

EFFECTS OF DOMESTIC SHEEP GRAZING ON
BIGHORN SHEEP POPULATIONS: A REVIEW

Nike J. Goodson¹, Helena National Forest, Drawer 10014 Federal Office
Building, Helena, MT 59626

ABSTRACT

The Gates of the Mountains area in west-central Montana exemplifies areas where potential effects of domestic sheep grazing on bighorn sheep populations must be assessed. Based on review of published and unpublished reports and observations, effects of domestic sheep grazing on bighorn sheep can be classified into three categories: 1. Competition for forage; 2. Competition for space (social competition); and 3. Transmission of diseases. The ability of domestic sheep to utilize steep slopes and arid ranges permits a high degree of overlap in habitat use between bighorn and domestic sheep on shared ranges. Similar food preferences increase the potential for direct competition for forage. While individual bighorn have been observed to associate with domestic sheep, social avoidance is the rule on shared ranges. This avoidance can lead to bighorn occupying only part of the available habitat. The close genetic relationship of bighorn sheep to domestic sheep is reflected in hybridization and susceptibility of bighorn to many diseases which affect domestic sheep. However, observations indicate bighorn lack resistance to pneumophilic bacteria which domestic sheep can carry without ill effects. Co-use of ranges by domestic and bighorn sheep has been consistently linked with declines, die-offs, and extinctions of bighorn populations from historical to recent times. While much of the evidence for competition between domestic sheep and bighorn is circumstantial, it is sufficiently strong to have prompted management decisions against co-use of ranges by bighorn and domestic sheep by federal land management agencies and state wildlife departments.

The Gates of the Mountain area is located in the Big Belt Mountains of west-central Montana. Rocky Mountain bighorn sheep (Ovis canadensis canadensis) were originally numerous in the Big Belt Mountains and in the hills to the north of the range (Couey 1950). In the early 1880's, following introduction of domestic stock into the area, great losses of bighorn sheep occurred which were attributed to scabies and bighorn sheep disappeared from the area soon afterward (Couey 1950).

¹ Present Address: Department of Animal Science, University of Alberta,
Edmonton, Alberta, Canada T6G 2P5

In the early 1900's, domestic sheep were grazed in the Gates of the Mountains area in the Candle Mountain and Moors Mountain Allotments (Helena National Forest Allotment Files) (Figure 1). The Beartooth Game Management Area was privately owned and grazed by domestic stock (pers. comm. Hubert Ellwein).²

In 1942 and 1943, unsuccessful transplants of bighorn sheep were made into the Gates of the Mountains. In 1966, the Candle Mountain Allotment became vacant. In 1970, the Beartooth Game Management Area was purchased by the Montana Department of Fish, Wildlife and Parks (MDFWP) and livestock grazing was eliminated (pers. comm. Hubert Ellwein). Grazing of domestic sheep was limited to the eastern part of the Moors Mountain allotment and the allotment became inactive in 1973.

Bighorn sheep from the Sun River herd were transplanted onto the Beartooth Game Management Area in 1971, 1973 and 1975 (MDFWP 1975). One hundred and fourteen bighorn were transplanted in these reintroductions compared with only 14 bighorn in the unsuccessful transplants in 1942 and 1943. A bighorn herd which is currently estimated at 200 head (pers. comm. Jim McLucas³) and is expanding in both distribution and numbers (pers. comm. Frank Fiest⁴) was successfully established in the Beartooth Game Management Area and the Gates of the Mountains Wilderness. (Figure 2). The bighorn sheep in the Gates of the Mountains provide sport hunting as well as nonconsumptive use, including viewing by hikers in the Gates of the Mountains Wilderness and by pleasure boat from the Missouri River.

The current non-use agreement on the Moors Mountain Allotment ends in 1982. The permittee is interested in restocking the allotment with domestic sheep. Cochran Fields and Favorite Gulch are cattle allotments located south of the Gates of the Mountains Wilderness (Figure 3). They have been vacant since 1973 (Cochran Fields) and 1975 (Favorite Gulch). The Helena National Forest, Montana Department of Fish, Wildlife and Parks and the permittee are considering grazing management options on the three allotments. Alternatives under consideration include stocking them with domestic sheep or cattle and leaving them vacant.

This paper explores the question: What effect would stocking of domestic sheep on these allotments have on the bighorn sheep of the Gates of the Mountains?

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- 2 MDFWP, Wildlife Area Manager, Beartooth Management Area, Wolf Creek, Montana.
 - 3 MDFWP (retired), 890 Granite, Helena, Montana.
 - 4 MDFWP, Great Falls, Montana.

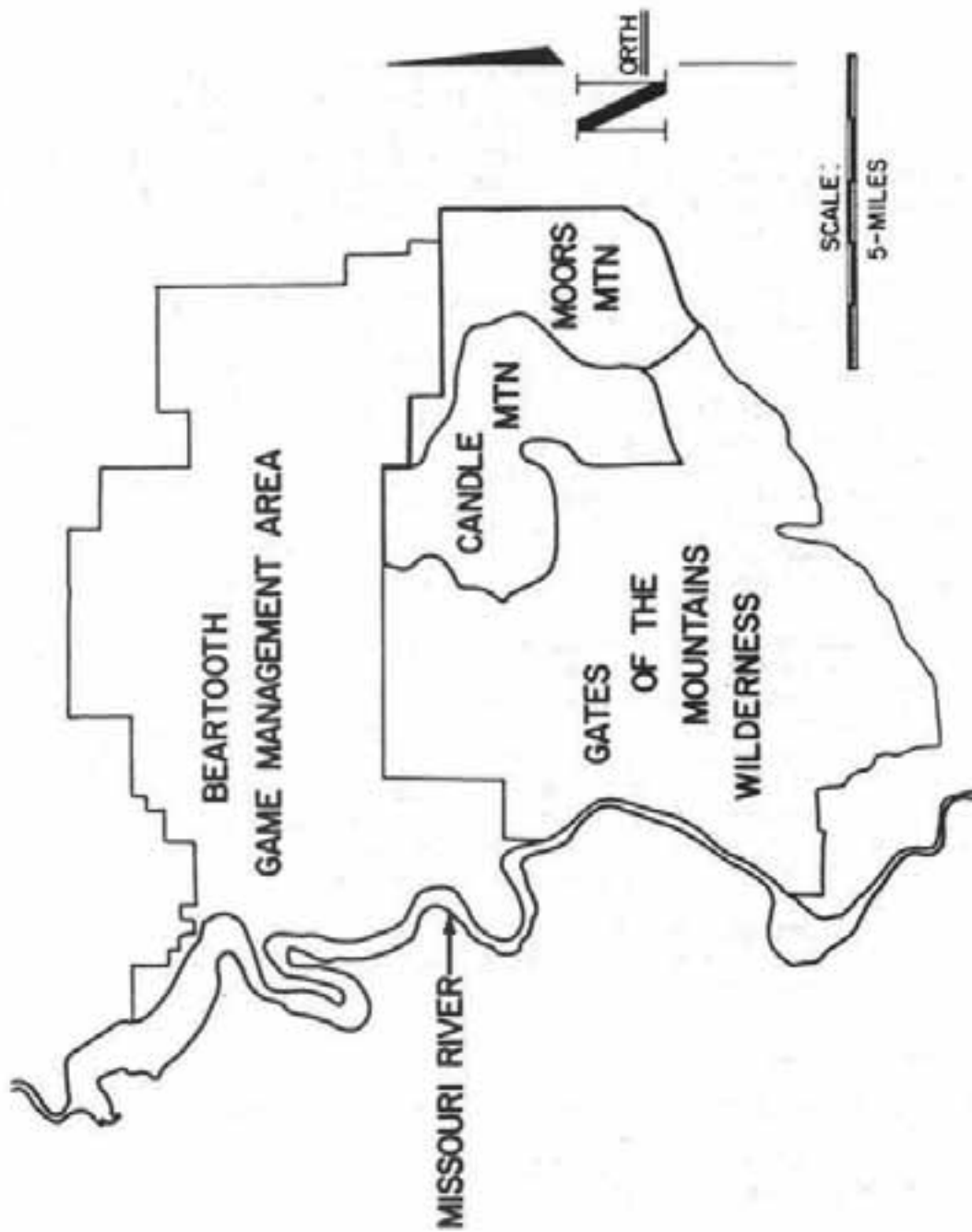


Figure 1. Domestic sheep allotments which were active in the early 1900's located in the Gates of the Mountains Wilderness (established in 1964). The Beartooth Game Management Area (established in 1970) was privately owned and grazed by domestic stock in the early 1900's.

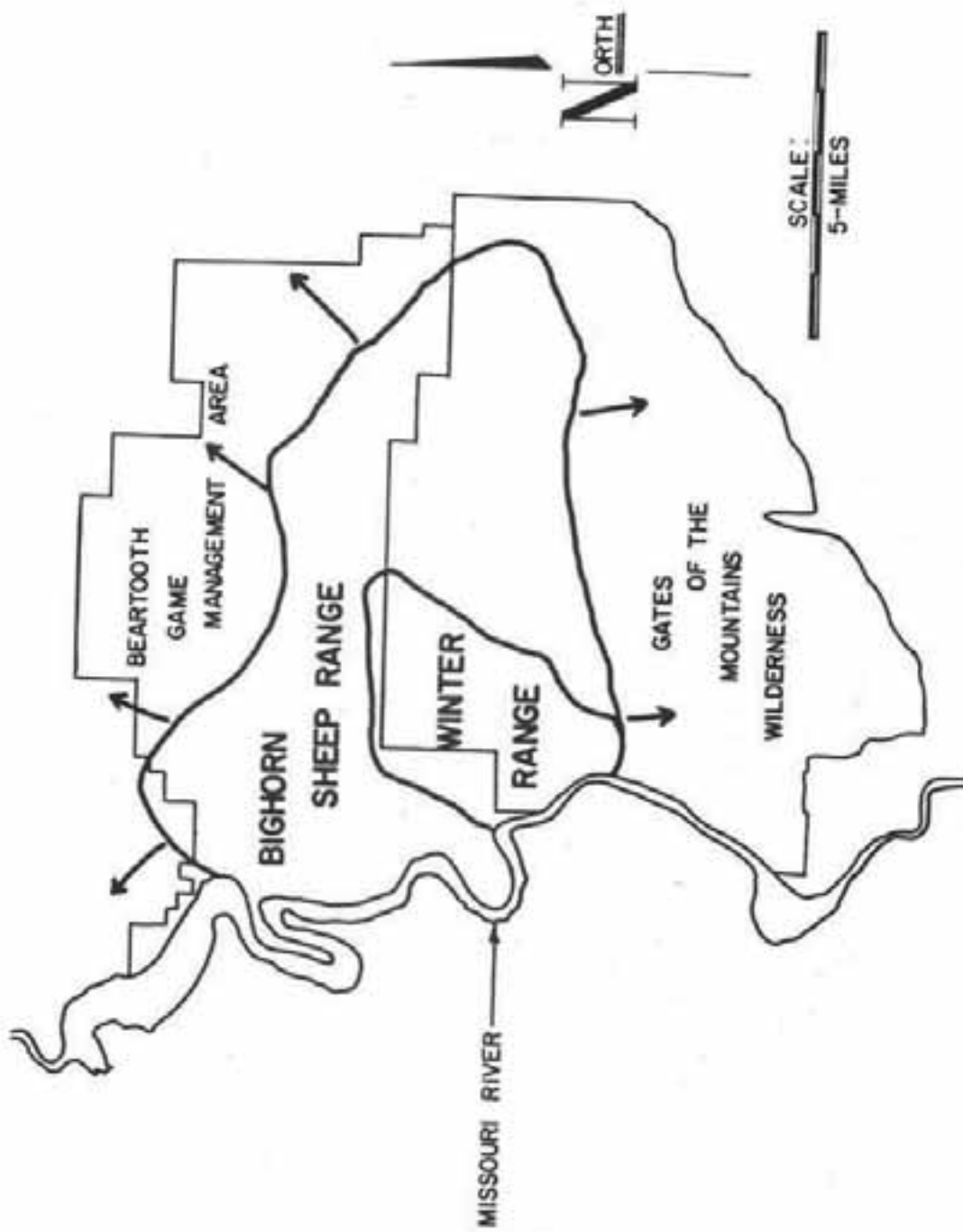


Figure 2. Currently occupied bighorn sheep range in the Beartooth Game Management Area and the Gates of the Mountains Wilderness. The arrows indicate directions of active range expansion.

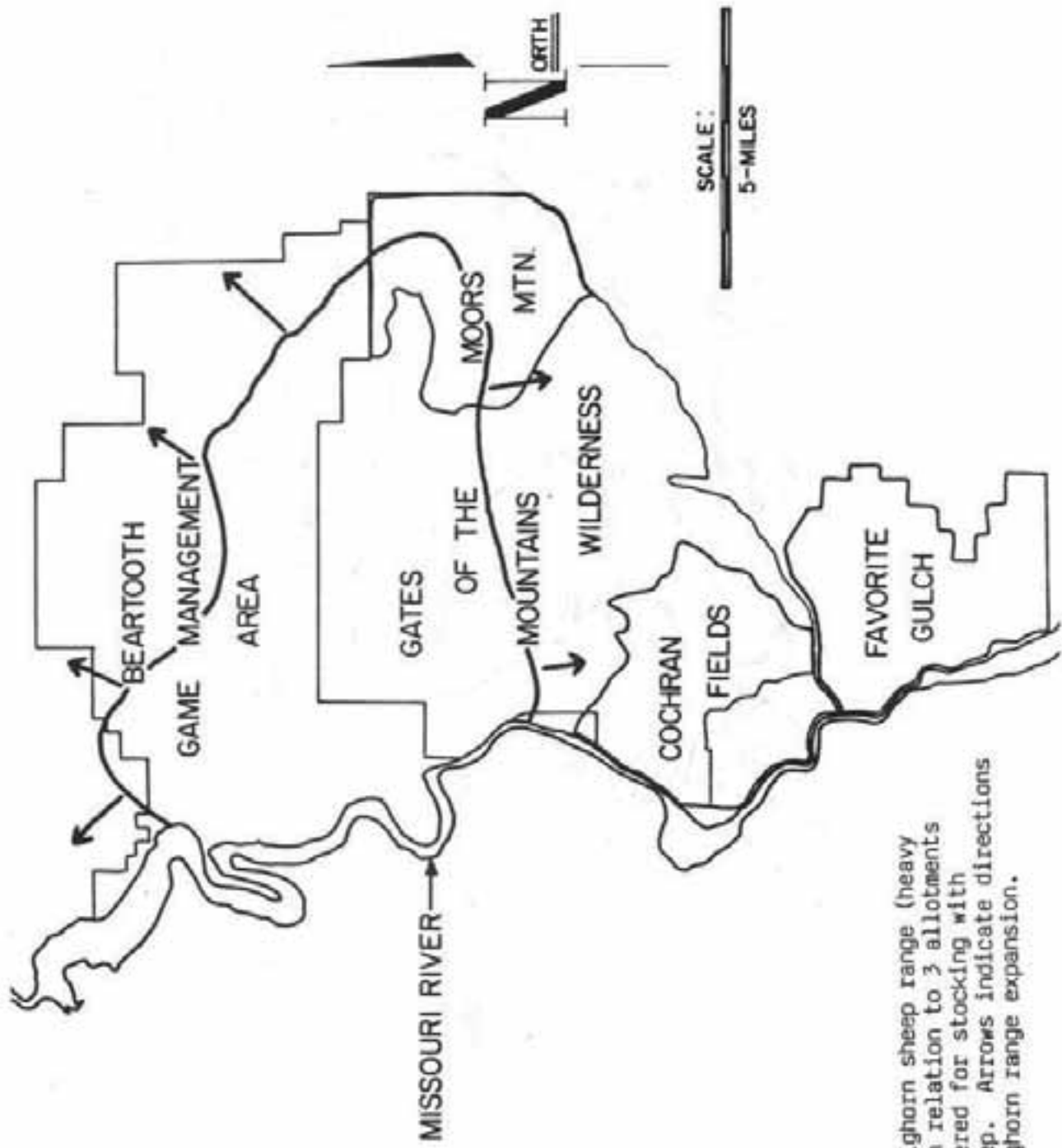


Figure 3. Bighorn sheep range (heavy dark line) in relation to 3 allotments being considered for stocking with domestic sheep. Arrows indicate directions of active bighorn range expansion.

I am indebted to a number of biologists who generously provided me with personal observations and/or unpublished reports. They are individually acknowledged throughout the paper. The United States Forest Service (USFS), Helena National Forest, provided support during preparation of this paper.

METHODS

This paper is based on review of published and unpublished findings and personal communications with wildlife biologists and range conservationists.

RESULTS

HISTORICAL DECLINES

The introduction of domestic livestock onto bighorn sheep ranges in the late 1800's and early 1900's was followed by severe and widespread die-offs of bighorn sheep attributed to scabies, caused by Psoroptes spp. mites (Honest and Frost 1942, Couey 1950, Buechner 1960, Bear and Jones 1973, Jones 1980, Lange 1980) (Table 1). Die-offs coincided with dates of introductions of domestic sheep (Packard 1939, Couey 1950, Buechner 1960, Lange 1980). In northern Colorado, Wyoming and parts of Montana domestic sheep were introduced in the mid-late 1800's and scabies epidemics followed in the 1860's to 1880's. In Canyonlands, where domestic sheep were introduced in 1910, scabies induced die-offs of bighorn followed during 1916-1922 (Dean 1977). The disease was not observed in bighorn prior to the introduction of domestic sheep (Buechner 1960).

Early observers were convinced that bighorn sheep contracted scabies from domestic flocks (Packard 1939, Couey 1950, Buechner 1960, Bear and Jones 1973), however, recent attempts to transfer Psoroptes sp. mites from desert bighorn (O.C. nelsoni), to domestic sheep, elk (Cervus elaphus), mule deer (Odocoileus hemionus) and Rocky Mountain bighorn have been inconclusive (pers. comm. Charles Hibler)⁵. Transient infestations were achieved on domestic sheep, elk, and mule deer. Infestation did not occur on Rocky Mountain bighorn (pers. comm. Charles Hibler).

Uncontrolled hunting for sport and market also impacted bighorn sheep populations during 1860-1900 (Packard 1939, Buechner 1960). Additionally, an encroaching civilization, with its associated roads, fences, and settlements influenced bighorn herds (Packard 1939, Buechner 1960).

⁵ Wild Animal Disease Center, Colorado State University, Fort Collins, Colorado.

Declines of bighorn sheep prior to 1900 probably resulted from several factors, however competition with domestic stock for range and losses due to scabies, believed to be contracted from domestic sheep, were considered of major importance by reviewers (Packard 1939, Honess and Frost 1942, Couey 1950, Buechner 1960, Sugden 1961, Bear and Jones 1973).

Table 1. Die-offs of bighorn sheep attributed to scabies during 1859-1939.

Location	Dates of Die-offs	References
Colorado	1859 - 1931	Lange 1980, Buechner 1960
Utah	1916 - 1922	Dean 1977
Wyoming	1881, 1885	Lange 1980, Buechner 1960
Montana	1880 - 1890	Lange 1980, Buechner 1960
Idaho	1870 - 1880	Smith 1954
California	1870 - 1879, 1898	Lange 1980, Buechner 1960
Oregon	1936	Lange 1980, Buechner 1960

The number of domestic sheep grazed on rangelands in the 11 western states increased to a peak about 1920 and remained high through 1945 (Figure 4) (Wagner 1978). Grazing of domestic sheep on bighorn ranges was widespread. Concurrent with the peak was a pronounced die-off throughout most Rocky Mountain bighorn sheep range in the United States, while similar declines occurred in Rocky Mountain and California bighorn (*O.C. californiana*) in British Columbia (Stelfox 1974). The severe declines of bighorn sheep led to widespread concern among biologists. Some believed bighorn were in danger of extinction (Couey and Schallenberger 1971, Dixon 1940). In 1939, biologists from Colorado, Idaho, Montana and Wyoming formed the Rocky Mountain Cooperative Bighorn Sheep Conference to study the decline of bighorn populations throughout the Rocky Mountains (Capp 1968).

A few examples illustrate declines occurring throughout bighorn range in the western United States (Table 2). In each case grazing by domestic sheep alone or in combination with cattle coincided with a decline or die-off of bighorn sheep.

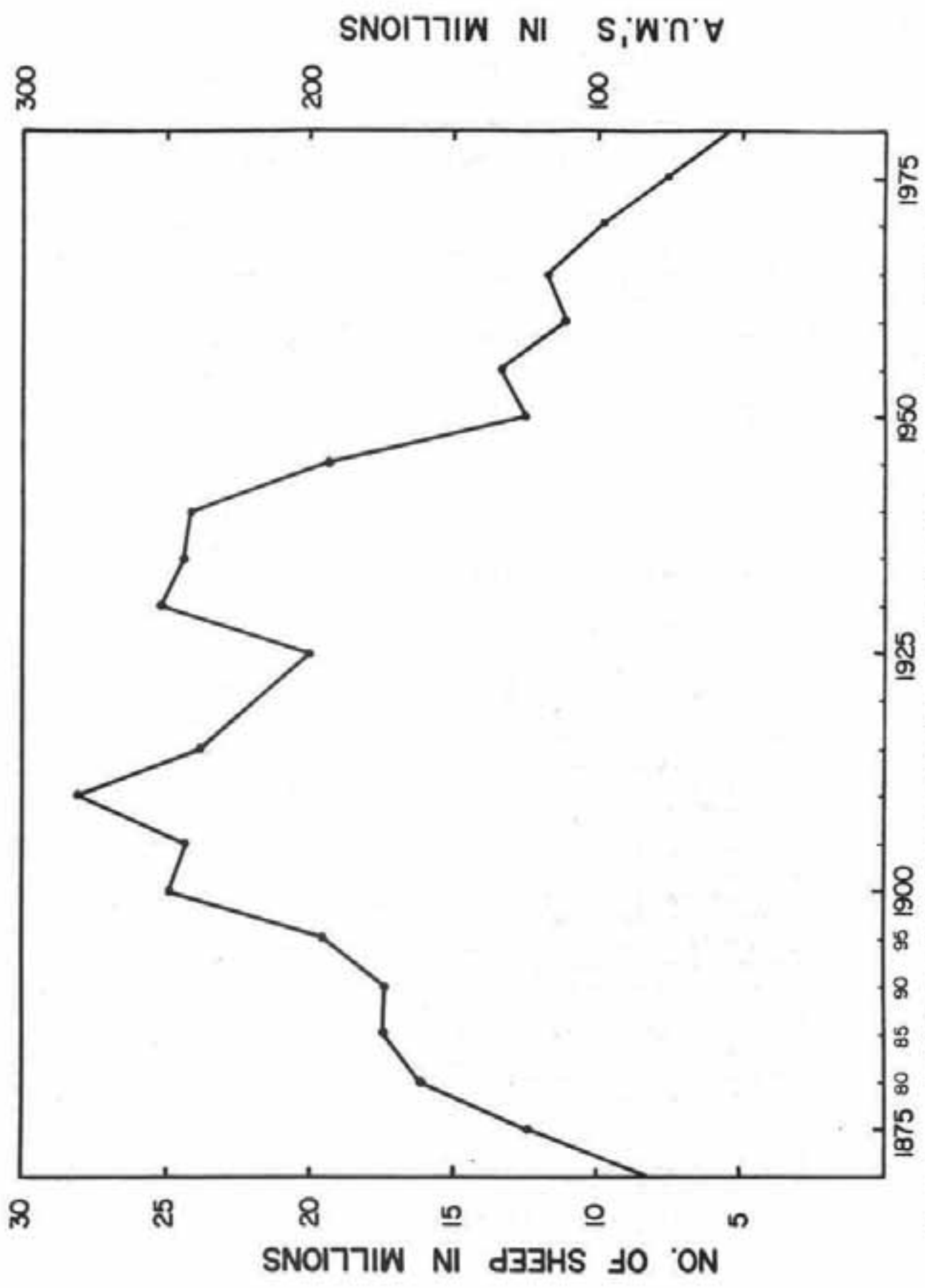


Figure 4. Numbers of domestic sheep grazed on rangelands of 11 western states, 1875-1975 (Wagner 1978).

Table 2. Historical examples of bighorn declines during periods of grazing by domestic sheep.

Location	Dates of Domestic Sheep Grazing	Status of Bighorn Sheep	References
Rocky Mountain National Park Colorado	1917 - 1930	All-age die-off pneumonia	Packard 1939a, Packard 1939b, Shepherd 1976
Rock Creek Montana	1900 - 1920	Bighorn declined to low of 8	Berwick 1968 Aderhold 1972
Dinosaur National Monument, Colorado	1920 - 1950	Severe declines in early 1930's died out completed by 1950	Barmore 1962
Sun River, Montana	1910 - 1925	All-age die-off of 70% of herd	Picton and Picton 1975

RECENT REPORTS

Since 1945, declines in native herds have slowed or stopped and bighorn sheep numbers have increased in several states due to transplants onto historical ranges (Rutherford 1972, Couey and Schallenberger 1971). In many cases, bighorn sheep disappeared from these ranges during periods of heavy grazing by domestic livestock (Buechner 1960, Brown 1974, Goodson 1980, Butts 1980) and were successfully reintroduced after reductions in livestock use, often including removals of domestic sheep.

Declines in grazing of domestic sheep on western rangelands between 1945 and 1978 have been due largely to economic factors including rising costs of transporting and herding sheep and lower prices for wool and mutton (USFS 1976). Most sheep allotments on public lands were not closed but remain vacant if the permittee has relinquished his permit or in a non-use status. Some have been converted to cattle use (Allotment Files, Arapaho and Roosevelt National Forests, Helena National Forest.) Since 1978, improvements in the economics of sheep-raising have resulted in efforts to restock sheep allotments or convert cattle allotments to sheep allotments on public lands in California (USFS 1979), Wyoming (pers. comm. Bruce Johnson)⁶, Colorado (pers. comm. Fritz Foutz)⁷, New Mexico (pers. comm. Kurt Nelson)⁸, Montana, and Oregon (pers. comm. Guy Sheeter)⁹.

⁶ Wyoming Department of Fish and Game, Big Piney, Wyoming.

⁷ USFS, Pine RD, San Juan NF Bayfield, Colorado.

⁸ USFS, Seward RD, Chugach NF, Seward, Alaska.

⁹ BLM, Burns District, Burns, Oregon.

Studies of interspecific competition often involve monitoring the response of one species to the introduction or removal of a second. Changes in public and private land management have provided examples of the reduction, removal and introduction of domestic sheep on bighorn ranges and the responses of bighorn herds. These were not experiments, however, and it is important to note that other variables were not controlled.

Montana

The Upper Rock Creek herd in western Montana was estimated at 150 bighorn in winter 1964-1965, based on an actual count of 103 (Aderhold 1972). The herd had been steadily increasing since the early 1950's with moderate use by cattle and horses on its fall-spring range. On June 1, 1965, 300 domestic ewe-lamb pairs were introduced onto the bighorn fall-spring range and remained until late October (Aderhold 1972). Contact between bighorn sheep and domestic sheep was possible during June. Fall counts indicated a decline to 71 bighorn during the summer. Losses continued through the winter, and by May 61 bighorn remained. An unusually cool and wet summer and fall may have been a factor in the decline (Aderhold 1972). Domestic sheep grazing was reduced in following years, however, the bighorn continued to decline, dying out completely in the early 1970's (pers. comm. Tom Butts)¹⁰.

In 1975, 31 bighorn sheep were transplanted from the Sun River, Montana herd to the Upper Rock Creek range. The transplanted sheep increased to an estimated 150 bighorn by 1981. Factors believed contributing to the success of the transplant were elimination of domestic sheep, establishment of a rest-rotation grazing system for cattle, establishment of a livestock enclosure and control of human disturbance (Butts 1980).

The Thompson Falls bighorn herd in northwestern Montana was estimated at 50 head in 1942 (Brown 1974). From 1940 through 1955, 200 to 500 domestic sheep grazed the bighorn range. Bighorn sheep disappeared from the area during the early 1950's (Brown 1974). In 1959, bighorn were reintroduced (after removal of domestic sheep) and increased rapidly to an estimated 240 in 1974 (Brown 1974).

Shawn Stewart of the Montana Department of Fish, Wildlife and Parks counted 11 bighorn sheep on the Monument Peaks winter range in 1975, after many years of grazing of domestic sheep. Following a management decision (USFS 1976) domestic sheep grazing was eliminated from 95 percent of the bighorn winter range. Domestic sheep were grazed on the remaining 5 percent during 2 years (1977, 1981) since 1975. In 1981, the count on the winter range had increased to 36 bighorn sheep (pers. comm. Shawn Stewart)¹¹.

¹⁰ MDFWP, Roundup, Montana.

¹¹ MDFWP, Red Lodge, Montana

Utah

In 1974, 4000 domestic sheep were grazed on the White Rim of Canyonlands National Park (pers. comm. Bill Bates). Clay Dean, a graduate student at Utah State University found no use by bighorn sheep on the White Rim or west of the White River Road during his studies (1974-76)(Dean 1977). Dean estimated the bighorn herd in Canyonlands at 80-130 head in 1975 when domestic sheep use was terminated. Bill Bates, who is currently completing a graduate study on bighorn in Canyonlands, found bighorn now utilize the White Rim and areas west of the White Rim Road within .8 kilometer (.5 mile) of escape terrain. Since 1975, the population has increased rapidly and is currently estimated to number over 500 (pers. comm. Bill Bates ¹², Mike King ¹³, Gar Workman ¹⁴). Other factors which may have contributed to depressed bighorn sheep populations during the 1950's and 1960's were disturbance due to uranium mining and poaching by miners (Dean 1977).

Nevada

Jessup (1981) reported an all-age die-off of bighorn sheep in the Mormon Mountains of Nevada. Although domestic sheep normally are grazed only at the base of the Mormon Mountains, prior to the die-off two domestic sheep were observed running with a band of bighorn. Bronchopneumonia was identified in 4 hunter-killed bighorn examined. Counts indicated a 50 percent decline from approximately 600 to 300 bighorn sheep.

New Mexico

The bighorn herd in the Latir Peaks Wilderness of northern New Mexico was the result of a transplant of 20 bighorn in fall of 1978. In spring 1981, 36 bighorn sheep were counted and the herd was estimated at 50 head (pers. comm. Kurt Nelson, Stephen Henry¹⁵). In mid-July 1981, 115 domestic sheep were allowed to graze the allotment, which had been vacant for 10 years. The area grazed included parts of the summer range used regularly by bighorn sheep. By the end of July coughing bighorn were observed. During August-October coughing, rough, dry hair coat, lethargy and weak condition were noted in the bighorn, and only 10-12 individuals could be located. Four carcasses were found before winter weather ended field investigations. Necropsies indicated bronchopneumonia was the cause of death of all 4 sheep (pers. comm. Stephen Henry, Kurt Nelson, Charles Hibler). All radio-collared sheep were found dead during field

¹² Department of Fisheries and Wildlife, Utah State University, Logan, Utah

¹³ Department of Fisheries and Wildlife, Utah State University, Logan, Utah

¹⁴ Department of Fisheries and Wildlife, Utah State University, Logan, Utah

¹⁵ New Mexico Department of Game and Fish, Santa Fe, New Mexico

Hibler). All radio-collared sheep were found dead during field investigations in 1982, and no live sheep were observed indicating a complete die-off (pers. comm. Stephen Henry).

Colorado

Bear and Jones (1973) reported 12 bighorn sheep herds in Colorado with domestic sheep grazing on their ranges prior to 1970. In the late 1960's and early 1970's, nine of these herds experienced significant reductions or complete removals of domestic sheep from their ranges (Table 3). Six of the herds (67 percent) experiencing reductions have increased. For the Dinosaur National Park herd no counts are available; however, there is some evidence that the herd may be expanding its range into areas used by domestic sheep and cattle prior to 1975 (pers. comm. Gary Skiba)¹⁶. On the ranges of three herds (25 percent) domestic sheep grazing has remained the same and bighorn numbers have remained fairly constant. Only two of these herds have been treated for lungworms (Hibler et al. 1976), Georgetown and Ouray, and neither of these herds increased significantly (Table 3). Of 14 herds in 1970 without domestic sheep grazing, seven have increased; however, five of these have been treated for lungworm (Table 4). Overall six of nine herds treated for lungworm have increased and six of the nine herds experiencing reductions or removals of domestic sheep have increased (Tables 3,4).

Canada - British Columbia

In British Columbia, three die-offs of bighorn sheep have occurred since 1939, following contact between bighorn sheep and domestic sheep on their ranges. The 8 herds involved in one or more of the die-offs winter on contiguous ranges spanning over 130 map kilometers (80 map miles) on the Rocky Mountain Trench (pers. comm. Ray Demarchi¹⁷, Peter Davidson¹⁷, Bandy 1968).

In 1939, approximately 100 domestic sheep were introduced onto the range of the Radium-Stoddard bighorn herd near Kootenay National Park. In the fall of 1939, bighorn rams were observed breeding domestic ewes. A die-off of bighorn began the following winter. Hemorrhagic septicemia (pneumonia) was diagnosed as the proximate cause of death. Over the next several years the die-off spread through adjacent bighorn herds (pers. comm. Ray Demarchi, Peter Davidson).

A second die-off began in the Bull River bighorn herd in January 1965 (Bandy 1968, Demarchi 1980). Domestic sheep had not been grazed on this range except for a period in 1955 (Smith 1955, Demarchi 1980). In 1961, or 1962, a sheep rancher began grazing about 150 head of domestic sheep on the bighorn range. In January 1965, bighorn sheep were observed feeding on haystacks in the rancher's field with his domestic sheep. Several bighorn died, apparently from rumen compaction (Demarchi 1980). A die-off in the bighorn followed which reduced the herd from about 250 to 8 head.

¹⁶ Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado.

¹⁷ Fish and Wildlife Branch, Cranbrook, British Columbia.

Table 3. Trends of Bighorn Sheep Herds in Colorado with Domestic Sheep Grazing in 1970.

Bighorn Range	Domestic Sheep Grazing 1960-1970 ¹	Domestic Sheep Grazing Pressure 1970/1980		Trend	Population Estimates Bighorn Sheep	
		Trend %	% Reduced		1970 ¹	1980 ²
Cimarron Peak	Heavy	Down	100 ³	Up	40	75
Gore Range	Moderate	Stable	0 ⁴	Stable	40	75
Lake City	Heavy	Down	25 ⁵	Up	70	90
Ouray Pole	Moderate	Stable	10 ⁵	Stable	90	100
Mountain	Moderate	Stable	0 ⁶	Stable	14	14
Redstone	Moderate	Down	100 ⁴	Up	25	60
San Luis Peak	Heavy	Down	50 ⁵	Up	150	200
Sheep Mountain	Moderate	Down	100 ³	Stable	40	40
Snowmass	Moderate	Down	100 ³	Up	25	75
Vallecito	Heavy	Down	100 ³	Up	12	30
Dinosaur National Monument	Moderate	Down	100 ⁷	? ⁷	? ⁷	? ⁷
Georgetown	Moderate	Down	100 ⁸	Down	75	40

1 Bear and Jones 1973.

2 Schmidt and Rutherford 1980.

3 pers. comm. Dave Cook, Fritz Foutz, San Juan, NF, Durango, Colorado.

4 pers. comm. Bernie Rios, White River NF, Glenwood Springs, Colorado.

5 pers. comm. Fred Wilde, Duane Harp, Grand Mesa, Uncompahgre and Gunnison National Forests, Delta, Colorado.

6 pers. comm. John Verner, Rio Grande NF, Monte Vista, Colorado.

7 pers. comm. Gary Skiba, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado

8 Allotment Files, Roosevelt and Arapahoe National Forests, Fort Collins, Colorado

Table 4. Trends of bighorn sheep herds in Colorado without domestic sheep grazing.

	Population Estimates Bighorn Sheep			Dates of Lungworm Treatment ²
	Trend	1970 ¹	1980 ²	
Collegiate Range	Up	100	200	1976-79
Battlement Mesa	Stable	35	35	
Buffalo Peaks	Up	50	110	
Clinetop Mesa	Stable	15	15	
Mt. Evans	Up	160	250	1976-77
Poudre Canyon	Up	75	250	1976-79
*Pikes Peak	Down/Up	300	200	1976-79
Rocky Mountain National Park	Stable	200	200	
Tarryall	Up	100	250	1976-79
Taylor River	Down	40	30	1977-78
Trickle Mountain	Up	175	500	1976-79
Waterton	Stable	80	80	
Arkansas River	Stable	20	30	
Sangre de Cristos	Up	70	100	

¹ Bear and Jones 1973.

² Schmidt and Rutherford 1980.

*This herd underwent a decline and subsequent increase during 1970-1980.

The die-off spread north through 6 contiguous bighorn ranges covering a 130 kilometer (80 mile) span during the next 2 years. About 70 percent of the bighorn in 6 herds died (Bandy 1968). The Radium-Stoddard, Wigwam and Kootenay Park herds were affected. Bighorn died from acute pneumonia. Pasteurella multocida bacteria were isolated from bighorn during the die-off. Heavy lungworm (Protostrongylus spp.) burdens were also found in the bighorn (Bandy 1968). The die-off was sudden and unexpected since the bighorn herds had maintained stable population densities for over 10 years. Most of the herds involved in the die-off recovered to pre-die-off levels within the next 10-20 years, however, the Bull River herd has recovered very slowly and is currently estimated at 50 head.

A third die-off began during the winter of 1981-82 on the Maquire Creek-Red Canyon bighorn range (Davidson 1982a,b). This traditional year-round range supported about 50 bighorn prior to the die-off. Domestic sheep grazing began about 1978. Generally, domestic sheep were grazed for 3 weeks to 2 months during the summer, however, in October 1981, the bighorn herd was known to be in direct contact with about 60 domestic sheep (Davidson 1982a, b). The die-off began in December with at least 26 bighorn dying during December-January. Necropsies of 2 bighorn indicated acute pneumonia was the cause of death. Pasteurella spp. bacteria were isolated from 1 ram. Both bighorn had heavy lungworm burdens. (Davidson 1982a, b).

Bighorn on the Wigwam winter range about 1.6 kilometers (1 mile) north of the Maquire Creek-Red Canyon range began dying in late March 1982. During the next 3 weeks about 150 bighorn (50 percent of the herd) died. An acute bronchial pneumonia was the cause of mortality. Pasteurella multocida was found in necropsied sheep. Little lungworm damage was discovered in bighorn which died during the first 10 days of the die-off.

Seventeen bighorn were transplanted from the Wigwam range to the Bull River range to augment the native herd in mid-March about a week prior to the beginning of the die-off. The transplanted sheep remained in excellent condition for 6 weeks. During the seventh week, 7 of them developed acute pneumonia. Pasteurella multocida was isolated from 2 ewes which were necropsied. The ewes carried moderate-heavy lungworm burdens. The transplanted sheep had been foraging on green vegetation for about 5 weeks prior to the die-off (Davidson 1982a, b). The native Bull River sheep remained healthy.

The die-off continued to spread during the summer and by fall 1983, 8 herds were affected including most of the herds involved in the first 2 die-offs. Bighorn were dying on summer ranges where densities were low. Lungworm burdens in most of the herds were low. While the ranges of most of these herds were contiguous, one affected herd was over 60 kilometers (40 miles) from the nearest die-off and two herds between appeared unaffected (as of fall 1982) (pers. comm. Peter Davidson). Total mortality from this die-off will probably equal or exceed the losses of the 1939-42 and 1965-67 die-offs (pers. comm. Peter Davidson).

POTENTIAL COMPETITION MECHANISMS

Competitive interactions between bighorn and domestic sheep can involve direct competition for forage and more subtle interference including social intolerance and disease transmission.

Competition for Forage

Evidence for direct forage competition includes food habits overlap, habitat use overlap and the relative importance of shared foods in the diets of bighorn and domestic sheep. Domestic sheep may utilize the same habitats as bighorn sheep. Steepness is no barrier and they are capable of grazing arid and high elevation ranges (Bowns 1971, McDaniel and Tiedman 1981). These characteristics have frequently made them the preferred livestock on bighorn sheep ranges too high in elevation, rugged or dry for cattle (Allotment files, Arapaho-Roosevelt National Forests and Helena National Forest).

Food habitats of domestic sheep are similar to those of bighorn sheep. On spring and summer ranges, both prefer grasses and forbs (Todd 1972, Johnson and Smith 1980, MacCracken and Hansen 1981). On arid and winter ranges both consume greater proportions of browse (Todd 1972, Browning and Monson 1980, Cook et al. 1962, Olsen and Hansen 1977). Both domestic sheep and bighorn sheep feed selectively on more nutritious forage. Few data are available on food habits of domestic sheep and bighorn sheep on shared ranges. Stewart (1975) found domestic sheep preferred and heavily utilized sedges and bluegrass which were extremely important in the diet of bighorn sheep on shared summer ranges in southern Montana.

Social Intolerance

Typically, domestic sheep on mountain ranges are grazed in large bands, often of 1000 or more managed by a herder using several dogs (Allotment files, Arapaho and Roosevelt National Forests, Helena National Forest). After passage of such a band little forage may remain. It is impossible, based on casual observation, to separate the effects of domestic sheep, dogs, human herders and forage removal. Bighorn sheep avoid domestic bands on their ranges; in Colorado, in the Never Summer Range, on San Luis Peak, on Pole Mountain, and in the Gore Range (Bear and Jones 1973), and in Dinosaur National Park (Barmore 1962); in Utah, in Canyonlands National Parks (Dean 1975, Dean and Spillet 1976, Dean 1977), in Wyoming, on the Carter Mountain Alpine Research Area (Thilenius 1975), and in Montana on Monument Peak (USFS 1976). Removals of domestic sheep from bighorn ranges in the Never Summer Range, on San Luis Peak and in Canyonlands National Park were followed by expansion of bighorn sheep distribution into areas formerly used by domestic sheep (Bear and Jones 1973, pers. comm. Bill Bates). Duane Harp (pers. comm.)¹⁸ mentioned bighorn on the Lake City range maintain a "buffer zone" between themselves and domestic sheep and

¹⁸ Duane Harp, USFS.

that the zone is greater during the lambing period. David Reeder (pers. comm.)¹⁹ mentioned bighorn used areas domestic sheep "could not get to" and considered such areas important to the survival of bighorn, Tom Thorne (pers. comm.)²⁰ noted domestic sheep tended to use the more level and mesic meadows while bighorn remained on steeper slopes on shared ranges. Thilenius (1975) noted bighorn used alpine ranges in Wyoming mainly before and after domestic sheep were present. In Canyonlands, bighorn expanded their distribution onto areas of gentle terrain up to .8 kilometer (.5 mile) from escape cover after domestic sheep were removed (pers. comm. Bill Bates).

These observations suggest that social intolerance may limit bighorn distribution and habitat use on shared ranges before forage competition. In Canyonlands, although surplus forage existed on some areas used by domestic sheep, bighorn did not use these areas until domestic sheep were removed (Dean 1977, pers. comm. Bill Bates).

Disease Transmission

Bighorn sheep are closely related to domestic sheep. They readily hybridize to produce fertile offspring (Monson and Sumner 1980). They are susceptible to virus-caused diseases (bluetongue, contagious ecthyma), bacteria-caused diseases (pasteurellosis, paratuberculosis), parasites (nasal botfly-induced chronic sinusitis, psoroptic scabies), and other pathogens (*Chlamydia* spp. induced pinkeye) that also affect domestic sheep (Jessup 1979, Hibler in press, pers. comm. Charles Hibler). While some of these diseases are currently controlled in domestic sheep (scabies), other are still common (pasteurellosis, contagious ecthyma, chronic sinusitis) or difficult to diagnose and control (paratuberculosis) (pers. comm. Charles Hibler, Williams and Hibler this volume). Of these diseases, contagious ecthyma, pasteurellosis, pinkeye, chronic sinusitis, and scabies have caused debilitation and/or death in free-ranging bighorn herds (Samuel et al. 1975, Spraker and Hibler this volume, Bunch in press, Meagher this volume, Lange 1980).

Chronic Sinusitis. Chronic sinusitis is currently considered to be an important cause of mortality in desert bighorn. According to a recent review (Bunch in press) chronic sinusitis has been found in bighorn populations throughout the warmer and drier parts of their range including Arizona, California, Nevada, New Mexico, and Utah. Prevalences as high as 45 percent in ewes and 27 percent in rams have been found in free-ranging herds. Severity is greater in desert regions where environmental conditions favor the nasal bot fly and where bighorn sheep concentrate at limited water sources which increase their vulnerability to fly strike. The disease is considered to be terminal in bighorn sheep and has

¹⁹ USFS, Lander Ranger District, Shoshone NF, Lander, Wyoming.

²⁰ Wyoming Game and Fish Department, Game and Fish Research Laboratory, Laramie, Wyoming.

contributed to the decimation of some herds and limits productivity of others (Bunch in press). Chronic sinusitis was introduced with domestic sheep and its occurrences in bighorn is the result of association with domestic sheep (Hibler in press). Currently, management recommendations are to maintain at least a 2-mile buffer between densities and bighorn sheep (Bunch 1978, USFS 1978).

Pasteurellosis. Two recent die-offs of bighorn sheep from acute bronchopneumonia following association with domestic sheep were reported by Foreyt and Jessup (1982). Both incidents involved healthy bighorn herds which were in enclosures for 10 months or more before the deaths occurred suggesting that capture stress or acclimatization to the new habitat was not a problem. In each case, nose to nose contact with domestic sheep was followed within weeks by a die-off. In Lava Beds National Monument, California, all 43 bighorn died. In Washington, at the Methow Game Range, one ewe of 14 bighorn survived. No sickness or mortality was reported in the domestic sheep. Circumstantial evidence suggests that apparently healthy bighorn sheep transmitted pneumophilic bacteria (Pasteurella multocida was isolated in the California outbreak) to the bighorn sheep resulting in mortality (Foreyt and Jessup 1982).

These incidents are similar to others experienced by researchers attempting to maintain bighorn sheep in captivity in association with domestic sheep. While bighorn sheep are generally prone to pneumonia in captivity (Spraker 1977) association with domestic sheep seems to significantly increase the probability of developing pneumonia. Incidents of apparently healthy adult bighorn in captivity dying from pneumonia shortly after exposure to domestic sheep have occurred at Utah State University (pers. comm. J. Juan Spillet)²¹, University of British Columbia (pers. comm. Daryll Hebert)²² and Colorado State University (pers. comm. Charles Hibler). Workers at the Sybille Wildlife Research Unit of the Wyoming Department of Fish and Game have spent years developing a cross-bred bighorn-domestic sheep herd for research purposes. They found bighorn sheep and the hybrid offspring of bighorn-domestic crosses to be more susceptible to pneumonia than domestic sheep maintained under the same conditions (pers. comm. Tom Thorne). Hybrid lambs developed pneumonia within the first 3 weeks of life, and prompt treatment was necessary to prevent mortality. Second hand reports related by ranchers in Wyoming indicated the same process occurred in the free-ranging situation (pers. comm. Tom Thorne). When bighorn rams joined their domestic flocks and bred the ewes, the resulting hybrid lambs experienced a remarkably high mortality during the first few weeks of life. These observations are consistent with Foreyt and Jessup's (1982) hypothesis that domestic sheep are more resistant to pneumophilic bacteria than bighorn and are able to carry strains of bacteria capable of causing acute pneumonia in bighorn.

Circumstances of the Rock Creek, Mormon Mountains and Latir Peaks die-offs in the United States and the Radium-Stoddard, Bull River and

²¹ USFS, Caribou NF, Pocatello, Idaho.

²² Fish and Wildlife Branch, Williams Lake, British Columbia.

Maquire Creek-Wigwam die-offs in British Columbia are consistent with the hypothesis that a pathogen transmitted from domestic sheep to bighorn sheep was the cause. In each of these cases, association of bighorn with domestic sheep was followed by an all-age die-off due to acute pneumonia, and significant mortality occurred in summer-fall rather than in winter when a malnutrition problem would be expected. In the Canadian die-offs, the spread of the die-off to adjacent populations suggests contagious spread of a disease. The delayed response of bighorn which were transplanted from the Wigwam range prior to the die-off is consistent with the hypothesis that a pathogen with a variable incubation period rather than a range-related factor triggered the die-off.

MANAGEMENT RESPONSES

Some land and wildlife management agencies have responded to the available information on interactions between domestic sheep and bighorn sheep by developing direction or guidelines or by specific management decisions. In 1954, the Colorado Division of Wildlife purchased 630 acres on the Pikes Peak bighorn range to prevent grazing of domestic sheep (Bear and Jones 1973). The San Bernardino and Angeles National Forests in California have a policy against domestic livestock on occupied bighorn range, which has been in force since 1967 (Light et al. 1967, pers. comm. Steve Loe)²³. The Inyo National Forest, also in California, completed an Environmental Analysis Report in 1979, in which the preferred Forest Service Alternative was not to convert an allotment partially on bighorn sheep range from cattle to domestic sheep. This decision was based largely on concern about the potential for disease transmission between domestic and bighorn sheep (USFS 1979). The San Bernardino National Forest also recently documented a decision not to convert a cattle allotment to domestic sheep use because of its proximity to bighorn range and the potential for disease transmission (USFS 1981). The Bureau of Land Management in Idaho has a policy against grazing domestic sheep within 3.3 kilometers (2 miles) of occupied bighorn range in its Land Management Plan for 1 resource area (pers. comm. Alan Sands)²⁴.

In April 1981, Dale Jones, Director of Wildlife and Fisheries, U.S. Forest Service, sent a memo to Regional Foresters in 6 western regions drawing their attention to a note in "The Shepherd" (Newsletter of the Society for Conservation of Bighorn Sheep) which referred to the die-offs at Lava Beds National Monument in California and at the Methow Game Range in Washington reported by Foreyt and Jessup (1982). Jones stated, "Although this is not conclusive evidence, it indicates that domestic sheep are a probable source of infection of bighorns and underscores the need to assess carefully the probability of disease transmission where domestic sheep are permitted to graze on bighorn sheep range or where domestic

²³ USFS, San Bernardino National Forest, San Bernardino, California.

²⁴ BLM, Boise District, Boise, Idaho.

sheep may come into contact with bighorn held within enclosures, etc. Appropriate caution should be exercised to prevent contact between the species" (Jones 1981).

SUMMARY AND DISCUSSION

A review of published and unpublished information provides evidence of incompatibility between bighorn sheep and domestic sheep on shared ranges. Introductions of domestic livestock onto bighorn ranges in the late 1800's were followed by massive die-offs attributed to scabies, believed by contemporaneous observers to have been contracted from domestic sheep. Widespread grazing of domestic sheep on bighorn sheep ranges in the early 1900's was associated with severe declines in bighorn populations throughout bighorn sheep ranges in the western United States and British Columbia. While other factors such as uncontrolled hunting and construction of roads and settlements contributed to declines, competition with domestic livestock for forage and space and diseases, possibly contracted from domestic sheep, were considered the most important factors. In general, bighorn sheep have survived in their most remote and rugged habitats where the impacts of civilization, including competition with domestic livestock have been least (Buechner 1960, McQuivey 1978, Goodson 1980). They have been successfully reintroduced into many historical ranges after reduction in livestock grazing, often including removals of domestic sheep.

Since 1940, declines or die-offs in 7 free-ranging and 2 captive bighorn herds in the U.S. and Canada have been reported following introductions of domestic sheep onto bighorn ranges. Eight bighorn herds have increased significantly following reduction or removal of domestic sheep from their ranges. Interpretation of these observations is complicated by the facts that some bighorn herds have not increased following domestic sheep removal and that some herds have survived for many years with domestic sheep on their ranges. However, no herds I researched with domestic sheep on their ranges are increasing except those on ranges where use by domestic sheep has been significantly reduced. The rest are typically small and static or declining in numbers (Bear and Jones 1973, pers. comm. Dave Reeder, Shawn Stewart). The ranges of large, productive bighorn herds are conspicuously free from domestic sheep grazing, though most experience conservative cattle or horse use on parts of their range. Examples include the Sun River herd in Montana, the Whiskey Mountain herd in Wyoming, the Trickle Mountain and Poudre Canyon herds in Colorado, the Salmon River herd in Idaho, and desert bighorn herds in Nevada (Bear and Jones 1973, Picton and Picton 1975, McQuivey 1978, Thorne et al. 1979, Schmidt and Rutherford 1980. pers. comm. Bill Hickey)²⁵.

Declines and die-offs have occurred in bighorn populations without any known association with domestic sheep (Marsh 1938, Bear and Jones 1973, Feuerstein et al. 1980, Wishart et al. 1980, Simmons this volume). The

²⁵ Idaho Department of Fish and Game, Salmon, Idaho.

proximate cause of mortality in these die-offs as well as those following association with domestic sheep was bacterial pneumonia. Bacteria of the genus Pasteurella, most frequently P. multocida and P. haemolytica, were invariably found when sought (Buechner 1960, Post 1962, Spraker and Hibler in press). However, Pasteurella are also found in the upper respiratory tract of healthy, normal bighorn (Spraker 1977). Several mechanisms have been proposed through which bighorn resistance to infection can be reduced allowing development of pneumonia.

Mortality from stress-induced pneumonia is well-documented in captive bighorn sheep (Spraker 1977). Long term chronic stress due to captivity results in increased output of adrenal hormones which depress the immune responses of bighorn. Lowered defences permit bacteria such as Pasteurella to invade the lungs (Spraker 1977). A similar mechanism may be operative in die-offs of free-ranging sheep under conditions of stress due to disturbance (Simmons this volume), or poor nutrition and crowding (Feuerstein et al. 1980).

Stress-induced immune deficiency can also allow lungworm burdens to increase. Heavy lungworm burdens induced by stress, crowding and/or poor nutrition may compromise lung tissue creating favorable conditions for bacterial attack (Spraker in press). Respiratory irritation, caused by inhaling dust under severely dry conditions may similarly increase the vulnerability of lung tissue (Simmons this volume).

Alternatively, pneumonia may be induced through introduction of virulent strains of Pasteurella (Foreyt and Jessup 1982). Pasteurella spp. occur as antigenically different strains, which differ so much that vaccines effective for one or several strains may be totally ineffective against others. Although bighorn may be capable of carrying some strains without ill effects, others may induce acute pneumonia.

Circumstantial evidence reviewed in this paper indicates grazing of domestic sheep on bighorn ranges can precipitate bighorn declines or die-offs. Domestic sheep can negatively affect bighorn sheep through direct forage competition and restriction of bighorn distribution and habitat use through social avoidance, thereby causing crowding and/or poor nutrition of bighorn. Bighorn resistance to infection may be lowered due to stress caused by crowding, poor nutrition and/or harassment caused by the presence of domestic sheep and their associated dogs and herders. Additionally, domestic sheep may carry virulent strains of Pasteurella capable of inducing severe pneumonia in healthy bighorn. In addition to Pasteurella, domestic sheep may carry a number of other diseases which can continually challenge the bighorn population causing subtle or dramatic increases in mortality.

Current bighorn populations in the western United States are estimated to be 1 percent of pre-settlement numbers (Wagner 1978). Following enormous losses in the 1800's and early 1900's, bighorn populations have remained low, in contrast to the remarkable recoveries of elk and mule

deer. Bighorn have shown less tolerance of poor range conditions and interspecific competition than other wild ungulates and greater susceptibility to disease. They are less able to adapt to rapid habitat changes and increased harassment resulting from the development of their ranges for man's use (Buechner 1960, Goodson 1980). Conservation of bighorn herds requires careful management which minimizes the potential for interspecific competition and disease. On ranges where bighorn sheep are considered an important resource, domestic sheep should not be introduced. Where domestic sheep are currently grazed on bighorn ranges, reduction or elimination of such use is recommended if enhancement of bighorn status is a management goal.

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