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THE INCREASE AND DIEOFF OF WATERTON CANYON BIGHORN SHEEP: BIOLOGY, MANAGEMENT AND DISMANAGEMENT

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Abstract: The Waterton Canyon bighorn sheep (Ovis canadensis) herd, near Denver was studied intensively during 1978-1982, coincident with construction of Strontia Springs Dam, and was observed occasionally thereafter. The herd has a restricted range, smaller than that reported during 1950-1970. Range restriction is correlated with gradual encroachment of conifers and shrubs, especially on federal land, and with a limited availability of water during summer in the lower Canyon. During construction, the herd increased from 48 to 78 animals. An all-age dieoff with acute bronchopneumonia occurred in late 1980. Several natural and human-related stressors were identified but not quantified. The most acute stressor was airborne dust. Subsequent lamb crops had poor survival, with pneumonia causing deaths of lambs for 1-3 years after the dieoff. A critical need for habitat management, including vegetation control and water development, was noted as early as 1979 and 1980. The Forest Service has received considerable private, state and urban support for developing a plan to manage sheep habitat in the Canyon. The current plan does not address habitat abandoned by this herd before 1978. Vegetation has been manipulated under the plan, but only in the lower Canyon. Critical migration corridors to the upper Canyon have not been treated. Since 1982, reliable data on herd size and composition have not been obtained. The recent history of Waterton bighorn sheep and their habitat suggests that (1) when projects are constructed on bighorn range, adequate mitigation may require pre-project knowledge of the range, and perhaps pre-project mitigation by habitat improvement; (2) long-term plans for managing bighorn ranges are needed; (3) our ability to manage bighorn ranges will be limited by lack of funding, personnel and dedication, risks associated with vegetation manipulation, and personnel turnover; and (4) there is a need to realistically assess how many bighorn ranges we will be able to manage well, in the long term.

The objective of this paper is to document the ecology and demography of bighorn sheep in Waterton Canyon, Colorado, during 1978-1985. In this period, Strontia Springs Dam was constructed in the Canyon. The bighorn herd suffered an all-age dieoff in 1980-81. This episode has often been referenced as an example of the impacts of construction and development activities upon bighorn sheep, as if construction, stress and a dieoff were a certain and simple relationship. Neither biology nor management will benefit from so simplistic a conclusion. In contrast, a more complete awareness of events in Waterton Canyon could enhance our abilities to manage other herds and their habitats, and to mitigate when habitats and herds are threatened by development activities.

A study of Waterton Canyon bighorn sheep was funded by the city of Denver and its Water Department during 1978-1982. The Colorado Division of Wildlife, particularly its Northeast Regional Office, also funded

important aspects of the study. The U.S. Forest Service allowed the study on federal land. The Rocky Mountain Bighorn Society, Martin-Marietta Corporation, and Denver funded habitat manipulation on private land in the Canyon. In 1986, the U.S. Forest Service conducted a prescribed burn, again mostly on land owned by Denver and Martin-Marietta.

The following biologists (and their reports and publications) contributed importantly to the study: K. Risenhoover (1981, Risenhoover and Bailey, 1980, 1985, 1986), B. Simmons (1982), E. Rominger (1983, Rominger and Bailey 1982, 1986, Rominger et al. 1986), A. Dale (1986, Dale and Bailey 1982), G. Schoonveld and R. Schmidt of the Colorado Division of Wildlife, and C. Hibler, T. Spraker and E. Williams of the Colorado State University Department of Pathology (Spraker et al. 1984). For clarity, these publications will not be cited repeatedly in this text.

WATERTON CANYON

Waterton Canyon is about 40 km southwest of Denver, Colorado. It contains 13 km of the South Platte River. Elevations vary between 1707 and 2370 m. The lower canyon is dominated by shrubs, especially true mountainmahogany (Cercocarpus montanus) on south aspects, and Gambel oak (Quercus gambelii) in dense stands on north aspects. Gambel oak occurs on south aspects in mid-canyon, where Douglas-fir (Pseudotsuga menziesii) and ponderosa pine occupy north aspects. The upper canyon is dominated by conifers, especially on north aspects, and some conifer stands have oak understories.

Cliffs and steep slopes, used for escape terrain by bighorns, are abundant, especially near the River. Little is known of the bighorn herd in the Canyon prior to 1950. A historic herd of 200-250 has been reported. During 1955-1975 estimates of herd size were between 18 and 50. Bear and Jones (1973) reported that this herd ranged throughout Waterton Canyon and for 10 km upstream from the Canyon (Fig. 1).

The city of Denver constructed Strontia Springs Dam in the upper Canyon during 1978-1982. In the same period, the Colorado Division of Wildlife and Colorado State University (CSU) were funded to monitor the Canyon's bighorn herd, evaluate impacts on the sheep and on sheep habitat and develop mitigation methods. Construction activities on the Canyon road had begun before the study, however.

BIGHORN RANGE

In January and in December, 1979, bighorn sheep were captured and fitted with collars or ear tags. Seven, 5 ewes and 2 rams, received radio collars. Based on almost daily monitoring of the herd during 1978-1982, the bighorn range was determined to be much smaller than that described by Bear and Jones (1973; Fig. 1). The former, larger range was presumably based on observations in the 1950's and 1960's. In 1978-82, the sheep were restricted to Waterton Canyon. The upper Canyon was used

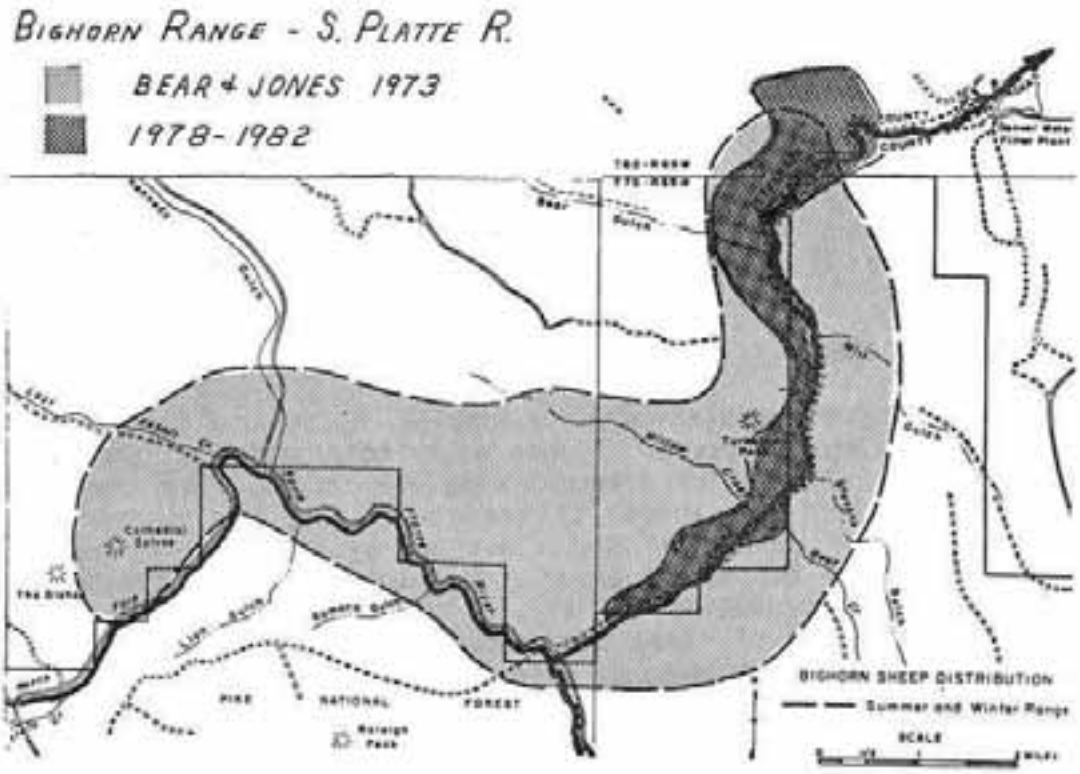

Fig. 1. Historic distribution of bighorn sheep along the South Platte River near Denver. The range reported by Bear and Jones is based on observations from the 1950's and 1960's.

for lambing during April-July, and was summer range for rams and some ewes without lambs. The lower Canyon was used as winter range. In addition, ewes with lambs left the upper Canyon lambing area and moved quickly to the lower Canyon in June or July in 1979 and 1980. Thus, most ewes, including almost all ewes with lambs, used primarily the lower 5 km of the Canyon during summer, fall and winter, or 75% of the year.

The sheep range was also restricted ecologically. The sheep preferred grassy openings, mountain shrub types, and cliffs; they avoided the conifer and oakbrush types, which constituted 78% of the study area. Risenhoover and Simmons documented behavioral adaptations (foraging efficiency, alertness and sociality) of these sheep to habitats that were near escape terrain and afforded good visibility. The sheep were limited mostly to steep, relatively open habitat near the South Platte River and its adjacent road. In late summer, the River afforded the only free water for sheep in the lower Canyon.

Wakelyn (1984) compared habitat conditions between the range of this herd before 1970 vs. the range in 1978-82 (Fig. 1). The recently abandoned portion of the range contained a greater proportion of forest cover and smaller proportions of shrubland, grassland and rocky habitat.

Waterton Canyon has a unique bighorn herd. It is one of only six indigenous low-elevation (below 2440 m) herds left in Colorado. The herd has relatively early and asynchronous breeding and lambing periods. More like desert bighorn sheep, their summer diet consists largely of shrub leaves. Sheep from this and other low-elevation herds in Colorado have exhibited exceptional rates of body and horn growth and have contributed inordinately to the Boone and Crockett and the Pope and Young record books.

POPULATION TRENDS

The bighorn population was estimated, by sex and age classes, each month for almost 4 years. Almost daily observation of the herd on its small range allowed for frequent complete counts. Our conclusion that the entire herd was known, by sex-age class, was supported by the consistency of counts for each class and by frequent samples containing most or all of the marked sheep. Frequent Petersen-estimates indicated that we were accounting for all, or all but one or two, sheep. Each year, the number of lambs born was uncertain, but we began to attain consistent counts of lambs by July.

As the study, and construction for Strontia Springs Dam, began in the fall of 1978, there were 48 sheep in Waterton Canyon (Fig. 2). These included 6 1978 lambs and 6 yearlings. The lamb:yearling:ewe ratio was 25:25:100, indicating low reproductive success and/or recruitment success from the 1977 and 1978 seasons.

As construction activities and the sheep study proceeded, the herd increased through the 1979 and 1980 lambing seasons (Fig. 2). There were 14 lambs in 1979 and 16 in 1980. Survival of lambs (counted in summer) to the yearling class was 100% for the 1978 and 1979 cohorts. Lamb:ewe ratios improved to 52:100 and 55:100 in 1979 and 1980, respectively. By summer, 1980, there were 78 sheep in the herd, a 62% increase during less than 2 years of construction activity in the Canyon (Fig. 2).

The Dieoff

Coughing sheep were first observed on 19 September 1980. By late October most sheep were coughing. The first dead sheep was found in early October and 39 carcasses were found by frequent searches of the Canyon during October-January (Fig. 3). Within age classes, mortality ranged from 69% in ewes and lambs to 88% in rams (Table 1). Spraker et al. (1984) reported necropsies of 18 animals. All had bronchopneumonia which was acute to peracute in the earliest cases, causing death in several days to a week. In later cases the disease was chronic. Early in the dieoff, all sheep had excellent hair coat and body fat (Fig. 4). Of three pathologists conducting necropsies, one consistently noted that the lungs had numerous macrophages containing what appeared to be dust. Lungworm (Protostongylus) burdens were judged low to moderate. The adrenal glands were enlarged and hyperplastic in 9 of the 15 sheep suitable for this examination. In 9 of 14 sheep, the thymus ranged from smaller than normal to completely involuted.

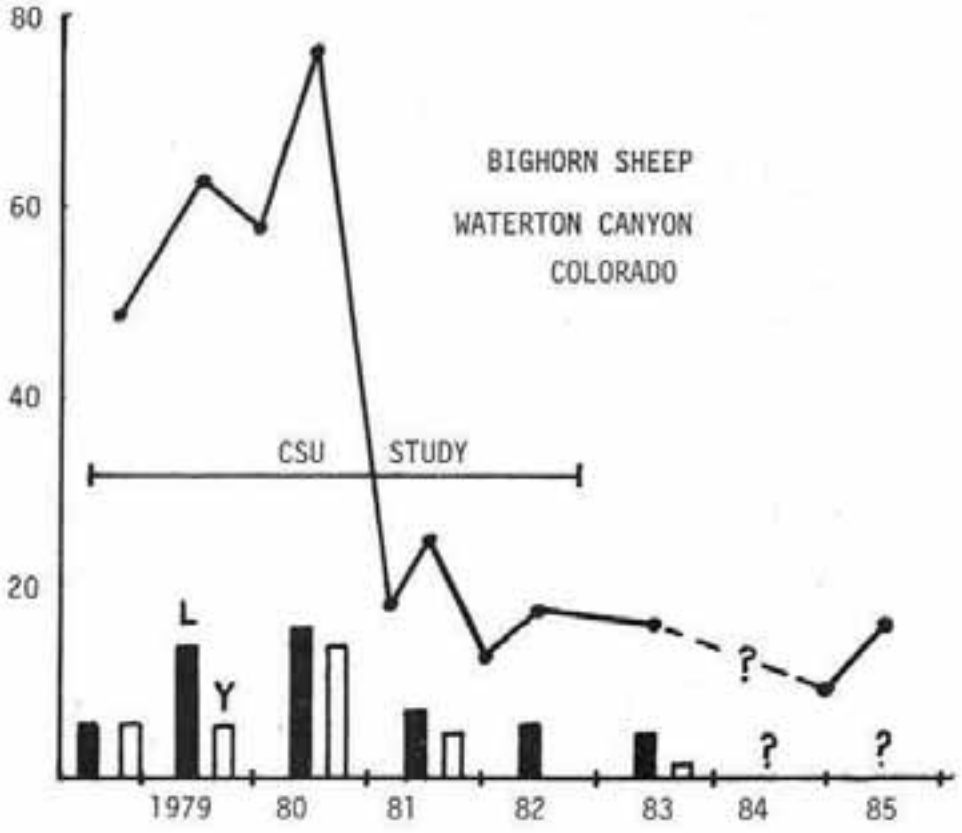

Fig. 2 The bighorn population in Waterton Canyon, Colorado, during and after the Colorado State University study. Shaded and open bars represent numbers of lambs and yearlings, respectively.

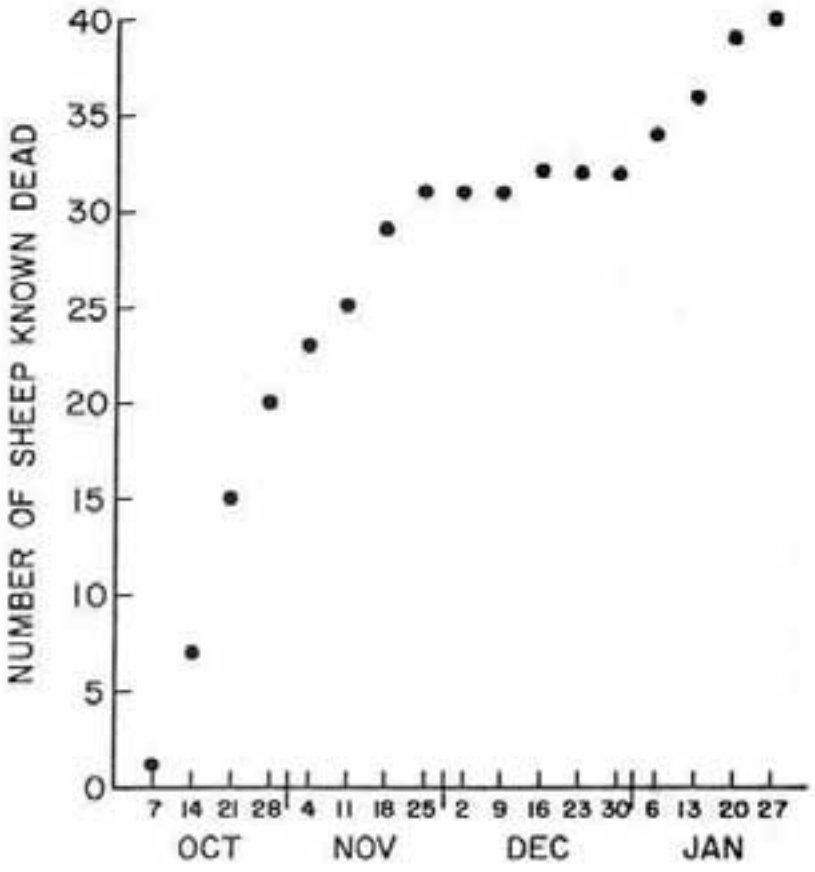

Fig. 3. Cumulative number of bighorn carcasses found during periodic searches of Waterton Canyon, 1980-1981 (from Simmons 1982).

Table 1. Mortality by sex-age class, Waterton Canyon bighorn sheep, October 1980-April 1981 (from Simmons 1982).

Sex-age class	Minimum population Jul 1980	Known alive Apr 1981	Mortality (%)
Ewes	30	9	69[a]
Lambs	16	5	69
Yearlings	(14)	(2)	(86)
Male	8	1	88
Female	6	1	83
Rams	(17)	(2)	(88)
Class I-II	11	--	100
Class III-IV	6	2	67
Total	77	18	77

[a]Excludes ewe poached on 7 Oct. 1980.

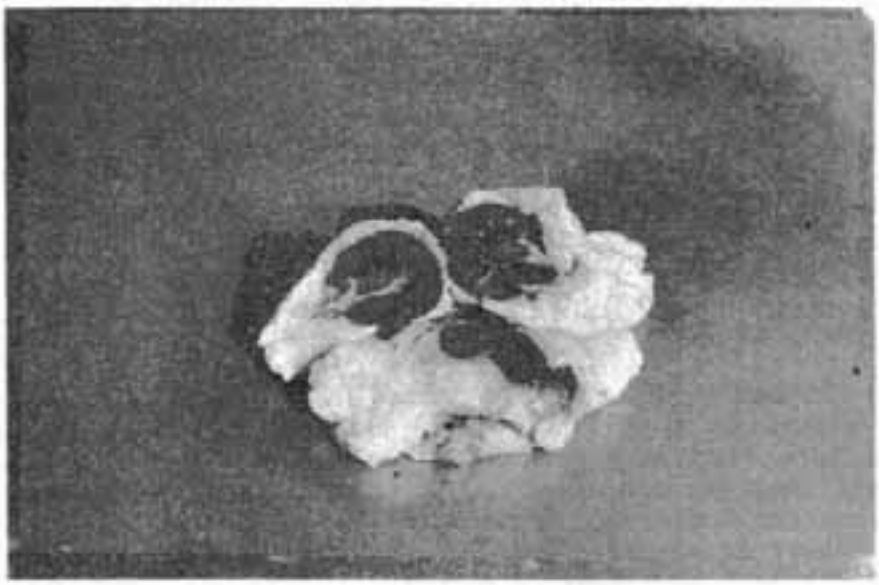

Fig. 4. Kidneys (one sectioned) and associated fat from bighorn dying of bronchopneumonia in Waterton Canyon. Early in the dieoff, the sheep had excellent fat reserves (from Simmons 1982).

Post Dieoff

There were but 18 sheep in Waterton Canyon in April 1981: 11 ewes, 5 yearlings and 2 rams. At least 8 lambs were born (73:100 ewes), mostly in June. This peak of lambing was about a month later than in 1979 and 1980. All 8 lambs were dead by 11 August. They had appeared healthy until 3.5-6 weeks of age, when they coughed and had nasal discharges. Two lambs were necropsied and revealed the familiar pneumonia condition. In contrast to previous years, none of these lambs was moved to the lower Canyon. Their ewes, however, moved down Canyon after the lambs had died.

Five older sheep disappeared during October 1981 - February 1982. Three of the four missing ewes were old and considered chronic pneumonics. The fourth ewe and a yearling had appeared in good condition before their disappearance.

There were but 13 sheep in Waterton Canyon in late winter, 1982: seven ewes, 4 yearlings and two rams. Funding of the intensive study ended with completion of Strontia Springs Dam. Monitoring the herd became the responsibility of the Colorado Division of Wildlife, although Alan Dale of the Denver Water Department observed the herd occasionally.

In summer, 1982, 8 ewes were seen with 6 lambs (75:100). Peak of birth was once again in the first half of May. Two female lambs reached the lower Canyon by 21 July. The other 4 lambs died in the upper Canyon, perhaps from pneumonia. Two 1982 lambs became yearlings in 1983 (Fig. 2).

There were at least 6 lambs again in 1983 (85:100 ewes), with peak lambing in early May. Four lambs reached the lower Canyon, but one with a broken leg was collected and necropsied. It had the same pneumonic conditions as had all previously necropsied sheep.

Lambing success in 1984 and 1985 is unknown. Ten sheep were observed in the Canyon at the end of 1984. The population was presumed to have 16 sheep in summer, 1985 (Fig. 2).

Stress and Stressors

The all-age dieoff was interpreted as stress-related (Spraker et al. 1984). Stress is a well-documented pattern of biochemical, functional and structural responses of higher animals to negative stimuli (Selye 1976), and this pattern inhibits or reduces an animal's immune capacity (Gabrielson and Good 1967, Gisler 1974, Solomon et al. 1974). Attributing the dieoff to stress clarifies the proximate mechanism of mortality, but does little to elucidate the ultimate causes. Without clarification of causes, we have no basis for placing blame, or for avoiding similar debacles in the future. Moreover, if we become satisfied with, or promote, "stress" as an explanation, we may impede development of understanding of the causes of stress in bighorn sheep.

Stress is the cumulative effect of negative stimuli which are termed stressors. For bighorn sheep, the ultimate goal of stress research would be to identify and quantify the various stressors operating on a herd. In Waterton Canyon, several potential stressors were identified (Table 2). While few were quantified in any way, there was evidence for speculation on the relative importances of some of these stressors. Spraker et al. (1984) have considered the roles of lungworms and microparasites in detail.

Table 2. Stress factors that may have predisposed sheep to all-age dieoff, Waterton Canyon, 1980 (from Simmons 1982).

Natural	Man-related
Lungworm	Construction
Microparasites	Traffic
Weather	Dust
Social density	Research
Limited habitat Population density	

Summer and fall 1980 were dry along Colorado's Front Range and were among the driest seasons on record for Waterton Canyon. Sheep in the lower Canyon had to cross the Canyon road to drink from the South Platte River. Lack of water away from the River may have abnormally restricted their range to areas near the road.

In 1979 the Canyon road was treated with a dust-reducing substance which deteriorated. The road was subsequently oiled several times but a durable surface was not attained. In the dry summer and fall of 1980 dust was often in the air throughout most of the lower Canyon. While Strontia Springs Dam was being poured, there was a vehicle passage every 5-6 minutes. Occasional watering of the road accomplished little. Airborne dust settled on shrubs and became airborne again as animals walked through the vegetation. Inhaled dust can compromise the immune system of mammals (Rylander 1969, Green 1970, Adney 1981). This dust was the most acute stressor associated with the sheep dieoff (acute in the sense that dust was a potentially serious problem that occurred abundantly and primarily just preceding the dieoff).

Waterton sheep were in excellent physical condition, indicating no shortage of forage. However social density had increased during 1978-80. There were about 31 sheep per square km of used range in the summer of 1980. The level or role of social stress at this density is unknown. If social stress were important in predisposing sheep, subordinate age

classes may have suffered inordinately. Yet mortality was high in all sex-age classes.

Since Waterton sheep were restricted primarily to a narrow corridor along the Canyon and its road, they were subjected to abundant traffic and construction noise and activity. Work on the road, including blasting, began in late 1978. Thereafter there was more blasting and abundant, noisy construction equipment almost daily. Our study caused additional stress. Twice in 1979, sheep were trapped and handled. They were observed almost daily, often from within 25 m or less. However, Waterton bighorns were habituated to people and vehicles. They were often on the road and did not always flee when approached. They were observed to walk among parked vehicles, to cross the River on a new one-lane bridge, and to show only modest "head-up responses" to sudden noises such as explosions or the starting of diesel engines. We compared working vs. non-working days for construction crews and found the sheep, on average, slightly farther from the road and slightly nearer to escape terrain on working days in 1980, but not in 1979. With care, biologists could join and remain with a group of foraging sheep to record behavior. The contribution of all this disturbance to stress in these habituated sheep remains unknown. Appearances of sheep may hide physiological changes, including elevated heart rates (MacArthur et al. 1982, Stemp 1982). A key factor in Waterton Canyon was that limited range and lack of free water obligated the sheep to be near the construction activity.

HABITAT MANAGEMENT

A need for improving sheep habitat in Waterton Canyon was recognized early in the CSU study of the herd. Much habitat in the lower Canyon is owned by Denver and by Martin Marietta Corporation. Almost all habitat in the middle and upper Canyon is managed by the United States Forest Service. During 1979-1982, these agencies were frequently alerted to the need for habitat management in several reports. The need for vegetation manipulation was noted in 1979. A water development in the lower Canyon was proposed in 1980. Denver did brush clearing and tree limbing as mitigation for habitat lost due to Strontia Springs Dam in 1979 and 1980. (The Forest Service requested that no large trees be cut in these mitigation clearings.) The sheep used these mitigation clearings, adjacent to existing range, almost immediately. In 1980, the opportunity to improve sheep habitat in the upper Canyon with a fuelwood harvest was noted. This opportunity would be lost when flooding behind the dam would eliminate easy access. In 1981 it was suggested that greatest habitat deterioration due to forest succession had occurred on federal lands in the upper Canyon. Also, the risk of inbreeding in the herd was noted. This risk made habitat improvement more urgent. Two sites for water developments were proposed in 1981. Twelve areas were proposed for vegetation control in 1982. In 1983 Martin-Marietta and Denver bulldozed oakbrush on private lands in the lower Canyon. In addition, local data, results of experimental vegetation manipulation, literature reviews, draft habitat-management plans, funding, volunteer labor, and a public relations program were given or offered to the Forest Service by the CSU study, students from CSU, the Rocky Mountain Bighorn Society, the

Colorado Division of Wildlife and Martin-Marietta Corporation. The Director of the Colorado Division of Wildlife and the Regional Forester both supported, with written correspondence, habitat manipulation in Waterton Canyon. All this support should have hastened development of necessary environmental analyses and a habitat management plan by the Forest Service.

The Forest Service cooperated in a small prescribed burn of oakbrush and mountain shrub habitats on private land in the lower Canyon in 1984. A larger burn, again in the lower Canyon, was conducted in 1986. This burn was funded by the Forest Service, the Colorado Division of Wildlife, the Foundation for North American Wild Sheep, and Martin-Marietta. The Division of Wildlife used the entire habitat-management budget of its Denver Region (one of 5 Regions in the state) for this burn. A wildfire occurred in the middle Canyon in 1986. There has been no development of a water source for sheep in the lower Canyon. In late summer, the only water is in the River alongside the Canyon road where recreationists, on foot or bicycles, are abundant. Other than mitigation clearings established by Denver, there has been no habitat manipulation to maintain a migration corridor between the upper and lower Canyons. Chance observation of young lambs in 1986 has suggested that lambing occurred in the lower Canyon, perhaps an indication that sheep are abandoning the lambing area in the upper Canyon.

Sheep numbers are not being monitored on a regular basis in Waterton Canyon. There were at least 15 sheep in late 1985. The 1986 lamb crop is uncertain. The state Division of Wildlife is considering a transplant to augment the herd, probably with sheep from a high-elevation gene pool. If there are unique genes in low-elevation sheep in Waterton Canyon, the potential for swamping these genes with a transplant is unknown. A conservative approach, using a low-elevation source, or fewer sheep, for augmentation, and monitoring the results, would be more expensive than simply transplanting 10-20 sheep. The Forest Service has a plan for continued habitat management in Waterton Canyon. Funding of activities in this plan is uncertain. The plan does not address habitat, upstream from Waterton Canyon, that sheep abandoned before 1978 (Fig. 1).

During 1978-1986 there was considerable turnover of personnel who dealt with bighorn sheep and their habitat in Waterton Canyon. In the Forest Service there were 4 District Rangers on the South Platte District; there were at least two wildlife biologists in the Forest Supervisor's office; there were three Regional Foresters in the Denver office, two of whom commented in writing on the need for sheep habitat management in the Region. There were two Directors in the Colorado Division of Wildlife. In addition, administration of Waterton Canyon was switched from the Northeast Region of the Division to the new Denver Region. There were at least three state District Wildlife Managers responsible for Waterton Canyon. At least before 1986, there was no trained wildlife biologist on the South Platte District of the Forest Service. The current biologist in the Forest Supervisor's office is responsible for range management, soils, watersheds and mining, as well as for wildlife. Thus lack of adequate personnel and personnel turnover, as well as lack

of adequate funding, must have contributed to the slow and uncertain responses of the Forest Service and the Colorado Division of Wildlife to the needs for preserving a unique bighorn herd.

MANAGEMENT IMPLICATIONS

Events during 1978-1986 in Waterton Canyon have important implications for the management of many bighorn herds in the Rocky Mountain Region. It is likely that many bighorn ranges in the region have been degraded by forest and shrub succession (as they have been in Colorado; Wakelyn 1984), and that many are threatened by developments including reservoirs, roads, mines and urban expansion.

Mitigation Opportunities

When bighorn sheep range is threatened by development such as reservoir construction, effective and timely mitigation of impacts will often depend upon having prior knowledge of the seasonal ranges, migration corridors and movement patterns of the sheep herd. Obtaining this knowledge in a project-monitoring study concurrent with construction activities may not be adequate to forestall impacts on the sheep. At Waterton Canyon, the sheep range had been degraded by decades of plant succession before construction of Strontia Springs Dam. The range was already limited to an extent that obligated the sheep to remain near to construction activities. They had no options. Had this been known earlier, habitat manipulation before construction of the Dam, to attract sheep away from the construction activities, may have prevented the dieoff. In the future, pre-project studies of bighorn ranges, and in some situations, pre-project mitigation, will be necessary to avoid impacts on bighorn herds.

Forest fires have been suppressed for up to 65 years in much of the Rocky Mountains. It is therefore likely that very many bighorn ranges have been degraded by forest succession. Consequently, when construction activities and other developments are localized on bighorn ranges, there should be abundant opportunities to mitigate by manipulating vegetation to improve comparable habitat away from the project.

Dust was the most acute stressor preceding the Waterton bighorn dieoff. Yet the importance of dust in this dieoff is unknown. Some herds of northern mountain sheep live in the frequently dusty chinook-zones of recently glaciated mountains, apparently without impacts on their lungs. However, dust-particle sizes may determine these impacts. Until more is known about this threat, it would be prudent to control dust generation when development projects invade bighorn ranges.

At Waterton Canyon, the continuing post-dieoff mortality of subsequent lamb crops emphasizes the need to avoid such a dieoff. Loss of these lambs, due to persisting prevalence of the disease and/or persisting susceptibility of the sheep herd, is delaying any density-dependent response to the current low population size. (The highest lamb:ewe ratios reported here are from the post-dieoff period and perhaps are a response to density.)

Management Planning

I believe that most bighorn herds and ranges are not known well enough for successful management in the long term. We do not adequately monitor populations. More commonly, we do not know the seasonal ranges, migration corridors and movement patterns of herds. In Colorado, the vague herd and range descriptions in Bear and Jones (1973) and the experience of Wakelyn (1984) in questioning field biologists, trying to delineate bighorn ranges, support my position. If we do not know where all of a yearround bighorn range is, we are not managing the range, and we cannot protect it from threats of development. There is a great need for studies, probably with radio telemetry, to determine seasonal ranges and migration corridors of bighorn herds.

Waterton sheep are a mini-example of many bighorn herds in the Rocky Mountains. They have lost range, lost migration traditions, and become more sedentary (Fig. 1). In contrast, most migratory bighorn herds in mountain areas will have a more complex year-round range than one resulting from simple migration within a river corridor (Fig. 5). But

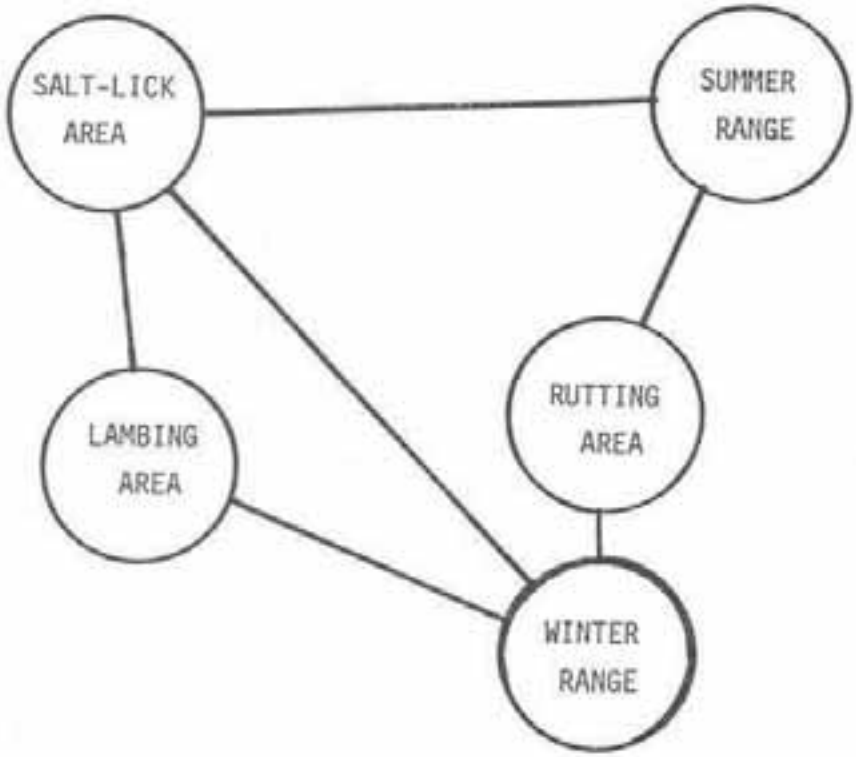

Fig. 5. Hypothetical year-round range of a bighorn herd in a topographically complex mountain area. Several seasonally used ranges are connected by migration corridors. Maintaining a migratory herd will require identification of seasonal ranges and migration corridors and long-term plans for protecting and perhaps managing these range components.

many herds have lost the migratory tradition and are now sedentary on one former seasonal range. They have lost options for responding to variation in weather or to forage conditions, or to threatening human activities. They may be subsisting on poor quantities or qualities of forage, at least in some seasons. The predation and disease implications of their sedentariness are unclear, but could be serious. Thus I believe the goal of most bighorn habitat management plans should be to reestablish or maintain seasonal ranges, migration corridors and migratory sheep. I know of only one such long-range plan. Moreover, most federal land managers are not aware of the value of migration to sheep or of past losses of bighorn ranges and migration corridors on the federal lands they manage.

There is a growing awareness of the impacts of succession on bighorn habitat and a growing interest in habitat improvement, especially on currently used low-elevation winter ranges. However most habitat-improvement projects have a limited, inadequate goal--to improve habitat conditions on one already used seasonal range. Meanwhile, abandoned seasonal ranges and abandoned or still-used migration corridors are ignored. Worse, habitat improvement on the one seasonal range, usually with prescribed fire, is often limited to areas that are safe or convenient to burn, to years with adequate weather for (usually) conservative burning conditions, to years when funds are available, and to times when adequate numbers of interested personnel are present. These limitations are due to serious problems and risks related to funding, to safety, to personnel turnover, and to the career aspirations of individuals. Such problems will always be with us. But a plan with this inadequate goal and these limitations is doomed to a slow failure. The failure occurs so slowly as not to be noticed during the average tenure of a federal biologist on a land unit.

To perpetuate healthy, productive migratory bighorn populations in forested mountains, our land-management agencies must (1) officially recognize establishment or maintenance of migratory herds as a goal; (2) identify existing or needed seasonal ranges and migration corridors that must be protected and managed to achieve this goal; (3) develop long-term plans for manipulating habitat on these ranges and corridors; and (4) realistically evaluate the continuing costs in dollars and personnel that will be necessary to manipulate these habitats.

Currently, such realism is lacking. We are trying to manage bighorn habitat whenever and wherever we find the opportunity. But we have few long-range plans. Realism will force us to ask, "Given the funding, safety, personnel and career problems we will always have, how much bighorn migration and how many bighorn herds can we afford?" For a given bighorn herd, perhaps it will be better to succeed at maintaining a 5-mile migration than to fail at maintaining a 10-mile migration. For a given area, perhaps it will be better to succeed at maintaining 4 healthy, productive bighorn herds than to struggle at maintaining 8 herds that are always unthrifty because of our program limitations. How many herds can we afford to protect and manage <u>well</u>? Which strategy is apt to produce more value from bighorn sheep in the long run?

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