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WILDLIFE HABITATS IN MANAGED RANGELANDS-- THE GREAT BASIN OF SOUTHEASTERN OREGON

BIGHORN SHEEP

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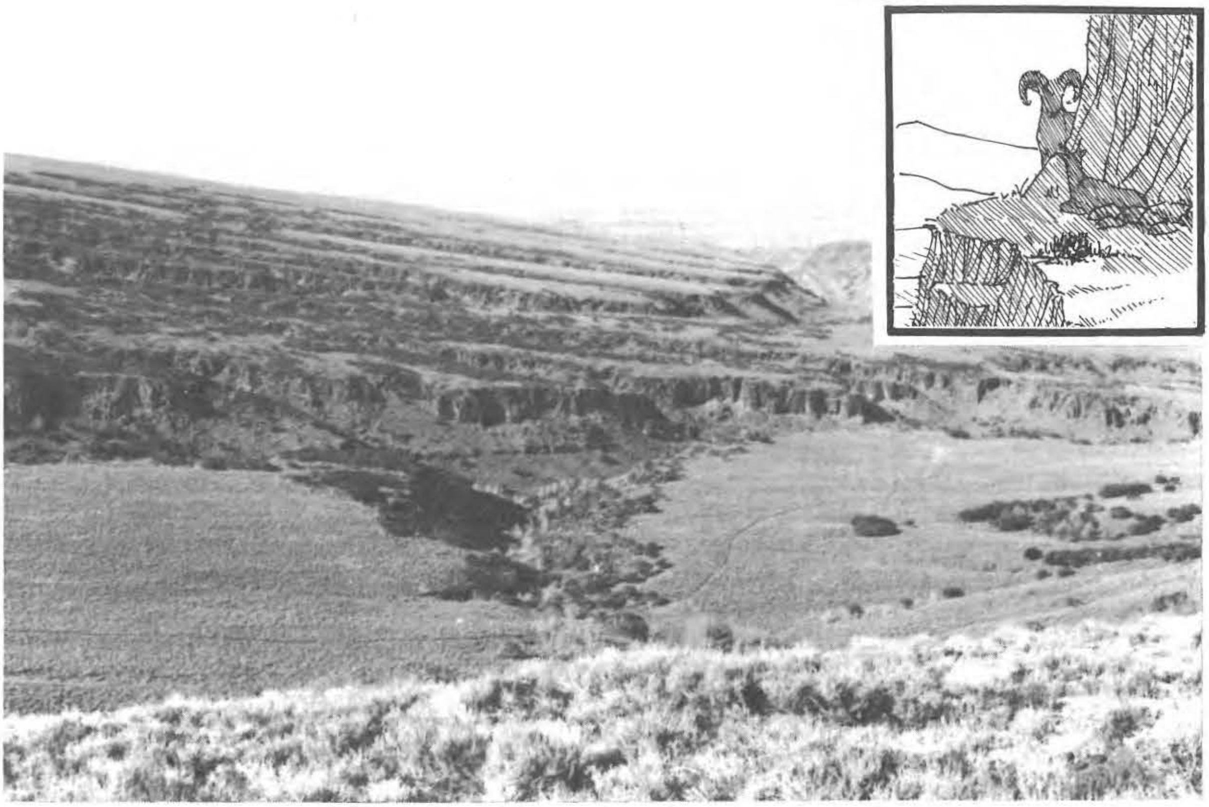

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
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Abstract

Habitat in southeastern Oregon that was used by California bighorn sheep until about 1916 can be managed to maintain herds that have been reintroduced into the area and to accommodate additional herds. Survival and productivity are enhanced by management based on an understanding of the animal's needs. These include appropriate interspersion of adequate water, forage, and escape terrain, lack of competition with other grazing ungulates for food and water, and absence of disturbance.

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This publication is part of the series **Wildlife Habitats in Managed Rangelands—The Great Basin of Southeastern Oregon.** The purpose of the series is to provide a range manager with the necessary information on wildlife and its relationship to habitat conditions in managed rangelands in order that the manager may make fully informed decisions.

The information in this series is specific to the Great Basin of southeastern Oregon and is generally applicable to the shrub-steppe areas of the Western United States. The principles and processes described, however, are generally applicable to all managed rangelands. The purpose of the series is to provide specific information for a particular area but in doing so to develop a process for considering the welfare of wildlife when range management decisions are made.

The series is composed of 14 separate publications designed to form a comprehensive whole. Although each part will be an independent treatment of a specific subject, when combined in sequence, the individual parts will be as chapters in a book.

Individual parts will be printed as they become available. In this way the information will be more quickly available to potential users. This means, however, that the sequence of printing will not be in the same order as the final organization of the separates into a comprehensive whole.

A list of the publications in the series, their current availability, and their final organization is shown on the inside back cover of this publication.

Wildlife Habitats in Managed Rangelands—The Great Basin of Southeastern Oregon is a cooperative effort of the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, and United States Department of the Interior, Bureau of Land Management.

Introduction

Bighorn sheep[1] were once abundant throughout Western North America. Since 1900, however, they have declined in most areas (fig. 1) and many populations have been eliminated (Buechner 1960, Wagner 1978). Population declines have been attributed to hunting, to parasites and disease, and to competition with domestic livestock for forage, and with humans for space (Buechner 1960, Davis and Taylor 1939, Honess 1942, Honess and Frost 1942, Packard 1946). Wildlife agencies in the western regions of Canada, the United States, and Mexico have initiated programs to maintain or enhance existing populations of bighorn sheep and to reintroduce them into historic ranges (Spalding and Mitchell 1970, Trefethan 1975). But, unless there is better land management, a decline of 8 percent can be expected in the next 25 years on land managed by the Bureau of Land Management (BLM), U.S. Department of the Interior (Jahn and Trefethen 1978).

In the Great Basin the situation is somewhat different. Although some transplant attempts have failed (Trefethan 1975), the States have been successful in reintroducing bighorn sheep into some historic ranges (Trefethan 1975, Yoakum 1973).

Three subspecies of bighorn sheep were endemic to the Great Basin in the past: Rocky Mountain, California, and desert bighorns (Bailey 1936, Buechner 1960, Cowen 1940, Hall and Kelson 1959, Seton 1929). The California bighorn sheep, indigenous to the southeastern Oregon portion of the Great Basin, disappeared around 1916 (Bailey 1936). As a result of transplants, the area again has several populations of California bighorn sheep (Trefethan 1975). If these once-native sheep are to remain, it is essential to maintain or enhance habitats that meet their biological requirements.

Bighorn sheep have evolved unique social and behavioral traits. They occupy traditional ranges and are slow to pioneer new habitats (Geist 1971). This means that careful manage-

[1] Scientific and common names and their sources are listed in the appendix.

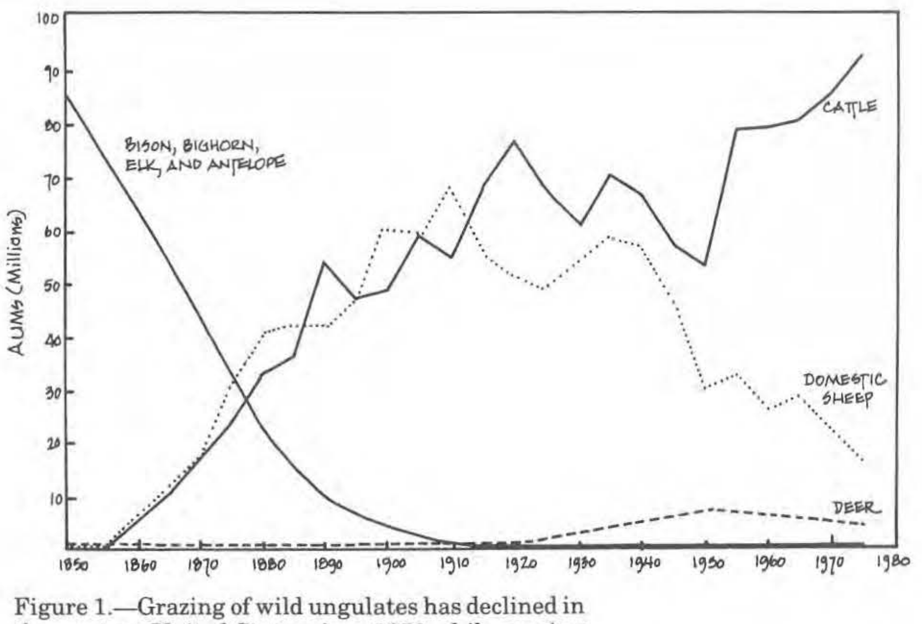

Figure 1.—Grazing of wild ungulates has declined in the western United States since 1850 while grazing of domestic ungulates has increased (redrawn from Wagner 1978:137).

ment of the habitat of existing herds is critical. Much habitat used by herds in the past is publicly administered and is suitable for additional transplant attempts (Yoakum 1971, 1973). Some publicly administered habitat, however, is now unsuitable because of past abuse (McCutchen 1981). Management techniques are available to make these areas again suitable for bighorn sheep, and interim management should not preclude opportunities to reestablish herds in the future.

Our purpose is to help land and wildlife managers evaluate, maintain, and enhance habitat for bighorn sheep by providing information that will enable them to: (1) recognize potential habitat on the basis of geomorphic features and plant communities; (2) predict the consequences of management actions; and (3) select appropriate management alternatives.

Information in this chapter was developed specifically for California bighorn sheep habitat in the Great Basin of southeastern Oregon. Few scientific studies of bighorn sheep habitat and management have been made in that part of the Great Basin. Consequently, we have used some information from other areas of the Great Basin or from other regions. Because such studies have frequently dealt with the desert or Rocky Mountain subspecies, the information presented here should have application to all bighorn sheep, with appropriate local adjustments.

We have made the following assumptions:

1. Extensive areas of historic habitat, presently unoccupied by bighorn sheep, can support herds or can be made capable of supporting herds.

2. Land uses can be tailored to provide areas of sufficient size to maintain viable populations.

3. Where there are conflicts between bighorn sheep and other ungulates for forage, water, or cover on public land, it may be necessary to give priority to bighorn sheep.

4. The information presented here is concerned with maintaining natural populations of free-ranging wild sheep; we are not addressing situations where populations can be maintained only by artificial means.

Characteristics of Habitat

Bighorn sheep generally inhabit remote, steep, rugged terrain, such as mountains, canyons, and escarpments where precipitation is low and evaporation is high (fig. 2). Plant communities are usually low and open in structure and stable, at or near climax. Sagebrush/grassland steppes and cold desert shrublands are the dominant types.

Bighorn sheep ranges in southeastern Oregon include several plant communities (Dealy et al. 1981) that reflect variations in elevation, slope, aspect, soil type, and precipitation (fig. 3). Summer ranges vary from subalpine meadows or grasslands at elevations above 2 287 meters (7,500 ft), to sagebrush/grasslands or shrublands that are dominant at elevations above 1 220 meters (4,000 ft). Winter ranges are usually below 1 830 meters (6,000 ft) and are characterized by shrub/grasslands or shrublands. Communities dominated by trees or tall shrubs such as aspen, cottonwood, fir, pine, juniper, mountainmahogany, squaw apple, and cherry, may occur throughout both summer and winter ranges, but there are no large densely forested areas.

Some bighorn sheep herds are year-long residents on a given area, with little or no spatial separation of summer and winter ranges (Blood 1963a, Drewek 1970, Demarchi and Mitchell 1973, Haas 1979, Kornet 1978, Van Dyke 1978). Other herds migrate several miles between summer and winter ranges and occupy areas that include a variety of elevations and environmental conditions (Blood 1963a, Geist 1971, Shannon et al. 1975). Both summer and winter ranges must provide freedom from disturbance and a proper juxtaposition of forage, escape terrain, and water if viable populations are to be maintained.

The major needs of bighorn sheep are: forage, water, thermal protection, and areas for escape, rutting, and lambing. If forage, water, and escape terrain are available, varying amounts of thermal protection will also be provided and rutting and lambing will normally occur. There are, however, cases where bighorn sheep move to particular areas to rut or lamb (Geist 1971, Kornet 1978). Management should not interfere with this movement.

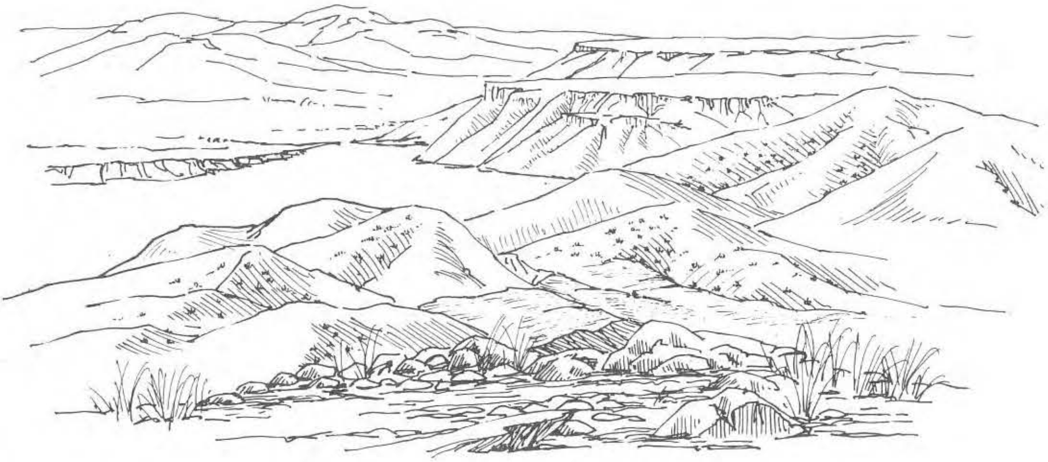

Figure 2.—Mountains, canyons, and escarpments provide bighorn sheep habitat.

Figure 3.—An example of bighorn sheep habitat in southeastern Oregon (photo by Walt Van Dyke).

ESCAPE AREAS

Cliffs, rock rims, rock outcroppings, and bluffs typify escape habitat, which is primarily used for bedding (Davis and Taylor 1939, Hailey 1971, Hansen 1980, Kornet 1978, Van Dyke 1978) and for escape from perceived danger (Frisina 1974, Geist 1971, Hansen 1980, Leslie and Douglas 1979, Woolf 1968). Steep broken cliffs with traversable terraces are desirable; sheer, vertical cliffs are not (fig. 4). Where cliffs are lacking, steep slopes are used for escape (Demarchi and Mitchell 1973). Unstable geomorphic features such as talus are also used for escape and bedding.

We have no specific data on sizes of cliffs suitable for bedding and escape areas. We have estimated minimum size requirements on the basis of criteria provided by Maser et al. (1979). The importance of cliffs varies with size (fig. 5). For example, cliffs that provide thermal cover, bedsites, and escape terrain may not be large enough for lambing.

Figure 4.—Comparison of vertical and terraced cliffs as escape terrain for bighorn sheep.

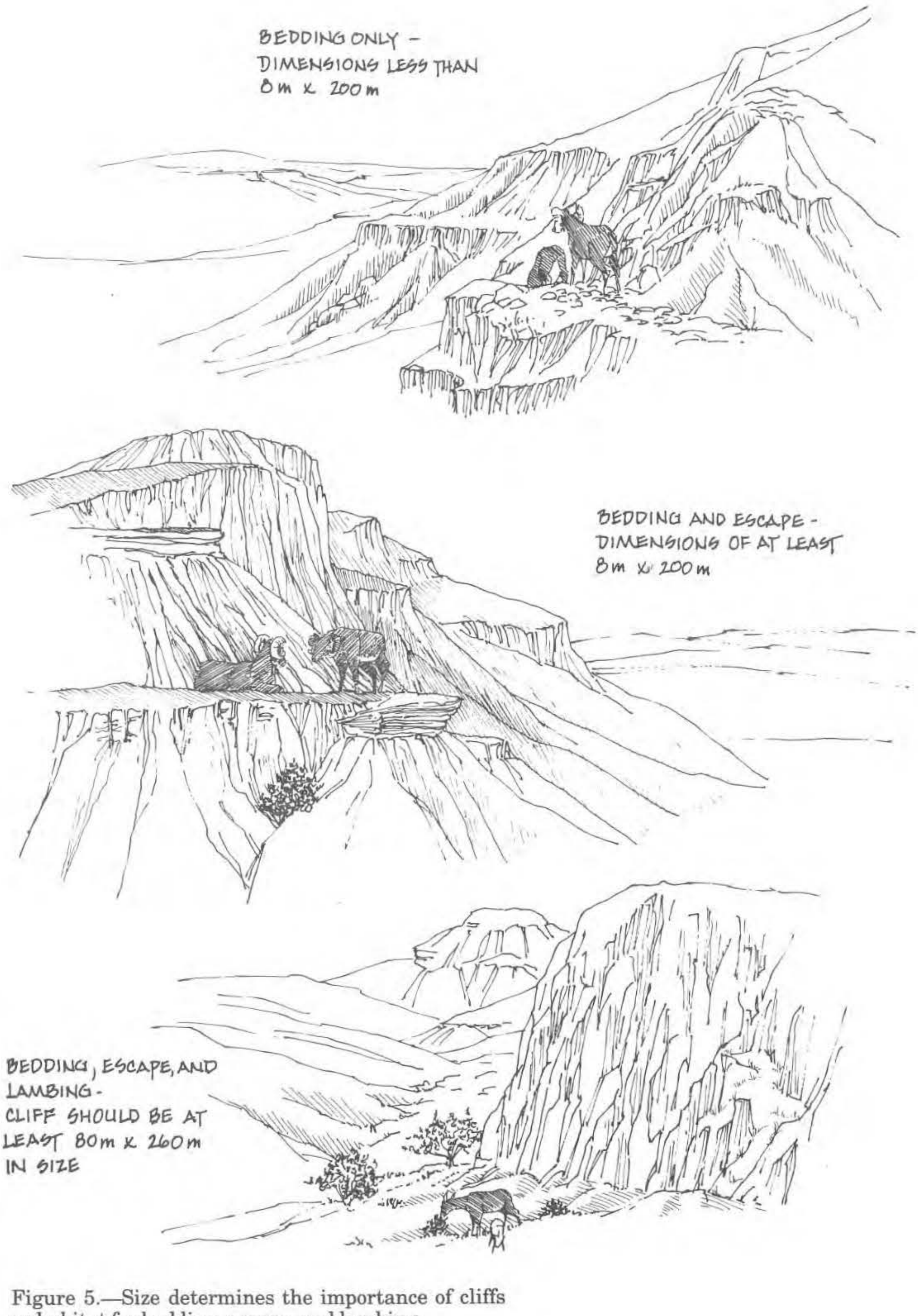

Figure 5.—Size determines the importance of cliffs as habitat for bedding, escape, and lambing.

Cliffs less than 8 meters (26 ft) high by 200 meters (656 ft) long can provide both bedding and thermal areas because they offer some shade in summer and reflect the sun or dissipate absorbed heat in winter. To provide escape terrain cliffs must be at least 8 meters (26 ft) high by 200 meters (656 ft) long or larger (Bailey 1980, McCollough et al. 1980). A series of smaller cliffs with less than 10 meters (33 ft) between them effectively equals a larger cliff. Another way to evaluate cliffs is on the basis of area. Cliffs 0.16 hectare (0.4 acre) and larger can serve as escape terrain as well as bedding and thermal areas, whereas smaller cliffs provide only thermal and bedding areas. To suffice as a lambing area, a cliff or series of cliffs must be at least 2 hectares (5 acres).

Cliffs provide sparse forage and are used for foraging, particularly during lambing season (Van Dyke 1978) and in winter, when forage in adjacent cliffless habitat is unavailable because of crusted snow and ice (Baumann and Stevens 1978, Geist 1971, Geist and Petocz 1977, Shannon et al. 1975). Cliffs do not accumulate as much snow as flatter areas; they reradiate sunrays that melt snow and keep it soft, making it easier for bighorn sheep to paw away snow to obtain forage.

Ewe-lamb groups prefer more rugged topography than ram groups (Blood 1963a, Drewek 1970, Leslie and Douglas 1979) and are more restricted in use of their range (Geist 1971, Leslie and Douglas 1979, Van Dyke 1978). Ram groups will range farther from escape terrain than ewe-lamb groups (Leslie and Douglas 1979). This behavior may be related to their reproductive roles (Geist 1971). Escape terrain may be located above, below, or beside forage and water areas because bighorns can move up or down easily from bedsites to such areas.

The distribution of escape terrain regulates the extent to which other habitat components are used. Most bighorn sheep use forage areas within 0.8 kilometers (0.5 mi) of escape terrain and generally are not seen farther than 1.6 kilometers (1 mi) from escape terrain (Bailey 1980, Denniston 1965, Drewek 1970, Kornet 1978, Leslie and Douglas 1979, McQuivey 1978, Oldemeyer et al. 1971, Van Dyke 1978). Sources of water more than 0.5 kilometer (0.3 mi) from escape terrain receive limited use (Leslie and Douglas 1979). Distances may increase or decrease, depending on the magnitude and frequency of disturbance sheep receive from humans or predators. In general, use decreases as the distance from escape terrain increases. (fig. 6).

LAMBING AREAS

Terrain commonly used for lambing is rugged, precipitous and remote (Drewek 1970, Geist 1971, Irvine 1969, Van Dyke 1978) (fig. 7). Such terrain provides pregnant ewes security and isolation for the lambing period, which includes the time lambs need to become strong enough to follow the ewes. Large cliffs and rock outcroppings with sparse cover of trees or shrubs, such as mountainmahogany, afford both thermal and hiding cover to ewes and lambs (Van Dyke 1978). Ideally, adequate forage and water are found within or near lambing areas so ewes with young lambs do not have to venture far to water or forage (Light et al. 1966, 1967). Ewe-lamb groups stay in lambing areas for about a month after lambing before venturing into adjoining, less rugged habitats (Geist 1971, Van Dyke 1978).

Use of lambing areas is frequently traditional but may be altered by lingering deep snow or insufficient forage or water. Lambing occurs on winter, summer, or spring-fall ranges, depending on prevailing environmental conditions, the location of a pregnant ewe at the critical time, and the nature of the available terrain. The birthplace is usually secluded and in rugged terrain. A ewe may travel several kilometers to such an area to give birth (Geist 1971).

Ruggedness and remoteness influence the size of areas required for lambing. If harassment is great, a larger area is more desirable. Ewes appear to select rugged cliffs of at least 2 hectares (5 acres) with dimensions of at least 80 meters (262 ft) by 260 meters (853 ft). Several ewes may lamb within one such area. Adequate size of an area for lambing depends on outside influences. For example, in remote, extremely rugged topography, where harassment is low, only 1 hectare (2.5 acres) may be sufficient.

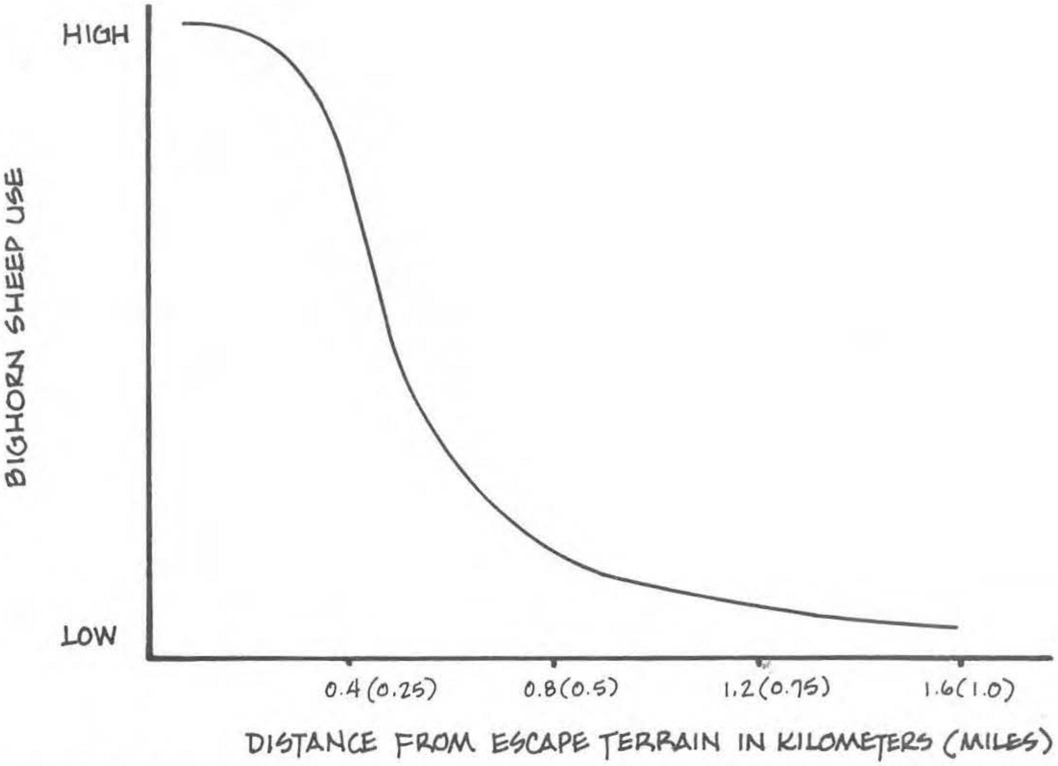

Figure 6.—Distance from escape terrain determines the extent of use.

Figure 7.—Large areas of rugged terrain are preferred for lambing (photo by Walt Van Dyke, courtesy Oregon Cooperative Wildlife Research Unit).

Figure 8.—Plant communities that provide open, low structure are suitable forage areas (photo by Walt Van Dyke, courtesy Oregon Cooperative Wildlife Research Unit).

FORAGE AREAS

Bighorn sheep tend to forage in open areas with low vegetation, such as grasslands, shrublands, or mixes of these (Geist 1971, Hansen 1980, Sugden 1961, Van Dyke 1978) (fig. 8). Perennial bunchgrasses, which make up a large part of bighorn diet (Barrett 1964, Blood 1967, Browning and Monson 1980, Constan 1972, Demarchi 1965, Geist 1971, McQuivey 1978, Pitt and Wikeem 1978, Sugden 1961, Todd 1972) are an important characteristic of these areas.

The importance of grass in a bighorn sheep's diet was substantiated by a study that compared plant consumption in the Great Basin of Nevada to plant availability (Yoakum 1964). On a year-long basis, more grass was consumed (59 percent) than forbs (32 percent), and shrubs (9 percent) (fig. 9). These percentages are noteworthy because a diet primarily of grass was selected from a cold desert where shrubs predominated. Similar findings were reported by Barrett (1964) in Nevada.

A variety of plant species, common to southeastern Oregon, provide important forage for bighorn sheep (table 1). Lists of plant species can be used to predict the importance of areas for forage, but amounts consumed by bighorn sheep will vary with species composition, range condition, and plant productivity.

Although grass is a staple of the bighorn sheep's diet, a variety of browse and forbs are also used seasonally in varying amounts (Johnson and Smith 1980, Todd 1972). On some ranges where grass or forbs are sparse, diets may consist primarily of browse (Howard and Lorenzo 1975). For the most part, bighorn sheep seem to be opportunistic foragers and, if the physical structure of the habitat is appropriate, can adapt their diet to available plant communities—whether they are dominated by grass, forbs, or shrubs (Browning and Monson 1980, Robinson and Cronemiller 1954).

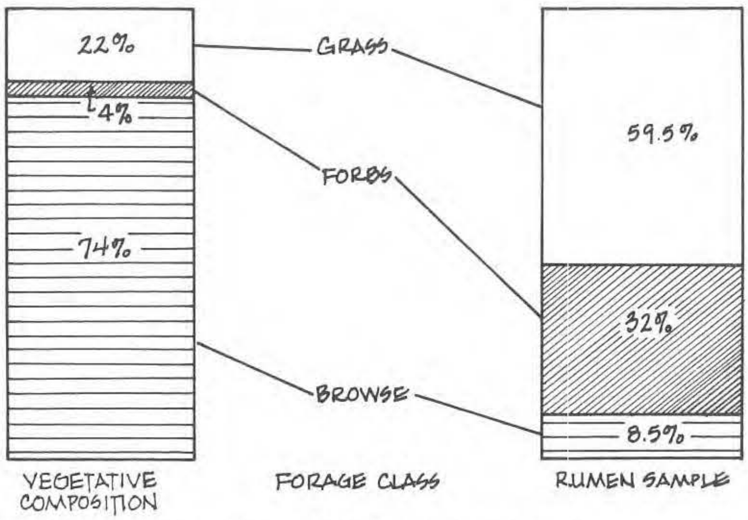

Figure 9.—Comparison of vegetative composition and percent volume of forage classes represented in 12 rumen samples from bighorn sheep on the Silver Peak range, Nevada. (Redrawn from Yoakum 1964)

Table 1—Plants common to the Great Basin of southeastern Oregon and their seasonal occurrence in the diet of bighorn sheep[1]

Plant species by	Level of use[2]			
forage class	Winter	Spring	Summer	Fall
Grasses:				
Bearded bluebunch wheatgrass	H	H	M	M
Idaho fescue	M	M	L	M
Bluegrass	L	H	M	M
Bottlebrush squirreltail	L	L	—	L
Prairie junegrass	L	M	L	L
Pinegrass	L	L	L	M
Indian ricegrass	M	M	—	M
Giant wildrye	M	M	M	L
Cheat grass	L	M	—	—
Sedge	L	M	M	L
Thurber's needlegrass	M	M	L	M
Meadow barley	M	—	—	—
Forbs:				
Arrowleaf balsamroot	L	M	L	—
Phlox	—	—	L	L
Milkvetch	L	L	L	—
Lupine	L	L	L	L
Cushion buckwheat	—	M	M	—
Buckwheat	L	L	L	L
Penstemon	L	—	L	—
Lomatium	M	M	—	—
Erigeron	—	M	M	—

Table 1—Continued

Plant species by forage class	Level of use[2]			
	Winter	Spring	Summer	Fall
Cobre rockcress	—	M	M	—
Western tansymustard	—	L	—	—
Daggerpod	—	—	M	—
Yarrow	L	L	L	L
Trees and shrubs:				
Big sagebrush	M	L	L	—
Low sagebrush	M	—	M	M
Bud sagebrush	M	L	—	—
Winterfat	M	M	M	H
Rabbitbrush	L	L	L	L
Fourwing saltbush	M	L	L	M
Bitterbrush	H	H	M	—
Mountainmahogany	H	M	L	M
Service berry	L	L	M	L
Elderberry	—	—	L	L
Chokecherry	L	L	L	L
Spiraea	L	L	M	L
Wild rose	L	L	M	L
Ninebark	M	M	M	L
Currant	L	—	—	L
Cinquefoil	—	—	—	M
Willow	L	L	M	M
Snowberry	L	L	M	L
Oceanspray	—	L	L	L
Spiny hopsage	—	—	—	M

[1] Adapted from Blood (1967), Cooperrider et al. (1980), Drewek (1970), Dunaway (1972), Estes (1979), Fairaizl (1978), Hansen (1982), Kornet (1978), Lauer and Peek (1976), McCullough and Schneegas (1966), Pitt and Wikeem (1978), Sugden (1961), Todd (1972), Van Dyke (1978), Yoakum (1966).

[2] L = light, 1 to 5 percent; M = moderate, 6 to 20 percent; H = heavy, 21 to 50+ percent.

Production of forage depends on the amount and timing of precipitation. Managers can estimate the amount of forage available for bighorn sheep only after deducting for plant needs and the amount to be used by other grazing animals.

Forage intake of bighorn sheep is determined by their energy requirements and the availability and quality of forage (Hebert 1973). The amount needed varies with protein content, ambient air temperature, and the sex, age, and activity level of the animal. Apparently consumption does not vary markedly from year to year. Few studies have been conducted to determine the amount of forage required by bighorn sheep, but estimates have been made by Anderson and Denton (1978), Hansen (1980), and Hebert (1973). Such estimates should be used only as a guide in southeastern Oregon and should be updated as more data become available.

Hansen (1980) found that desert bighorn sheep consumed from 1.5 to 1.8 kilograms (3 to 4 lbs) of dry alfalfa per day. Anderson and Denton (1978) in Idaho, and Hebert (1973) in British Columbia, figured the year-round average intake for Rocky Mountain bighorn sheep was 1.44 kilograms per 45.40 kilograms of body weight (3.17 lbs per 100 lbs). A bighorn sheep with an average weight of 56.4 kilograms (124 lbs) would consume 1.77 kilograms (3.90 lbs) of dry matter each day. Once the percentages of grasses, forbs, and shrubs in the diet of sheep are known and the percentages of each that can be provided by the plant communities are known, a more accurate computation of forage available can be made.

Because they depend largely on their acute vision to detect danger, bighorn sheep shun areas of dense, tall vegetation, such as riparian zones and forests (Geist 1971, Kornet 1978, McCann 1956, Oldemeyer et al. 1971, Risenhoover and Bailey 1980, Turner and Weaver 1980) (fig. 10). They avoid extensive forage areas with shrub or canopy cover in excess of 25 percent and shrubs about 60 centimeters (2 ft) high on mild slopes (Van Dyke 1978), whereas, on steep slopes they have been noted to travel through and bed in dense brush (Light et al. 1967).

The availability of water and escape terrain also affects use of forage areas. The more abundant and evenly dispersed these components are, the more uniform use of a forage area will be. Forage areas located farther than 0.8 kilometers (0.5 mi) from escape terrain and farther than 1.6 kilometers (1 mi) from water are little used (Bailey 1980, Blong and Pollard 1968, Denniston 1965, Irvine 1969, Kornet 1978, Leslie and Douglas 1979, McQuivey 1978, Oldemeyer et al. 1971, Van Dyke 1978).

Snow accumulation seems to be the principal factor that triggers bighorn sheep to move from summer to winter ranges (Geist 1971, Geist and Petocz 1977). Where winter and year-long ranges accumulate snow, animals seek areas of least snow depth and paw away snow to uncover forage (Drewek 1970, Geist 1971, Geist and Petocz 1977, Shannon et al. 1975). In Idaho, Lauer and Peek (1976) found that from November through May, 87 percent of bighorn sheep sightings were in areas with less than 5 centimeters (2 inches) of snow, and 97 percent were in areas with less than 16 centimeters (6 inches).

Bighorn sheep prefer green forage and will move up or down or to different aspects to acquire more palatable forage (Hebert 1973, Lauer and Peek 1976, McCann 1956, Shannon et al. 1975, Van Dyke 1978).

Forage areas that present a variety of aspects are preferable because they provide green forage for longer periods. For example, south aspects are generally warmer and provide green forage earlier in spring, while north aspects are generally cooler and provide green forage later in summer. Because they are warmer, south aspects generally have less snow during winter and are selected by bighorn sheep (Bailey 1980, Drewek 1970, Lauer and Peek 1976, Light et al. 1967, McCollough et al. 1980, Van Dyke 1978).

Suitable versus Unsuitable Forage Areas

It is difficult to classify forage areas as suitable or unsuitable solely on the basis of plant species composition. Topography, substrate, vegetative structure, distance to escape terrain

Figure 10.—Bighorn sheep prefer open areas and shun tall dense stands of trees or shrubs (photo by Walt Van Dyke, courtesy Oregon Cooperative Wildlife Research Unit).

and water, snow depth, and season are also important. Forage areas suitable for bighorn sheep usually have tree or shrub canopy cover of less than 25 percent and shrub height less than 0.6 meters (2 ft). They are less than 1.6 kilometers (1 mi) from water and less than 0.8 kilometers (0.5 mi) from escape terrain. If the above criteria are met, any of the plant communities of southeastern Oregon can provide some forage.

We have rated the major plant communities (in the order listed by Dealy et al. (1981)) according to their suitability as forage for bighorn sheep. On a scale of 1 (low) to 10 (high), ratings are:

Plant Community	Rating
Riparian	5
Quaking aspen/grass	2
Quaking aspen/mountain big sagebrush	2
Curlleaf mountainmahogany/mountain big sagebrush/bunchgrass	5
Curlleaf mountainmahogany/mountain snowberry/grass	4
Curlleaf mountainmahogany/Idaho fescue	4
Curlleaf mountainmahogany/bearded bluebunch wheatgrass-Idaho fescue	4
Curlleaf mountainmahogany/pinegrass	3
Western juniper/big sagebrush/bearded bluebunch wheatgrass	6
Western juniper/big sagebrush/Idaho fescue	6
Basin big sagebrush/bunchgrass	7
Mountain big sagebrush/bunchgrass	9
Subalpine big sagebrush/bunchgrass	9
Wyoming big sagebrush/bunchgrass	8
Three-tip sagebrush/bunchgrass	1
Bolander silver sagebrush/bunchgrass	1
Mountain silver sagebrush/bunchgrass	1
Stiff sagebrush/bunchgrass	7
Low sagebrush/bunchgrass	7
Cleftleaf sagebrush/bunchgrass	1
Black sagebrush/bunchgrass	7
Early low sagebrush/bunchgrass	7
Squaw apple/bunchgrass	2
Black greasewood/bunchgrass	1
Shadscale saltbush/bunchgrass	3
Meadow, seasonally wet	10
Meadow, permanently wet	8
Subalpine bunchgrass	10

Several plant communities in the Great Basin seldom provide forage because of their structure or distance from escape terrain. Communities unsuitable because of structure are: quaking aspen, mountainmahogany, western juniper, and riparian communities dominated by tall shrubs or trees. Communities usually located far from escape terrain and little used for foraging include: squaw apple/bunchgrass, black greasewood/grass, early low sagebrush/bunchgrass, black sagebrush/bunchgrass, Bolander silver sagebrush/bunchgrass, mountain silver sagebrush/bunchgrass, threetip sagebrush/bunchgrass, shadscale saltbush/bunchgrass, and cleftleaf sagebrush/bunchgrass. These communities will get incidental use along migration routes or within established herd ranges.

Successional communities that result from wildfire or seedings, such as crested wheatgrass, are also encountered in the Great Basin and may provide forage if the location and successional/seral structure are appropriate.

Summer versus Winter Range

The variation in elevation and topography in the Great Basin creates microsites that differ in accumulations of snow. Some areas may be available for foraging only during a 3-month summer period before snow depth precludes use. In such cases, bighorn sheep may establish patterns of seasonal use of such areas.

Other areas suitable for foraging may accumulate little or no snow and receive year-long use. Areas that provide suitable forage year-round are particularly vulnerable to overuse because of competition among a variety of wild or domestic herbivores.

WATER

Bighorn sheep use fresh water from many sources. These include dew, streams, lakes, springs, ponds, catchment tanks, troughs, guzzlers, and developed seeps or springs (Blong and Pollard 1968, Drewek 1970, Halloran and Deming 1958, Jones et al. 1957, Sugden 1961, Turner and Weaver 1980, Van Dyke 1978, Welles and Welles 1961, Yoakum et al. 1980). Alkaline waters, however, apparently are not suitable (Jones et al. 1957). Although the degree of alkalinity tolerated by bighorn sheep is unknown, the maximum dissolved solids suitable for ungulate wildlife has been described as 4,500 p/m (McKee and Wolf 1963). We assume that this figure also applies to bighorn sheep.

The amount of water needed by a bighorn sheep depends on several factors, including: size of the animal, activities, time between waterings, physiological adaptation, environmental stress (humidity and temperature), succulence of ingested forage, and reproductive status (Turner and Weaver 1980). A bighorn sheep ingesting succulent forage on a cool day requires little or no free water, whereas one ingesting dry forage on a hot day needs more free water (Turner and Weaver 1980). There is a greater need for water during periods of physiological stress, such as during rutting or lambing seasons (Wilson 1968).

Desert bighorn sheep have been known to go without water for more than 5 days during summer (Turner and Weaver 1980). They may drink as little water per day as 4 percent of their body weight and as much as 23 percent of their body weight at one time (Turner 1973, Turner and Weaver 1980). Koplin (1960) found that a captive herd of desert bighorn sheep that were fed a dry ration and provided unlimited water drank an average of 4.9 liters (1.3 gal) per day, while free-ranging bighorns were observed to drink as much as 9.5 liters (2.5 gal) per day during summer. Frequency of watering and succulence of vegetation both influence water consumption. A reasonable estimate of the minimum amount of water needed by free-ranging, adult California bighorn sheep of average size (56.4 kilograms, 124 lbs), is 3.5 liters (1.5 gal) per day.

Bighorn sheep spend most of their time within 1.6 kilometers (1 mi) of free water but have been located as far as 3.2 kilometers (2 mi) from it (Blong and Pollard 1968, Irvine 1969, Leslie and Douglas 1979). Water sources more than 0.5 kilometer (0.3 mi) from escape terrain or surrounded by tall dense vegetation are shunned by bighorn sheep (Hansen 1980, Leslie and Douglas 1979, Turner and Weaver 1980).

As the number of water sources declines, habitat use becomes more confined around remaining water sources (Jones et al. 1957, Leslie and Douglas 1979, Welles and Welles 1961). But as precipitation, new plant growth, and cooler temperatures reduce dependence on permanent water, the animals can temporarily extend their range (Leslie and Douglas 1979).

THERMAL PROTECTION

Elevation, thermal winds, cliffs and rock outcroppings, and trees and shrubs, provide animals the opportunity to minimize stress caused by temperature extremes (fig. 11). Some bighorn sheep herds move to higher elevations in summer because of available forage and a cooler environment (McCann 1956, Shannon et al. 1975). On subalpine summer ranges where winds were consistent bighorn sheep used little shade.[2] Where summer ranges are below the subalpine zone, bighorn sheep seek shade from geomorphic features to moderate the effects of high temperatures (Leslie and Douglas 1979, Welles and Welles 1961). The amount of energy bighorn sheep expend in thermoregulation will be reduced if the geomorphic features offer a variety of aspects, thus increasing the amount of shade available at different times of day.

[2] Van Dyke, Walter A., wildlife biologist. 1978 data on file at Oregon Department of Fish and Wildlife, Enterprise, Oregon 97828.

Figure 11.—Cliffs, trees, and shrubs provide shade.

Shrubs and trees with dense canopies provide varying degrees of thermal cover for deer and elk (Thomas et al. 1976). Bighorn sheep normally occupy open areas and consequently do not benefit from the thermal protection offered by tall, dense-canopied vegetation, but they do use trees and shrubs to some extent for this purpose (Hansen 1980, Smith 1954). Mountainmahogany stands, with 25-percent canopy cover, located on cliffs or ground steeper than 35 percent, are apparently used for protection from the sun, especially by ewes during lambing season (Van Dyke 1978). Habitats with dense canopy cover on gentle slopes (less than 35 percent) are used less or even avoided, probably because sheep have poor visibility from within such stands (Van Dyke 1978). In general, use of trees and shrubs for thermal cover is positively correlated with slope and roughness of terrain and negatively correlated with increasing canopy cover, density, and distance from escape terrain.

Cliffs and rock outcroppings provide shade on hot days and reflect solar radiation during cold periods. Bighorn sheep seek shade during midday and thus conserve body water (Leslie and Douglas 1979) and enhance metabolic efficiency (Moen 1973). Caves are sometimes used for this purpose (Hansen 1980, Leslie and Douglas 1979, Welles and Welles 1961) as well as for lambing (Fairaizl 1978, Hansen 1980) and for shelter during severe storms (Smith 1954) (fig. 12).

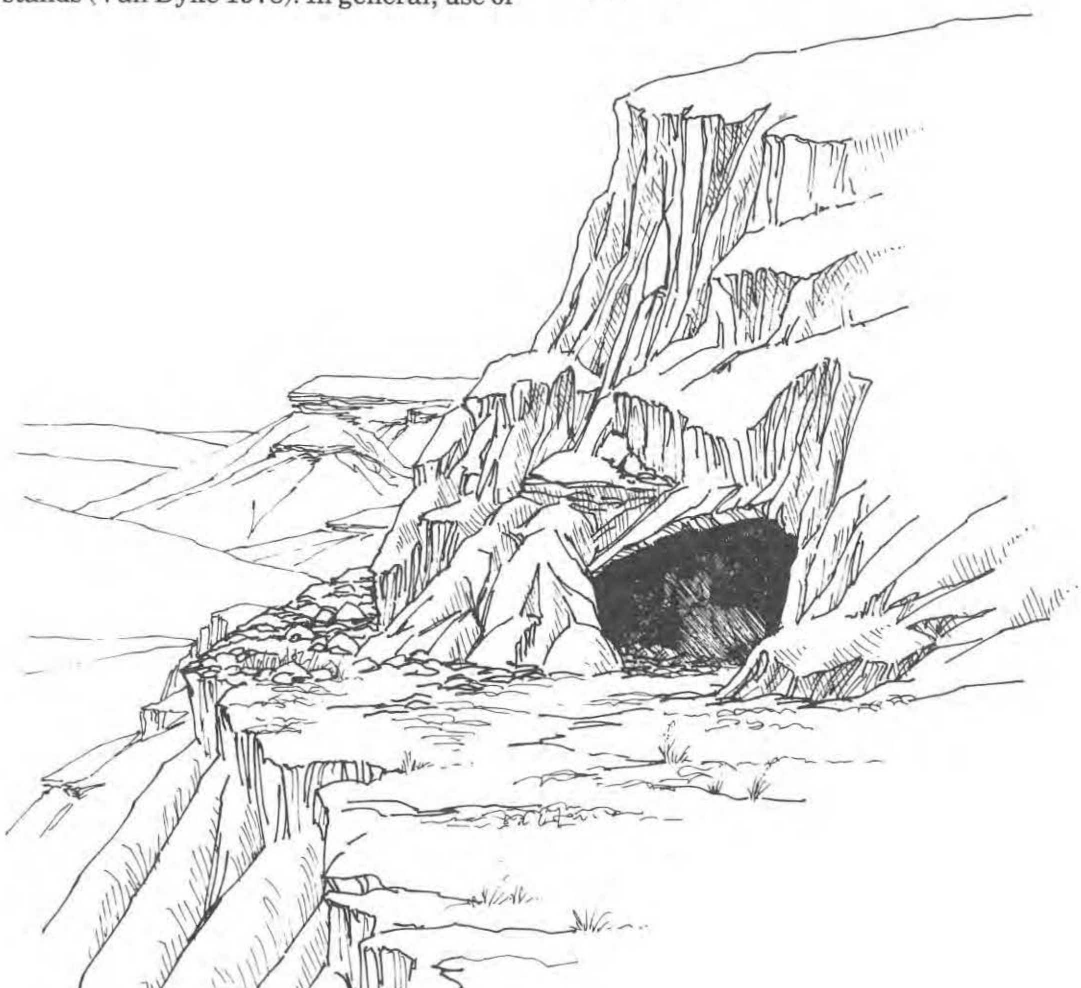

Figure 12.—Caves provide thermal cover and lambing sites.

RUTTING AREAS

A bighorn sheep herd usually has discrete areas within its range where breeding occurs. A herd may move to traditional rutting areas (Demarchi and Mitchell 1973, Geist 1971) or rams may move to ewe-lamb ranges (Kornet 1978, Van Dyke 1978) for the rut.

During the rut, which occurs from late October to mid-December, the need for forage and water changes. For example, bighorn sheep forage less when rutting (Geist and Petocz 1977) but require more water than usual (Wilson 1968).

ARRANGEMENT OF HABITAT COMPONENTS

Forage, water, and escape terrain are the most important components of bighorn sheep habitat, but the size, quality, and distribution of these components are also important. In the best habitats, water sources and escape terrain are distributed throughout foraging areas and thus make more grazing available. This intermingling of habitat components reduces pressure on forage near water and escape routes and helps prevent degradation of plant communities.

Forage areas within 0.8 kilometer (0.5 mi) of escape terrain on two or more sides receive more frequent and uniform use than forage areas with escape terrain on only one side (fig. 13).

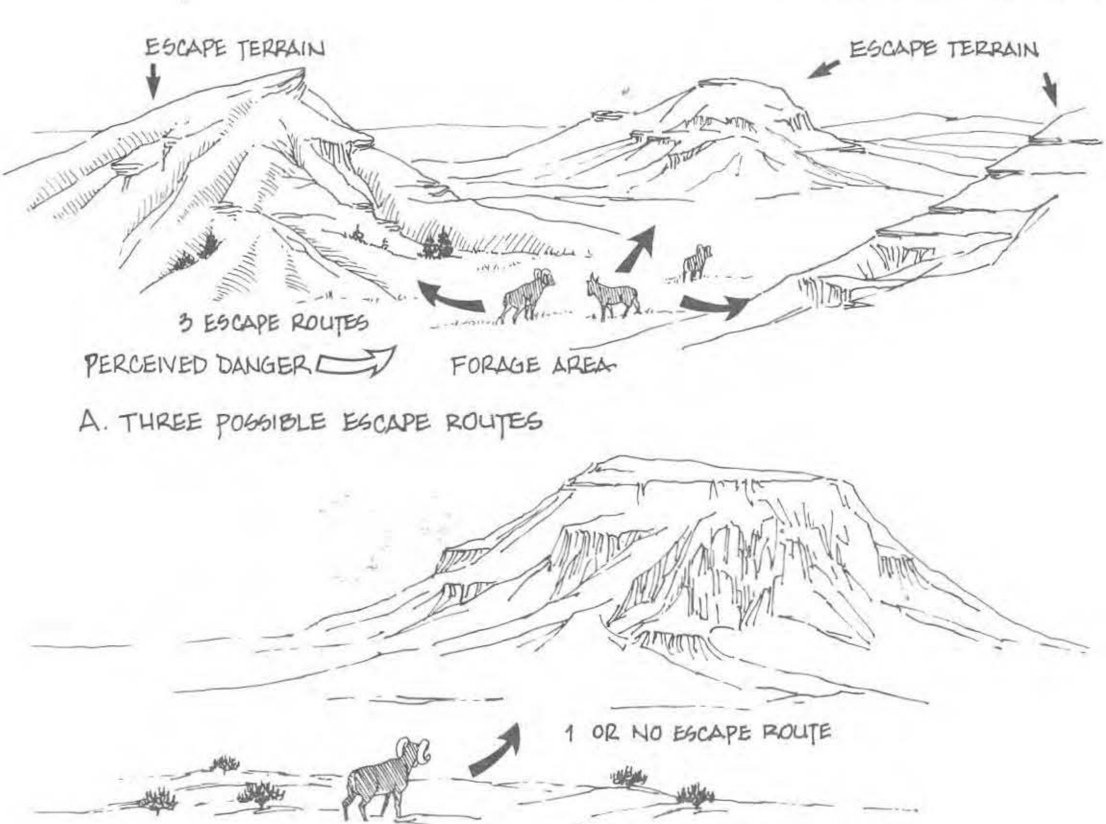

Figure 13.—Uniform distribution of sufficient escape terrain is important to bighorn sheep. In A three different escape routes are available; in B only one; consequently, sheep will forage closer to escape terrain in B than in A.

The location of water also influences use of forage areas. If water is distributed at intervals of 3.2 kilometers (2 mi) or less throughout a range and is not farther than 0.5 kilometer (0.3 mi) from escape terrain, optimum use of the habitat can be expected. Sheep will then forage in a circuit, covering more area and putting less grazing pressure on desirable portions of the area.

SPACE REQUIREMENTS

Bighorn sheep require more than the essential components of appropriately arranged habitat. They also need space. Hansen (1980:74) described space as "... a lack of crowding." The amount of space needed depends on quality of habitat, the amount of negative impact from humans and other animals, and the size of the bighorn herd. Trefethan (1975) suggested that a minimum herd size of 125 animals is necessary for a long-term, viable population. The area required by such a herd depends on the quality of the habitat. Kornet (1978) and Van Dyke (1980) have calculated minimum densities of 13 bighorns per square kilometer (5/sq mi) for herds in the Great Basin of southeastern Oregon. These figures can be used as a guide for estimating the population potential of a given habitat but may exceed the capacity of poorer quality habitat.

Individuals of every bighorn sheep population apparently vary in their tolerance of crowding. For example, individual Rocky Mountain bighorn sheep accustomed to people in a National Park can be photographed from a car window, but individuals unaccustomed to people may flee at the sight of a person or vehicle a mile or more away. Once the limit of tolerance is exceeded, even in otherwise optimum habitat, sheep may abandon an area temporarily or permanently (Light 1971, Spalding and Bone 1969, Wehausen 1980, Welles and Welles 1961). Although bighorn sheep are naturally gregarious, crowding can be detrimental. Crowding may result from a lack of suitable habitat, snow accumulation, structural condition of plant communities, presence of other ungulates, or harassment by humans or predators. The amount of space needed by bighorn sheep varies with habitat conditions and size of the population. Adverse effects on a sheep population are indicated by abandonment of an area, a drop in productivity, or excessive mortality.

Productivity and survival are enhanced by appropriate interspersion of adequate water, forage areas, and escape terrain, as well as sufficient space, to allow bighorn sheep to use habitat efficiently and minimize energy expenditures and exposure to disturbance.

Management Tips

The attributes of bighorn sheep habitat can be created, preserved, destroyed, or altered by management action.

ESCAPE AREAS

Escape terrain is provided naturally by the environment. Without it bighorn sheep will not flourish (Hansen 1980). Rarely can it be enhanced, but it can be altered detrimentally by such activities as mining and constructing roads and reservoirs (fig. 14). In many cases, physical alterations are much less important than the disturbance these alterations introduce. For example, human use of a road along or through a lambing or bedding area eliminates the solitude needed by sheep. Likewise, development of a large reservoir may allow human access by boat to areas formerly remote and inaccessible.

LAMBING AREAS

The relatively isolated and rugged cliffs cannot be created, but other attributes of prime lambing habitat can be enhanced. Size of lambing areas can be increased by manipulation of adjacent forage areas, development of water sources, and control of competing animal species and people.

The availability of forage and water within and bordering lambing areas is critical. More water can be made available by development or conservation. Forage can be conserved and made available to ewes and young lambs.

Figure 14.—Reservoirs may submerge habitat suitable for bighorn sheep (photo by Walt Van Dyke, courtesy Oregon Cooperative Wildlife Research Unit).

Bighorn sheep will tolerate some human intrusion most of the year, but the lambing period is critical, and the less disturbance the better.

If a herd has traditional areas for lambing (Geist 1971), management should insure that travel corridors to such areas are protected and maintained.

FORAGE AREAS

Plant communities vary widely. Differences in species composition and structural features are largely the result of past fire and grazing. Fire tends to reduce the abundance of shrubs and trees, while grasses and forbs are affected less or even increased (Franklin and Dyrness 1973, Graf 1980). Prolonged, heavy grazing by livestock has the opposite effect (McQuivey 1978); grazing pressure is directed to palatable plants, and unpalatable plants tend to dominate over time (Stoddart et al. 1975).

Dense shrub and tree canopy or undesirable woody plants can be reduced temporarily or eliminated by prescribed fire. Bighorn sheep select forage areas that have been burned (Geist 1971, Graf 1980, Peek et al. 1979, Riggs 1977, Shannon et al. 1975, Stelfox 1971) (fig. 15). Burning may improve plant production and palatability (Peek et al. 1979). Logging, chaining, or spraying should give similar results, but not as quickly, and debris may present a problem (Morgan 1969, Spalding and Bone 1969, Sugden 1961). The goal of any treatment to enhance forage areas is to create the more open habitat preferred by bighorn sheep. The extent to which mechanical methods of vegetative manipulation can be implemented depends on geomorphic features and topography.

Figure 15.—Fire has removed shrub canopy and created a suitable forage area (photo by Walt Van Dyke, courtesy Oregon Department of Fish and Wildlife).

Conflict between bighorns and other grazing species in forage areas appears in two primary forms—social interaction and direct competition. Detrimental social interactions have been documented between bighorn sheep and cattle (Dean 1977, Irvine 1969, Russo 1956, Wilson 1968) and goats (Russo 1956, Wilson 1968). When cattle or goats occupy ranges used by bighorn sheep, the sheep move to less desirable areas or concentrate on the remaining habitat. If bighorn sheep are to be featured, socially conflicting species may have to be removed. Fortunately, the nature of bighorn sheep and the severe topography they inhabit usually results in their isolation from domestic livestock. Adverse social interactions between bighorn sheep and mule deer, elk, or pronghorns have not been reported in the literature.

Whenever two or more species of grazing animals are found in the same area, competition for forage is possible, but inherent characteristics usually allow species to partition a particular resource. Competition between two species may be caused by inclement weather, the introduction of exotic ungulates, or the improper management of animal numbers—domestic or wild (Crump 1971, Sugden 1961, Weaver 1972). There are documented accounts of competition for forage between bighorn sheep and cattle (Blood 1961, Demarchi 1965, Demarchi and Mitchell 1973, Lauer and Peek 1976, Morgan 1968, Stelfox 1971); horses (Crump 1971; McQuivey 1978; Schallenberger 1965; Stelfox 1971, 1976; Woodgerd 1964); elk (Buechner 1969, Cowan 1947, Schallenberger 1965, Stelfox 1971); deer (Berwick 1968, Buechner 1960, Cooperrider 1969, Drewek 1970, Morgan 1968, Schallenberger 1965, Stelfox 1971); and domestic sheep (Morgan 1968, Uhazy et al. 1971). Most of the competition was on bighorn winter ranges. In the case of domestic livestock, competition for forage resulted from livestock grazing on bighorn winter ranges during summer.

The result of competition was generally twofold—inadequate forage for one or more species and severe impairment of range quality. Forage allocation and grazing management to accommodate bighorn sheep and other grazers has been achieved by reducing the number of domestic or wild ungulates and/or controlling the intensity of domestic livestock grazing and season of use (Crump 1957, 1971; Stelfox 1971). Similar solutions can be implemented on other seasonal ranges. Livestock grazing on bighorn range has been completely stopped in some areas (Lange et al. 1980).

Competition for forage is more pronounced where livestock grazing occurs on ranges of nonmigratory bighorn sheep. Because of social conflicts and the forage needs of bighorn sheep, it is preferable that domestic livestock not be grazed within the year-long home ranges of bighorn sheep. If grazing by livestock must occur, it should be confined to only a portion of the bighorn range and periodically moved in a planned grazing system (Anderson 1967). Such action will minimize competition between domestic livestock and bighorn sheep (Anderson and Scherzinger 1975).

The best way to assure an adequate food source for bighorn sheep may be to reserve forage areas adjacent to their escape terrain, lambing areas, and water sources. Allowing domestic livestock in such areas risks depletion of the food supply, which may be limited (Crump 1957, 1971; Stelfox 1971). Food supplies may also be limited by the bighorn sheep's inability or unwillingness to readily change home ranges (Geist 1971).

If domestic livestock are grazed on bighorn sheep range, their use should alternate with sheep use. Livestock grazing must be done with utmost care to insure: adequate forage supplies for the sheep at the appropriate season, protection of the range vegetation and soils, and minimum harassment of the sheep. These objectives may be attained by fencing, limiting numbers of livestock, grazing on rotational or seasonal systems, placing salt and water to attract livestock away from bighorn forage, and using fertilizers to improve palatability of forage for livestock (Bear 1978, Bodie and Hickey 1980, Martin 1978, McCollough et al. 1980, Meehan and Platts 1978, Skovlin 1965, Stoddart et al. 1975). If the management priority is the welfare of bighorn sheep, other wild or feral ungulates (primarily deer, elk, and horses) may have to be reduced by killing or capture and removal to maintain sufficient forage for bighorn sheep and minimize adverse social interactions.

Managers will often be faced with problems caused by the effects of fences on bighorn sheep. Fences restrict movement and cause mortality, especially of rams that get their horns tangled in the wire (Welsh 1971). Helvie (1971) has given guidelines for building fences in areas occupied by bighorn sheep. Fences should not be constructed with woven wire, but with smooth or barbed wire, pipe, rails, or poles. Helvie also recommended that posts or stays be placed no farther apart than 3 meters (10 ft). Wires should be spaced 51, 89, and 99 centimeters (20, 35, and 39 inches) above the ground, and poles, pipes or rails 51, 97, and 112 centimeters (20, 38, and 44 inches) above the ground (fig. 16). Such spacing allows bighorns to go through or under a fence while restricting livestock movement.

Another type of fence that can be used is the lay-down fence (fig. 16). It can be erected when cattle are present and dropped flat when bighorn sheep are present.

Use of fences should allow bighorn sheep to move through an area while keeping cattle on designated pastures.

In selecting objectives for managing a range for bighorn sheep, a manager should answer three questions: (1) What are the requirements of the particular bighorn sheep population? (2) Do other wild, feral, or domestic ungulates occupy the area with the sheep? and (3) Do these occupants alter the habitat in ways that are detrimental to the sheep? Bighorn sheep are a much more sensitive part of the management equation than mule deer, elk, feral horses, or domestic livestock. Bighorn sheep are comparatively rare. They occupy habitats that are sensitive to alteration, and they respond adversely to disturbance. Unless they are given primary emphasis, bighorn sheep are unlikely to become established or to continue in existence.

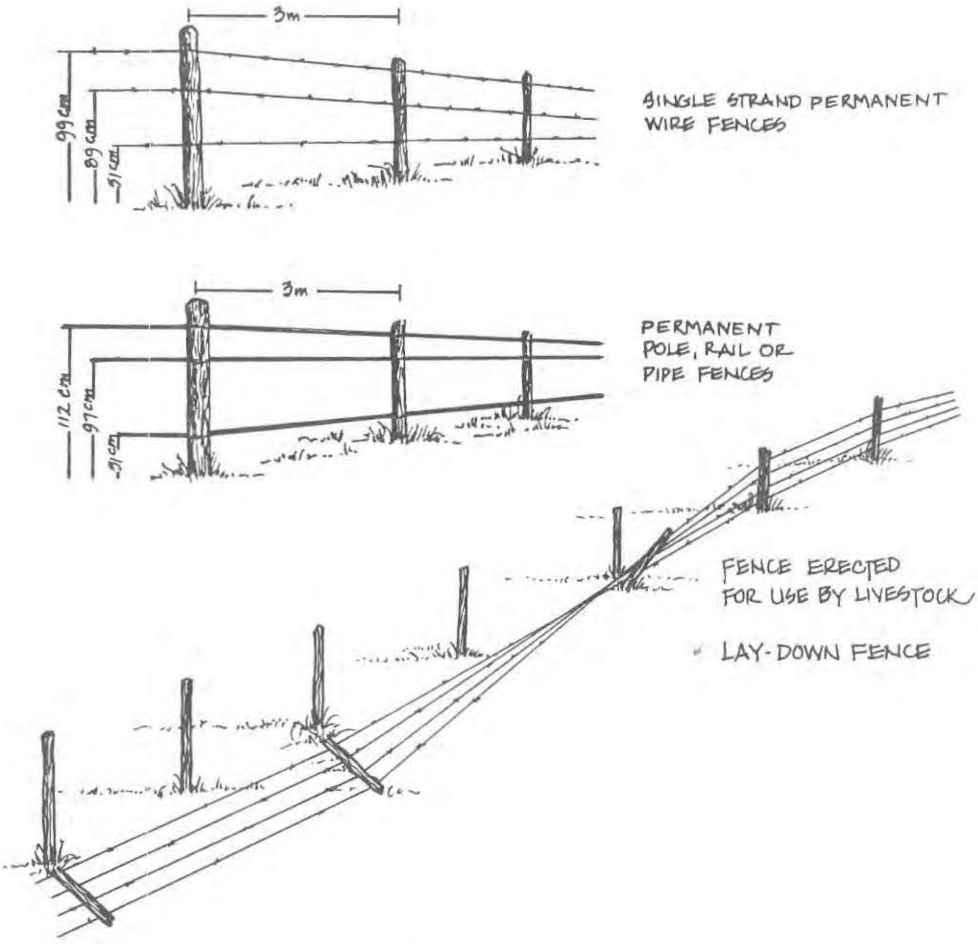

Figure 16.—Types and dimensions of fences that can be used on bighorn sheep range.

Bighorn sheep ranges, present and potential, occupy such a small percentage of area suitable for grazing domestic livestock, that reserving forage for bighorn sheep will have little overall impact on domestic livestock (fig. 17).

WATER

If water is absent or limited on otherwise suitable bighorn sheep range, steps can be taken to conserve existing water and to make new sources available under circumstances that encourage bighorn sheep use.

If water is not available from permanent, natural sources, impoundments can be developed to provide it. Water from seeps, low-flow springs, seasonal springs, and seasonal streams can be collected, stored, and conserved to make it available during critical periods of the year (Halloran and Deming 1958, Jones et al. 1957, Wilson 1977, Yoakum et al. 1980).

If water from runoff, springs, or seeps is absent, guzzlers with large collection aprons (Yoakum et al. 1980) can be used to collect it (fig. 18). Water sources that are constructed to collect runoff or seepage water will be most beneficial in ravines or crevices where such water is likely to be available. It may be desirable to pipe water from a development to troughs—to prevent mucking—or to locations better suited for use by bighorn sheep.

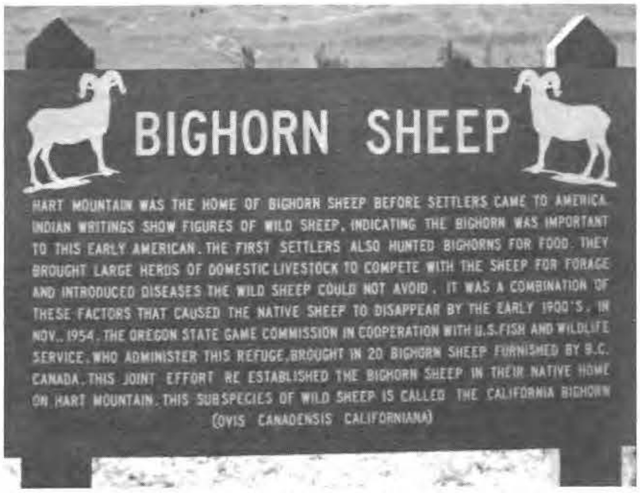

Figure 17.—In the future, bighorn sheep may depend on parcels of land set aside and managed primarily for them (photo by Alan Sands).

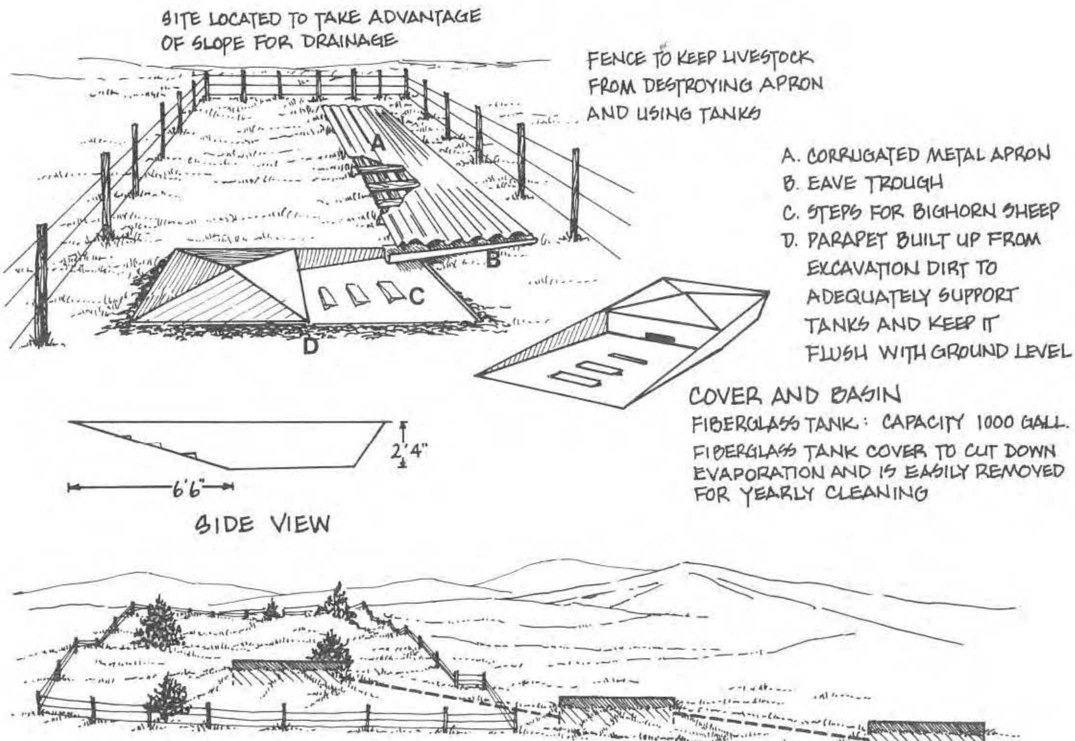

Figure 18.—Water developments that can be installed on bighorn sheep ranges include collection aprons with storage tanks and springs or seeps developed with troughs. (Adapted from Yoakum et al. 1980)

In the Great Basin, naturally occurring water is least available during hotter portions of the year, after surface water is gone, so impoundments should provide water during this period. Where possible, they should be shaded from the sun to reduce evaporation. Development of "permanent" water sources can make available areas that have all the other components of bighorn sheep habitat (Jones et al. 1957). During the colder portions of the year, water should be available in locations where it is least likely to freeze and where the animals are most likely to be, such as on south-facing slopes.

Care should be taken to ensure that watering devices will not trap or injure bighorn sheep (Mensch 1969). Periodic maintenance will be needed to keep such devices functioning (Jones et al. 1957).

The most desirable placement of water sources is at intervals of 3.2 kilometers (2 mi) and within 0.5 kilometer (0.3 mi) of escape terrain. Larger intervals will not allow bighorn sheep to use the habitat uniformly and will impose stress on the animals.

Creating water sources may increase conflict between bighorn sheep and other ungulates or people. Conditions detrimental to bighorn sheep that may result include severe grazing (Stelfox 1971); the potential for exchange of parasites or disease between bighorns and other ungulates, particularly domestic sheep (Bunch et al. 1978, Samuel et al. 1975); and degradation of water quality by mucking or defecation (Welles and Welles 1961; Wilson 1968, 1977).

Steps can be taken to remedy such problems. Conflicting species can be removed by trapping or killing. Existing waterholes can be fenced to exclude conflicting ungulate species (Morgan 1969, Schallenberger 1965, Trefethan 1975, Wilson 1977). Water sources can be developed in rugged topography that only bighorn sheep frequent, or other ungulates can be excluded by fences while bighorn sheep have access via escape terrain (Halloran and Deming 1958) (fig. 19). Water sources for livestock can be installed in areas distant from bighorn sheep habitat to attract livestock away from such habitat (McCollough et al. 1980).

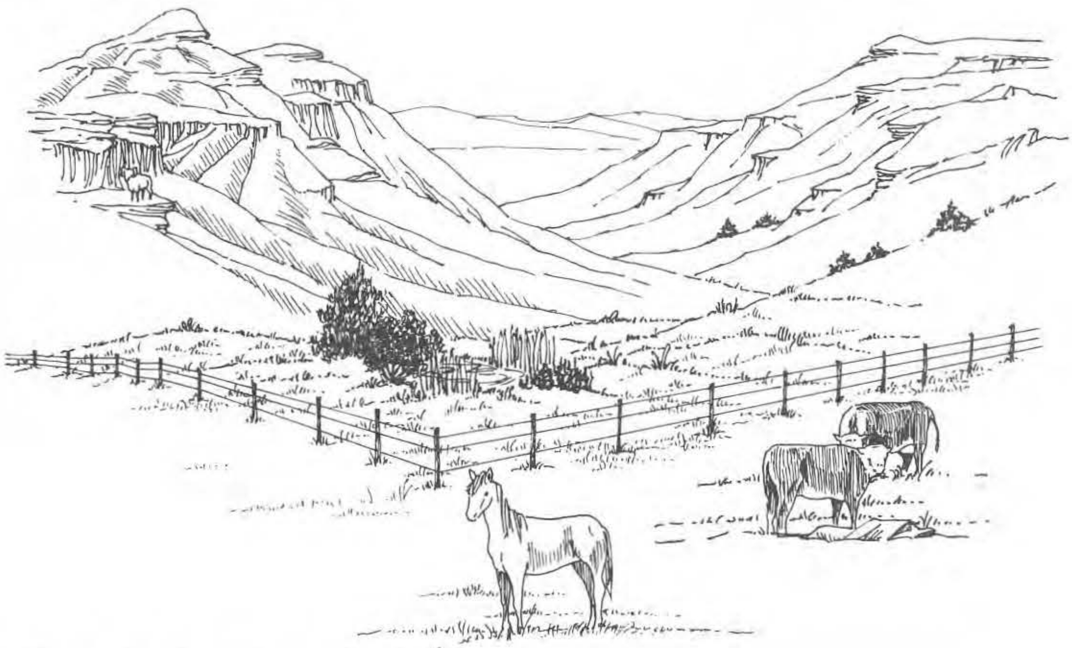

Figure 19.—Domestic and feral ungulates can be fenced away from a water source to preserve it for bighorn sheep.

Regular human activity can cause bighorn sheep to alter or terminate their use of water sources (Blong and Pollard 1968, Buechner 1960, Welles and Welles 1961). Where this occurs, special restrictions can be implemented for people and their equipment (Hicks and Elder 1979). For best results, water should be conserved and reserved for bighorn sheep through proper location and control of conflicting species.

THERMAL FACTORS

Thermal protection for bighorn sheep comes from two primary sources—vegetation and geomorphic features. These sources provide shade or reradiate heat. A manager must work with existing geomorphic features because they cannot be produced. Their effectiveness, however, can be enhanced by restricting human activity and insuring that water and forage are provided in close proximity to reduce travel for bighorns.

Where trees are lacking, or where trees and shrubs have dense or extensive canopies that discourage use by bighorn sheep, a manager can improve the thermal qualities or use of existing stands. Canopies that are too dense can be opened by prescribed burning or thinning. If, on the other hand, additional cover is needed, species compatible with the site, such as mountainmahognay or juniper, can be planted and livestock fenced out to allow seedlings to become established. In arid or semi-arid areas, growing trees or tall shrubs is a relatively slow process and providing thermal cover may require 10 to 30 years.

RUTTING AREAS

Human disturbance is detrimental to breeding. Restricting the use of roads, trails, or areas open to travel by people and controlling other management activities helps insure that breeding progresses normally. The rut is a critical part of the bighorn sheep's life cycle, and solitude is conducive to successful breeding. Excessive disturbance in any form may cause a decline in productivity.

If a bighorn sheep herd migrates to traditional areas for the rut (Geist 1971), it is of utmost importance that travel corridors to such areas be protected and maintained.

PARASITES AND DISEASES

Some of the factors responsible for the large reduction in the number of bighorn sheep since the turn of the century have been practically eliminated. Indiscriminate shooting has been curbed by tightly regulated and enforced hunting systems. In some cases, proper allocation of forage between bighorn sheep and other grazers has made sufficient forage available for bighorn sheep (Crump 1957, 1971; Stelfox 1971). But, parasites and diseases are still a threat.

Numerous parasites and diseases have been documented in bighorn sheep (Allen 1971, Becklund and Senger 1967). Species-specific parasites, such as lungworms and intestinal nematodes that have evolved with bighorn sheep play a natural role in regulating numbers and rarely decimate entire populations (Blood 1963b, Buechner 1960, Forrester 1971, Kistner et al. 1977, McCullough and Schneegas 1966). Other co-evolved parasites specific to bighorn sheep may not be detrimental to herd health (Allen 1971, Samuel et al.1978).

Although species-specific parasites and diseases may threaten bighorn sheep populations, some of the parasites and diseases contracted from domestic livestock are a greater threat. Although most parasites and diseases carried by domestic livestock do not appear to have undesirable effects on bighorn sheep, others apparently have been responsible for decimating entire herds. In most of these instances there was no direct evidence that domestic livestock were the source of the disease or parasite, but conditions prevailing at the time suggested that domestic livestock were the source. For example, bluetongue, a common disease of domestic sheep usually transmitted by insect vectors (Trainer 1970), was responsible for the death of a captive bighorn sheep in Texas (Robinson et al. 1967). Subsequently, the captive herd was nearly wiped out by the disease.[3] Bluetongue also caused the death of several bighorn sheep from a herd in northern California (Campbell 1980). In both instances, domestic sheep had ranged in areas adjacent to those used by the bighorn sheep. Entire herds in California and Washington have recently been lost to bacterial pneumonia. The source of the disease probably was domestic sheep (Campbell 1980, Foreyt and Jessup 1982, Jessup 1980).

The sheep bot fly, usually associated with domestic sheep and occasionally with domestic goats and deer (Capelle 1971), has been reported in bighorn sheep (Capelle 1966). It was recently identified as a cause of mortality in desert bighorn sheep (Bunch et al. 1978). To date, there has been no satisfactory way to control the spread of the bot fly, whose life cycle can be completed in bighorn sheep.

The scab mite, which causes psoroptic mange, apparently can be carried by domestic livestock and at the turn of the century was thought to be responsible for significant losses of bighorn sheep. Although psoroptic mange has since been considered eradicated or controlled, it has recently been associated with losses of desert bighorn sheep in New Mexico (Lange 1980, Lange et al. 1980, Williams 1980). Because this mite can still have drastic effects on herds of bighorn sheep, the best prevention is to eliminate opportunities for its transmission from domestic livestock.

Contagious ecthyma (soremouth) has commonly been diagnosed in domestic and bighorn sheep (Blood 1971, Campbell 1980, Samuel et al. 1975). Although some biologists think this condition has minimal impacts on bighorn sheep (Blood 1971), it has been responsible for numerous deaths, primarily of lambs (Campbell 1980).

A species of lungworm common to domestic sheep was responsible for deaths in a captive herd of bighorn sheep (DeMartini and Davies 1976, 1977). The animals died from pnuemonia that developed only after they were infected by the lungworm.

Other parasites and diseases borne by domestic sheep that can be harmful to bighorn sheep include: helminths (Uhazy and Holmes 1970); coccidia (Uhazy et al. 1971); and pneumonia (DeMartini and Davies 1976, Howe et al. 1966, Parks et al. 1972). Pneumonia is serious only when bighorn sheep have suffered lung tissue damage or are subject to unusual physiological or psychological stress (DeMartini and Davies 1977, Woolf and Kradel 1973). Any herd of bighorn sheep can become stressed—by predators, by association or competition with livestock or humans, or by inclement weather (Foreyt and Jessup 1982, Parks et al. 1972).

Therefore, if bighorn sheep are to have the best opportunity to survive, they should be spatially separated as far as possible from domestic livestock to prevent contamination (Foreyt and Jessup 1982, Jessup 1980, Robinson et al. 1967) (fig. 20). This is especially important where flying insect vectors are involved. Attractants such as salt stations should be used sparingly because they tend to concentrate use by all ungulates and increase the possibility of disease transfer (Blood 1971, Samuel et al. 1975). Likewise, water sources and feeding stations should be placed so they are never used at any time by both domestic and bighorn sheep (fig. 21).

Pesticides can be used to retard or control some outbreaks of disease (Bunch et al. 1978). For example, the lungworms of bighorn sheep, and the land snails that are the lungworms' intermediate hosts, can be controlled by administering drugs or molluscicides and larvicides to animals or by applying the treatment to a range (Hibler 1976, 1977; Hibler and Spraker 1976). Bighorn sheep infested with scab mites have been injected with drugs to kill the mites and temporarily prevent reinfestation (Williams 1981). The difficult step is to catch the bighorns so they can be treated.

[3] Thomas, Jack Ward, wildlife biologist, Pacific Northwest Forest and Range Experiment Station, La Grande, Oregon, personal communication.

Figure 20.—Domestic sheep should be kept as far as possible from areas inhabited by bighorn sheep (photo by Walt Van Dyke, courtesy Oregon Department of Fish and Wildlife).

Figure 21.—Water sources and salt stations should be located so they are not used by both bighorn sheep and livestock (photo by Walt Van Dyke, courtesy Oregon Department of Fish and Wildlife).

PREDATION

Important predators of bighorn sheep in the Great Basin include cougar, bobcat, coyote, and golden eagle. Of these, the cougar is considered the most capable of killing bighorn sheep (Buechner 1960, Smith 1954). Most authors addressing this topic indicate that the number of animals taken by predators is usually of little consequence to healthy populations of bighorn sheep (Buechner 1960). Losses frequently can be attributed to a single predatory animal that can be selectively removed (Blaisdell 1961). Predators are most effective when locations of escape terrain or water limit sheep movement and allow predators to concentrate hunting effort in a small area (Blaisdell 1961, Light et al. 1967). The impact of predation must be evaluated on a herd-by-herd basis and appropriate action taken.

HUMAN IMPACTS

Even if all the individual components of a habitat are satisfactory, the habitat as a whole will be unsuitable for bighorn sheep if human use is excessive. Human intrusion reduces the number of bighorn sheep, by causing sheep to reduce or terminate their use of prime habitat, stop migration, or split large existing herds into smaller herds (Dunaway 1971, Ferrier 1974, Horejsi 1976, Jorgensen and Turner 1973, Light 1971, Rutherford 1972, Spalding and Bone 1969, Weaver 1972, Wehausen 1980, Welles and Welles (1961). Human activities responsible for declines in sheep use include hiking and backpacking (Blong and Pollard 1968, Dunaway 1971, Nelson 1966, Wehausen 1980, Welles and Welles 1961), snow skiing (Light 1971), and water skiing and fishing (Ferrier 1974). Additional causes of declines are motorbiking (DeForge 1972), driving 4-wheel vehicles (Jorgensen and Turner 1973), construction and use of highways (Ferrier 1974), urban development (Ferrier 1974), and recreational development (Spalding and Bone 1969). When bighorn sheep are pushed from prime to marginal habitat, mortality usually increases and productivitiy decreases (Thorne et al. 1978).

Some herds of bighorn sheep have become conditioned to human activity (Hicks and Elder 1979). For most herds, however, the amount of human activity they can stand varies with the herd and the type and amount of activity (Dunaway 1971, Light 1967, McQuivey 1978). Some herds have become conditioned to human activity (Hicks and Elder 1979). For example, biweekly encounters between bighorn sheep and humans may have no measurable effects; whereas, daily encounters may cause sheep to discountinue use of an area.

Roads have an important association with human activity (Ferrier 1974). Although roads themselves are not necessarily detrimental to bighorn sheep, they greatly facilitate human access (fig. 22). Backcountry roads that receive little use may have little or no effect, but other roads have caused bighorn sheep to alter traditional migration routes (Ferrier 1974). Roads must be individually evaluated. If human access is detrimental, it can be controlled through road closures. When bighorn sheep are on summer range, human use of roads on their winter range will have little effect. The opposite is also true. Where bighorn sheep occupy year-long ranges, permanent road closures should be considered.

Road closures may not be feasible when bighorn sheep ranges lie adjacent to major roads or highways, but restricting off-road use of such areas may be feasible.

Remote, roadless bighorn sheep ranges sometimes receive heavy daily use from hikers and backpackers. In such situations, closures or restrictions may be required.

Land developments such as resorts, housing subdivisions, private dwellings, and hydroelectric installations, and activities such as mining, logging, and road construction, cause bighorn sheep to alter their use of habitat (Ferrier 1974, McQuivey 1978, Sugden 1961, Yoakum 1971). If the management objective is to maintain bighorn sheep, a careful evaluation of potential habitat alteration and human activity is critical to the planning process. For the most part, bighorn sheep now exist in the wild because of human decisions, and the fate of the species in the Great Basin of southeastern Oregon and other areas will be determined by future management of public lands (fig. 23).

Figure 22.—Roads through prime bighorn sheep habitat increase human access and associated negative impacts (photo by Walt Van Dyke).

Figure 23.—The future of bighorn sheep depends on the response of people to the bighorns's needs (photo by Walt Van Dyke, courtesy Oregon Cooperative Wildlife Research Unit).

Literature Cited

Allen, R. W.
1971. Present status of lungworm and tapeworm infections in bighorn sheep. Trans. Desert Bighorn Counc. 15:7-11.

American Ornithologist's Union.
1957. Checklist of North American birds. 5th ed. 691 p. Port City Press, Inc., Baltimore, Maryland.

Anderson, E. W.
1967. Grazing systems as methods of managing range resources. J. Range Manage. 20(6):383-388.

Anderson, E. W., and R. J. Scherzinger.
1975. Improving quality of winter forage for elk by cattle grazing. J. Range Manage. 28(2):120-125.

Anderson, L. D., and J. W. Denton.
1978. Determining forage consumption rates for big game. Bureau of Land Manage., Salmon, Idaho. 5 p.

Bailey, J. A.
1980. Trickle Mountain forage allocation research. U.S. Dep. Inter. Bur. Land Manage. Rep. No. 5, 30 p. Denver Service Center, Denver, Colo.

Bailey, V.
1936. The mammals and life zones of Oregon. North Am. Fauna No. 5., 416 p. U.S. Gov. Print. Off., Washington, D.C.

Barrett, R. H.
1964. Seasonal food habits of the bighorn at the Desert Game Range, Nevada. Trans. Desert Bighorn Counc. 8:85-93.

Baumann, T. G., and D. R. Stevens.
1978. Winter habitat preferences of bighorn sheep in the Mummy Range, Colorado. *In* Proceedings of the 1978 nothern wild sheep and goat conference, p. 320-330. British Columbia Fish and Wildl. Branch. Penticton.

Bear, G. D.
1978. Evaluation of fertilizer and herbicide applications on two Colorado bighorn sheep winter ranges. Colo. Div. Wildl. Rep. No. 10, 75 p. Denver.

Becklund, W. W., and C. M. Senger.
1967. Parasites of *Ovis canadensis* in Montana with a checklist of the internal and external parasites of the Rocky Mountain sheep in North America. J. Parasitol. 53:157-165.

Berwick, S. H.
1968. Observations on the decline of the Rock Creek, Montana, population of bighorn sheep. M.S. thesis. Univ. Montana, Missoula. 245 p.

Blaisdell, J. A.
1961. Bighorn-cougar relationships. Trans. Desert Bighorn Counc. 5:42-46a.

Blong, B., and W. Pollard.
1968. Summer water requirements of desert bighorn in the Santa Rosa Mountains, California, in 1965. Calif. Fish and Game 54(4):289-296. Sacramento.

Blood, D. A.
1961. An ecological study of California bighorn sheep *Ovis canadensis californiana* (Douglas) in southern British Columbia. M.S. thesis. Univ. British Columbia, Vancouver. 127 p.

Blood, D. A.
1963a. Some aspects of behavior of a bighorn herd. Can. Field-Nat. 77(2):77-94.

Blood, D. A.
1963b. Parasites from California bighorn sheep in southern British Columbia. Can. J. Zool. 41(6):913-918.

Blood, D. A.
1967. Food habits of the Ashnola bighorn sheep herd. Can. Field-Nat. 81(1):23-29.

Blood, D. A,
1971. Contagious ecthyma in Rocky Mountain bighorn sheep. J. Wildl. Manage. 35(2):270-275.

Bodie, W. L., and W. O. Hickey.
1980. Response of wintering bighorn sheep to a rest-rotation grazing system in central Idaho. *In* Proceedings of the biennial symposium of the northern wild sheep and goat council, p. 60-69. Idaho Dep. Fish and Game. Salmon.

Browning, B. M., and G. Monson.
1980. Food. *In* The desert bighorn, its life history, ecology, and management, p. 80-99. G. Monson and L. Sumner, eds. Univ. Arizona Press, Tucson.

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

Bunch, T. D., S. R. Paul, and H. McCutchen.
1978. Chronic sinusitis in the desert bighorn (*Ovis canadensis nelsoni*). Trans. Desert Bighorn Counc. 22:16-20.

Campbell, D.
1980. Lava Beds Bighorn:—from 10 to 43 to 0. Outdoor Calif. 41(6):5-7.

Capelle, K. J.
1966. The occurrence of *Oestrus ovis* L. (Diptera: Oestridae) in the bighorn sheep from Wyoming and Montana. J. Parasitol. 52(3):618-621.

Capelle, K. J.
1971. Myiasis. *In* Parasitic diseases of wild animals, p. 279-305. J. W. Davis and R. C. Anderson, eds. Iowa State Univ. Press, Ames.

Chapman, Joseph A., and George A. Feldhammer.
1982. Wild mammals of North America: biology, management, and economics. 1,147 p. The Johns Hopkins Univ. Press, Baltimore, Maryland.

Constan, K. J.
1972. Winter foods and range use of three species of ungulates. J. Wildl. Manage. 36(4):1068-1076.

Cooperrider, A. Y.
1969. Competition for food between mule deer and bighorn sheep on Rock Creek winter range, Montana. M.S. thesis. Univ. Montana, Missoula. 92 p.

Cooperrider, A. Y., S. A. McCollugh, and J. A. Bailey. 1980. Variation in bighorn sheep food habits as measured by fecal analysis. *In* Proceedings of the biennial symposium of the northern wild sheep and goat council, p. 29-41. Idaho Dep. Fish and Game. Salmon.

Cowan, I. M.
1940. Distribution and variation in the native sheep of North America. Am. Midl. Nat. 24(3):505-580.

Cowan, I. M.
1947. Range competition between mule deer, bighorn sheep, and elk in Jasper Park, Alberta. Trans. 12th North Am. Wildl. and Nat. Resour. Conf., p. 223-227. Wildl. Manage. Inst., Washington, D.C.

Crump, W.
1971. The Wind River bighorn herd – a new approach to sheep habitat management. Trans. 1st North Am. Wild Sheep Conf., p. 174-181. E. Decker, ed. Colo. State Univ., Dep. Fish and Wildl. Biol., Fort Collins.

Crump, W. I.
1957. Bighorn sheep reproduction and lamb survival study. Wyo. Game and Fish Dep. P-R Proj. Rep. W-27-R-10, 28 p. Cheyenne.

Davis, John W., Lars H. Karstad, and Daniel O. Trainer (eds.)
1970. Infectious diseases of wild mammals. 421 p. Iowa State Univ. Press, Ames.

Davis, John W., and Roy C. Anderson (eds.).
1971. Parasitic diseases of wild mammals. 364 p. Iowa State Univ. Press, Ames.

Davis, W. B., and W. P. Taylor.
1939. The bighorn sheep of Texas. J. Mamm. 20(4):440-455.

Dealy, E., D. A. Leckenby, and D. Concannon.
1981. Plant communities and their importance to wildlife. *In* Wildlife habitats in managed rangelands – the Great Basin of southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-120, 66 p. Pac. Northwest Forest and Range Exp. Stn., Portland, Oreg.

Dean, H. C.
1977. Desert bighorn sheep in Canyonlands National Park. M.S. thesis. Utah State Univ., Logan. 86 p.

DeForge, J. R.
1972. Mans' invasion into the bighorns habitat. Trans. Desert Bighorn Counc. 16:112-115.

Demarchi, D. A., and H. B. Mitchell.
1973. The Chilcotin River bighorn population. Can. Field-Nat. 87:433-454.

Demarchi, R. A.
1965. An ecological study of the Ashnola bighorn winter ranges. M.S. thesis. Univ. British Columbia, Vancouver. 103 p.

DeMartini, J. C., and R. B. Davies.
1976. *Muellerius capillaris* associated pneumonia in captive bighorn sheep. Trans. Northern Wild Sheep Counc., p. 117-124. Wyo. Game and Fish Dept., Cheyenne.

DeMartini, J. C., and R. B. Davies.
1977. An epizootic of pneumonia in captive bighorn sheep infected with *Muellerius* sp. J. Wildl. Dis. 13:117-124.

Denniston, A.
1965. Status of bighorn in the River Mountains of Lake Mead National Recreation Area. Trans. Desert Bighorn Counc. 9:27-34.

Drewek, J., Jr.
1970. Population characteristics and behavior of introduced bighorn sheep in Owyhee County, Idaho. M.S. thesis. Univ. Idaho, Moscow. 46 p.

Dunaway, D. J.
1971. Human disturbance as a limiting factor of Sierra Nevada bighorn sheep. Trans. 1st North Am. Wild Sheep Conf., p. 165-173. E. Decker, ed. Colo. State Univ., Dep. Fish and Wildl. Biol., Fort Collins.

Dunaway, D. J.
1972. Winter food habits of California bighorn sheep in the Sierra Nevada. Trans. Desert Bighorn Counc. 16:21-29.

Estes, R. D.
1979. Ecological aspects of bighorn sheep populations in southeastern Washington. M.S. thesis. Wash. State Univ., Pullman. 124 p.

Fairaizl, S. D.
1978. Bighorn sheep in North Dakota: Population estimates, food habits, and their biogeochemistry. North Dakota Dep. Game and fish P-R Proj. Rep. W-67-R-17, 51 p. Bismarck.

Ferrier, G. J.
1974. Bighorn sheep along the lower Colorado River, 1974-2050. Trans. Desert Bighorn Counc. 18:40-45.

Foreyt, W. J., and D. A. Jessup.
1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Dis. 18(2):163-168.

Forrester, D. J.
1971. Bighorn sheep lungworm-pneumonia complex. *In* Parsitic diseases of wild animals, p. 158-173. J. W. Davis and R. C. Anderson, eds. Iowa State Univ. Press, Ames.

Franklin, J. F., and C. T. Dyrness.
1973. Natural vegetation of Oregon and Washington. USDA For. Serv. Gen. Tech. Rep. PNW-8, 417 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Frisina, M. R.
1974. Ecology of bighorn sheep in the Sun River Area of Montana during fall and spring. Mont. Fish and Game Dep. P-R Prog. Rep. W-120-R-4, 5, 68 p. Helena.

Garrison, G. A., J. M. Skovlin, C. E. Poulton, and A. H. Winward.
1976. Northwest plant names and symbols for ecosystem inventory analysis. 4th ed. USDA For. Serv. Gen. Tech. Rep. PNW-46, 263 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.
Geist, V.
1971. Mountain sheep, a study in behavior and evolution. 383 p. Univ. Chicago Press, Chicago and London.
Geist, V., and R. G. Petocz.
1977. Bighorn sheep in winter: Do rams maximize reproductive fitness by spatial and habitat segregation from ewes? Can. J. Zool. 55:1802-1810.
Graf, W.
1980. Habitat protection and improvement. *In* The desert bighorn, its life history, ecology, and management, p. 310-319. G. Monson and L. Sumner, eds. Univ. Arizona Press, Tucson.
Haas, W. L.
1979. Ecology of an introduced herd of Rocky Mountain bighorn sheep in south-central Wyoming. M.S. thesis. Colo. State Univ., Fort Collins. 343 p.
Hailey, T. L.
1971. Bighorn bedding and lambing sites. Texas parks and Wildl. Dep. P-R Proj. Rep. W-67-D-15, 4 p. Austin.
Hall, E. R., and K. R. Kelson.
1959. The mammals of North America. 1,083 p. Ronald Press, New York.
Halloran, A. F., and O. V. Deming.
1958. Water development for desert bighorn sheep. J. Wildl. Manage. 22(1):1-9.
Hansen, C. G.
1980. Habitat. *In* The desert bighorn, its life history, ecology, and management, p. 64-79. G. Monson and L. Sumner, eds. Univ. Arizona Press, Tucson.
Hansen, M. C.
1982. Status and habitat preference of California bighorn sheep on Sheldon National Wildlife Refuge, Nevada. M.S. thesis. Oreg. State Univ., Corvallis. 47 p.
Hebert, D. M.
1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph.D. thesis. Univ. British Columbia, Vancouver. 357 p.
Helvie, J. B.
1971. Bighorns and fences. Trans. Desert Bighorn Counc. 15:53-62.
Hibler, C. P.
1976. Investigation of spontaneous diseases of bighorn sheep. *In* P-R Prog. Rep. W-41-R-25/wk. pl. 1/Job No. 26, p. 75-114. Colo. Div. Wildl., Denver.
Hibler, C. P.
1977. Investigation of spontanious diseases of bighorn sheep. *In* P-R Prog. Rep. W-41-R-26/wk. pl. 1/Job No. 25, p. 93-110. Colo. Div. Wildl., Denver.
Hibler, C. P., and T. R. Spraker.
1976. Treatment of bighorn sheep for lungworm. Trans. 2nd North Am. Wild Sheep Conf., p. 66-68. Colo. State Univ., Dep. Fish. and Wildl. Biol., Fort Collins.
Hicks, L. L., and J. M. Elder.
1979. Human disturbance of Sierra Nevada bighorn sheep. J. Wildl. Manage. 43(4):909-915.
Honess, R. F.
1942. Lungworms of domestic sheep and bighorn sheep in Wyoming. Univ. Wyo. Agric. Exp. Stn. Bull. No. 255, 25 p. Laramie.
Honess, R. F., and N. M. Frost.
1942. A Wyoming bighorn sheep study. Wyoming Dep. Game and Fish Bull. No. 1, 127 p.
Horejsi, B.
1976. Some thoughts and observations on harassment and bighorn sheep. *In* Proceedings of the northern wild sheep council, p. 149-155. Wyo. Fish and Game Dep., Cheyenne.
Howard, V. W., Jr., and D. G. Lorenzo.
1975. Vegetation and food habits of Mexican bighorn sheep in the Game-Coin Enclosure near Red Rock. New Mexico State Univ. Agric. Exp. Stn. Rep. 303, 17 p. La Cruces.
Howe, D. L., G. T. Woods, and G. Marquis.
1966. Infection of bighorn sheep (*Ovis canadensis*) with *Myxovirus parainfluenza – 3* and other respiratory viruses. Results of serologic tests and culture of nasal swabs and lung tissue. Bull. Wildl. Dis. Assoc, 2:34-37.
Irvine, C. A.
1969. The desert bighorn sheep of southeastern Utah. Utah Div. Fish and Game Publ. No. 69-12, 99 p. Salt Lake City.
Jahn, L. R., and J. B. Trefethan.
1978. Funding wildlife conservation programs. *In* Wildlife and America—contributions to an understanding of American Wildlife and its conservation, p. 456-470. H. P. Brokaw, ed. Counc. Environ. Qual., Washington, D.C.
Jessup, D. A.
1980. Lava Beds bighorn sheep dieoff report as of 9/4/80. Calif. Dep. Fish and Game, Sacramento. 6p. typescript.
Johnson, B. K., and D. R. Smith.
1980. Food habits and forage preferences of bighorn sheep in alpine and subalpine communities. *In* Proceedings of the biennial symposium of the northen wild sheep and goat council, p. 1-17. Idaho Dep. Fish and Game.
Jones, F. L., G. Hittner, and R. Gard.
1957. Report on a survey of bighorn sheep in the Santa Rosa Mountains, Riverside County. Calif. Fish and Game 43(3):179-191.
Jorgensen, M. C., and R. E. Turner, Jr.
1973. The desert bighorn sheep of Anza-Borrego Desert State Park. Trans. Desert Bighorn Counc. 17:81- 88.

Kistner, T. P., S. M. Matlock, D. Wyse, and G. E. Mason.
1977. Helminth parasites of bighorn sheep in Oregon. J. Wildl. Dis. 13(4):125-130.
Koplin, J. R.
1960. New developments on water requirements on the desert game range. Trans. Desert Bighorn Counc. 4:54-57.
Kornet, C. A.
1978. Status and habitat use of California bighorn sheep on Hart Mountain, Oregon. M.S. thesis. Orego. State Univ., Corvallis. 49 p.
Lange, R.
1980. Part 2: The scabies mite. New Mexico Wildl. 25(1):8-12.
Lange, R. E., A. B. Sandoval, and W. P. Meleney.
1980. Psoroptic scabies in bighorn sheep (*Ovis canadenis mexicana*) in New Mexico. J. Wildl. Dis. 16(1):77- 82.
Lauer, J. L., and J. M. Peek.
1976. Big game-livestock relationships on the bighorn sheep winter range, East Fork Salmon River, Idaho. College of For., Wildl. and Range Sci. Bull. No. 12, 44 p. Moscow, Idaho.
Leslie, D. M., Jr., and C. L. Douglas.
1979. Desert bighorn sheep of the River Mountains, Nevada. Wildl. Monogr. No. 66, 56 p.
Light, J. T.
1971. An ecological view of bighorn habitat on Mt. San Antonio. Trans. 1st North Am. Wild Sheep Conf., p. 150-157. E. Decker, ed. Colo. State Univ., Dep. Fish and Wildl. Biol., Fort Collins.
Light, J. T., F. A. Winter, and H. Graham.
1967. San Gabriel bighorn habitat management plan. Angeles and San Bernadino National Forests, San Bernadino, Calif. 32 p.
Light, J. T., T. R. Zrelack, and H. Graham.
1966. San Gorgino bighorn habitat management plan. San Bernadino National Forest, San Bernadino, Calif. 24 p.
Martin, S. C.
1978. Grazing systems – what can they accomplish? Rangeman's J. 5(1):14-16.
Maser, C., J. M. Geist, D. M. Concannon, R. Anderson, and B. Lovell.
1979. Geomorphic and edaphic habitats. *In* Wildlife habitats in managed rangelands – the Great Basin of southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-99, 84 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.
McCann, L. J.
1956. Ecology of the mountain sheep. Am. Midl. Nat. 56(2):297-324.
McCollough, S. A., A. Y. Cooperrider, and J. A. Bailey.
1980. Impact of cattle grazing on bighorn sheep habitat at Trickle Mountain, Colorado. *In* Proceedings of the biennial symposium of the northern wild sheep and goat council, p. 42-59. Idaho Dep. Fish and Game. Salmon.
McCullough, D. R., and E. R. Schneegas.
1966. Winter observations of the Sierra Nevada bighorn sheep. Calif. Fish and Game 52(2):68-84.
McCutchen, H. E.
1981. Desert bighorn zoogeography and adaptation in relation to historic land use. Wildl. Soc. Bull. 9(3):171-179.
McKee, J. E., and H. W. Wolf (Eds.).
1963. Water quality criteria. State Water Qual. Control. Board Publ. No. 3-A, 548 p. Sacramento, Calif.
McQuivey, R. P.
1978. The bighorn sheep of Nevada. Nevada Dep. Fish and Game Biol. Bull. No. 6, 81 p. Reno.
Meehan, W. R., and W. S. Platts.
1978. Livestock grazing and the aquatic environment. J. Soil and Water Conserv. 33(6):274-278.
Mensch, J. L.
1969. Desert bighorn (*Ovis canadensis nelsoni*) losses in a natural trap tank. Calif. Fish and Game 55(3):237-238.
Moen, A. N.
1973. Wildlife ecology. 458 p. W. H. Freeman and Company, San Francisco.
Morgan, J. K.
1968. Rocky Mountain bighorn sheep investigations. Idaho Fish and Game Dep. P-R Proj. Rep. W-85-R-18/Job. No. 11, 80 p. Boise.
Morgan, J. K.
1969. Rocky Mountain bighorn sheep investigations. Idaho Fish and Game Dep. P-R Proj. Rep. W-85-R-18/Job No. 11, 73 p. Boise.
Nelson, M.
1966. Problems of recreational use of game refuges. Trans. Desert Bighorn Counc. 10:13-20.
Oldemeyer, J. L., W. J. Barmore, and D. L. Gilbert.
1971. Winter ecology of bighorn sheep in Yellowstone National Park. J. Wildl. Manage. 35(2):257-269.
Packard, F. M.
1946. An ecological study of the bighorn sheep in Rocky Mountain National Park, Colorado. J. Mamm. 27(1):3-28.
Parks, J. B., G. Post, T. Thorne, and P. Nash.
1972. Parainfluenza – 3 virus infection in Rocky Mountain bighorn sheep. J. Am. Vet. Med. Assoc. 161(6):669-672.
Peek, J. M., R. A. Riggs, and J. L. Lauer.
1979. Evaluation of fall burning on bighorn sheep winter range. J. Range manage. 32(6):430-432.
Pitt, M. D., and B. M. Wikeem.
1978. Diet preference of California bighorn sheep on native rangeland in south-central British Columbia. *In* Proceedings of the 1978 northern wild sheep and goat conference, p. 331-349. British Columbia Fish and Wildl. Branch. Penticton.
Riggs, R. A.
1977. Winter habitat use patterns and populations of bighorn sheep in Glacier National park. M.S. thesis. Univ. Idaho, Moscow. 85 p.

Risenhoover, K. L., and J. A. Bailey.
1980. Visibility an important factor for an indigenous, low-elevation bighorn herd in Colorado. *In* Proceedings of the biennial symposium of the northern wild sheep and goat council, p. 18-28. Idaho Dep. Fish and Game.

Robinson, C. S., and F. P. Cronemiller.
1954. Notes on the habitat of the desert bighorn in the San Gabriel Mountains of California. Calif. Fish and Game 40:267-271.

Robinson, R. M., T. L. Hailey, C. W. Livingston, and J. W. Thomas. 1967. Bluetongue in the desert bighorn sheep. J. Wildl. Manage. 31(1):165-168.

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

Rutherford, W. H.
1972. Status of transplanted bighorn sheep in Colorado. Colo. Div. Game, Fish and Parks Game Inf. Leafl. No. 92, 3 p.

Samuel, W. M., G. A. Chalmers, J. G. Stelfox, A. Loewen, and J. J. Thomsen.
1975. Contagious ecthyma in bighorn sheep and mountain goat in western Canada. J. Wild. Dis. 11(1):26-31.

Samuel, W. M., W. K. Hall, J. G. Stelfox, and W. D. Wishart.
1978. Parasites of mountain goat, *Oreamnos americanus* (Blainville), of west central Alberta with a comparison of the helminths of mountain goat and Rocky Mountain bighorn sheep, *Ovis c. canadensis* Shaw. *In* Proceedings of the first international mountain goat symposium, p. 212-225. Kalispell, Mont.

Schallenberger, A.
1965. Big game forage competition in Sun River Canyon. M.S. thesis. Mont. State Univ., Bozeman. 44 p.

Seton, E. T.
1929. The lives of game animals. vol. 3, part 2. 780 p. Doubleday, Doran, and Co., Garden City, NY.

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts.
1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wild. Manage. 39(2):387-401.

Skovlin, J. M.
1965. Improving cattle distribution of western mountain rangelands. U.S. Dep. Agric. Farmers Bull. No. 2212, 14 p. Washington, D.C.

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

Spalding, D. J., and J. N. Bone.
1969. The California bighorn sheep of the south Okanagan Valley, British Columbia. British Columbia Fish and Wildl. Branch, Wildl. Manage. Publ. No. 3, 45 p. Vancouver.

Spalding, D. J., and H. B. Mitchell.
1970. Abundance and distribution of California bighorn sheep in North America. J. Wildl. Manage. 34(2):473-475.

Stelfox, J. G.
1971. Bighorn sheep in the Canadian rockies: a history 1800-1970. Can. Field-Nat. 85(2):101-122.

Stelfox, J. G.
1976. Range ecology of Rocky Mountain bighorn sheep in Canadian national parks. Ca. Wildl. Serv. Rep. Ser. No. 39, 50 p.

Stoddart, L. A., A. D. Smith, and T. W. Box.
1975. Range management. 532 p. McGraw-Hill Book Co., New York.

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

Thomas, J. W., R. J. Miller, H. Black, J. E. Rodiek, and C. Maser.
1976. Guidelines for maintaining and enhancing wildlife habitat in forest management in the Blue Mountains of Oregon and Washington. Trans. 41st North Am. Wildl. and Nat. Resour. Conf., p. 452-476.

Thorne, E. T., T. Varcalli, K. Becker, and G. B. Butler.
1978. Some thoughts on the consequences of nontrophy sheep hunting in the Wind River Mountains of Wyoming. *In* Proceedings of the 1978 northern wild sheep and goat conference, p. 42-51. British Columbia Fish and Wildl. Branch. Penticton.

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

Trainer, D. O.
1970. Bluetongue. *In* Infectious diseases of wild mammals, p. 55-59. J. W. Davis, L. H. Karstad, and D. O. Trainer, eds. Iowa State Univ. Press, Ames.

Trefethan, J. B. (Ed).
1975. the wild sheep in modern North America. 302 p. Winchester Press, New York.

Turner, J. C., Jr.
1973. Water, energy and electrolyte balance in the desert bighorn sheep, *Ovis canadensis*. Ph.D. thesis. Univ. Calif., Riverside. 138 p.

Turner, J. C., and R. A. Weaver.
1980. Water. *In* The desert bighorn, its life history, ecology, and management, p. 100-112. G. Monson and L. Sumner, eds. Univ. Arizona Press, Tucson.

Uhazy, L. S., and J. C. Holmes.
1970. Helminths of the Rocky Mountain bighorn sheep in western Canada. Can. J. Zool. 49:507-512.

Uhazy, L. S., J. L. Mahrt, and J. C. Holmes.
1971. Coccidia of Rocky Mountain bighorn sheep in western Canada. Can. J. Zool. 49:1461-1464.
Van Dyke, W. A.
1978. Population characteristics and habitat utilization of bighorn sheep, Steens Mountain, Oregon. M.S. thesis. Oreg. State Univ., Corvallis. 87 p.
Wagner, F. H.
1978. Livestock grazing and the livestock industry. *In* Wildlife and America – contributions to an understanding of American wildlife an its conservation, p. 121-145. H. R. Brokaw, ed. Counc. Environ. Qual., Washington, D.C.
Weaver, R. A.
1972. California bighorn in the Sierra Nevada Mountain Range. Calif. Dep. Fish and Game Wildl. Manage. Adm. Rep. No. 72-7, 17 p.
Wehausen, J. D.
1980. Sierra Nevada bighorn sheep: history and population ecology. Ph.D. diss. Univ. Michigan, Ann Arbor. 240 p.
Welles, R. E., and F. B. Welles.
1961. The bighorn of Death Valley. Natl. Parks Fauna Ser. No. 6, 242 p. U.S. Gov. Print. Off., Washington, D.C.
Welsh, G. W.
1971. What's happening to our sheep? Trans. Desert Bighorn Counc. 15:63-68.
Williams, J.
1980. Desert rescue. New Mexico Wildl. 25(2):2-5, 25-29.
Williams, J.
1981. A success story. New Mexico Wildl. 26(2): 2-5.
Wilson, L. O.
1968. Distribution and ecology of the desert bighorn in southeast Utah. Utah Div. Fish and Game Publ. 68-5, 220 p. Salt Lake City.
Wilson, L. O.
1977. Guidelines and recommendations for design and modification of livestock watering developments to facilitate safe use by wildlife. U.S. Dep. Inter. Bur. Land Manage. Tech. Note 305, 20 p. Boise, Idaho.
Woodgerd, W.
1964. Population dynamics of bighorn sheep in Wildhorse Island. J. Wildl. Manage. 28(2):381-391.
Woolf, A.
1968. Summer ecology of bighorn sheep in Yellowstone National Park. M.S. thesis. Colo. State Univ., Fort Collins. 112 p.
Woolf, A.,and D. C. Kradel.
1973. Mortality in captive bighorn sheep – clinical, hematological, and pathological observations. J. Wildl. Dis. 9:12-17.
Yoakum, J.
1971. Habitat management for the desert bighorn. Trans. 1st North Am. Wild Sheep Conf., p. 158-164. E. Decker, ed. Colo. State Univ., Dep. Fish and Wildl. Biol., Fort Collins.
Yoakum, J.
1973. Survey of potential bighorn habitat on National resource land in the Southwest. Trans. Desert Bighorn Counc. 17:123-136.
Yoakum, J. D.
1964. Bighorn food habit-range relationships in the Silver Peak Range, Nevada. Trans. Desert Bighorn counc. 8:95-102.
Yoakum, J. D.
1966. Comparison of mule deer and desert bighorn seasonal food habits. Trans. Desert Bighorn Counc. 10:65-70.
Yoakum, J., W. P. Dasmann, H. R. Sanderson, C. M. Nixon, and H. S. Crawford.
1980. Habitat imnprovement techniques. *In* Wildlife management techniques manual, p. 329-404. S. D. Schemnitz, ed. Wildl. Soc., Washington, D.C.

Appendix

Common and Scientific Names[1]

Common name	Scientific name
	MAMMALS
Bighorn sheep	*Ovis canadensis*
California bighorn sheep	*Ovis canadensis californiana*
Cougar	*Felis concolor*
Coyote	*Canis latrans*
Deer	*Odocoileus* spp.
Desert bighorn sheep	*Ovis canadensis nelsoni*
Domestic cow	*Bos taurus*
Domestic goat	*Capra hircus*
Domestic sheep	*Ovis aries*
Horse	*Equus caballus*
North American elk	*Cervus elaphus*
Pronghorn	*Antilocapra americana*
Rocky Mountain bighorn sheep	*Ovis canadensis canadensis*
	BIRDS
Golden eagle	*Aquila chrysaetos*
	PLANTS
Antelope bitterbrush	*Purshia tridentata*
Arrowleaf balsamroot	*Balsamorhiza sagittata*
Aspen	*Populus* spp.
Basin big sagebrush	*Artemisia tridentata tridentata*
Bearded bluebunch wheatgrass	*Agropyron spicatum*
Big sagebrush	*Artemisia tridentata*
Black greasewood	*Sarcobatus vermiculatus*
Black sagebrush	*Artemisia nova*
Blue elderberry	*Sambucus cerulea*
Bluegrasses	*Poa* spp.
Bolander silver sagebrush	*Artemisia cana bolanderi*
Bottlebrush squirreltail	*Sitanion hystrix*
Bud sagebrush	*Artemisia spinescens*
Cheatgrass brome	*Bromus tectorum*
Cherry	*Prunus* spp.
Chokecherry	*Prunus virginiana*
Cinquefoil	*Potentilla fruiticosa*
Cleftleaf sagebrush	*Artemisia arbuscula thermopola*
Cobre rockcress	*Arabis cobrensis*
Common snowberry	*Symphoricarpus albus*
Common winterfat	*Eurotia lanata*
Cottonwood	*Populus* spp.
Creambush rockspirea	*Holodiscus discolor*
Curlleaf mountain-mahogany	*Cercocarpus ledifolius ledifolius*

[1] Mammal names from Chapman and Feldhammer (1982); bird names from American Ornithologist's Union (1957); plant names from Garrison et al. (1976); parasite and disease names from Davis et. al. (1970).

Appendix (continued)

Common name	Scientific name
Currant	*Ribes* spp.
Cushion buckwheat	*Eriogonum ovalifolium*
Douglas-fir	*Pseudotsuga menziesii*
Early low sagebrush	*Artemisia longiloba*
Erigeron	*Erigeron* spp.
Fairway crested wheatgrass	*Agropyron cristatum*
Fir	*Abies* spp.
Fourwing saltbush	*Atriplex canescens*
Giant wildrye	*Elymus cinereus*
Idaho fescue	*Festuca idahoensis*
Indian ricegrass	*Oryzopsis hymenoides*
Juniper	*Juniperus* spp.
Lomatium	*Lomatium* spp.
Low sagebrush	*Artemisia arbuscula arbuscula*
Lupine	*Lupinus* spp.
Mallow ninebark	*Physocarpus malvaceus*
Meadow barley	*Hordeum brachyantherum*
Milkvetch	*Astragalus* spp.
Mountain big sagebrush	*Artemisia tridentata vaseyana*
Mountain-mahogany	*Cercocarpus* spp.
Mountain silver sagebrush	*Artemisia cana* sub. *viscidula*
Mountain snowberry	*Symphoricarpus oreophilus*
Penstemon	*Penstemon* spp.
Phlox	*Phlox* spp.
Pine	*Pinus* spp.
Pinegrass	*Calamagrostis rubescens*
Pinnate tansymustard	*Descurainia pinnata*
Prairie junegrass	*Koeleria cristata*
Quaking aspen	*Populus tremuloides*
Rabbitbrush	*Chrysothamnus* spp.
Rose	*Rosa* spp.
Sagebrush	*Artemisia* spp.
Saskatoon serviceberry	*Amelanchier alnifolia*
Sedge	*Carex* spp.
Shadscale saltbush	*Atriplex confertifolia*
Shinyleaf spiraea	*Spiraea lucida*
Spiny hopsage	*Atriplex spinosa*
Squaw apple	*Peraphyllum ramosissimum*
Subalpine big sagebrush	*Artemisia tridentata* form *spiciformis*
Threetip sagebrush	*Artemisia tripartata*
Thurber's needlegrass	*Stipa thurberiana*
Wallflower phoenicaulis	*Phoenicaulis cheiranthoides*
Western juniper	*Juniperus occidentalis*
Wild buckwheat	*Eriogonum* spp.
Willow	*Salix* spp.
Wyoming big sagebrush	*Artemisia tridentata wyomingensis*
Yarrow	*Achillea millefolium*

Appendix (continued)

Common name	Scientific name
	PARASITES AND DISEASES
Bacteria	*Corynebacterium pogenes*
	Pasteurella multocida
Lungworms	*Muelleruis* sp.
	Protostrongylus stilesi
	Protostrongylus rushi
Nematodes	*Nematodirus* spp.
	INSECTS
Scab mite	*Psoroptes ovis*
Sheep bot fly	*Oestrus ovis*