUNNINGHAM ENTITLED THE BIGHORN SHEEP OF BATTLEMENT MESA - A LOW ELEVATION POPULATION BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

THE BIGHORN SHEEP OF BATTLEMENT MESA-

A LOW ELEVATION POPULATION

I studied bighorn sheep on Battlement Mesa, Colorado, from 12/88 to 7/90, to determine present and past herd status and distribution, so that 1) management options are clarified and 2) future management activities may be evaluated. I studied the herd by tracking 1 radio-collared ewe and obtaining visual observations and by systematically sampling study area units for sheep, sheep sign, potential competitors, potential predators and sheep carcasses. I recorded water sources that were encountered. I developed an historic perspective of the herd by searching agency files and local newspapers and interviewing local residents.

The herd numbered up to 200-250 animals in the early 1900s and declined to an estimated 50 animals by 1970. Minimum herd sizes during 1989 and 1990 were 23 and 26, including lambs, respectively. Since 1961, the herd has abandoned approximately 56 km^2 of historic range in the Mamm Peaks area. The herd decline corresponded with probable vegetation changes on Battlement Mesa, intensive livestock grazing through the 1950s, reports of poaching and an increasing elk herd.

Sheep remained on the western portion of the range during winter and spring, 1989. Ewe/juvenile groups migrated to Anderson and Durant Gulches between 5/15-7/15/89 for lambing. Rams were more dispersed and in groups of 1-3, except during the

rutting season. Ewe/juvenile group size ranged from 1-13. During dry months, (7/89, 8/89,6/90) sheep concentrated in Anderson and Durant Gulches where a free-flowing spring and a seep were located.

Bighorn sheep on Battlement Mesa appear limited by dense mountain shrub stands which separate all productive meadows from escape terrain and cover historic migration routes. A significantly greater use of the shale slope habitat contributed most to rejecting the null hypothesis that sheep use habitat types in proportion to their availabilities on Battlement Mesa. Sheep remained on shale slopes most (75% of all observations) of the time, using scattered grasses, forbs and shrubs for forage and seeps for water. Intensive and long term habitat management for bighorn sheep on Battlement Mesa is required. I suggest a 4-phase management program to improve existing range and later to reestablish and maintain historic migration corridors to productive historic summer range. Without management to improve existing conditions, this small, unique herd will remain static or decline.

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Dedicated to Mom and Dad

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INTRODUCTION

When white explorers traveled through the Rocky Mountains in the 1800s they commonly reported seeing bighorn sheep *(Ovis canadensis)*. A conservative pre-settlement estimate set the bighorn population at 2 million throughout Canada, Mexico and the United States (Seton 1929). A decline in sheep numbers followed settlement into the Rockies and throughout the West (Buechner 1960).

In 1915 Colorado supported about 7,320 Rocky Mountain bighorns but by 1970, only about 2,200 remained (Bear and Jones 1973). Today there are approximately 6,100 sheep in 67 herds, including about 2,400 in transplanted populations (Bailey 1990, Colorado Division of Wildlife (CDOW) 1989). Many of these sheep are found in small remnant herds intermittent throughout historic range. Herds that were not extirpated persisted in isolated or highly productive portions of their range. The bighorns of Battlement Mesa are a classic example of a remnant, isolated population. The Battlement Mesa bighorn sheep herd is 1 of 4 low elevation, indigenous bighorn herds remaining in Colorado (Bailey, pers. comm. 1988). Battlement Mesa is within the geographic range of 'desert bighorn' as reported by Manville (1985). It is not clear if Battlement Mesa bighorns should be considered *O. c. canadensis* or *O. c. nelsoni*, as no definitive subspecies designation has been reported. At the start of my study, information on the herd was limited to scattered CDOW aerial counts and hunter surveys, scattered United States Forest Service (USFS) reports, local newspaper clippings and knowledge held by local residents. A Colorado State University (CSU) internship project in 1976 (McGowan and Van Sant 1976) and an Environmental Assessment developed for the herd in 1986 (White River Wildlife Team 1986) provided the most current herd data. CDOW

classified the herd as declining or static. Seasonal ranges and factors limiting the herd were uncertain. The 1986 Environmental Assessment concluded that more study of the Battlement Mesa herd was needed to develop a sound, long-term management plan to insure the well-being of the herd. I initiated a research/descriptive study to gather the data necessary to effectively manage this unique herd. Pre-treatment data on numbers of sheep and areas of use are essential to successfully measure post-treatment effects for any type of herd or habitat management adopted. The purpose of my study was to determine present herd status and distribution, so that:

1. Management options were clarified, and
2. future management activities can be evaluated.

Specific objectives of my study were:

1. To develop an historic perspective of bighorn sheep on Battlement Mesa.
2. To determine herd size and sex-age composition, including lamb production and lamb survival through 1989 and 1990.
3. To determine seasonal distributions, including lambing area(s), water sources, migration corridors, timing of major activities and movements including rutting (1989) and lambing (1989, 1990).
4. To evaluate potential limiting factors to bighorn sheep on Battlement Mesa.
5. To suggest management options to the agencies involved.

DESCRIPTION OF STUDY AREA

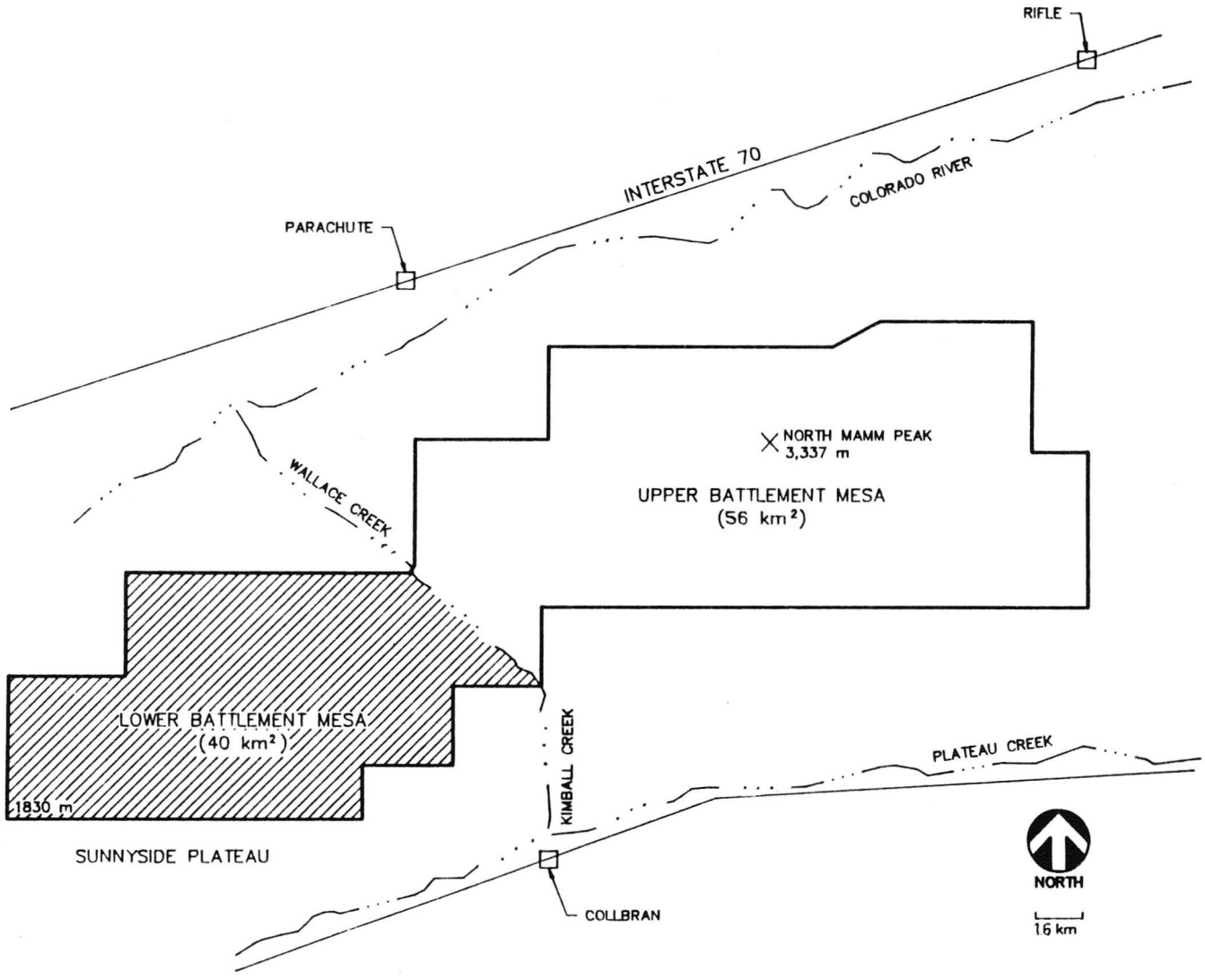
I. Location

Battlement Mesa is located in northwest Colorado, approximately 80 km east of Grand Junction, and encompasses 96 km^2 on National Forest, Bureau of Land Management (BLM) and private lands. The range crests northeast to southwest, with lands of the Grand Mesa National Forest (GMNF) and BLM on the south slopes and White River National Forest (WRNF) on the north slopes. Elevations on Battlement Mesa range from 1830 m at the extreme west to 3337 m on North Mamm Peak (Fig. 1). Bighorn sheep remain on the west end of Battlement Mesa at elevations of 2040-2700 m (referred to as lower Battlement Mesa for the remainder of thesis). Lower Battlement Mesa encompasses approximately 40 km^2. There are 2 private inholdings within the range. Topography is characterized by steep south facing cliffs with scattered shrubs, forbs and grasses and steep north facing slopes with forest and shrub communities.

II. Geology

Yeend (1969) described the geologic processes that created Battlement Mesa. The Mesa is an erosional remnant of a large late Tertiary (early Pliocene) basalt plain in the arid to semi-arid lands of western Colorado. The Mesa rises 3000 m above sea level on the east end, adjacent to the Colorado River and Plateau Creek valleys. Battlement Mesa existed as

Figure 1. Schematic diagram of Battlement Mesa, Colorado, depicting nearby towns, upper and lower Battlement Mesa and important land features.


RIFLE
INTERSTATE 70
COLORADO RIVER
PARACHUTE
NORTH MAMM PEAK
3,337 m
WALLACE CREEK
UPPER BATTLEMENT MESA
(56 km²)
LOWER BATTLEMENT MESA
(40 km²)
1830 m
KIMBALL CREEK
PLATEAU CREEK
SUNNYSIDE PLATEAU
COLLBRAN
NORTH
16 km

a nearly level highland of more than 3000 m throughout most of the Pleistocene. An icecap covered most of nearby Grand Mesa at least twice during the late Pleistocene but Battlement Mesa lacked an icecap.

Uplift in the late Tertiary caused streams to cut through the extensive, virtually flat-lying basalt flows into the underlying sedimentary rocks of the Green River, Wasatch and Mesa Verde formations of early Tertiary to late Cretaceous age. More than 1500 m of downcutting since the uplift began has produced long, steep slopes, steep cliffs and narrow canyons. Geologic processes operating throughout the area varied greatly over time and produced very different effects on the landscape because of the extremes in elevation, slope, exposure, and range of bedrock types.

No evidence of recent glaciation has been found on Battlement Mesa. Widespread talus deposits, rock glaciers, earthflows and debris are thought to correlate with recent glaciation elsewhere in the Rocky Mountains. While glaciers were eroding and modifying nearby Grand Mesa to the south during the late Pleistocene, Battlement Mesa was being eroded by colluvial processes, slumping, frost breakup of basalt, and landslides. The processes moved debris from the high parts of the mesa onto the surrounding slopes and into the bordering stream valleys. Mudflows were common in the valleys and frequently poured out onto the older terraces bordering the Colorado River to the north. The topography north of Plateau Creek (lower Battlement Mesa, present bighorn range) is characterized by steep canyons, arroyos, pediment surfaces adjacent to Battlement Mesa, and silt covered surfaces. The south facing slopes receive little precipitation and are almost completely devoid of vegetation. Upper Battlement Mesa (historic bighorn range) consists of 2 small basalt flow remnants (North and South Mamm Peaks), >3000 m in elevation. These isolated flow remnants total <1.6 km^2 and are surrounded by slump blocks broken into basalt block rubble. The extreme northwest area is dry and virtually vegetation free. Surficial deposits are scarce (Yeend 1969).

III. Soils

Soils information was obtained from USFS documents and USFS soil scientists (Ron Wright, pers. comm., Terry Hughes, pers. comm.) Soils at lowest elevations at the base of lower Battlement Mesa are clay-loam and loam intermittent with sandstone outcrops. Water intake and movement are slow and the surface layer is subject to puddling and eroding with wetting and drying. Soils exhibit a shrink/swell cycle, expanding when wet and cracking deeply when dry. Soluble salts and sodium increase with depth, becoming high enough to affect plant growth at 41-76 cm.

Between 1830-2196 m, the soils are typically hot and dry (ustic torriorthents). Most of these soils developed from shale of the Wasatch formation. The landforms are dissected fans and badlands. Between 2196-2806 m in elevation the soils are frigid to cold (typic orgiborolls). These soils also developed from shale. The landforms are foothills, cliffs, upper fans and backslopes. Between 2806-3337 m (the highest elevations on upper Battlement Mesa, historic bighorn summer range), soils are typically cryochrysts. The steep areas are comprised of mostly shallow and extremely stony soils. Basalt boulder fields and mixed sedimentary rocks occupy the highest portion of Battlement Mesa (Hughes, in press, GMNF 1989; Wright, in press, WRNF 1989). The landforms range from nearly level mesa tops to steep side slopes with rock outcrops.

IV. Climate

Climatic conditions vary widely with elevation and aspect on Battlement Mesa. Arid to sub-arid conditions exist at low elevations, especially on south-facing slopes. At the highest elevations on upper Battlement Mesa, humid to sub-humid conditions exist.

The town of Collbran, located approximately 8 km south of the east end of lower Battlement Mesa at approximately 1830 m, receives an annual precipitation of 33 cm with no well-defined wet season. Maximum precipitation occurs March-May with a secondary maximum during August-October. Drought conditions during 1987-1990 eliminated this second maximum.

June and July are the driest months with an average monthly rainfall of < 2.5 cm. Mean annual temperature is 9 degrees C. July is the warmest month with a mean of 22 degrees C. Summer temperatures > 37 degrees C are common at lower elevations. Data from the United States Weather Bureau station in Collbran reflect climate warming and drying in the years following 1930 with a drop in mean annual precipitation and an increase in mean annual temperatures.

Lower Battlement Mesa (2400-2500 m) receives 38.1-63.5 cm annual precipitation while upper Battlement Mesa (2806-3416 m) receives 50.8-76.2 cm annual precipitation (Berry 1959).

V. Flora and fauna

Lower Battlement Mesa consists of 5 major habitats: 1) pinyon pine *(Pinus edulis)*/juniper *(Juniperus osteosperma)* at lower elevations, 2) Douglas fir *(Pseudotsuga menziesii)* on north-facing slopes at higher elevations and in draws, 3) mountain shrub, predominantly gambel oak *(Quercus gambelii)* and serviceberry *(Amelanchier alnifolia)* at middle to higher elevations, in draws and on dry sidehills, 4) aspen *(Populus tremuloides)* on north-facing slopes at higher elevations and 5) fescue meadow *(Festuca thurberi/Festuca idahoensis)* at higher elevations on north facing slopes (White River Wildlife Team 1986).

These 5 habitats are subdivided into specific plant associations as described in Plant Associations of Region Two (Johnston 1987; Appendix 1). Shale slopes and cliffs are considered a sixth habitat for purposes of this study.

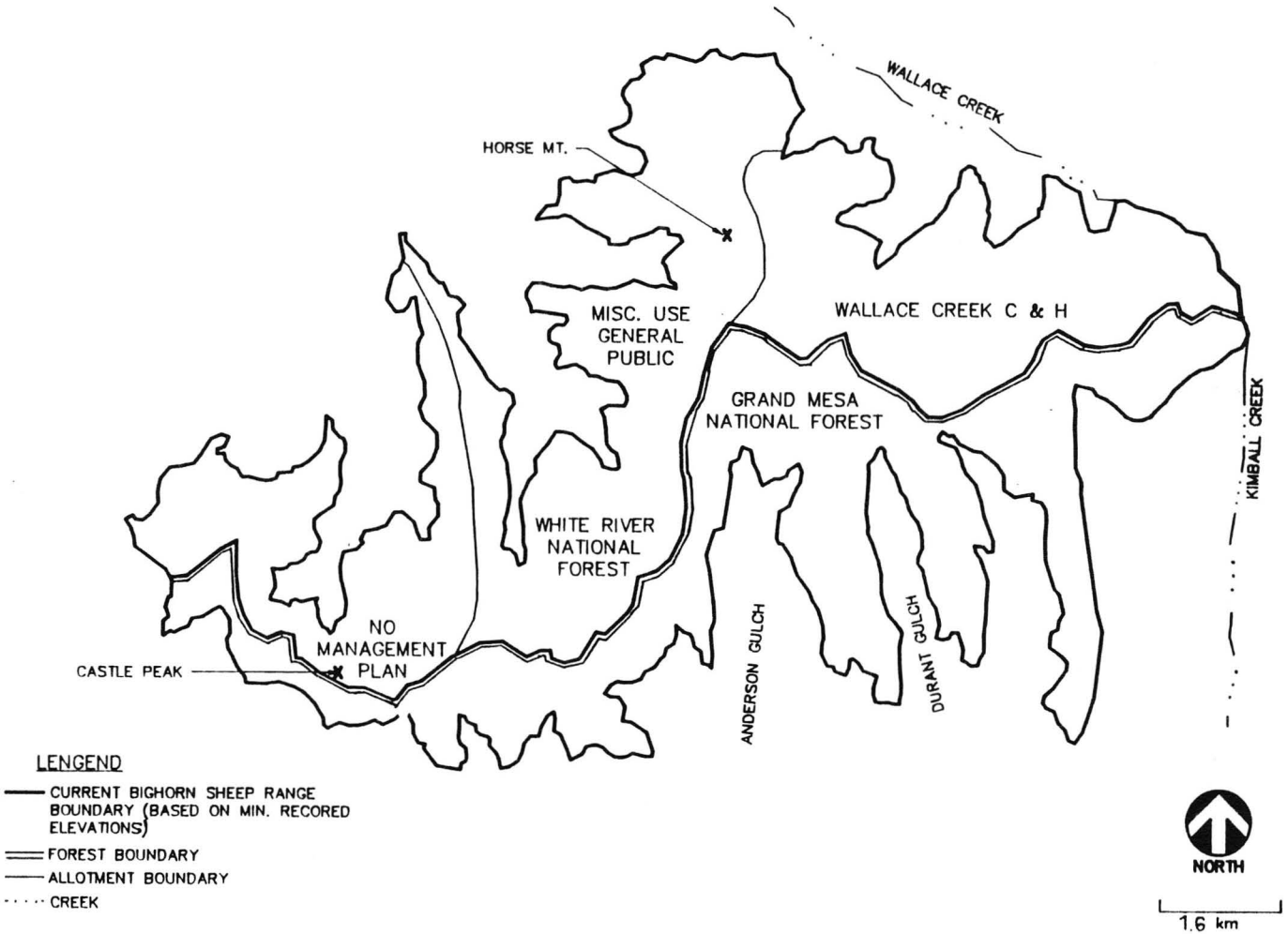
Wildlife species lists for Battlement Mesa are in the White River National Forest/Rifle Ranger District Wildlife Plan (USFS 1981). Important species related to bighorn sheep include potential competitors and predators. Potential competitors include elk *(Cervus elaphus)* and mule deer *(Odocoileus hemionus)*. Potential predators include coyote *(Canis latrans)*, mountain lion *(Felis concolor)*, bobcat *(Felis canadensis)*, black bear *(Ursus americanus)*, golden eagle *(Aquila chrysaetos)*, and bald eagle *(Haliacetus leucocephalus)*.

VI. Livestock use

Lower Battlement Mesa is presently divided among 3 allotments (Fig. 2). The northeast Wallace Creek Cattle and Horse (C&H) Allotment is used by 2 permittees on 1,427 useable ha (USFS 1914-1990). The allotment supported 44 cows and calves on a 3- pasture rotation system for 117 days from 6/16-10/10/89. During 1990 the allotment supported 151 cows and calves for the same duration. The central allotment is designated for 'Miscellaneous Use-General Public' and the far west allotment has no management plan. No livestock grazing occurs on either of these 2 allotments. Currently, domestic sheep graze on the north side of the present bighorn range in Alkali Creek on a locally owned ranch.

In the early 1900s the Wallace Creek livestock grazing allotment extended from Wallace Creek east to Mamm Creek and supported 3,500 cattle in Grazing District 9. When the National Forest System was established, the allotment was originally part of the Battlement National Forest (BNF) and later became part of the GMNF. In 1948, the present allotment boundaries were established and in 1954 the Wallace Creek allotment became a part of the WRNF.

Figure 2. Designated livestock grazing allotments on lower Battlement Mesa, Colorado.


WALLACE CREEK
HORSE MT.
MISC. USE
GENERAL
PUBLIC
WALLACE CREEK C & H
GRAND MESA
NATIONAL FOREST
KIMBALL CREEK
WHITE RIVER
NATIONAL
FOREST
NO
MANAGEMENT
PLAN
CASTLE PEAK
ANDERSON GULCH
DURANT GULCH
LENGEND
CURRENT BIGHORN SHEEP RANGE BOUNDARY (BASED ON MIN. RECORED ELEVATIONS)
FOREST BOUNDARY
ALLOTMENT BOUNDARY
CREEK
NORTH
1.6 km

Historically, rangelands on Battlement Mesa were overgrazed by both domestic sheep and cattle. Early-season grazing coupled with excessive numbers of livestock contributed to the historically poor range conditions of the area (USFS historic range files). Formal action to alleviate the grazing pressure came in 1915, when domestic sheep were forbidden on the Battlement allotment.

Range inspection reports from the late 1940s indicate the allotment was heavily overstocked with extremely heavy use. Range inspections from the late 1950s and 1960s indicated only localized areas of heavy use. The improvement was reportedly from the increase in cowboys that rotated the cattle between different pastures of the allotment from the early 1950s through the mid 1960s. Cattle numbers were reduced by 50% in 1950 and by 12% in 1959. In 1959 the grazing season was also reduced by 5 days (USFS 1914-1990).

The Sunnyside Plateau extends along the southern boundary of lower Battlement Mesa, adjacent to the shale cliffs utilized by bighorn sheep (Fig. 1). Pat Ottman (pers. comm.) contended that in 1952-53 as many as 40,000 head of domestic sheep, owned by Plateau Valley ranchers, utilized the area from the Sunnyside Plateau east to 'The Meadows' (a higher elevation summer pasture southeast of Battlement Mesa) during the summer. Ottman also stated that up to 25,000 cattle were brought across the Sunnyside Plateau in the spring during the 1950s, headed for higher pastures to the east. No records of these numbers of livestock were found as most of the land is private with several adjacent landowners.

The Sunnyside Plateau is currently managed by BLM and private landowners, who use the Plateau for spring cattle grazing. The CDOW manages the Plateau Creek State Wildlife Area on the Plateau, primarily for big game winter range. Although bighorn sheep were not observed on the Sunnyside Plateau during 1989 and 1990, past use is probable based on historic observations. According to Pitts (1965), the Sunnyside Plateau was "a thick mat of native grasses similar to the unwatered portion of Clover Cemetery in the 1890s" (Settlement of Collbran occurred in 1892). Pitts also claimed that this mat of grasses

extended to the bottoms of the large canyons and there were "no washes of any consequence". What happened to the area is best told by Pitts in his 1965 autobiography:

> "When the snows melted or rains came, the water spread out over a grass sodded floor of these canyons on its course to Plateau Creek. The deep washes were started in all of the big and small canyons by cattle trails, where the cattle, traveling from grasslands to Plateau Creek for water, cut out a trail. After the sod was destroyed by the cattle walking these trails, erosion quickly followed as the water ran down the same trails as a natural route to the creek."

The BLM Sunnyside Allotment Management plan (BLM 1969) reported that the western boundary experienced a short, high intensity runoff period in spring and was in a high erosion hazard class. The plan also stated, "Last, but most important from the management standpoint, the area has been overgrazed to a point where vegetation does not contribute to the reduction of runoff" (BLM 1969).

The Sunnyside Plateau is today characterized by pinyon/juniper vegetation covering the hills at the base of the canyons and the ridges that extend onto the sagebrush grassland. Numerous washes run from the canyons to Plateau Creek, forming deep channels with spring runoff. The erosion rate in the area is extremely high.

VII. Other resource use

There are no harvestable timber or developed recreation sites on Battlement Mesa due to limited access and steep slopes. Access is limited to a private road with a locked gate on the east edge of lower Battlement Mesa and steep shale cliffs on the southern and western borders on GMNF lands. The northern boundary is a mosaic of private, BLM and WRNF lands, to which access is limited and difficult. Human activity encountered during 1989 and 1990 consisted of a few hunters during the fall hunting seasons. Hunting occurs on Battlement Mesa for mule deer, elk, bear, mountain lion, small game and game birds during the regular seasons. Hunting for bighorn sheep occurred from 1960-1982. Over the 22 years,

121 licenses were issued and 17 rams harvested for a success rate of 14%. The area was closed to sheep hunting in 1982. This closure was based on the low density of sheep believed to occupy the area and hunter complaints of seeing few to no sheep during the hunting seasons of 1979-1982 (CDOW 1960-1982).

Seismographic activity occurred in the area during 7/89 and 8/89. Exploration routes on lower Battlement Mesa ran from Pole Gulch southwest to Bull Basin and from West Kimball Creek across lower Anderson Gulch. Most seismographic activity occurred on upper Battlement Mesa. Seismographic activity included helicopter transport of ground crews and equipment daily to survey lines. Ground crews then surveyed exploration lines, flagged and drilled holes, and conducted underground blasts along lines.

VIII. Bighorn sheep habitat requirements

Five components of bighorn sheep habitat have been discussed in the literature, including 1) seasonal ranges, 2) forage requirements, 3) escape terrain, 4) visibility, and 5) water. I have provided a brief discussion of each but readers are urged to consult references cited for further information.

A. Seasonal ranges

Geist (1971) reported that bighorns typically occupy as many as 6 seasonal home ranges, although use of available habitats varies among herds (Blood 1963). Remnant herds such as that of Battlement Mesa lost historic ranges through human encroachment and habitat succession resulting in unfavorable conditions for sheep (Wakelyn 1984). A long-term loss in viability is often a consequence of habitat loss (Woodard et al. 1974).

B. Forage requirements

Bighorn sheep diets are highly variable with preference and forage availabilities differing among herds (Cooperrider et al. 1980). Geist (1971) reported that bighorn sheep are primarily grazers, similar to domestic sheep. This has been supported by Todd (1972), McCullough (1982) and Van Dyke et al. (1983). Todd (1972) reported that Rocky Mountain bighorn sheep will utilize browse during the winter months. Rominger et al. (1988) reported that shrubs, particularly true mountainmahogany *(Cercocarpus montanus)*, were an important component of sheep diets in the Waterton Canyon herd, another low elevation bighorn sheep herd.

Van Dyke (1983) noted that the use of browse by desert bighorn is due to the lack of herbaceous forage. Browning and Monson (1985) reported that desert bighorn subsist on diets consisting of grass, browse, and forbs. They also reported that it is difficult to conclude what forage bighorn prefer based on available data (Browning and Monson 1985).

C. Escape terrain

Escape terrain consists of rough, rocky, steep areas where bighorn sheep can successfully out-climb their predators and guard their young (Hansen 1985). On Battlement Mesa, escape terrain consists of steep shale cliffs and slides, where slope often exceeds 200%. This percent slope may seem extreme, however the 200% slope shale cliffs offer narrow ledges, 0.3-2.4 m, that the sheep travel on. Escape terrain is the most consistent characteristic of bighorn sheep habitat (Hansen 1985).

D. Visibility

Bighorn sheep evolved in open mountain habitats where they were potential prey for several large predators (Geist 1971). Their evolved predator-evasion strategy includes foraging in large groups on open habitat near escape terrain (Risenhoover and Bailey 1985). Visibility is an important component in this strategy as predators must be detected and the rest of the group alarmed by visual communication among sheep (Risenhoover and Bailey 1985). Foraging efficiency is reduced in areas where visibility is poor as sheep are forced to be more alert and forage closer together in smaller groups. Dense, tall vegetation allows limited visibility for foraging bighorns.

E. Water

Water has been cited as the single most limiting factor for desert bighorn (Turner and Weaver 1985). Lower Battlement Mesa exhibits desert-like conditions therefore water availability must be considered. Water must be in close proximity to escape terrain and not surrounded by brush or other obstructions (Turner and Weaver 1985).

METHODS

I. Determining current and historic bighorn ranges

I determined present bighorn sheep range on Battlement Mesa by mapping all locations of sheep reported during 1980-1990. Seasonal range boundaries followed the lowest elevation contour recorded for locations during summer and winter. I searched CDOW, WRNF, GMNF files and local newspapers for information on historic bighorn sheep sightings and distribution to gain an historic perspective of the Battlement herd. I interviewed local residents, including ranchers and outfitter-guides familiar with the area, for any knowledge of past herd numbers and areas of use.

Historic migration routes were estimated from historic observations and the locations of potential sheep escape terrain. I searched these areas for sheep and sheep sign on 6 occasions, once on foot and 5 times by horseback. I estimated historic bighorn sheep summer range (upper Battlement Mesa) from past CDOW surveys and documents and from interviewing local residents. I searched upper Battlement Mesa for sheep and sheep sign on 8 occasions, once by fixed wing aircraft and 7 times by horseback, to validate range abandonment.

II. Determining herd size and sex-age composition

A. Trapping and immobilizing sheep with Carfentanil

We (CDOW and USFS personnel, project assistants and I) attempted to capture bighorn sheep for radio-collaring from 1988 through 1990. Having radio-collared sheep would enhance documenting herd size, sex-age composition and seasonal ranges. Nine radio collars were obtained in January, 1989. Using a helicopter, CDOW personnel distributed 5 Clover traps (Clover 1956) throughout the range. We used alfalfa hay mixed with apple pulp and salt blocks for bait, as this combination has been successful in attracting sheep during other trapping operations (Gene Byrne, pers. comm.; Bob Schmidt, pers. comm.; Hunter and Clark 1989). We packed bait and salt blocks into the study area and set them on slopes suitable for working Clover traps, where we observed sheep or recent sheep sign.

Sheep immobilization with drug-filled syringes fired from a dart gun was the only alternative if Clover traps proved unsuccessful. The preferred method was to hike into an area occupied by sheep and immobilize animals with Carfentanil contained in projectiles fired from a dart gun; Naloxone would then be administered as an antagonist (Jessup et al. 1989).

B. Systematic searching and sheep observations

We (project assistants and I) began intermittent observations of sheep on 12/5/88, with intensive data collection occurring from 1/3/89 through 1/12/90 and 6/5/90 through 7/11/90. Observations were interrupted during 4/11/89 through 7/12/89 (except for 2 sheep observations made on 5/4/89 and 6/30/89 by fixed-wing flight). We observed sheep using a Bausch and Lomb variable power (15-60 mm) scope and binoculars. I divided the suspected present range into 16 units to effectively search for sheep in the case that radio collaring

animals proved unsuccessful (Cochran 1977). I based unit boundaries on topographic features and the ability of field personnel to completely search a single unit in 1-2 days (Fig. 3).

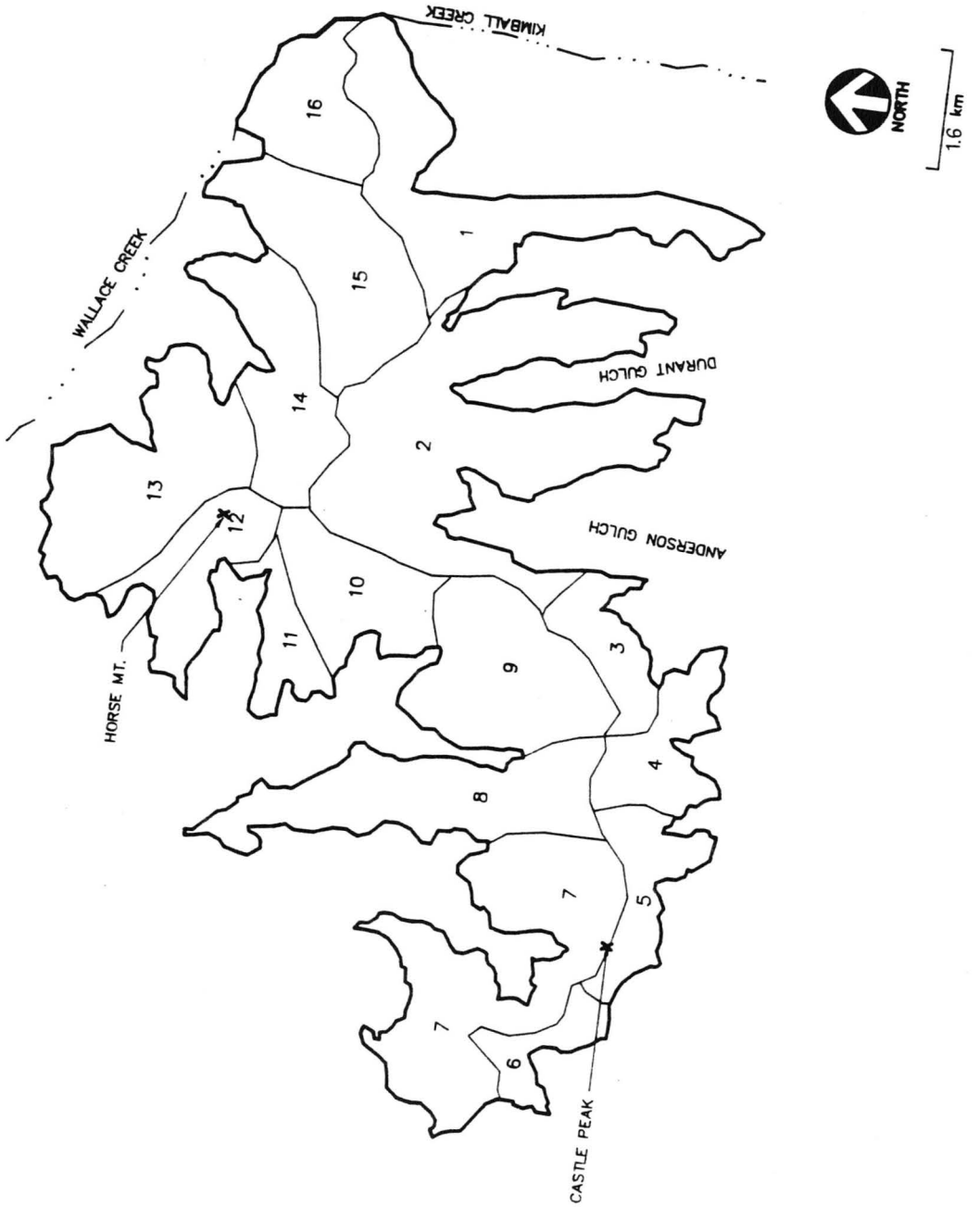
From 12/5/88 to 1/12/90, we located sheep by 1) tracking 1 radio-collared ewe from the ground with a Telonics receiver and a hand-held antenna to obtain visual observations (after 3/15/89); 2) searching with a spotting scope from a vehicle along Sunnyside Road which runs along the cliffs on the southern boundary of the study area; 3) systematically searching the 16 study area units between 7/13/89 and 10/27/89 (4 complete systematic searches) when all units were accessible; 4) flying over the area in a fixed-wing airplane (Cessna 185) or a helicopter, utilizing a Telonics receiver and a 2-element Yagi antenna mounted on the aircraft to track the radio-collared ewe after 3/15/89; and 5) searching accessible areas by horseback. We made other opportunistic observations by hiking to locations where we had previously observed sheep to collect additional data on herd sex and age composition, habitat use, group size, and behavior.

We located the radio collared ewe $\geq$ once weekly during 3/15-4/10, 1989; 7/13-1/12, 1989-90; and 6/5-7/11, 1990. I attempted to observe her directly to insure proper identification of habitat use. Between 10/27/89-1/12/90, access into the sheep range was limited by snow. We located but did not always observe the radio-collared ewe during this time.

In the rugged terrain of Battlement Mesa, we could not use triangulation to accurately locate the radio-collared ewe. Bearing error due to signal reflection is common to many studies (Garrot et al. 1986). Consequently, we recorded habitat-use by the radio-collared ewe only from visual observations. Due to budget, time, and feasibility, a 3-tower triangulation system was not an option.

I observed sheep on lambing grounds and summer range reported for 1989 in units 2 and 10 (Fig. 3) during 1990, to maximize data collection within the limited time available. This method presumably biased sampling, therefore was not included in the analysis of data

Figure 3. Units systematically sampled on lower Battlement Mesa, Colorado, 1989.


KIMBALL CREEK
WALLACE CREEK
HORSE MT.
CASTLE PEAK
DURANT GULCH
ANDERSON GULCH
NORTH
1.6 km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

collected while systematically sampling during 1989. I realized diminishing returns during 1989 when searching for lambs in units other than 2 and 10, therefore we concentrated search effort in these 2 units during 1990, to locate lambs and record lambing dates.

When we located sheep, we completed a standard observation form (Appendix 2). We approximated date of birth for newly observed lambs (Hansen and Deming 1985) and recorded any identifying features on sheep. Sex and age classification followed Geist (1971). I plotted all locations of bighorn sheep on United States Geological Survey (USGS) 7.5-minute series topographic maps and recorded them using the Universal Transverse Mercator (UTM) system (Grubb and Eakle 1988). When possible, we determined slope percent by marking an observation site on a USGS topographic map then visiting the site after the sheep had moved. We measured slope with a clinometer from approximately 10 m above the observation site to approximately 10 m below when visibility and terrain permitted. Often, the specific sites of bighorn use were not accessible due to the rugged terrain and steepness of slopes. In these cases, we would stand on the edge of the cliff or steep slope and record the slope percent with a clinometer to approximately 10 m beyond the actual location of the observation. I tested the null hypothesis that there was 'no difference in use of slope categories between uncollared and radio-collared groups of sheep' with the Chi-square test for association (Steel and Torrie 1980).

I summed the maximum unduplicated counts of sheep in each sex-age class to determine a known minimum population for 1989 and for summer, 1990.

C. Aerial survey

Census of the Battlement Mesa bighorn herd by fixed-wing aircraft was not feasible. The sheep are colored similar to the light brown to ash-grey cliffs they inhabit, thus locating animals is difficult. Further, the rugged shale cliffs, outcrops and overhangs effectively conceal

sheep. Claude E. White, Regional Game Management Biologist for the CDOW in 1972, commented on problems associated with helicopter census of the Battlement sheep. White reported, "I have no doubt that we missed many sheep (22 sheep were sighted). The size of the area plus their fear of the chopper renders it impossible to find them all." (Colorado Department of Game, Fish and Parks (CDOW) 1972).

After reviewing the range, we (CDOW pilot and I) established a flight plan which surveyed the several draws in a systematic fashion at the lowest, safe elevation possible. We conducted fixed-wing flights after snowfall to record sheep and areas of sheep use. Sheep tracks were verified by scoping from a vehicle on Sunnyside Road to locate sheep directly after the flight, when possible. CDOW personnel searched the area for sheep during the January 1989 and 1990 elk and deer helicopter counts. A total of 3 helicopter flights and 5 fixed-wing aircraft flights were made over the current range during 1989 and 1990 (not including CDOW elk and deer helicopter counts).

III. Seasonal ranges

I determined seasonal ranges by locating sheep in the 4 seasons described by Dale (1987) for the Waterton Canyon bighorn sheep herd. The Waterton Canyon herd is also an indigenous, low elevation (1707-2370 m) population in Colorado. Battlement Mesa and Waterton Canyon share similar elevations and some vegetation communities, including a high proportion of mountain shrub habitat. Based on forage phenology observed in Waterton Canyon, seasons were: 1) spring, 2/16-5/30, 2) summer, 6/1-9/30, 3) fall, 10/1-11/15 and 4) winter, 11/16-2/15.

I monitored movements by the radio-collared ewe and by other identifiable sheep and inferred the migration corridors within the present sheep range by analyzing movement data. I located potential lambing areas based on the lambing-area requirements of desert bighorn

sheep because of the similarities between the present sheep range and desert environments (Bear and Jones 1973, Hansen 1985). Characteristics of good desert bighorn sheep lambing areas are: 1) water needs of ewe are met, 2) adequate food supply occurs on or near escape terrain and 3) rough, broken country facing south or southeast with adequate cover for protection from inclement weather or predators is available (Hansen and Deming 1985). I located ewes with lambs <2 months old and mapped nearby areas meeting lambing ground requirements to define present and potential lambing areas. I determined rutting periods and rutting range by observing sheep behavior, changes in group composition, and locations during the fall.

IV. Determining Potential Limiting Factors

I summarized factors affecting the Battlement Mesa bighorn sheep herd for the past 75 years and all data collected from 1988-90, to identify potential limiting factors. Literature review revealed factors limiting to other Rocky Mountain and desert sheep herds, including 1) habitat, 2) predation, 3) hunting and poaching, 4) conflicts with elk, deer and livestock, 5) disease and parasites, 6) exotic, free-ranging ungulates, and 7) limited summer water supply.

"Potential" is the key word in this summary of limiting factors. Unless a factor postulated as limiting to a herd of sheep is manipulated and a treatment and control group of animals defined, we cannot demonstrate the factor is indeed limiting. I evaluated the potential for each of the above factors to be limiting the Battlement Mesa bighorns as follows:

A. Habitat

I measured the hectarage available to sheep for each of the 6 habitat types within the present range from USFS Resource Information System maps (USFS 1986). Randomly

selected sites were ground-truthed during 1989 and 1990 to confirm habitat types. Planimetered hectares on cliffs underestimated actual hectarage because of steep slopes not compensated for with a planimeter.

I tested the null hypothesis that 'bighorn sheep use the habitat available to them on Battlement Mesa in proportion to the availability of each habitat type' with the Chi-square goodness-of-fit test (Neu et al. 1974, Steel and Torrie 1980). A significant difference between observed and expected habitat use results in rejection of the null hypothesis when using the Chi-square statistic. I developed a preference index for each habitat type by dividing the proportion of observations within a habitat type by the proportion of that habitat type that is available out of the total hectarage. 'Preference' is defined here as the likelihood that a habitat will be selected more frequently than predicted based on availability, also termed 'selection' in other studies (Thomas and Taylor 1990). A preference index >1 indicates the habitat is used more frequently by the sheep than predicted based on availability; thus it is 'preferred'. A preference index <1 indicates the habitat is used less frequently than predicted; thus 'avoided' (Petrides 1975).

B. Predation

I recorded all observations of predators and their sign during systematic searching of study area units. Carcasses and skulls of sheep and other large prey located on the study area were examined for any sign of predation. I recorded reports from local residents, including outfitter-guides, on predation of bighorn sheep.

C. Hunting and poaching pressure

I summarized CDOW bighorn sheep harvest records for the Battlement Mesa herd between 1960 and 1982. I interviewed long time residents of the Colorado River and Plateau Creek valleys and investigated and summarized reports of poaching incidents on the Battlement Mesa herd.

D. Conflicts with elk, deer and livestock

I documented incidental observations of elk, mule deer and cattle on lower Battlement Mesa. This documentation provides information on the extent of overlap in ranges between the 3 wildlife species and cattle during 1989-90.

E. Diseases and parasites

I collected 9 fresh bighorn sheep fecal samples between 1/89-4/89 from known bed sites on Battlement Mesa. Samples were analyzed for lungworm larvae *(Protostrongylus sp.)* at the CDOW Research Laboratory in Fort Collins, Colorado. Levels of lungworm larvae in bighorn sheep fecal pellets are generally highest during spring (Mike Miller, CDOW, pers. comm.). I recorded any clinical signs of pneumonia (i.e. nasal discharge and coughing) or indications of other sickness when we observed sheep. We took nasal swabs, ear swabs and skin scrapings from the ewe captured on 3/15/89 and analyzed these for incidence of the *Psoroptes* mite or other external parasites.

Domestic sheep may carry diseases that are detrimental to wild sheep (Goodson 1982). I documented areas of domestic sheep use adjacent to the bighorn range to investigate the extent of contact and range overlap between the 2 species.

F. Exotic, free-ranging ungulates

I documented and investigated reports of exotic, free ranging ungulates in the area.

G. Water supply

I summarized all water developments in the area and recorded all permanent water sources for sheep on the present range. I recorded all permanent water sources while searching historic range for sheep and sheep sign.

H. Human disturbance

I recorded and summarized all sources of human disturbance on lower Battlement Mesa during 1989 and 1990. Human disturbance was easily monitored as very few people recreate or hunt in this area. The only access from the east is controlled by a locked gate and access from the west is controlled by arduous terrain or private property.

RESULTS

I. Trapping and immobilizing sheep with Carfentanil

Baiting sheep for subsequent capture in Clover traps proved unsuccessful during 12/88-2/89. Sheep used neither bait nor salt blocks. We continued to bait with salt throughout the summer but the sheep never used the blocks. After 3 months without trapping success, we resorted to collaring sheep utilizing drug capture techniques.

One ewe was immobilized with Carfentanil administered by a Cap-chur syringe shot from a dart gun on 3/15/89 (Table 1) and fitted with a radio collar and ear tag. Due to the rugged terrain and safety hazards imposed on both field personnel and sheep, we abandoned drug capture efforts in 4/89.

II. Sample sizes

A. Systematic searching and opportunistic observations

Between 12/5/88-6/28/90, we observed uncollared groups of sheep on 84 occasions (Table 2) and groups of sheep with the radio-collared ewe on 21 occasions (Table 3). We observed sheep 14 times during 4 systematic searches of study area units between 7/12-11/16/89 (included in 105 total) (Table 4). Most observations were made during the summers of 1989 and 1990 (45 observations). Fall was the most difficult time to observe sheep due to the limited access to many study area units and sheep migration to winter range

Table 1. Capture report and measurements of bighorn sheep ewe, immobilized with Carfentanil, on 3/15/89, Battlement Mesa, Colorado.

Age (by horn annuli)	2.5 yrs
Estimated Weight	36 kg
Horn Length	12.7 cm
Body Length	127.0 cm
Sex	Female
Ear Tag Identification Number	421-1
Radio Collar Identification Number	I-100
Radio Collar Frequency	148.600

Table 2. Uncollared bighorn sheep observed on Battlement Mesa, Colorado, 12/5/88-6/27/90.

Date	Number of individuals in Group	Habitat type[1]	Slope %	Distance to escape terrain (m)[2]	UTM coordinates (XxY)[3]
12/5/88	3	-	-	-	52.9x50.8
12/5/88	2	-	-	-	50.2x49.9
12/5/88	4	-	-	-	48.6x50.4
12/20/80	1	-	-	-	49.0x50.1
12/30/88	2	-	-	-	49.8x49.8
1/11/89	8	SSV	101-150	-	49.4x49.6
1/12/89	9	-	-	-	49.4x49.6
1/12/89	4	-	-	-	47.2x50.4
1/13/89	9	SSV	-	-	49.4x49.6
1/14/89	9	PJO	-	-	50.0x49.6
1/21/89	6	-	-	-	52.8x51.0
1/30/89	7	SSV	51-100	-	52.6x50.4
2/6/89	8	PJO	101-150	-	51.4x50.2
2/15/89	2	SSV	101-150	-	50.3x49.9
2/21/89	3	SSV	101-150	-	50.5x50.1
2/21/89	5	PJO	51-100	-	49.6x49.7
2/22/89	5	PJO	101-150	-	49.4x49.7
2/23/89	5	PJO	51-100	-	49.0x50.0
2/23/89	3	SSV	51-100	-	50.4x50.0
2/24/89	5	SSV	51-100	-	48.6x50.3

[1]SSV=shale slope with scattered vegetation
PJO=pinyon/juniper with open canopy cover (<20%)
SS=shale slope/cliff
DF=Douglas fir

[2]escape terrain is defined as steep, rocky terrain on which sheep would be able to safely outmaneuver or outdistance predators. Escape terrain on Battlement Mesa was steep shale cliffs (>200% slope) with 0.3-2.4 m ledges that sheep could travel on.

[3]UTM coordinates are abbreviated here. The first number represents the vertical axis value and assumes a prefix of 43. The second number represents the horizontal axis value and assumes a prefix of 7. For example: 52.9x50.8 = 4,352,900x750,800.

Table 2. Uncollared bighorn sheep observed (cont.)

2/27/89	4	SSV	51-100	-	47.4x50.8
2/27/89	2	SS	0-50	-	50.3x50.0
2/28/89	2	DF	101-150	-	47.4x50.8l
3/2/89	4	SSV	>200	0.0	50.4x50.0
3/2/89	4	SSV	>200	0.0	47.4x50.9
3/7/89	8	SSV	>200	0.0	47.1x50.6
3/7/89	1	SSV	101-150	4.6	47.2x50.8
3/7/89	3	SS	51-100	3.1	50.0x50.1
3/10/89	1	PJO	101-150	45.8	48.5x50.3
3/13/89	8	-	-	-	48.4x50.3
3/14/89	1	SSV	0-50	-	48.6x50.4
3/14/89	9	SSV	101-150	-	48.6x50.4
3/15/89	8	-	-	-	48.6x50.3
3/16/89	2	SSV	>200	0.0	50.7x50.5
3/30/89	2	SSV	51-100	-	47.0x51.0
3/31/89	1	SSV	51-100	6.1	50.8x49.5
4/10/89	4	SSV	51-100	-	48.2x50.3
7/12/89	2	SS	>200	0.0	56.8x55.3
7/12/89	2	SS	>200	0.0	56.1x55.4
7/13/89	10	SS	101-200	0.9	56.4x55.2
7/14/89	10	SS	>200	0.0	56.1x55.4
7/18/89	7	SS	>200	0.0	56.1x55.5
7/19/89	10	SS	>200	0.0	55.8x55.5
7/19/89	1	SSV	151-200	0.9	56.2x55.2
7/20/89	10	SS	>200	0.0	56.2x55.5
7/31/89	1	SS	>200	0.0	56.1x55.4
7/31/89	1	SS	>200	0.0	56.1x55.3
7/13/89	2	SS	>200	0.0	56.2x55.4
8/1/89	1	SS	>200	0.0	56.1x55.3
8/2/89	1	SS	51-100	6.9	53.0x51.4

Table 2. Uncollared bighorn sheep observed (cont.)

8/4/89	4	SS	>200	0.0	56.9x54.9
8/11/89	1	SSV	>200	0.0	54.1x56.0
8/13/89	9	SS	>200	0.0	56.2x55.4
8/21/89	3	SS	>200	0.0	56.1x55.3
8/22/89	8	SSV	>200	0.0	56.1x55.3
9/23/89	2	SS	101-150	1.9	56.3x55.4
9/23/89	2	SSV	>200	0.0	55.2x55.2
9/26/89	3	SSV	51-100	2.1	51.0x49.1
11/7/89	3	PJO	51-100	4.7	47.5x50.6
11/12/89	1	SS	>200	0.0	47.2x50.7
11/12/89	1	PJO	51-100	9.3	47.4x51.4
11/28/89	?	PJO	51-100	7.0	53.8x56.4
11/29/89	2	SSV	101-150	1.9	50.3x50.2
11/29/89	2	SSV	101-150	2.8	47.1x51.0
12/4/89	1	SSV	>200	0.0	51.1x50.7
12/4/89	1	SSV	51-100	1.4	53.0x51.3
12/8/89	3	SSV	0-50	2.8	50.9x50.7
12/13/89	4	SSV	51-100	4.7	50.9x50.6
6/5/90	2	SSV	>200	0.0	54.8x56.0
6/19/90	3	SSV	151-200	3.1	55.4x56.1
6/19/90	5	SSV	151-200	6.1	55.3x55.8
6/20/90	1	SSV	>200	0.0	55.3x56.1
6/27/90	1	SSV	>200	0.0	55.4x56.1
6/27/90	1	SSV	>200	0.0	55.3x55.9
6/27/90	1	SSV	>200	0.0	55.3x56.2
6/27/90	2	SSV	>200	0.0	55.4x56.1
6/27/90	1	SS	>200	0.0	55.3x56.1
6/27/90	3	SS	>200	0.0	55.2x56.1
6/28/90	1	SS	>200	0.0	55.4x56.1
6/28/90	5	SS	>200	0.0	55.3x55.9

Table 3. Observations of radio-collared ewe from 3/30/89-6/27/90 on Battlement Mesa, Colorado.[4]

Date	Number of Individuals in Group	Habitat Type	Slope %	Distance to Escape Terrain(m)	UTM coordinates (XxY)
3/30/89	1	SSV	101-150	-	47.1x51.0
4/4/89	2	SSV	101-150	2.4	48.5x50.4
3/31/89	1	SSV	101-150	3.1	48.6x50.4
4/7/89	2	SSV	>200	0.0	46.9x51.2
4/10/89	2	SSV	51-100	-	48.4x50.3
5/4/89	1	SSV	-	-	50.5x50.4
6/30/89	4	SS	-	-	55.6x55.3
7/31/89	11	MSO	51-100	22.9	56.9x54.9
8/10/89	11	SS	51-100	6.1	57.0x55.2
8/11/89	13	SS	51-100	3.1	57.1x55.1
9/14/89	4	SS	51-100	4.6	58.2x54.3
9/20/89	4	SS	>200	0.0	57.6x54.9
9/23/89	4	SS	51-100	6.1	56.9x55.1
10/9/89	6	MSO	51-100	183.0	57.5x55.3
10/10/89	6	SSV	101-150	15.3	56.7x55.2
11/28/89	?	MSO	0-50	152.5	57.5x55.2
11/16/89	10	SS	101-150	18.3	58.4x54.7
1/12/90	10	SS	101-150	15.3	47.2x51.3
6/5/90	9	SSV	>200	0.0	55.4x56.1
6/27/90	14	SS	>200	0.0	55.5x56.2
6/27/90	10	DF	151-200	30.5	55.6x56.2

[4]See Table 2 for footnotes on column specifics.

Table 4. Results of systematic searching of 16 study area units, 7/12/89-11/16/89, Battlement Mesa, Colorado.

Unit Identification[5]	Number of Times Searched		Number of Observations	
	Systematically	(Total)[6]	Systematically	(Total)[7]
1	4	(4)	1	(1)
2	4	(19)	8	(27)
3	4	(6)	1	(1)
4	4	(5)	1	(1)
5	4	(4)	1	(1)
6	4	(4)	0	(0)
7	4	(4)	0	(0)
8	4	(4)	0	(0)
9	4	(8)	0	(0)
10	4	(7)	2	(2)
11	4	(6)	0	(0)
12	4	(4)	0	(0)
13	4	(4)	0	(0)
14	4	(14)	0	(0)
15	4	(4)	0	(0)
16	4	(4)	0	(0)

[5]Units are delineated in Fig. 3.

[6]Total number of times that this unit was searched, including systematic searching and opportunistic searching.

[7]Total number of observations in this unit, including systematic searching results and opportunistic observations.

(5 observations, 1989). The field season included 1 complete spring, summer and fall (1989), portions of 2 winters (1988-89, 1989-90) and the first half of summer 1990.

B. Radio-collared ewe

We located the radio-collared ewe on 33 occasions between 3/15/89-6/28/90 and observed her on 21 occasions (Table 3). On the average, we maintained 3 days between observations with 4 exceptions (Table 3) to maintain independency of observations over time. We recorded and analyzed habitat use for the entire group observed, as sheep are gregarious and not independent of each other. We observed sheep from considerable distances, usually from a ridge parallel to their location, thus the animals were undisturbed by our presence. Only on 1 occasion were sheep looking at us before we saw them. Typically, the great distance between us and the sheep resulted in no movement or change in behavior by the animals. Sampling bias may have occurred on 6 occasions when we succeeded in recording a strong radio signal, but did not observe the ewe. On these occasions, the radio collared ewe may have been in less open habitat, such as a mountain shrub stand or deep in a gulch, and thus not visible.

C. Aerial survey

During the 5 fixed-wing flights, we located the radio collared ewe 4 times, observed 2 other groups of sheep and identified several areas of use. During 3 helicopter flights we located 4 groups of sheep. Snow melt was rapid on the south-facing cliffs after snowstorms, increasing the difficulty of locating bighorn sheep or areas of sheep use. Fixed-wing flights in the area following a snow storm served primarily to record where sheep did not occur on snow retaining slopes.

III. Bighorn range

A. Current Range

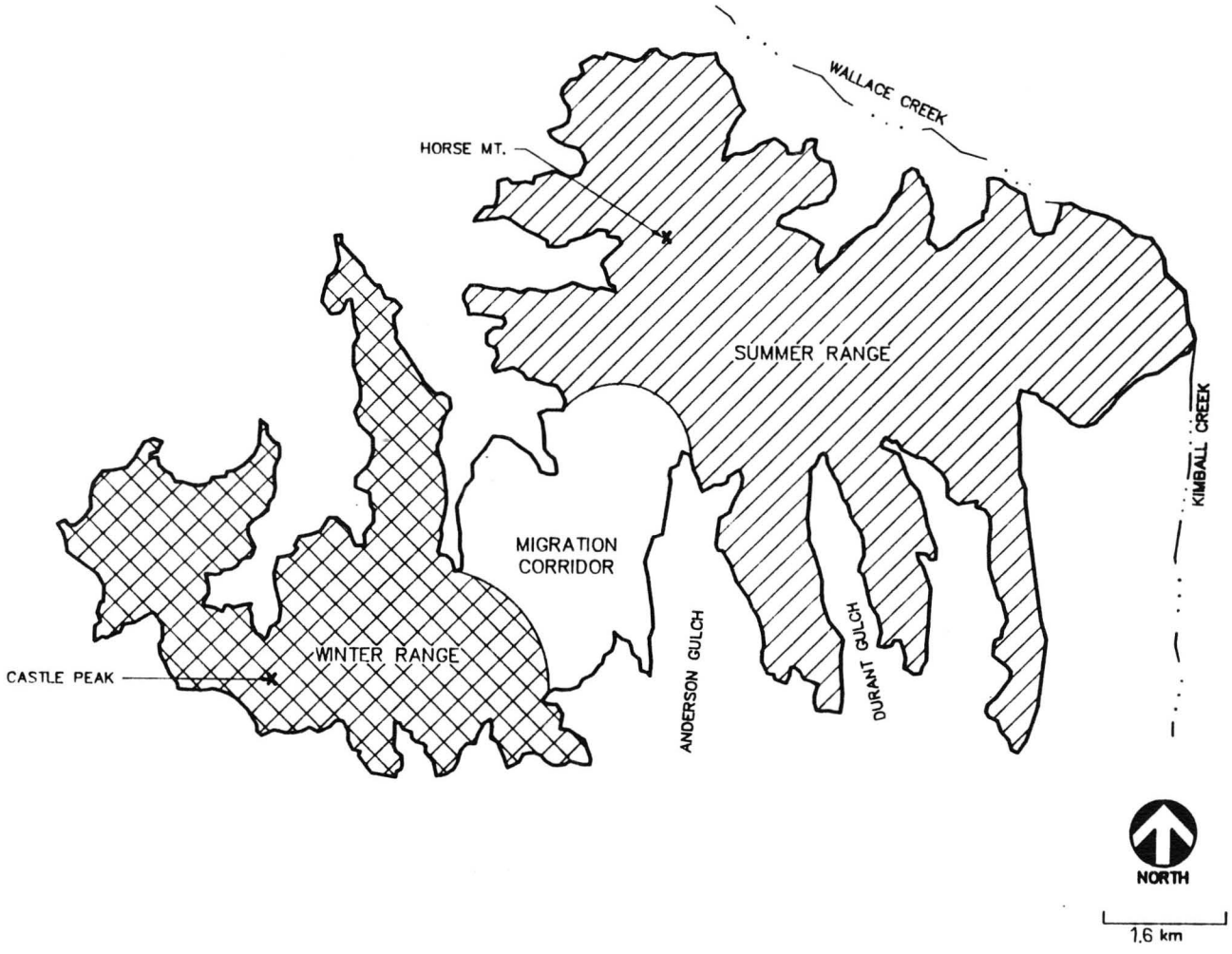
The current range of bighorn sheep on Battlement Mesa is approximately 40.0 km^2, including summer and winter ranges. The west and southwest range boundary is the 2073 m contour while the southeast boundary is the 2195 m contour. The 2438 m contour defines the north and the 2499 m contour defines the northeast. Sheep observations between 1988-90 revealed 2 somewhat overlapping seasonal ranges and 1 migration corridor (Fig. 4). Mature rams were scattered over a larger area than were ewe-juvenile groups, especially during summer. Ewe-juvenile groups were concentrated in unit 2 (Fig. 3) during the lambing season and for most of the summer.

Sheep remained on the west end of the range from 12/88-5/89 at elevations between 2073 and 2400 m. From 4/89-7/89, sheep migrated to summer range between 2340 and 2700 m. Ewe-juvenile groups moved 4.8-9 km northeast from winter locations between 4/10-6/30/89. Rams moved 3-9 km northeast from winter locations between 4/10-7/20/89. One class II and 2 class III rams were observed in Anderson Gulch (Fig. 4) until the last week in July and the first week in August during 1989.

The primary migration corridor on lower Battlement Mesa (Fig. 4) was across the south facing cliffs from unit 5, through units 4 and 3, to lambing grounds and summer range in unit 2 (Fig. 3).

In 1989 we observed no sheep in unit 2 after 9/23. The last large ewe-juvenile group we observed in unit 2 during 1989 on 8/22 consisted of 3 lambs, 4 ewes, and a class I ram. I suggest the sheep not observed during September and October on summer range had already moved to fall/winter range to the west and that fall migration for these sheep began on 9/24/89.

Figure 4. Seasonal home ranges and migration corridor used by bighorn sheep on lower Battlement Mesa, Colorado, 1989-90.


WALLACE CREEK
HORSE MT.
SUMMER RANGE
KIMBALL CREEK
MIGRATION
CORRIDOR
ANDERSON GULCH
DURANT GULCH
WINTER RANGE
CASTLE PEAK
NORTH
1.6 km

Sheep utilized more study area units from 10/28/89-1/10/90 than had previously been documented. One group of 10 sheep, including the radio collared ewe, remained in units 1 and 2 during these 2 months and was not observed frequently due to the limited access.

A fixed-wing aircraft flight aided by 5.1 cm of new snowfall on 11/28/89 revealed 4 areas of sheep use, based on 2 sightings of sheep and 2 sightings of sheep tracks on cliff areas. These 4 areas included units 2, 5, 9 and 10 (Fig. 3). On 1/10/90, I observed the group of 10 sheep aforementioned (now 11) which included the radio collared ewe, in unit 7, approximately 3.5 km west of their location on 12/15/89. On 1/10/90, the south facing cliffs of unit 2 were covered with snow while the units at lower elevations to the west were devoid of snow in January.

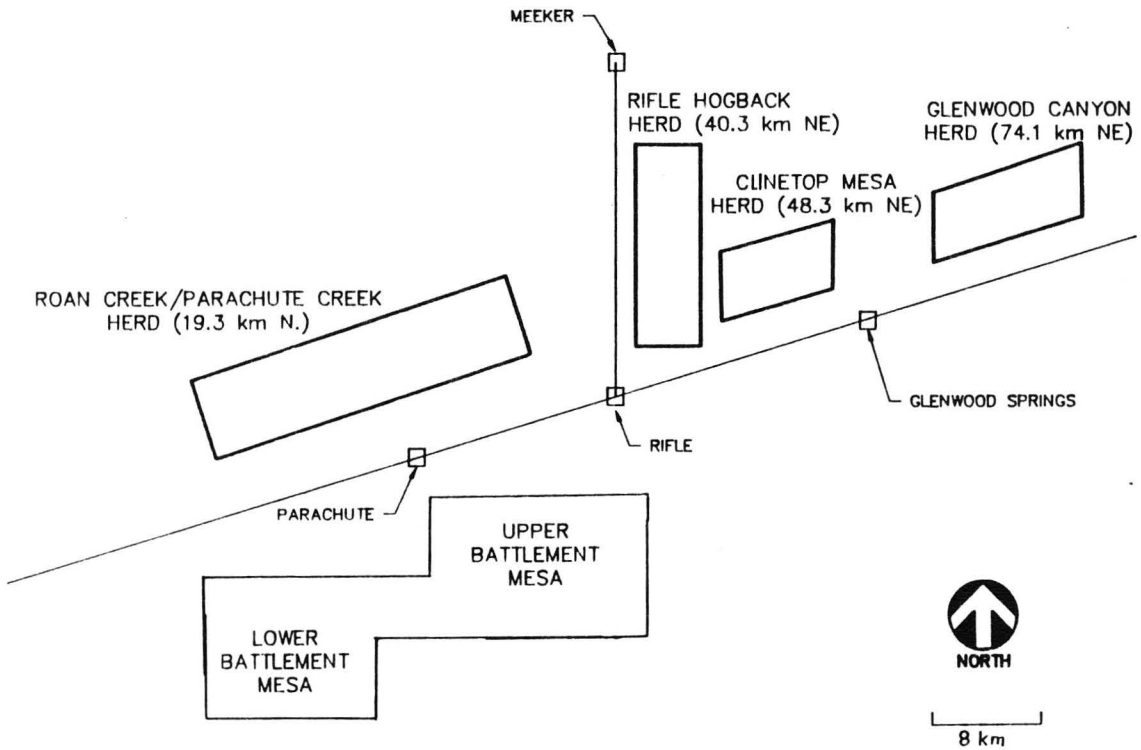
Observations between 1/90-7/90 revealed seasonal ranges similar to those recorded in 1989. Migration to lambing and summer range in unit 2 occurred from 5/15 to 6/28/90.

B. Historic range and herd size

Historic sheep populations once inhabited ranges near Battlement Mesa, to the north and east (Fig. 5). These included: 1) the Roan Creek-Parachute Creek herd now extirpated, 2) the Rifle Hogback herd, recently reintroduced, 3) the Clinetop Mesa herd, a remnant herd with 1989 and 1990 augmentations, and 4) the Glenwood Canyon herd, extirpated by disease and human interference and reintroduced in 1990 to No Name Creek (Bear and Jones 1973).

I observed no sheep or sheep sign during 8 searches of historic summer range on upper Battlement Mesa. I estimated historic range (including the 40.0 km^2 of present range) at 96.0 km^2. Talus slopes, rock piles and cliffs occurred in many areas adjacent to open meadows (potential and perhaps historic areas of sheep use) and I located numerous permanent water sources including creeks and reservoirs. All evidence suggests that bighorn sheep have abandoned historic summer range with no sheep observed on upper Battlement

Figure 5. Historic bighorn sheep herds and ranges with approximate distances to the Battlement Mesa herd, Colorado.


MEEKER
RIFLE HOGBACK
HERD (40.3 km NE)
GLENWOOD CANYON
HERD (74.1 km NE)
CLINETOP MESA
HERD (48.3 km NE)
ROAN CREEK/PARACHUTE CREEK
HERD (19.3 km N.)
GLENWOOD SPRINGS
RIFLE
PARACHUTE
UPPER
BATTLEMENT
MESA
LOWER
BATTLEMENT
MESA
NORTH
8 km

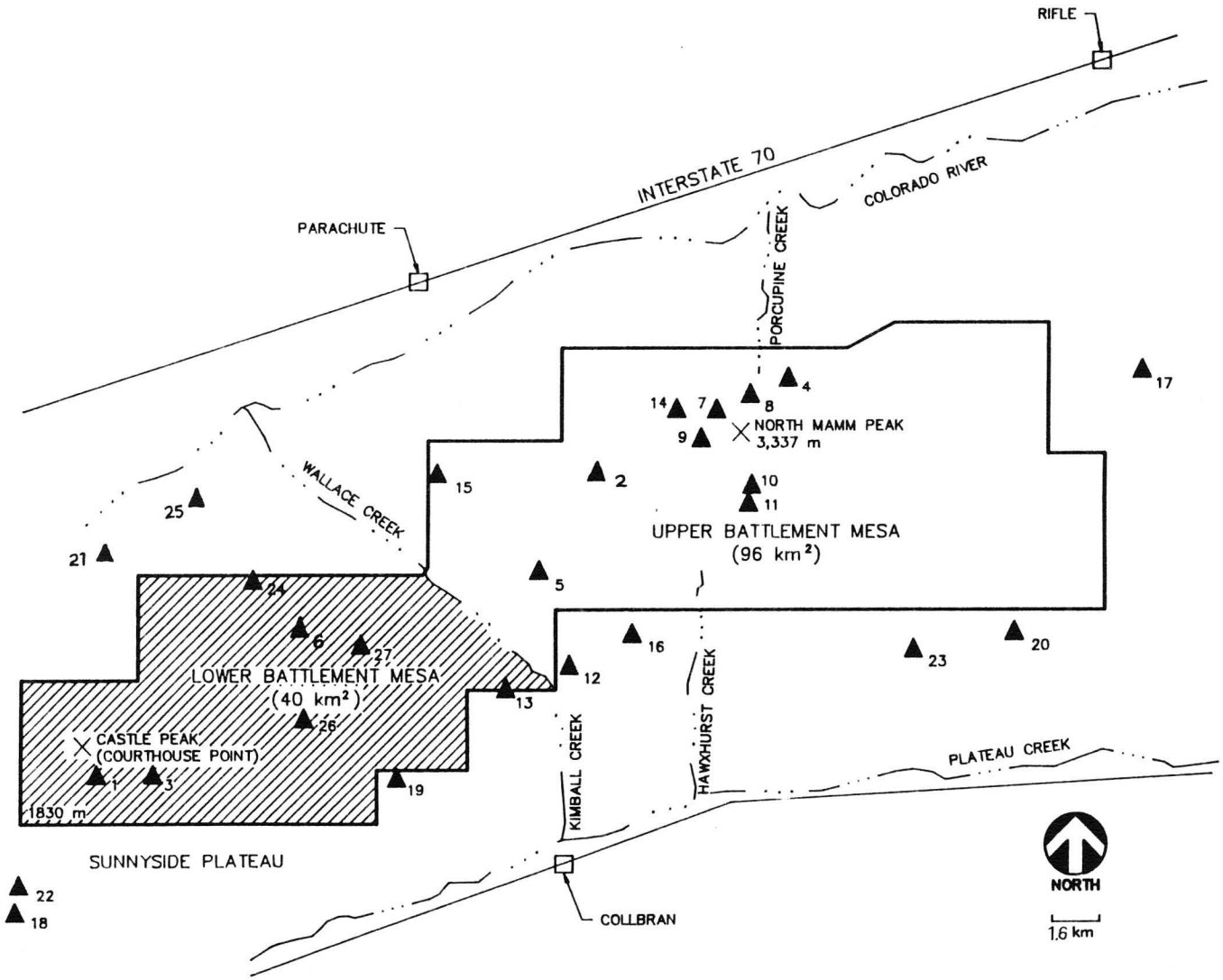
Mesa since a sighting on Mamm Peak in July, 1961 during a CDOW aerial survey. Snow depth on upper Battlement Mesa may eliminate the possibility of sheep utilizing the area during winter.

Written records and interviews with local residents document the distribution of bighorn sheep on Battlement Mesa between 1906-88 (Appendix 3; Fig. 6; numbers in () correspond to labels in Fig. 6). CDOW aerial and ground counts of sheep on Battlement Mesa from 1969-88 fluctuated widely (Fig. 7). A general downward trend began in 1970. Search effort was not consistent over years and search method varied between helicopter trend counts and more intensive, though less extensive, ground counts.

The first written report of these sheep by the Battlement Mesa Forest Reserve occurred in 1906. This report stated, "Forty five head of bighorn sheep" were found by Courthouse Point (now Castle Peak) (Anderson 1906 (1)). Ed Chamberlain, of Rifle, Colorado, has the horns of a ram poached by his father between 1910-20, from the Hogback area near Rio Blanco (40.3 km NE of present range) (CDOW 1976).

In 1923, the Battlement Mesa National Forest (now part of the GMNF and WRNF) reported to the Grand Junction Daily Sentinel that, "a handful of mountain sheep have been reported in and near the Forest" (Grand Junction Daily Sentinel 1923 (2)). The Sunday Magazine of the Daily Sentinel in 1927, reported on the sheep in the 'Yesteryear' segment. This article stated that 50 sheep were found in 1920, 19 in 1926 and none in 1927. At that time in 1927, "all of the sheep were believed to be exterminated by predatory animals, having declined steadily since 1920" (Grand Junction Daily Sentinel 1927 (3)). Bob Black (pers. comm. (4)) recalled a man named Ford from Whitewater Creek who grew up in Collbran. Ford, who passed away approximately 18 years ago, rode Battlement Mesa while working as a cowboy. Ford claimed that in the 1920s, approximately 800-1000 mountain sheep were in the area from Castle Peak east to Porcupine Creek (a drainage southwest of Rifle, 16.1 km NE of present range). Ford saw "great herds of sheep" while riding in the area but claimed

Figure 6. Locations (▲) of bighorn sheep observed on Battlement Mesa, Colorado, and vicinity, 1906-88.


RIFLE
INTERSTATE 70
COLORADO RIVER
PARACHUTE
PORCUPINE CREEK
WALLACE CREEK
NORTH MAMM PEAK
3,337 m
UPPER BATTLEMENT MESA
(96 km²)
LOWER BATTLEMENT MESA
(40 km²)
CASTLE PEAK
(COURTHOUSE POINT)
1830 m
SUNNYSIDE PLATEAU
KIMBALL CREEK
HAWXHURST CREEK
PLATEAU CREEK
COLLBRAN
NORTH
1.6 km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
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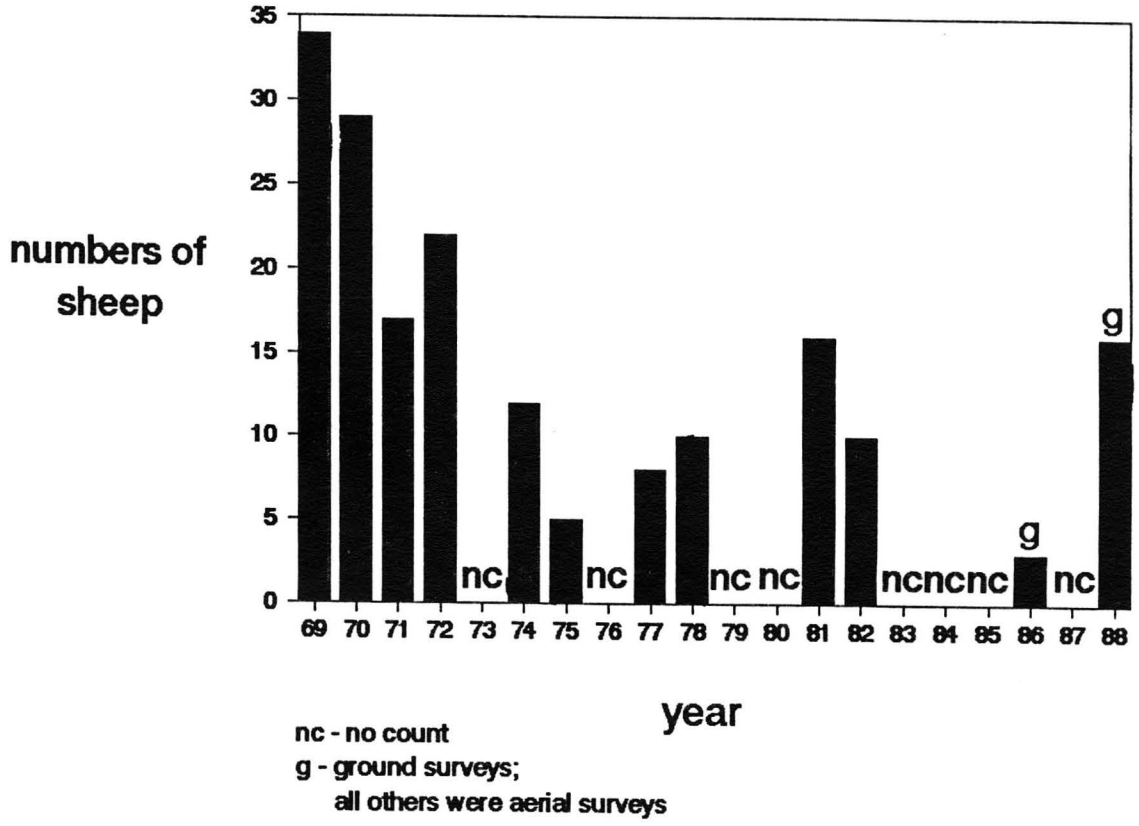
26
27

Figure 7. Colorado Division of Wildlife surveys from 1969-88, depicting the downward population trend of the Battlement Mesa bighorn sheep, Colorado.


numbers of sheep
35
30
25
20
15
10
5
0
nc
nc
nc nc
ncncnc
g
nc
g
69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
year
nc - no count
g - ground surveys;
all others were aerial surveys

he never saw any deer. Raymond Lyons (pers. comm. (5)) stated that from the late 1920s to the early 1930s, local residents estimated that 200-250 bighorn sheep traveled between the Sunnyside cliffs (lower Battlement Mesa) and the Mamm peaks (upper Battlement Mesa).

The Wallace Creek C&H allotment folder includes an area description, written in 1946. The description mentioned the Battlement sheep stating, "A band of mountain sheep use the area around Horse Mountain, the head of Bear Gulch and into Alkali Creek, as well as dropping over onto the south side of the drainages into Hawxhurst Creek, etc. on the GMNF." (USFS 1914-1990 (6)). Groups of sheep were reported in the Mamm Peaks area between 1940-50 by Raymond Lyons of Collbran, Colorado (CDOW 1976 (7)).

In 1950, 14 sheep were counted on Mamm Peak by CDOW aerial survey (Bear and Jones 1973 (8)). Ray Hittle (pers. comm. (9)) observed 4 sheep in the basalt rubble in the Mamm Peaks area 'a long time ago' (circa 1950), but hadn't seen sheep near his Hawxhurst Ranch. Raymond Lyons (pers. comm. (10)) recalled spotting approximately 45 sheep near McCurry Reservoir (24.2 km NE of present range) on upper Battlement Mesa in the 1950s. A landowner on the north side of Battlement Mesa (Rifle/Silt area) told Pat Ottman (pers. comm. (11)) that 35-40 bighorn sheep were observed in 1950 at McCurry Reservoir. In June of 1953, H. Hughes, then District Ranger on the Collbran District of the GMNF, reported seeing "5 head of mountain sheep on Kimball Creek, near the Wallace Creek divide" (USFS 1953 (12)). Bill Wallace (pers. comm. (13)) owns an outfitter guide service with base camps at Bear Gulch, McCurry Reservoir and at the head of Kimball Creek. He has seen bighorns only as far east as Dry Fork of Kimball Creek and never on upper Battlement Mesa. Wallace estimated the herd between 50-75 sheep from 1950-60.

The last recorded sighting of sheep on Mamm Peak was in 1961 when 9 were counted during a CDOW aerial survey (14). Several ewes were observed in the North Fork of Wallace Creek (5.6 km NE of present range) between 1961-66 by Ruedy Steele while working for the USFS (CDOW 1976 (15)). El McCurry (pers. comm. (16)) recalled seeing

sheep on the Smalley Gulch slides (2.4 km E of present range) during summers until the early 1960s. A sheep was reported in the Nuckolls Creek slides (25.8 km NE of present range) in 1966 by Paul Pittman of Silt, Colorado (CDOW 1976 (17)). Bob Black stated that he and Harold Lanning, former Wildlife Conservation Officer (CDOW), saw sheep on the sandstone cliffs of Plateau Valley at the southern edge of the Sunnyside Plateau (16.1 km SW of present range) until the 1970s (18).

Ted Walker (pers. comm. (19)) recalled spotting 30 bighorns in lower Anderson Gulch during the summer of 1970. Pat Ottman reported seeing sheep on south-facing slopes between Little Baldy Mountain and Kimball Creek during the early 1970s (16.0 km E of present range) (20). He believed there was not as much timber or brush in this area, (considered to be an historic migration route and summer range) during the early 1970s. Malcolm Jolley of Glenwood Springs, Colorado, observed 2 large rams in Smith Gulch (3.2 km NW of present range (21)) during 1972 and 1 sheep crossing I-70 near South Canyon (64.4 km NE of present range) in 1973 (CDOW 1976). Walker saw 8 sheep during the winter of 1978-79 in a sandstone draw (the mouth of Jerry Gulch) along highway 65 (the same location where Black and Lanning reportedly observed sheep until the 1970s) (22).

In summer of 1981, Ottman reportedly saw 7 sheep (none were lambs) on the west rim of Brush Creek Basin (9.6 km E of present range) (23). Nate Dutton (pers. comm. (24)) recalled spotting 7 sheep, including ewes and lambs, below the tank at Mud Springs (included in present range but no sheep observed in area) in 1981 or 1982. Dutton also recalled spotting a full curl ram along the Colorado River near Una 'a few years ago', approximately 8 km N of the present sheep range (25). The District Wildlife Manager at the time reportedly told Dutton the ram was probably a wanderer from the Gunnison herd since he appeared larger than most Battlement rams. Art Linn (pers. comm. (26)) recalled seeing bighorn sheep 'over the years' from Anderson Gulch to Castle Peak and on the foothills of the Sunnyside Plateau. Linn mentioned a 'large bighorn ram' was spotted by local residents, on the

sandstone cliffs to the north of Molina (approximately 3.2 km S of the Sunnyside Plateau). A follow up on this report revealed a mature mouflon ram inhabiting the area and feeding from a nearby haystack (see section on exotic ungulates).

Fred Wallace (pers. comm. (27)) worked at outfitter and guide camps on Battlement Mesa since approximately 1966. He never saw sheep on upper Battlement Mesa although he recalled spotting rams on the present range. Wallace spotted 2 rams (Class II and III) while hunting on a ridge west of Anderson Gulch in October 1989, and mentioned that he had never seen sheep in the oakbrush.

IV. Habitat use

A. Slope

I recorded slope categories for 73 observations of uncollared sheep and 19 observations of groups that included the radio-collared ewe (Table 5). The potentially biased observations of uncollared sheep emphasized slopes > 200% while the observations of the radio-collared ewe were more often on slopes 51-100%. Use of slope categories was not significantly different between sheep with the collared ewe and uncollared sheep.

Table 5. Steepness of terrain used by bighorn sheep in 73 observations of uncollared sheep and in 19 observations of a radio-collared ewe, Battlement Mesa, Colorado, 1989-1990.

Slope Category (%)	Observations (% of total)[a]	
	Uncollared (73)	Radio-collared ewe (19)
0-50	4	5
51-100	23	37
101-150	21	32
151-200	4	5
>200	48	21

[a]Chi-square=4.59; p=>0.05

B. Distance from escape terrain

When uncollared sheep were not observed on slopes of >200%, distance to escape terrain averaged 6.1 m (range: 0.9-45.8 m, N=19; 95% confidence interval (95% CI)=1.6-10.6 m; Table 2).

When collared sheep were not observed on slopes >200%, distance to escape terrain averaged 35.6 m (range: 2.4-183.0 m, N=13; 95% CI=2.2-68.0 m; Table 3).

C. Vegetation types

Sheep utilized 3 of the 6 habitat types available to them on lower Battlement Mesa in 73 observations of uncollared sheep and 21 observations of the radio-collared ewe and her group (Tables 6, 7). Both groups utilized shale slopes with scattered grasses, forbs and shrubs most of the time. We never observed sheep in the meadows that were separated from shale slopes by stands of mountain shrubs or aspen on the north facing slopes. Both groups were observed in open Douglas fir stands (<20% canopy cover) located on south facing slopes (1 occasion each). For both observations the Douglas fir stands were adjacent to a shale slope and the sheep never ventured further than 30.5 m from escape terrain while in the Douglas fir type. Pinyon/juniper habitat was utilized by uncollared sheep during winter and spring months when sheep were at lower elevations where this habitat was more available. We recorded use of mountain shrubs only once for the radio-collared sheep and her group but use of this habitat may have been under-represented due to sampling bias.

Table 6. Use of habitat types by uncollared bighorn sheep in 73 observations on Battlement Mesa, Colorado, 1989-1990.

Habitat Type	Hectares Available		Bighorn Observations[9]
	Hectares	(%)	(% of 73)
Pinyon/juniper	2320	38	12.3
Mountain shrub	1366	22	0.0
Douglas fir	1335	22	1.4
Shale slope	713	12	86.3
Aspen	303	5	0.0
Meadow	49	1	0.0

[9] X^2=381.1, p=<0.001; based on observed numbers of observations in each habitat type vs. expected numbers calculated from habitat composition.

Table 7. Use of habitat types by collared bighorn ewe in 21 observations on Battlement Mesa, Colorado, 1989-1990.

Habitat Type	Hectares Available		Bighorn Observations[10]
	Hectares	(%)	(% of 21)
Pinyon/Juniper	2320	38	0.0
Mountain shrub	1366	22	14.3
Douglas fir	1335	22	4.8
Shale slope	713	12	81.0
Aspen	303	5	0.0
Meadow	49	1	0.0

[10] X^2=96.6, p=<0.001; based on observed numbers of observations in each habitat type vs. expected numbers calculated from habitat composition.

V. Rutting and lambing areas and periods

We first observed Class II and III rams with ewes on 11/16/89 in units 1 and 2 (Fig. 3). At that time, rams were displaying rutting behavior, following but not yet mounting or guarding ewe 421-1. On 1/10/90, I observed rams in a mixed group in unit 7, with a Class III ram mounting and guarding a ewe.

We began collecting data for summer 1989 on 7/13. Although we did not observe sheep during the lambing season, the shale slopes of unit 2 (Fig. 3) were the only areas where young lambs were observed after 7/13. Data collection in 1990 began on 6/5. We observed 1 lamb on that date and 3 more lambs appeared over the next 4 weeks. As in 1989, unit 2 was the only area where lambs were observed during 1990. I estimated dates of birth at 4/15 (2 lambs) and 6/15 (2 lambs) during 1989 and 5/25, 6/1, 6/20 and 6/25 during 1990.

VI. Population status

A. Lamb production

We observed 4 lambs in 1989 and in 1990. Based on the known minimum numbers of ewes (below) lamb:ewe retios were 57:100 and 50:100, respectively (Table 8).

Table 8. Sex and age ratios for the known-minimum population of bighorn sheep on Battlement Mesa, Colorado, 1989-1990.

Ratio	1989	1990
lamb:ewe	57:100	50:100
yearling:ewe	43:100	38:100
lamb:older animal*	40:100	36:100
ram:ewe	129:100	135:100

*includes yearlings and ewes

B. Population size

The known minimum population of sheep during summer 1989 was 23 individuals including 4 1989 lambs, 3 yearlings (born in 1988), 7 adult ewes and 9 adult rams. The greatest number of sheep observed at 1 time during 1990 was 18. Less search time and a restricted search area during 1990 leaves no doubt that sheep were missed.

One lamb from 1989 was not observed after 8/89 and only 3 yearlings were observed during 1990. If I assume no loss in all age classes between 12/89 and 6/90, except for the 1 1989 lamb, the minimum population size increased to 26 individuals in 1990 (23 from 1989, less 1 1989 lamb, plus 4 1990 lambs; Fig. 8). Two class I rams and 1 ewe were added to the adult herd from the 1988 lamb crop (now 2+ years old). I will therefore increase the known minimum population size for 1990 from 18 sheep to a more likely 26 individuals (Fig. 8).

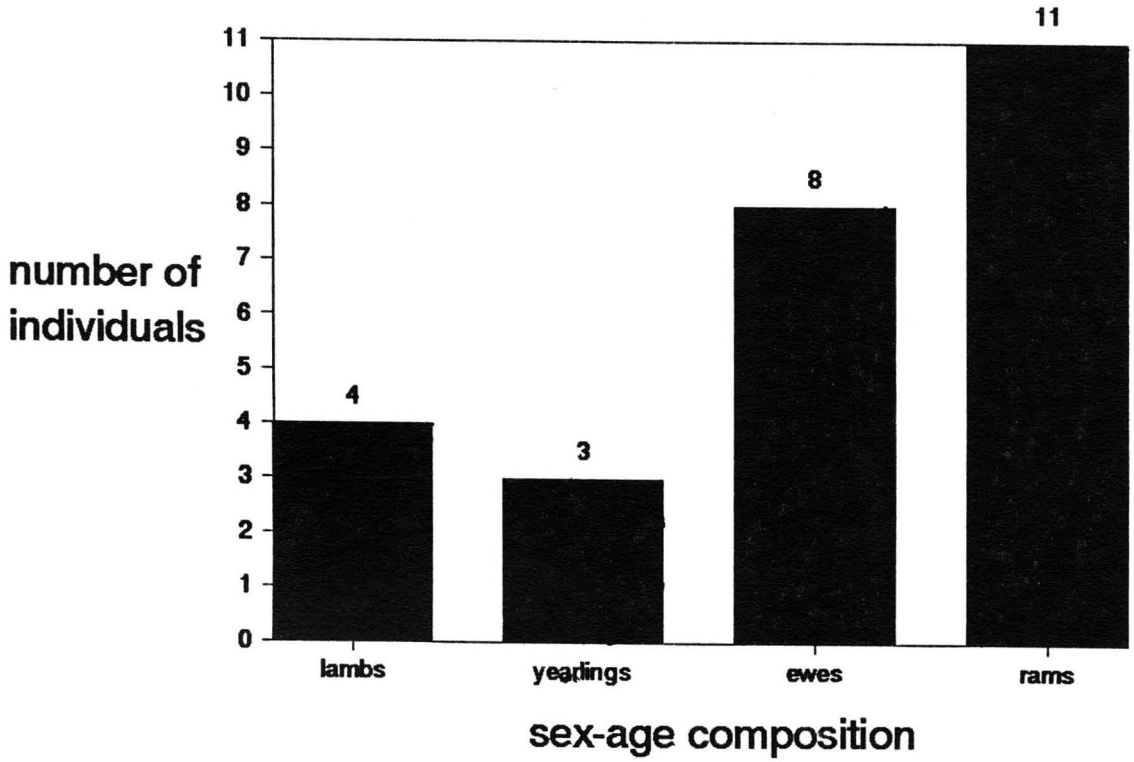
Mean ram group size for 23 observations was 1.9 (range: 1-4, N=25, 95% CI=1.5-2.3). Mean ewe-juvenile group size (including mixed-sex groups) was 5.1 (range: 1-13, N=76, 95% CI=4.3-5.9). I discounted 4 observations of ewe-juvenile groups because of imprecise counts and because the radio collared ewe remained alone for 16 days after capture.

VII. Potential limiting factors

A. Habitat

Bighorn sheep did not use habitats in proportion to their availabilities on Battlement Mesa (Tables 6, 7). The shale slope habitat contributed most to both high Chi-square values. This suggests bighorns on Battlement Mesa are selecting for more secure habitat near escape terrain and avoiding less secure, but more productive, foraging

Figure 8. Known minimum number of sheep on Battlement Mesa, Colorado, during summer, 1990.


number of individuals
11
10
9
8
7
6
5
4
3
2
1
0
4
3
8
11
lambs
yearlings
ewes
rams
sex-age composition

areas. Preference/avoidance indices for both uncollared and radio-collared sheep for each habitat support these results (Table 9).

B. Predation

I sighted mountain lions twice and commonly found tracks in the study area. We found fresh lion tracks near sheep trails and groups of sheep. Jim Dekam (pers. comm.) reported 2 rams killed by lions in Alkali Creek during recent years. Dekam stated that the carcasses were found partially covered by scratched up soil, typical of a lion kill.

We often observed golden eagles perched on ridges or soaring, but found no active golden eagle nests during 1989 or 1990. We did find 2 abandoned nests, reported in 1976, in the shale cliffs (McGowan and VanSant 1976). Eagles were not observed threatening sheep nor were sheep observed to be alarmed by eagles. We observed sheep within 45 m of perched eagles without disturbance or acknowledgement by the sheep. I observed 1 eagle 180 m from a ewe-juvenile group, first perched then soaring, with no reaction from the sheep. I spotted bald eagles daily during January, February and early March, 1989, flying over lower Battlement Mesa but never perched on ridges. Bald eagles frequented the Colorado River and Plateau Creek drainages during the winter and presumably flew over Battlement Mesa. McGowan and VanSant (1976) reported that sheep 'displayed a fear' of golden eagles on Battlement Mesa. They claimed on 1 occasion, 13 sheep (9 ewes and 4 lambs) scattered as a golden eagle passed directly overhead. The sheep reportedly scrambled from a ridgetop to under an overhanging ledge for protection.

Table 9. Preference indices for 6 habitat types available to bighorn sheep on Battlement Mesa, Colorado, 1989-1990.

Habitat type	Preference Index	
	Uncollared Sheep (N=73)	Radio-collared ewe (N=21)
Pinyon/juniper	0.3	0.0
Mountain shrub	0.0	0.6
Douglas fir	0.1	0.2
Shale slope/cliff	7.2	6.8
Aspen	0.0	0.0
Meadow	0.0	0.0

We observed coyotes twice, heard yipping frequently and encountered sign throughout the study area during all seasons. We observed bear sign in areas above 2100 m and sighted a sow and 3 cubs during 6/90, at the Anderson Gulch spring in unit 2 (Fig. 3) where ewe-juvenile bighorn groups often obtained water.

I found 3 lamb skulls in advanced stages of decay in unit 2, 1 in a small meadow between Anderson and Durant Gulches and 2 in the bottom of Anderson Gulch (Fig. 3). Causes of death could not be determined. One lamb skull was found in an advanced stage of decay in unit 5 with large holes resembling canine punctures on the parietal bone of the cranium, indicating possible mountain lion predation. I also found 1 fawn skull in unit 2 with small canine punctures on the parietal bone, indicating possible bobcat predation.

C. Hunting and poaching

There has been no legal hunting of the herd since 1982. Five of the 13 residents interviewed from 1/1/89-1/10/90 knew of incidents of poaching on the sheep. Bob Black (pers. comm.) reported that deer hunters along Sunnyside Road poach sheep when given an opportunity. Bill Wallace (pers. comm.) also reported that extensive poaching occurs by deer hunters on the Sunnyside Plateau. Dion Luke (pers. comm.) reported that "sheep poachers passed through his camp on their way to sheep cliffs" in the late 1970s on Battlement Mesa. Raymond Lyons (pers. comm.) stated that he witnessed a man poach a bighorn ram near the Battlement Reservoirs in the 1950s. Nate Dutton indicated extensive poaching on sheep occurred in the past, especially when sheep frequented upper Battlement Mesa.

D. Conflicts with elk, deer and livestock

On Battlement Mesa, elk, mule deer and bighorn ranges overlap throughout the year. Most overlap between elk, mule deer and bighorn occurred in winter when elk and deer moved into the pinyon, sagebrush and oakbrush communities in the western portion of the range. There was no range overlap between bighorn sheep and cattle during 1989-90.

E. Diseases and parasites

No parasites were recovered from nasal swabs, ear swabs and surface skin scrapings from ewe 421-1. Of 9 bighorn sheep fecal samples analyzed for larvae of *Protostrongylus sp.*, 3 had low incidences of lungworm larvae, ranging 0.4-8.6/g (Table 10). The remaining 6 samples were negative. No die-offs of Battlement sheep from lungworm/pneumonia have been recorded. Sheep did not exhibit clinical signs of pneumonia (nasal discharge and coughing). Contact between bighorn and domestic sheep probably occurred in the early 1900s when reportedly up to 40,000 domestic sheep grazed in the area. Chances for disease transmission were presumably high, but no records of die-offs were discovered. Reports from local residents (Bob Black, Nate Dutton, pers. comm.) claimed bighorn sheep 'graveyards' occur in units 1, 2, 7 and 13 (Fig. 3). The brushy areas described reportedly contain numerous piles of sheep bones, concentrated in a small area. Searches for these 'graveyards' during 1989 and 1990 were unsuccessful. Currently, domestic sheep graze on the north side of the present range in Alkali Creek, on a ranch owned by Malcolm Jolly. Jolly claimed bighorn rams successfully bred with his domestic ewes and produced hybrid lambs in the past.

Table 10. Incidence of lungworm larvae in bighorn sheep fecal samples collected on Battlement Mesa, Colorado.

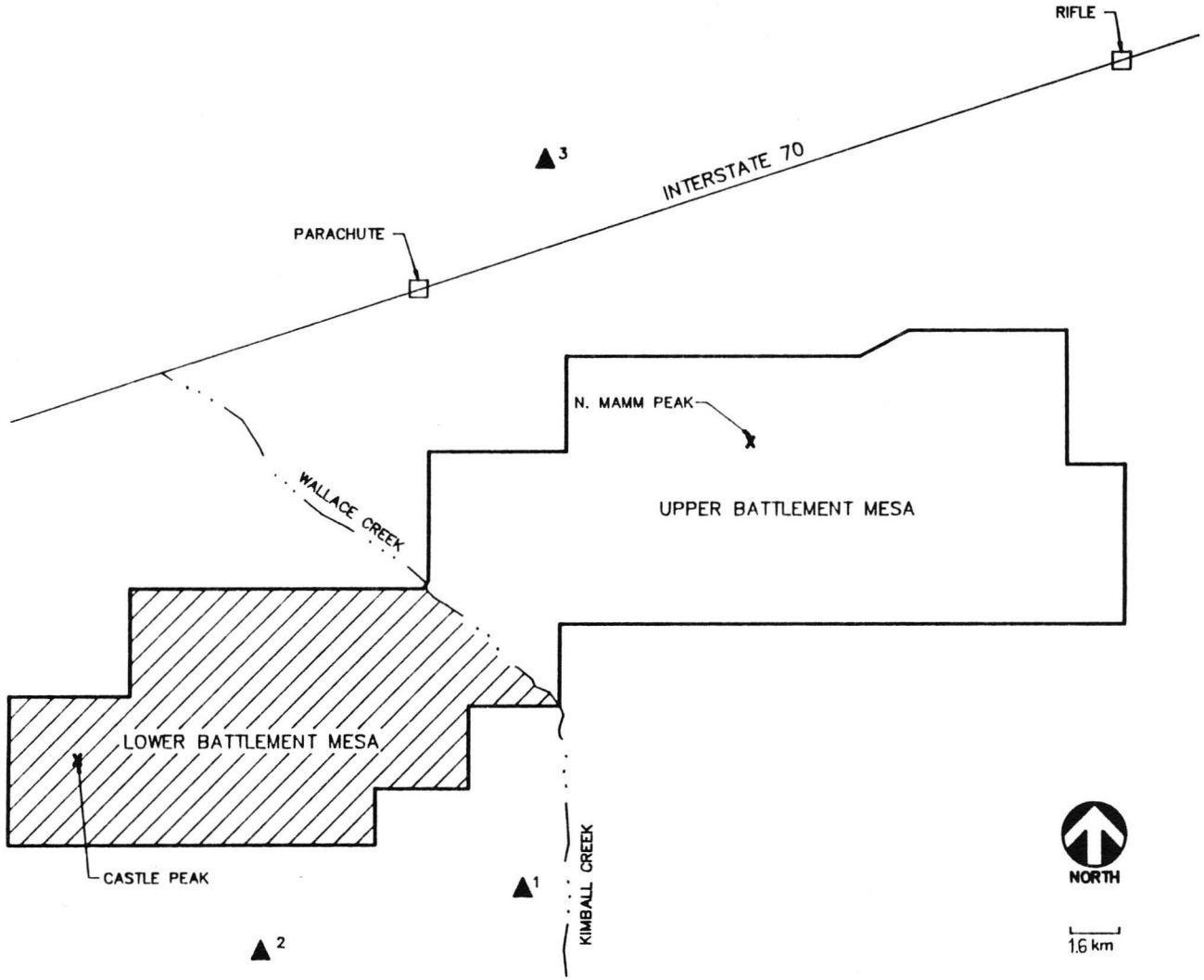
Location	Date	Larvae/g
Atwell Ridge (bed ground)	2/22/89	0
Atwell Ridge	3/15/89	0
Atwell Ridge (bed ground)	3/23/89	0
Atwell Gulch	3/23/89	0
Atwell Gulch	3/23/89	0
Atwell Ridge	3/23/89	1.2
Shire Gulch	3/30/89	0.4
Little Horsethief Gulch	4/7/89	0
Shire-Horsethief Ridge	4/7/89	8.6

F. Exotic, free-ranging ungulates

Exotic ungulate species occurred in 3 areas near the bighorn range (Fig. 9). During March 1989, 3 mouflon were observed in theKimball Creek drainage, 8 km from the sheep range (Fig. 9, Label 1). In December 1989, a mouflon ram was sighted on the sandstone cliffs in Plateau Valley and later detained near a haystack 8 km west of Collbran (Fig. 9, Label 2). I discussed both of these sightings with CDOW personnel who were aware of the reports and promptly eliminated the unclaimed exotic animals. On Kimball Creek, just east of currently used bighorn range, a private landowner was allowed to construct a game fence and hold exotic ungulates for hunting purposes.

Perhaps the greatest threat from exotic ungulates exists in the Roan Cliffs north of the Colorado River (19.3 km N of the present bighorn range) (Fig. 9, Label 3). In 1985, 20 exotic ungulates including aoudads, Corsican sheep and 'Texas dalls', were released in this vicinity by a local game rancher (Albert Trujillo, pers. comm., John Broderick, pers. comm.). It is not clear if this release was intentional. The herd became well established over the next 5 years and presently ranges from Parachute Creek east to Anvil Points, with sightings as far east as Rifle. In 1989 the CDOW estimated 25-30 individuals, but helicopter counts during 1/90 revealed about 100 of the exotic animals (John Broderick, CDOW, pers. comm.). Broderick stated that 76 animals had been eliminated since efforts began in 1990, thus a herd estimate of 100 was probably low. CDOW personnel are currently attempting to eliminate this herd of exotic ungulates. The Roan Cliffs are historic bighorn range where the exotic animals are filling a niche that is unclaimed since the extirpation of native sheep.

Figure 9. Locations (▲) of exotic ungulates observed or reported, 1989-90, near the Battlement Mesa bighorn sheep herd, Colorado.


RIFLE
INTERSTATE 70
3
PARACHUTE
N. MAMM PEAK
WALLACE CREEK
UPPER BATTLEMENT MESA
LOWER BATTLEMENT MESA
CASTLE PEAK
KIMBALL CREEK
1
2
NORTH
1.6 km

G. Limited water supply

We found and mapped 12 water sources on lower Battlement Mesa (Fig. 10). A water source was considered a spring if water surfaced and was free flowing; a seep dampened the area and sometimes formed a pool but was not free flowing. We found 7 springs and 5 seeps in units 2 (4), 12 (3), 13 (1) and 15 (4). One guzzler and 3 redwood tanks were installed on or near the sheep range in the early 1980s. The guzzler, installed in 1985, was located on a sage flat below Housetop Mountain. The guzzler was full of water when inspected during September 1990, after intermittent rains had begun in mid-August. It is not known if the guzzler offers a water supply during the dry summer months, as 2 attempts to inspect it during 1989 failed due to a locked gate encountered on private land.

The redwood tank installed at the head of Anderson Gulch was apparently destroyed from heavy precipitation and spring runoff during the year following installation. We found remains of the tank and pipe in 1989. A second redwood tank, installed in Little Alkali Creek, was examined by WRNF personnel in August 1990. The tank was not holding water and reportedly never had. A third redwood tank, located in Horsethief Creek, was holding water when we inspected it in September 1990. Slumping of the slope above the spring box apparently damaged the perforated pipe feeding into the spring box, as the box was empty and the tank was no longer filling. This spring development requires maintenance if expected to fill the redwood tank in the future.

We observed no sheep or sheep sign at any of the water development sites except for the failed Anderson Gulch spring site. Other wildlife sign was encountered, including elk, deer, coyote, snowshoe hare and passerine birds. Three of the 4 water developments were installed outside of the sheep range as defined by this study. We observed sheep and sheep sign at only 1 of the 7 springs. The

Figure 10. Permanent water sources located on lower Battlement Mesa, Colorado, 1989-90.


WALLACE CREEK
HORSE MT.
CASTLE PEAK
KIMBALL CREEK
ANDERSON GULCH
DURANT GULCH
LEGEND
SPRING
SEEP
GUZZLER
REDWOOD TANK (OR REMAINS)
NORTH
1.6 km

Anderson Gulch spring, located adjacent to escape terrain on lambing grounds, was used frequently. All other springs occurred in aspen, oakbrush or meadow habitats, usually on the north side of the range and no sign was observed. We observed sheep or sheep sign at 3 of 5 seeps, located on shale cliffs. Sheep would lick the dampened shale for 2-16 minutes to obtain water.

DISCUSSION

I. Historic perspective on the herd

The historic record of the Battlement Mesa bighorn sheep herd contains many gaps and conflicting reports of herd size. However, this most complete review indicates the herd once was larger and occupied a larger range. The herd migrated longer distances to summer range and wintered at lower elevations adjacent to the present winter range. Local residents reported changing vegetation on Battlement Mesa, indicating that more oakbrush and heavy timber are present in the area today than in past decades.

Wallace Creek and Dry Kimball Creek, north and east, respectively, of present sheep range, are proposed as historic migration routes. These drainages are now dominated by dense shrub stands, a habitat avoided by Battlement Mesa sheep. Beyond these migration routes, in the Mamm Peaks area, historic sheep summer range still has areas with escape terrain adjacent to permanent water sources and productive foraging areas with little visual obstruction. Abandonment of this 'ideal' summer range was verified during 1989-90. Range abandonment is correlated with habitat change including expansion of dense shrub vegetation on Battlement Mesa, presumably due to historic overgrazing by livestock and curtailment of wildfire for over 60 years. Other factors that may have contributed to range abandonment, decline of sheep numbers and the general decline of herd quality on this isolated range are considered in sections V and VI of this discussion.

II. Present condition of the Battlement Mesa bighorn sheep herd

The ram:ewe ratio exceeding 1.0 on Battlement Mesa in 1989 and 1990 is not unusual. High ram:ewe ratios have been reported on an island in Montana (Woodgerd 1964), in National Parks (Buechner 1960, Whitfield 1983) and in desert bighorn in Arizona (Russo 1956).

Lamb:ewe ratios on Battlement Mesa (0.57 and 0.50 in 1989 and 1990, respectively) were not unusual for bighorn sheep herds. Lamb:ewe ratios vary greatly among and within herds (Goodson 1978, Turner and Hansen 1985). This variation has been attributed to population density, forage quality (Geist 1971) and possibly to degree of inbreeding (Skiba and Schmidt 1982). Goodson (1978) concluded that yearling:ewe ratios, but not lamb:ewe ratios, have been correlated with herd trends. The yearling:ewe ratios at Battlement Mesa (0.41 and 0.38 in 1989 and 1990, respectively) are similar to those reported for "slowly increasing" herds by Goodson (1978). However, given the small number of sheep at Battlement Mesa, herd increase cannot be predicted from the recent yearling:ewe ratios. Loss of a single yearling (or ewe) would alter the ratio greatly.

The Battlement sheep exhibited 2 characteristics that Geist (1971) considered common in low quality bighorn herds with static or declining population size. These characteristics are 1) small body size, and 2) small, tightly curled horns. The 36-kg ewe captured on Battlement Mesa appeared similar in size to her associates. In contrast, Hansen (1985) estimated the average desert bighorn ewe at 47 kg. Risenhoover and Bailey (1988) reported an average weight of 66.4 kg for ewes at Waterton Canyon, Colorado and Blood et al. (1970) estimated the average Rocky Mountain bighorn ewe at 72 kg. Rams harvested from the Battlement herd also exhibited small body size and small horns (John Ellenberger, pers. comm.; Bob Black, pers. comm.). Geist's "dispersal theory" (1987) links herd quality to the duration of availability of green forage, which is enhanced when animals migrate altitudinally.

On Battlement Mesa, loss of migration and consequent loss of summer ranges, has reduced the duration of access to green forage for the bighorn sheep. On preferred habitats on Battlement Mesa (shale slopes), green forage is scarce, sparsely distributed, and available only briefly each year.

III. Seasonal Ranges of the Battlement Bighorns

Battlement sheep exhibited 2 seasonal home ranges, migrating 3-9 km between summer and winter ranges (Fig. 4). Geist (1971) reported rams may use up to 6 or 7 seasonal home ranges and most ewes up to 4; while a minority of herds, similar to the Battlement Mesa herd, use only 2 ranges. Options for additional seasonal ranges on Battlement were limited due to the small size of the present range and the bighorns' reluctance to travel through the surrounding shrub vegetation.

The Battlement sheep abandoned historic summer range approximately 30 years ago and today occupy approximately 40 km^2, about 42% of the historic yearround 96 km^2 range (Fig. 1). Historic sheep range on upper Battlement Mesa is characterized by rugged terrain, cliffs and rockslides adjacent to open parks with interspersed stands of conifers and aspen. Areas between present and historic bighorn range (historic migration routes) are characterized by dense mountain shrub stands, similar to the habitat that sheep avoided adjacent to the shale cliffs on the present range. Sheep appear isolated on the present range because of dense mountain shrub stands separating present range and historic summer range.

The present summer and winter ranges have similar vegetation. No water sources occur on winter range during summer, possibly forcing movement to summer range after snow has melted in spring.

Abandonment of 'ideal' sheep summer habitat by the Battlement herd has many implications. Forage options on present summer range are limited to true mountainmahogany,

bitterbrush *(Purshia tridentata)*, Indian ricegrass *(Oryzopsis hymenoides)* and scarce forbs and other grasses near permanent water sources. A few small meadows occur on summer range but are separated from sheep escape terrain by barriers of oakbrush and serviceberry. The Battlement sheep were observed mostly on the south-facing cliffs and did not travel into thick brush. The sheep are not utilizing the productive available forage but are opting for the security of the steep shale cliffs. Historic summer range was at a higher elevation where shrub types are absent and meadows are dominated by Idaho and Thurber fescue, Kentucky bluegrass *(Poa pratensis)*, other grasses and several species of forbs. This meadow habitat is more similar to the climax grass community described as bighorn summer habitat by Geist (1971) for other bighorn herds. Battlement sheep must have been primarily grazers during the summer on historic summer range. Today their summer diet is dominated by shrubs, similar to the Waterton Canyon herd (Rominger et al. 1988). The loss of grasses from the diet may have caused natural selection to favor smaller-bodied animals; or the current small size of Battlement sheep may be a phenotypic response to limited forage resources. Productivity of the herd may also be limited by quantity and quality of forage.

IV. Battlement Mesa bighorn sheep-*Ovis canadensis canadensis or O. c. nelsoni?*

The onset and duration of lambing on Battlement Mesa is consistent with a hypothesis that these sheep exhibit characteristics intermediate between desert and Rocky Mountain bighorns. The Battlement herd, located at 39 degrees N latitude, lambed during 5/15-7/15 in 1989 and 1990. The onset and duration are most similar to Moser's recording of the lambing period (1962) at 38 degrees N and Honess and Frost's (1942) recording at 43 degrees N for

desert and Rocky Mountain herds, respectively. The Battlement sheep are located just north of 38 degrees N, suggested by Bunnel (1982) as a dividing line between Rocky Mountain and desert bighorns.

Other characteristics of the Battlement Mesa bighorns have led agency personnel and biologists to be indecisive in designating a subspecies. As noted above, these sheep are considerably smaller than both desert and Rocky Mountain sheep. Small body size may be a genotypic or may be a habitat induced adaptation to limited forage and limited summer water supply. Their present range is semi-arid with little permanent water during summer, similar to ranges of desert bighorns. The possibility has been discussed that the Battlement herd is an extension of the desert sheep that once occupied the Green River Basin in Utah. On the other hand, their historic summer range typifies Rocky Mountain bighorn summer habitat. Tight horn curls, an indication of poor herd quality, are more characteristic of Rocky Mountain bighorns than are widely flared horns characteristic of desert bighorns.

I don't believe we should be overly concerned with designating the subspecies of the Battlement herd at this time. Verification of subspecies will require electrophoretic analysis of tissue samples. It may be important if the herd is to be augmented by a transplant, in which case the maintenance of the genetic integrity or uniqueness of the herd will be desirable. At least, sheep should be chosen with a similar body size and from a similar semi-arid habitat if subspecies is not designated. However, I suggest resources be used to alleviate factors currently limiting to the herd first.

V. Habitat as the limiting factor to the Battlement Mesa bighorn sheep

On Battlement Mesa, the preponderant use of shale slopes and abandonment of historic summer range and migration routes indicate current habitat conditions limit this population. Bighorn sheep are selecting for secure habitats (shale slopes) instead of productive foraging areas. Sheep must travel a considerable distance for water during summer (0.8-2.4 km), presumably an energy expensive strategy. Abandonment of historic summer range restricts the amount of foraging areas near escape terrain and the length of time that green forage is available to sheep. Geist (1987) concluded that ungulate herd quality is determined largely by the duration of abundant green forage.

In contrast to lower Battlement Mesa, bighorn sheep evolved in open, recently glaciated, mountainous habitats where unrestricted visibility was important for predator detection and intra-sheep communication (Geist 1971, Risenhoover and Bailey 1985). Studies of bighorn habitat preferences have concluded sheep prefer more open habitat types and avoid those habitats with dense, tall vegetation (Risenhoover and Bailey 1985, Tilton and Willard 1982). Risenhoover and Bailey (1985) also pointed out that foraging efficiency is enhanced by high visibility, abundant forage, and large group size. Although visibility on shale slopes on Battlement Mesa was high, forage productivity was low and group size was relatively small.

The Battlement Mesa bighorn range has not had a major fire for over 60 years. In 1987, a large wildfire burned historic sheep range on the north side of Battlement Mesa near Parachute, but did not reduce the dense shrubs. Core samples collected with an increment bore during 11/90 on lower Battlement Mesa revealed 60 year-old oakbrush and up to 175 year-old Douglas fir trees. Fire suppression since approximately 1930 and excessive grazing during the early 1900s have encouraged dense shrub growth in habitats that were more open

historically. All of the escape terrain available on lower Battlement Mesa is bordered by mountain shrub stands at higher elevations and pinyon/juniper at lower elevations. The only meadows available on the current range exist on north aspects, approximately 200 m from the head of Anderson Gulch. Elsewhere in Colorado, Wakelyn (1987) documented habitat changes on several bighorn sheep ranges and concluded that in the absence of fire or habitat management, the succession of vegetation has been a major cause of habitat loss.

Barry Johnston, Region 2 ecologist, USFS, spent 5 days on Battlement Mesa with our USFS/CDOW habitat typing crew in 1986. He concluded that the climax community in many of the shrub-invaded openings was fescue meadow. Thurber fescue and Idaho fescue grow in protection of dense shrubs, while Kentucky bluegrass grows in unsheltered areas. Johnston suggested this condition, along with snowberry (*Symphoricarpos oreophilus*) and serviceberry encroaching into the meadows, indicated that extensive grazing in open areas had altered the habitat enough to change the vegetation type.

VI. Other factors contributing to overall poor condition and small herd size of the Battlement Mesa bighorn sheep

Other than habitat deficiencies, factors that may limit the Battlement Mesa bighorn sheep could not be conclusively discounted. Hunting and poaching, conflicts with livestock, and diseases and parasites may have negatively affected the herd in the past. Predation, conflicts with elk and mule deer, human disturbance and a limited summer water supply may presently affect herd size, vigor or distribution, but habitat is the primary limiting factor today.

A. Predation

Tracks found during this study confirm the presence of mountain lions on the current sheep range. Habitat types on the sheep range are those cited by Russell (1978) as preferred mountain lion habitat in the Rocky Mountains. These habitats include areas of pinyon pine, juniper, mountain mahogany, and other brushlands, especially those supporting high populations of mule deer (Russel 1978). Mule deer are probably the staple in the diet of mountain lions on Battlement Mesa, however bighorn may be taken incidentally as reported for populations of desert bighorn (Kelly 1985). Due to this preference for habitats occurring on Battlement Mesa, mountain lions pose the largest predation threat to the sheep.

Golden eagles may prey on these small sheep, especially the lambs. Eagles were observed throughout the year, however Kelly (1985) reported that because the period when bighorn are vulnerable to eagle predation is short, this predation is believed to have little effect on bighorn population numbers.

Coyote predation on the Battlement sheep is presumably rare and opportunistic, although it may increase during winter months when sheep inhabit gentler terrain. Coyotes are known to attack bighorns, especially where escape terrain is not available (Kelly 1985). I dismissed bear, bobcat and bald eagles as important predators on the sheep due to timing of range occupancy, inaccessibility of sheep escape terrain, and the habitats preferred by these species.

Predation may be a symptom of habitat deficiency. Animals may be exposed to predation if the habitat provides poor escape cover, poor visibility for predator detection, or a lack of escape cover near other habitat resources (Bailey 1984). On the Battlement Mesa bighorn range, escape terrain is separated from forage by dense shrub stands. The sheep would sacrifice security for optimal forage if they traveled through the shrubs more often, potentially exposing themselves to increased predation. While predators may take few sheep

on Battlement Mesa, the loss of 1 or 2 lambs (or adults) per year from this small herd could negatively impact herd numbers.

B. Hunting and poaching pressure

Legal harvest of 17 rams between 1960-82 probably did not substantially affect the population size. Most people interviewed in this study believed poaching occurred in the Mamm Peaks area historically and now occurs when sheep occupy western portions of the range during deer and elk rifle seasons, from early October through mid-November. Due to the remoteness of Battlement Mesa, the herd may attract sheep poachers, who may take advantage of the limited human use of the area caused by difficult access. If poaching does occur, the number and sexes of sheep taken from Battlement Mesa are unknown. As with predation, 1 or 2 animals illegally harvested from this small herd could negatively impact both herd size and lamb production.

C. Conflicts with elk, deer and livestock

The possibility of interspecific competition between elk, mule deer and bighorn sheep exists on Battlement Mesa. Interspecific competition implies an overlap of habitat resources in the niches of the two species (Bailey 1984). This type of competition occurs when there is a limited supply of resources, as on Battlement Mesa. If resources are not limited in supply, interspecific competition occurs when the animals seeking a resource harm one another (Sinclair 1977, Bailey 1984). On Battlement Mesa, bighorn are the most restricted of the 3 big game species due to their preference for shale cliffs, and for snow-free or lower-elevation winter ranges, and their avoidance of brush or low-visibility habitats. Any interspecific competition occurring on Battlement Mesa would therefore be most detrimental to the small

sheep herd. When elk moved into an area occupied by sheep, the bighorns left the area and traveled to a different drainage, similar to Green's (1949) observations. On Battlement Mesa, sheep were observed most of the time on sparsely vegetated escape terrain while the elk occupied areas with better forage conditions. This situation was similar to that of bighorns on the Teton Range (Whitfield 1983). I did not quantify interspecific competition on Battlement Mesa, however mortality to the small bighorn herd is far more significant than to the large elk and deer herds.

Although the potential exists, no competition with livestock occurred during the summers of 1989 or 1990. I suggest in the Management Recommendations section that livestock not be grazed on the current bighorn range.

D. Diseases and parasites

Circumstantial evidence of domestic sheep utilizing areas on and adjacent to Battlement Mesa along with accounts of bighorn/domestic hybrid lambs born near the range, indicate that contact between the species occurred in the past. Many declines of bighorn sheep numbers during the past century in western North America have been attributed to disease, with the lungworm-pneumonia (*Protostrongylus spp./Pasteurella spp.*) complex receiving much attention. This respiratory disease complex has been deemed responsible for die-offs of bighorn herds, slow recovery rates observed for reduced herds and as the critical limiting factor for some Rocky Mountain bighorn herds (Forrester 1971, Hibler et al. 1972, Spraker et al. 1986, Onderka et al. 1988). Two major die-offs in Colorado have been recorded in detail (Feuerstein et al. 1980, Bailey 1986). Accounts from local residents of bighorn sheep 'graveyards' on Battlement Mesa indicate that large die-offs may have occurred but were not documented. Fresh fecal samples analyzed during this study contained few to no lungworm larvae and no evidence was found of disease presently affecting the herd.

Exotic, feral ungulates could pose a threat to the native Battlement sheep through disease transmission and competition for limited resources. Exotic animals inhabiting the Book Cliffs to the north of the present bighorn sheep range are a potential threat to the Battlement herd. The Colorado River and Interstate Highway 70 are geographic barriers between the ranges but do not guarantee isolation. Exotic escapees from game ranches in the areas surrounding Battlement Mesa are also a threat to the native herd. The exotic animals in an enclosure on Kimball Creek, approximately 2 km from recent bighorn sightings, should be considered a threat to the native sheep. Nasal contact could easily occur between the native and domestic ungulates, possibly to the detriment of the native herd. This potential hazard to the Battlement sheep should be addressed by CDOW officials.

E. Limited summer water supply

Bear and Jones (1973) concluded that water was a probable limiting factor to Battlement sheep and that the present, semi-arid range could be improved by providing water developments for the herd. Their report failed to consider permanent water sources located on historic summer range. Several lakes, springs and permanent creeks near escape terrain occur in the Mamm Peaks area; therefore lack of water did not cause range abandonment. On the present restricted range, a lack of permanent water sources appears to be limiting the summer distribution of the herd. Douglas and Leslie (1986) reported that the concentrated use of areas around permanent water sources in the River Mountains of Nevada, as occurs on the shale cliffs of Anderson and Durant Gulches on Battlement Mesa, accentuated intraspecific competition and contributed to poor forage quality.

Placement of additional guzzler developments could aid in spreading the sheep across the range and allow more efficient use of habitat resources. These would be especially helpful during the dry months, when lack of water appeared to affect bighorn distribution. Sites with

high visibility near escape terrain should be sought. I chose 2 sites for 2 additional guzzlers in locations and habitats that sheep prefer and reported these sites in the Management Recommendations portion of this thesis.

F. Human disturbance

During 1989 and 1990, human disturbance on Battlement Mesa consisted of, 1) disturbance caused by people on foot or horseback and 2) disturbance from aircraft. People on foot or horseback were limited to my crew and a few hunters during the fall. Unless substantial recreation facilities are erected and maintained in the vicinity, this form of disturbance will continue to be negligible due to the difficult access, arduous terrain and the semi-arid climate. Aircraft activity, mostly from helicopter flights to and from seismographic exploration lines, disturbed the sheep during July and August, 1989. Two lines were located on the present sheep range, the first on the north side of Bull Basin (northern range boundary) and a second on the south side from Kimball Creek southwest to Anderson Gulch (southern range boundary). We often observed sheep startled and running from aircraft (both fixed wing and helicopter). Recommendations to alleviate this disturbance during critical periods and in critical areas are reported in the Management Recommendations section of this thesis.

MANAGEMENT RECOMMENDATIONS

I. Introduction

Habitat was proposed as the most likely factor limiting the Battlement Mesa bighorn sheep herd. The future of the herd probably depends on habitat improvement. Successful habitat improvement will require long term management of several hundred hectares of bighorn habitat presently in mountain shrub communities. The extensive nature of the project will require cooperative funding between the White River National Forest (WRNF), Grand Mesa National Forest (GMNF), Colorado Division of Wildlife (CDOW) and private groups such as the Foundation for North American Wild Sheep (FNAWS), the Rocky Mountain Elk Foundation (RMEF) and the Rocky Mountain Bighorn Society (RMBS).

The portion of the Wallace Creek grazing allotment included in the present sheep range offers limited forage for livestock and little free-flowing water, while the north side of the allotment, away from the bighorn range, is more suitable to livestock grazing. The bighorns are potentially stressed from the semi-arid environment, lack of productive forage in preferred habitats, little permanent water and increased elk and mule deer populations. Livestock are a potential source of stress but their distribution is easily controlled. To avoid future competition or unnecessary stress to the bighorn herd, and to avoid complications in testing the effectiveness of proposed habitat treatments to benefit the bighorns, I suggest that livestock grazing areas be separated from the bighorn range.

Sheep appeared stressed from aircraft activity caused by seismographic explorations. Aircraft activity should be minimized from 4/15-8/15 over lower Battlement Mesa, while sheep are lambing and stressed from a lack of water. Unless the distribution of the sheep changes (perhaps in response to habitat improvement) they can be expected to be on lambing grounds in Anderson and Durant Gulches during this critical period. Aircraft should be forbidden to fly over those gulches during the lambing period.

The exotic ungulates present in the Book Cliffs, north of Battlement Mesa, require immediate attention. CDOW personnel should make a concerted effort to eliminate these unclaimed auodads, Corsican sheep and 'Texas dalls' as soon as possible to extinguish the threat of competition or disease transmission to the Battlement bighorns. The threat these exotic sheep impose is intolerable, given the current declining status of the native sheep on Battlement Mesa. Steps should be taken by the CDOW to insure that topographical boundaries occur between exotic game ranches and the Battlement bighorns. Private ranches surrounding Battlement Mesa should not be permitted to have exotic sheep species if nasal contact with the native bighorns is possible. Immediate attention is required to address this threat imposed by the private exotic game ranch on Kimball Creek.

II. Objectives

The overall long-term objective of this management plan is to reverse the documented historic loss of seasonal ranges and migration corridors that is producing a relatively sedentary herd. This will be accomplished by 1) improving currently used habitat, and 2) improving historic ranges and migration corridors to encourage reestablishment of historic movement patterns.

III. Proposed Management Plan

A. Phase 1: Attraction of elk from bighorn ranges

Phase 1 is designed to provide elk foraging areas north of the present bighorn sheep range on both public and private lands. The primary objective is to provide elk with adequate forage away from the sheep range in order to alleviate possible direct competition for forage and indirect competition resulting in displacement of sheep. Competition between sheep and other wildlife or livestock was not quantified during data collection. The possibility of interference competition between elk and bighorn sheep was suggested based on increasing elk numbers and no observations of sheep in areas occupied by elk. I considered Phase 1 as a starting point to alleviate possible competition, improving areas away from my study area, while I completed my data collection and analysis during 1990. I do not consider competition the most serious problem facing the Battlement Mesa bighorn sheep.

Phase 1 began in 1990, with cooperative dollars from the WRNF, CDOW and RMEF. A successful burn was executed on 486 ha of Wallace Creek, north of the present bighorn range. Burning was completed on an area northeast of the suspected historic sheep migration route and adjacent to the present sheep summer range. In 1991, an additional 400 ha were burned with added support from FNAWS, in Wallace Creek, Pole and Snowslide Gulches, adjacent to the sheep summer range.

Phase 1 is not complete. To insure sustained forage for elk away from the bighorn range, mountain shrub units away from the sheep range should be managed through burning on a regular cycle. Burning is not intended to increase habitat for elk, but to attract elk from range currently used by sheep and to discourage additional elk from moving to, and using the sheep range. Elk numbers must be controlled in the area, presumably through hunting, for Phase 1 to be effective in alleviating elk pressure.

B. Phase 2: Improvement of current bighorn range

Phase 2 involves habitat improvements on the current sheep range on both public and private lands. Primary objectives of Phase 2 are 1) to improve habitat structure for bighorns by increasing visibility in dense shrub stands adjacent to currently used areas, 2) to improve the nutritional status of the herd by providing access to high quality grasses and forbs near escape terrain, potentially enhancing the reproductive fitness of ewes, and 3) to disperse bighorn sheep during the dry summer months.

Activities of Phase 2 include 1) immediate reduction of shrubs and conversion to grassland on the ridge between Anderson and Durant Gulches, 2) prescribed burning to increase visibility in dense shrub stands adjacent to currently used escape terrain, and 3) installment of 2 guzzlers on the current range to disperse sheep during dry summer months.

The first activity of Phase 2 includes immediate reduction of shrubs between the 2 drainages, Anderson and Durant, that sheep use for lambing and summer range. This will convert the shrub-covered ridge to open grassland, increasing visibility, and allow the sheep to utilize the productive grasses and forbs currently growing beneath the shrub overstory. This management strategy may also provide ewes with high quality forage during late gestation which may, in turn, improve the vigor and condition of lambs (N. Thompson Hobbs, pers. comm.). I suggest the treated area be no less than 15 ha to create the open habitat preferred by sheep (Hobbs and Spowart 1984). Lauver et al. (1989) described the options available for managing oak communities, reporting that current methods to eradicate oak are ineffective and costly and may result in less desirable ranges in a few years following single applications. They did not, however, report on results of secondary treatments or repeated prescribed burning. Where dense oak is undesirable, as on bighorn sheep ranges, the benefits realized from habitat treatment should outweigh the costs of management. I suggest mechanical cutting of shrub stems in this area followed by secondary treatment of resprouts with an

herbicide. Rominger (1983) reported on herbicide treatment of oakbrush to address habitat deficiencies of bighorn sheep in Waterton Canyon. Glyphosate appeared the most effective herbicide for application to freshly cut stems without the reduction in the herbaceous understory caused by Hexazinone (Rominger 1983). Thompson et al. (1991) successfully applied Tordon by basal injection to trees followed by prescribed burning to defoliate the overstory in an oak/hickory forest. This method may be effective if scattered aspen or conifer trees are found on the edges of the shrub belts between Anderson and Durant Gulches.

The second activity of Phase 2 involves large-scale treatment of approximately 17% of the current bighorn range with the objective of improving habitat structure for bighorns by increasing visibility in dense brush stands. Prescribed fire is the most cost-effective vegetation treatment to cover the considerable area proposed for management in the second activity of Phase 2. Prescribed burning reportedly improves production, palatability, and nutrient content of forage species (Daubenmire 1968, Pearson et al. 1972, Peek et al. 1979) and creates open habitat preferred by bighorn sheep. The sites for burning must collectively be large enough to offer significant benefits to the majority of the herd and also to avoid concentration and overgrazing by sheep, livestock or other big game species in small, attractive, burned areas. Hobbs and Spowart (1984) suggested at least 10% of the currently used range should be burned to prevent negative effects when treating bighorn sheep habitat.

A burn plan to complete Phase 2 of this management proposal will be developed by Rifle Ranger District personnel. Before burning, the potential management areas should be surveyed by District personnel to identify any areas of concern where burning should be avoided based on other wildlife or resource values. Burning should be conducted in the fall, as spring burns tend to be cool and allow for rapid recovery of shrubs, an undesirable outcome on Battlement Mesa. A hot fire with good kill of shrubs will be required to create optimum bighorn sheep habitat. Fire ecology experts should be consulted to address the management objectives for bighorns and translate these into effective fire prescriptions. The

objective of producing high visibility habitat may require repeated burning for maintenance of desired conditions.

Proposed sites of habitat improvement areas for Phase 2 are delineated on USGS topographic maps filed at the Rifle Ranger District. General areas for habitat treatment include sites along the rims of Bull Basin, Alkali, Anderson, Durant, Dry Fork Kimball, Bear, Boxelder, and Pole Gulches.

Mature stands of conifers separate sheep escape terrain from productive forage areas on both the present range and portions of the historic summer range. Riggs and Peek (1980) reported that burning in the spruce/fir habitat of Glacier National Park resulted in more open habitat for sheep and increased availability of vegetation during winter. Due to steep slopes and inaccessibility of spruce/fir stands on Battlement Mesa, conifer treatment is not suggested as part of this management plan. The area is too steep and unstable for both commercial logging and fuelwood cutting operations, and too topographically rugged for controlled, prescribed burning (Mike Geary, pers. comm.).

Monitoring will be integral to the successful management of the Battlement Mesa bighorn sheep. Bighorn sheep use of burned areas on the present range, completed during Phase 2, should be documented. Observations of sheep should be plotted and range expansion monitored by agency personnel, college interns, seasonal employees or volunteers. This thesis is considered a pre-treatment control study (Bailey 1990), providing a basis for comparing and measuring sheep responses to future management activities. Data on productivity of the sheep (lamb:ewe, yearling:ewe ratios) and sheep use or non-use of treated areas should be collected annually. This will require workers on foot and on horseback to adequately cover the managed areas.

An annual survey, during 3-5 days every August, is suggested. Groups such as the RMBS or FNAWS should be contacted for such counts, as members will often volunteer for such "hand on" projects. If possible, WRNF, GMNF or CDOW interns or volunteers

(a minimum of 2) should be hired to monitor the herd each year from June through August (or longer). Many wildlife or natural resource management college students are available and willing to monitor such herds for volunteer subsistence, to obtain valuable field experience and intern credits with an agency. The inaccessibility of the range requires extensive effort to adequately count and classify sheep for estimates of productivity and yearling survival. I have suggested a specific strategy for this annual count in a letter on file at the Rifle Ranger District. My suggestions were based on our first attempt at an annual count during August 1991 and should be followed to increase the efficiency and success of this difficult project. I stress that the success or failure of this habitat management cannot be measured unless adequate monitoring procedures are followed.

The third activity of Phase 2 includes placement of water catchment devices, known as guzzlers, on 2 areas of the present bighorn range. A lack of permanent water sources throughout the present range appeared to limit sheep distribution during the dry summer months of this study.

The long-term management plan for the herd may take several years. Sheep may not move quickly into recently improved areas or use historic migration routes due to their reliance on traditional seasonal ranges (Geist 1971). Therefore, guzzlers are proposed to distribute sheep more evenly throughout their present range during the dry summer months, until Phases 2 and 3 are completed. Guzzlers will hold water during dry periods in areas without natural springs, and will benefit other wildlife species on Battlement Mesa. A more uniform distribution of sheep will encourage more dispersed use of forage resources. The proposed water developments will allow rams to remain away from ewe-juvenile groups during summer, in lieu of occupying lower elevations in the same drainages.

Anderson Gulch supports the largest permanent spring on the present range, provides lambing grounds, and is abundantly used by sheep during June-October. Two sites for guzzlers, west and east of Anderson Gulch, were chosen to alleviate the concentrated use in this area.

The first proposed location for a guzzler is on a ridge of upper Lugans Basin, to the west of Anderson Gulch. No permanent water sources were reported in this vicinity, on the western end of the range. Rams were observed in this area during periods of precipitation but later moved into Anderson Gulch during dry periods. A guzzler placed on this ridge would collect rainwater and provide a permanent water source for rams or other sheep that could remain in this unit if water was available.

The second proposed location for a guzzler is on the ridge of the Dry Fork Kimball Creek drainage, east of Anderson Gulch, within the present sheep range. According to the WRNF map, this site is located on public land. There is a private land inholding to the west of this site which encompasses part of the upper ends of Durant and West Fork Clover Gulches, therefore exact land status should be investigated. I believe this placement would be most beneficial for sheep as the ridge provides an open, currently utilized sheep foraging area. A guzzler placed on the ridge of Dry Fork Kimball Creek may attract sheep further east during summer months and increase chances of range expansion. The locations of these 2 suggested sites for guzzlers, as well as alternative sites, are recorded on topographic maps and described in a letter on file at the Rifle Ranger District, WRNF, and at the GMNF Supervisor's Office in Delta, Colorado. If the 2 guzzlers are successful in dispersing sheep, guzzlers may also be installed at these alternative sites. An inexpensive and durable guzzler was described by Elderkin and Morris (1989) and may be adapted for use on Battlement Mesa.

Funding for the 2 guzzlers could come from WRNF, GMNF, CDOW and private groups including FNAWS and RMBS. Monitoring and maintenance of the 2 developments should be

part of the development plans. Monitoring should document species use of the water, document use or non-use by sheep, and provide for any necessary maintenance.

C. Phase 3: Improvement of historic bighorn range

Phase 3 includes reducing the density and increasing the visibility in the mountain shrub stands covering historic migration routes northeast and east of present bighorn range on public land. Reducing shrub cover and increasing visibility may expand bighorn sheep range and will encourage, but not guarantee, movement into historic migration routes in 1) Pole Gulch, Wallace and North Fork Wallace Creeks to the north and 2) Dry Kimball, Kimball and Brush Creeks to the east. Methods for habitat improvement and monitoring during Phase 3 should follow those outlined under the second activity of Phase 2.

This phase is critical to the long-term welfare of the bighorn sheep on Battlement Mesa. This study indicates the limiting factor for the sheep is habitat deficiencies, caused by changes in vegetation which led to a loss of migration. The Battlement Mesa sheep are not expected to expand their range or increase substantially in number if the herd remains sedentary and isolated on the present limited range.

D. Phase 4: Importation of additional sheep

The objectives of Phase 4 are 1) to provide a small augmentation of similarly adapted sheep to the present herd, and 2) to transplant approximately 20 sheep to historic summer range. Ultimately, Phase 4 may not be necessary, or even desirable. Habitat improvement through prescribed burning (Phases 2 and 3), and monitoring sheep use of improved areas should be executed and thoroughly documented. A decision to execute Phase 4 will depend, in part, on the herd's response to habitat improvement.

A small augmentation (5-10) of similarly adapted sheep would diversify the gene pool of the isolated herd. If the existing herd responds to habitat improvement with a marked increase in productivity from the presently observed rate of 4 lambs per year and increased survival, the proposed augmentation is not suggested. The implications of augmentation to locally adapted, isolated populations are not fully understood and the deleterious effects of adding differently adapted sheep to the present herd may outweigh the benefits. Conversely, if sheep do not respond to habitat improvement with increased productivity, this small augmentation is suggested.

The second part of Phase 4 involves a transplant of sheep to upper Battlement Mesa. The objective of this transplant would be to establish a second herd of sheep on historic summer range, adjacent to the range of the present herd. This herd would potentially migrate to lower elevation in winter, utilizing migration routes on which habitat has been improved, and establish contact with the present herd. The ultimate goal of this management alternative would be to establish a productive, migrating herd of bighorn sheep with 2 definitive ranges including lower Battlement Mesa in winter and upper Battlement Mesa in summer. This option should be considered only after Phases 2 and 3 are completed and the present herd is monitored for several years after completing Phase 3 (5-7 years of monitoring are suggested). If results of monitoring indicate no attempts of the present herd to migrate to historic summer range via developed migration routes, this transplant should be considered. Prescribed burning and long-term management should be a cooperative effort among agency personnel, including WRNF, GMNF and CDOW. A long term commitment to intensive management including repeated burning is necessary to achieve the desired results of an increased and migrating bighorn sheep herd.

Berger (1990) summarized the longevity of 122 bighorn sheep populations in southwest North America and found that 100% of those herds numbering fewer than 50 individuals went extinct within 50 years. Berger concluded that local extinction of bighorn

sheep herds cannot be overcome with 50 or fewer individuals because 50 is not a minimum viable population size for this species. The Battlement Mesa herd should be considered at high risk for local extinction, barring management.

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APPENDICES

Appendix 1. Plant associations present on Battlement Mesa, Colorado. Each of the 5 vegetated habitat types present on the study area can be broken into 1 of the following plant associations. Numbers and descriptions are taken from Johnston (1987).

Number (Johnston, 1987)	Area description	Species present
01214 (Douglas fir)	Moderate to steep, upper to lower slopes or ridges (31-81%), variety of aspects, 6230-8530 ft.	*Pseudotsuga menziesii* *Quercus gambelii* *Amelanchier alnifolia* *Mahonia repens* *Symphoricarpos oreophilus* *Pachistima myrsinites* *Padus virginiana* *Poa fendleriana* *Koeleria macrantha* *Carex geyeri* *Bromus porteri* *Artemisia ludoviciana* *Solidago sparsiflora* *Antennaria rosea* *Senecio multilobatus* *Carex pityophila* *Erigeron speciosus*
01217 (Douglas fir)	Steep N-NW slopes in western Colorado. Shallow, gravelly rocky loam soils, usually steep hillsides and canyons (15-90%). 6200-9800 ft.	*Psuedotsuga menziesii* *Abies lasiocarpa* *Juniperus scopulorum* *Symphoricarpos oreophilus* *Mahaonia repens* *Amelanchier spp.* *Jumiperus communis* *Holodiscus dumosus* *Paxistima myrsinsites* *Quercus gambelii* *Robinia neomexicana* *Arnica cordifolia* *Clematis columbiana* *Smilacina stellata* *Vicia americana* *Osmorhiza spp.* *Galium septentrionale* *Geranium richardsonii* *Oreochrysum parryi* *Carex geyeri*
01201 (Douglas fir)	Moist, northerly aspects, often steep slopes, evident rock cover, associated with cold-air drainage. On the White River National Forest 8400-8700 ft.	*Pseudotsuga menziesii* *Populus tremuloides* *Abies laiocarpa* *Acer glabrum* *Amelanchier alnifolia* *Mahonia repens* *Arnica cordifolia* *Ozmorhiza chilensis* *Galium triflorum* *Smilacina amplexicaulis* *Penstemon spp.* *Calamagrostis rubescens* *Cares geyeri* *Poa nervosa*

Appendix 1. Plant associations present on Battlement Mesa, Colorado (cont.)

10512 (aspen)	More sheltered sites, swales, benches and lower slopes, moderately deep well-drained soils, moist deep loamy snad to silty loam to clay loam soil, moderate variable slopes (17-65%). On the White River National Forest, 8360-10,330 ft.	*Populus tremuloides* *Pseudotsuga menziesii* *Rosa woodsii* *Thalictrum fendleri* *Lathyrus leucanthus* *Ligisticum porteri* *Vicia americana* *Delphinium barbeyi* *Lupinus argenteus* *Geranium richardsonii* *Osmorhiza occidentalis* *Smilacina stellata* *Galium septentrionale* *Senecio serra* *Potentilla pulcherrima* *Fragaria spp.* *Achillea lanulosa* *Aster engelmannii* *Carex geyeri* *Elymus glaucus* *Bromus canadensis* *Elymus trachycaulus* *Poa nemoralis* *Bromus porteri* *Bromus marginatus* *Stipa lettermanii*
10501 (aspen)	Loam to silt loam soils, cool, moist sites, S slopes at lower elevations, non-southerly aspects higher, lower sub-alpine zone with low winter snow duration. Low-moderate slopes (0-60%). In northern Colorado 7720-10,000 ft.	*Populus tremuloides* *Juniperus communis* *Rosa woodsii* *Amelanchier alnifolia* *Mahonia repens* *Symphoricarpos oreoqhilus* *Arnica cordifolia* *Lathyrus leucanthus* *Thalictrum spp.* *Fragaria spp.* *Osmorhiza occidentale* *Galium septentrionale* *Achillea lanulosa* *Vicia americana* *Carex geyeri* *Bromus porteri* *Elymus trachycaulus* *Stipa lettermanii* *Poa nemoralis* *Elymus glaucus*

Appendix 1. Plant associations present on Battlement Mesa, Colorado (cont.)

20403 (pinyon/juniper)	Lower elevations, slopes above broad valleys, SW-S-SE slopes, moderately steep (37-75%), shallow, well-drained soils, barrens and rock outcrops 6890-7870 ft. No forbs of any constancy, those listed are most conspicuous. The forb and grass layers are typically very poorly developed.	*Pinus edulis* *Juniperus osteosperma* *Cercocarpus montanus* *Amelanchier utahensis* *Quercus gambelii* *Cryptantha minima* *Physaria acutifolia* *Senecio multilobatus* *Phlox austromontana* *Oryzopsis hymenoides* *Leymus cinerus*
31305 (mountain shrub)	Hillsides, well-drained lowlands, 0-70% slope. Ecotone between oak and sagebrush 6000-9200 ft.	*Quercus gambelii Symphoricarpos oreophilus* *Amelanchier spp.* *Prunus virginiana* *Pinus ponderosa* *Abies concolor*
42201 (meadow)	Heavy, deep soils; WRNF 9180-9760'. Rolling hillsides, less-exposed; more winter snow accumulation.	*Festuca thurberi* *Festuca idahoensis* *Solidago multiradrata* *Vicia americana* *Bromus ciliatus*

Appendix 2. Observation form and code sheet used for bighorn sheep study, Battlement Mesa, Colorado, 12/88-6/90.

Observer:

Date:

Time:

Location:

UTM Coordinates:

Aspect:

Total sheep observed (#):
Classifications:
lambs:
ewes:
yearlings:
adults:
unclassified:
rams:
yearlings:
Class I:
Class II:
Class III:
Class IV:
unclassified:
unclassified sheep:

Environmental conditions:

Activity:

Habitat type:

Slope %:

Distance from Escape Terrain:

Nearest Neighbor Distance:

Appendix 2. Observation form and code sheet (cont.)

Environmental conditions:

A 4-digit number: wind-sun-temperature-ground
wind: 1-no wind, 2-light, 3-gusty, 4-strong
sun: 1-clear, 2-scattered clouds, 3-overcast, 4-precipitation
temperature: 1-below 0, 2-1 to 30, 3-31 to 60, 4-61 to 90, 5-over 90
ground: 1-no snow, 2-scattered snow, 3-continuous, 4-over 2 ft.

Activity upon first seeing animal(s):

BE-bedded
FE-feeding (face turned towards or moving towards forage)
WA-watering
MO-moving (not alarmed)
AT-attentive (focusing attention, standing still)
AL-alarmed (showing alarm posture and moving)

Habitat type:

SS-shale slope
SSV-shale slope with scattered vegetation
PJO-pinyon/juniper, open (canopy cover <20%)
PJC-pinyon/juniper, closed (canopy cover >20%)
MSO-mountain shrub, open
MSC-mountain shrub, closed
DF-Douglas fir/mixed conifer
AA-aspen
ME-meadow

Slope classes:

0-50%, 51-100%, 101-150%, 151-200%, >200%

Distance from escape terrain:

Estimate distance of group to the nearest escape terrain.

Nearest neighbor distance:

Estimate distance for each sheep (not including lambs) only when view is not obstructed; take average for all in group.

Appendix 3. Bighorn sheep observed on Battlement Mesa, Colorado, 1906-1980.

Year	Location	Source	Comments
1.[11] 1906	Courthouse Point (now Castle Peak)	Battlement Mesa Forest Reserve (Anderson 1906)	"Forty five head of bighorn sheep were found by Courthouse Point."
2. 1923	"...in and near the Forest"	BMNF, (Grand Junction Daily Sentinel 1923)	"A handful of mountain sheep have been reported in and near the Forest."
3. 1920-1927	Battlement Mesa	(Grand Junction Daily Sentinel, "Yesteryear" segment 1927)	50 sheep (1920), 19 sheep (1926), none (1927). "...all of the sheep were believed to be exterminated by predatory animals, having declined steadily since 1920."
4. 1920s	Castle Peak east to Porcupine Creek	Bob Black (pers. comm.) quote from a man named 'Ford' from Whitewater Creek	"Approximately 800-1,000 head of mountain sheep were in the area." Ford saw "great herds of sheep" while riding in the area as a cowboy on Battlement Mesa.
5. late 1920s early 1930s	Sunnyside cliffs (lower Battlement Mesa) to the Mamm Peaks (upper Battlement Mesa)	Raymond Lyons (pers. comm.)	"Locals estimated that between 200-250 bighorn sheep traveled between the Sunnyside cliffs and Mamm Peaks."
6. 1946	Horse Mountain, Bear Gulch, Alkali Creek	Wallace Creek C&H Grazing Allotment Plan	"A band of mountain sheep use the area around Horse Mountain, the head of Bear Gulch and into Alkali Creek, as well as dropping over onto the south side of the drainages into Hawxhurst Creek, etc. on the Grand Mesa National Forest."
7. 1940s 1950s	Mamm Peaks	Raymond Lyons (pers. comm.)	"...groups of sheep in the Mamm Peaks area."
8. 1950	Mamm Peaks	CDOW aerial survey (1950)	
9. circa 1950	Mamm Peaks	Ray Hittle (pers. comm.)	"...4 sheep in the basalt rubble in the Mamm Peaks area a long time ago."
10. 1950s	McCurry Reservoir	Raymond Lyons (pers. comm.)	"...approximately 45 sheep in the vicinity of McCurry Reservoir."
11. 1950	Mamm Peaks	Pat Ottman (pers. comm.)	Observed 35-40 sheep in 1950 at McCurry Reservoir.
1950s	Battlement Reservoirs	Raymond Lyons (pers. comm.)	Witnessed a man poach a bighorn ram.
12. 1953	Kimball Creek	H. Hughes (District Ranger at Collbran in 1953, GMNF)	Observed "...5 head of mountain sheep on Kimball Creek, near the Wallace Creek divide."

[11]Numbers correspond with Label numbers in Fig. 6.

Appendix 3. Bighorn sheep observed 1906-1980, (cont.)

13. 1950-1960	Lower Battlement Mesa	Bill Wallace (pers. comm.)	Estimated the herd at 50-75 sheep, ranging as far east as Dry Fork Kimball Creek.
14. 1961	Mamm Peaks	CDOW aerial survey	Nine sheep observed on North Mamm Peak.
15. 1961-1966	North Fork Wallace Creek	Ruedy Steele (CDOW records)	"...several ewes observed."
17. 1966	Nuckolls Creek slides (east of upper Battlement Mesa)	Paul Pittman (CDOW records)	Observed a sheep in the Nuckolls Creek slides.
16. 1960s	Smalley Gulch slides	El McCurry (pers. comm.)	Recalled observing sheep on the Smalley Gulch slides during the summers until the early 1960s.
18. 1960s	Sandstone cliffs of Plateau Valley, at the southern end of the Sunnyside Plateau	Bob Black (pers. comm.) with Harold Lanning (former DWM, CDOW)	Observed sheep during the winters on the sandstone cliffs until the early 1970s.
19. 1970	Lower Anderson Gulch	Ted Walker (pers. comm.)	Observed 30 sheep in lower Anderson Gulch while working on a bulldozer.
20. early 1970s	Little Baldy Mountain to Kimball Creek (upper Battlement Mesa)	Pat Ottman (pers. comm.)	Observed sheep on south facing slopes.
21. 1972	Smith Gulch	Malcolm Jolley (CDOW records)	Observed 2 large rams.
1973	South Canyon, I-70	Malcolm Jolley (CDOW records)	Observed 1 sheep crossing I-70.
22. 1978-1979	Sandstone draw along Highway 65 (same location as Black and Lanning 1960s)	Ted Walker (pers. comm.)	Observed 8 sheep during the winter at the mouth of Jerry Gulch.
23. 1981	Brush Creek Basin, west rim	Pat Ottman (pers. comm.)	Observed 7 sheep with no lambs present. "Not as much timber and brush in this area during the early 1970s."
24. 1981 or 1982	Mud Springs	Nate Dutton (pers. comm.)	Observed 7 sheep, including ewes and lambs, near the tank at Mud Springs.
25. early 1980s	Una, near Colorado River	Nate Dutton (pers. comm.)	Observed a full curl ram. Dutton was told by the DWM that the ram was probably a wanderer from the Gunnison herd since he appeared much larger than Battlement rams.
26. 1960s-1980s	Anderson Gulch to Castle Peak, foothills of Sunnyside cliffs	Art Linn (pers. comm.)	Observed bighorn sheep 'over the years.'
27. 1960s-1980s	Lower Battlement Mesa	Fred Wallace (pers. comm.)	Observed rams 'through the years' on lower Battlement Mesa.