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Desert Bighorn Sheep in Canyonlands National Park

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DESERT BIGHORN SHEEP IN
CANYONLANDS NATIONAL PARK

by

H. Clay Dean

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Science

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In this period of quantitative emphases in wildlife studies, the encouragement of Dr. Juan Spillett, my major professor, and Drs. Gar Workman, and Neil West, members of my graduate committee, convinced me that a descriptive study such as this one was necessary. For their encouragement, advice, and assistance, I am grateful.

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The continued encouragement from my wife, Sue, made possible the completion of this study.

H. Clay Dean

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ABSTRACT

Desert Bighorn Sheep in Canyonlands National Park

by

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Utah State University, 1977

Major Professor: J. Juan Spillett
Department: Wildlife Science

The ecology of bighorn sheep in Canyonlands National Park, Utah was investigated between July 1974 and December 1975. Primary objectives of this study were: (1) to determine the distribution and abundance of bighorn sheep in the Park; (2) to examine the effects of human encroachment, and (3) to determine key habitat factors in relation to bighorn sheep movements. Data were collected by ground and aerial surveys.

There were between 60 and 100 bighorn sheep in the Island in the Sky District and between 20 and 30 in the Needles District. Bighorn sheep distribution was closely related to the history of livestock grazing and landform characteristics of the canyons. Human activities have restricted bighorn ewe distribution more than ram distribution. Bighorn ewes were observed in canyons which were not used by domestic livestock or where much of the canyon was isolated from domestic livestock.

Deer and bighorn sheep demonstrated different landform preferences. Deer occupied large level areas, washes, and river bottoms. Bighorn sheep remained on the more rugged terrain, moving to level

areas to feed. In canyons which were completely isolated from deer and livestock, bighorn sheep preferred the broad level areas and washes.

Bighorn ewes did not demonstrate seasonal movements, whereas rams had definite movement patterns. In the southern portion of the Island in the Sky District, rams formed small bands and remained in a series of four canyons throughout the late winter and spring. In June, these rams dispersed individually or in pairs to higher elevations. During October they returned to the canyons below the White Rim to search for ewes. In the eastern portion of the Island in the Sky District, mature rams remained below the White Rim only during the rut, dispersing to higher elevations for the rest of the year.

Physical barriers may minimize the impact of tourism upon bighorn sheep. If bighorn sheep were above or unable to see the source of disturbance, the impact was not as great as when bighorn were able to see the source. This may explain the tendency for bighorn ewes to quickly retreat when vehicles approached them on the White Rim Road where few physical barriers are present. Human encroachment also decreases the energy intake and increases the energy output of bighorn sheep.

Bighorn sheep appear to be at equilibrium with the current range they inhabit. The National Park Service should monitor the use of the White Rim Road to evaluate effects on the bighorn sheep and restrict hiking below the White Rim to minimize stress on the bighorn sheep within this range. Studies should be initiated to investigate the bighorn sheep expansion of its range within the Park as a result of the cessation of livestock grazing, and the role tourism plays in limiting it.

(95 pages)

INTRODUCTION

To many Americans, the bighorn sheep (*Ovis canadensis)* is a symbol of western wilderness. According to Buechner (1960), bighorn sheep formerly occupied most of the mountainous western states. However, the entire population has undergone a great reduction in numbers and distribution during the past 150 years. Not surprisingly, this coincides with the western movement of white men and his domestic livestock. Although Canyonlands National Park harbors one of the few remaining native populations of desert bighorn sheep in the West, very little is known about this population. Without knowledge of the ecology of the desert bighorn sheep, it is impossible to implement proper management programs that would ensure that the desert bighorn sheep will continue to constitute an integral part of the present Canyonlands National Park ecosystem.

Canyonlands National Park has unique responsibilities to both the public (present and future) and to the bighorn sheep. As people increasingly turn to camping and backpacking in wilderness areas, there will be increased pressures for more roads, camping facilities and hiking trails. If the National Park Service responds to these pressures without an adequate knowledge of bighorn sheep movements, habitat preferences, and the location of lambing grounds and watering sites, bighorn sheep could be eliminated from Canyonlands National Park. The continued integrity of ecosystems in Canyonlands will enhance the ecological and aesthetic values of the Park for future generations of Americans.

This baseline study was initiated to provide the National Park Service with information concerning the ecology of the bighorn sheep in Canyonlands National Park. Information concerning human encroachment and its effect upon bighorn sheep distribution, behavior, and movements should be applicable to other populations of bighorn sheep.

Objectives

Primary objectives were: (1) to determine the distribution and abundance of bighorn sheep in Canyonlands National Park; (2) to examine the activities of man in relation to the bighorn; and (3) to determine seasonal movements of bighorn sheep in relation to habitat factors.

REVIEW OF LITERATURE

Two studies have been conducted on the desert bighorn sheep in Utah (Wilson, 1968; Irvine, 1969). Both were administered through the Utah Cooperative Wildlife Research Unit and conducted in the Red Canyon drainage south of Canyonlands National Park.

Wilson's (1968) objectives were: (1) to determine the subspecies, distribution, and numbers of bighorn sheep in the Red Canyon area; (2) to determine habitat conditions on ranges utilized by bighorn sheep; (3) to determine productivity and factors affecting the same; and (4) to determine daily and seasonal movements, food preferences, natural salt licks, and water distribution.

His conclusions were: (1) the subspecies was *O. c. nelsoni;* (2) the population contained a minimum of 103 animals and possibly a maximum of 144 animals; (3) lamb mortality averaged 39.5 percent for the two years of his study and was due largely to a lack of water, with predation and mineral deficiency also contributing; (4) daily movements were affected by and centered around the proximity of water. Wilson also observed that ewes returned to the same lambing grounds each year.

Irvine (1969) attempted to determine: (1) winter distribution and migrational habits of the resident bighorn sheep population in the Red Canyon area; (2) productivity and ewe-lamb ratios over a two-year period; (3) winter water utilization; and (4) nutritional levels and general health conditions of sheep.

He concluded that: (1) spring and summer distribution of ewes, lambs, and yearlings followed patterns which were dependent upon rainfall. During fall and winter the animals were more evenly distributed, due to the greater availability of water; (2) lamb mortality was extremely low, indicating a possible population increase; and (3) the overall health conditions of bighorn sheep were excellent. With regard to lambing grounds, Irvine found that the ewes did not necessarily return to the same area each year, depending upon water distribution.

The other indepth bighorn sheep study, which has been conducted in Utah, was Barmore's (1962) study on "Bighorn Sheep and Their Habitat in Dinosaur National Monument." He found that livestock grazing had a negative effect on bighorn sheep distribution.

Follows (1969) is the only publication about bighorn sheep in Canyonlands National Park. Based primarily upon information collected through interviews, he discussed the historical range of the bighorn in the park area and cited human encroachment and parasite infestations as the possible causes for reductions in this population. Past bighorn sheep sightings in Canyonlands are listed also.

The Desert Bighorn Council Transactions comprise the most extensive sources of information on the desert bighorn. The transactions published annually, contain more than 250 papers on the history, ecology, behavior, and management of the desert bighorn sheep. In areas such as population dynamics, habitat requirements and human encroachment, major contributions have been made by Ralph and Florence Welles (1957, 1959), Charles Hansen (1960, 1961), Lanny Wilson (1967, 1969) and Gale Monson (1960, 1963).

Transactions for the first North American Wild Sheep Conference which was held in 1971 were published under a format similar to that of the Desert Bighorn Council. Included were contributions on the life histories, diseases, ecology, and management of the North American wild sheep.

Blong and Pollard (1965) studied water requirements of desert bighorn sheep in California. They concluded: (1) most ewes and lambs stay within a 0.75-mile radius of water during July and August; (2) during hot dry periods ewe groups stay within 0.5 miles of water; (3) during July and the first half of August, prime or older rams stay within 3.0 miles of water and make fewer trips to water; (4) at other times of the year, rams apparently travel to different waterholes; (5) bighorn sheep avoid water sources where there is continual human disturbance, but will adapt readily to new water sources.

Buechner's (1960) "The Bighorn Sheep in the United States, Its Past, Present, and Future" is an overview of the North American bighorn sheep. He gave particular attention to population dynamics, and believed high lamb mortality was normal for stable bighorn populations, with disease being the primary limiting factor in Rocky Mountain bighorn sheep populations with high densities. With desert bighorn sheep he believed water and vegetation were major limiting factors, with disease playing a minor role because of low densities.

Geist's (1971a) book on the Mountain Sheep A Study in Behavior and Evolution, is the most extensive bighorn sheep behavior study to date. It includes sections on home ranges and migrations which might be applicable to desert bighorn sheep. Geist concludes that ecological conditions and social adaptations are closely related.

Russo (1956) presented a general summary of the ecology and behavior of the desert bighorn sheep in Arizona. He concluded that: (1) water was a limiting factor, and new sources should be developed; (2) deer and bighorn sheep competition was greatest around watering sites; (3) stringent grazing control was necessary; (4) predators could be a limiting factor and control, if necessary, should be initiated; and (5) removal of surplus mature rams limited intraspecific competition.

Smith (1954) did a comprehensive study on the Rocky Mountain bighorn sheep in Idaho. Although much of this study was devoted to habitat preferences, his discussion of mineral requirements, carrying capacity, and reproduction are applicable to the desert bighorn sheep.

"The Bighorn of Death Valley" (Welles and Welles, 1961) is primarily a life history of the desert bighorn in Death Valley National Monument. Human encroachment appeared to be the major limiting factor, with water also being crucial. Lamb mortality was high, averaging 90 percent. In addition, they believed that competition from feral burros was not as severe as previously reported.

STUDY AREA DESCRIPTIONS

Canyonlands National Park, in southeastern Utah, contains more than 1300 km^2 (Figure 1). The park was established in 1964, with additional lands annexed in 1971. The two primary influences upon the Park, through geological time to the present, are the Green and Colorado rivers, which meet to form the Colorado at the geographical center of the Park. The rivers divide the Park into three districts: the Needles, the Maze, and the Island in the Sky (Figure 2). Elevations in the Park vary from 1333 m at the river level, to about 2000 m at the top of the Navajo Formation in the Island in the Sky District. Large plateaus covered by grasslands are characteristic of the higher elevations, with pinyon and juniper becoming abundant in the broken areas at higher elevations. Descending toward the river, various types of canyons and benches are encountered reflecting different resistances to erosion. Much of the Park is accessible only by four-wheel drive vehicles or by hiking trails.

Climate

Canyonlands is an arid area, with warm, dry summers and cool, dry winters. Annual precipitation varies between 17.8 and 22.9 cm being distributed primarily in the forms of winter showers and summer cloudbursts. During the study, precipitation averaged more than 23 cm per year. Winter temperatures occasionally fall below 18° C.

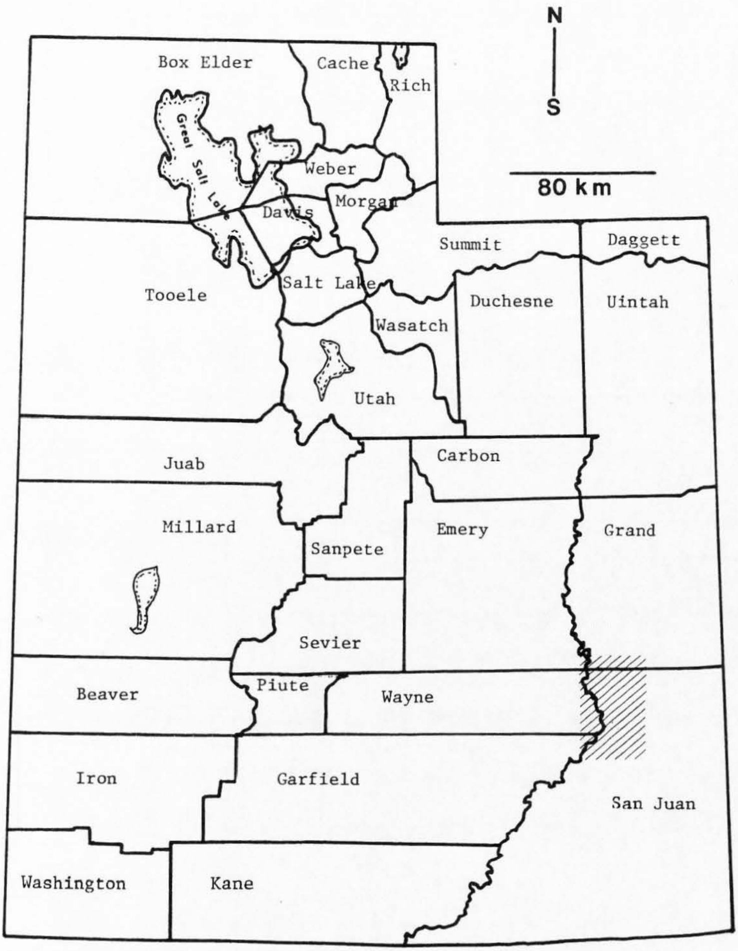
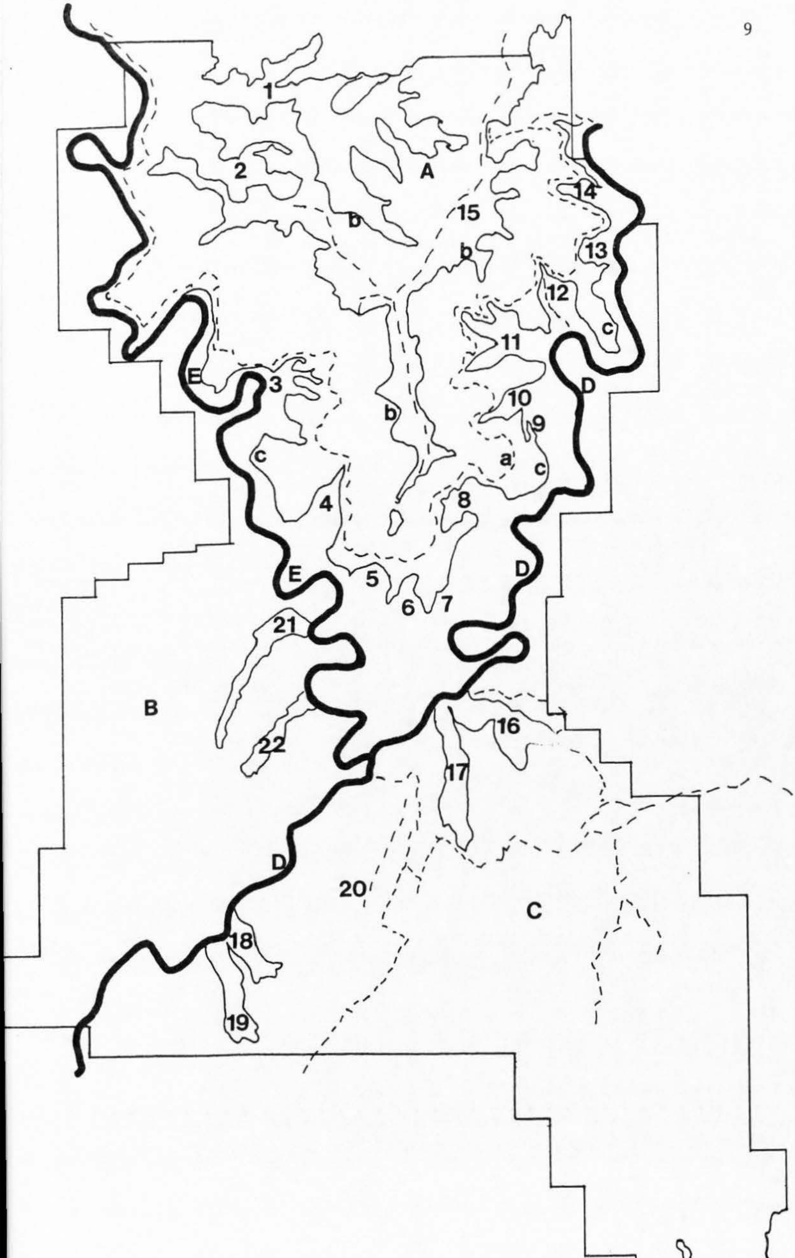


Figure 1. Map of Utah depicting the general location of Canyonlands National Park.



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but normally exceed 9° C during the day. Temperatures above 38° C are not uncommon during the summer. The temperatures during summer nights normally are below 18° C (Table 1).

Table 1. Climatological data for 1975 recorded at the Island in the Sky District, Canyonlands National Park, Utah

Month	Precipitation (cm)	High temperature (C)	Low temperature (C)	Mean high temperature (C)	Mean low temperature (C)
January	Trace	2	-8	14	-16
February	1	5	-4	13	-11
March	3	10	-1	17	-13
April	2	14	1	21	-9
May	3	20	7	29	-2
June	1	27	13	34	6
July	7	32	19	35	13
August	1	31	17	36	12
September	1	26	13	32	11
October	2	20	6	27	-7
November	1	13	-3	21	-12
December	1	9	-13	2	-6
Total	23				

Geology

Six geological formations are exposed in Canyonlands National Park. According to Baars, et al. (1971), the Navajo Sandstone, of the early Jurassic Period is the youngest formation in the Park (Figure 3). It is exposed only in the northern parts of the Island in the Sky District. This formation forms rounded cliffs and dome-like forms, with thicknesses often exceeding 100 m. It is composed of fine- to medium-grained sandstone, which is buff to pale orange in color.

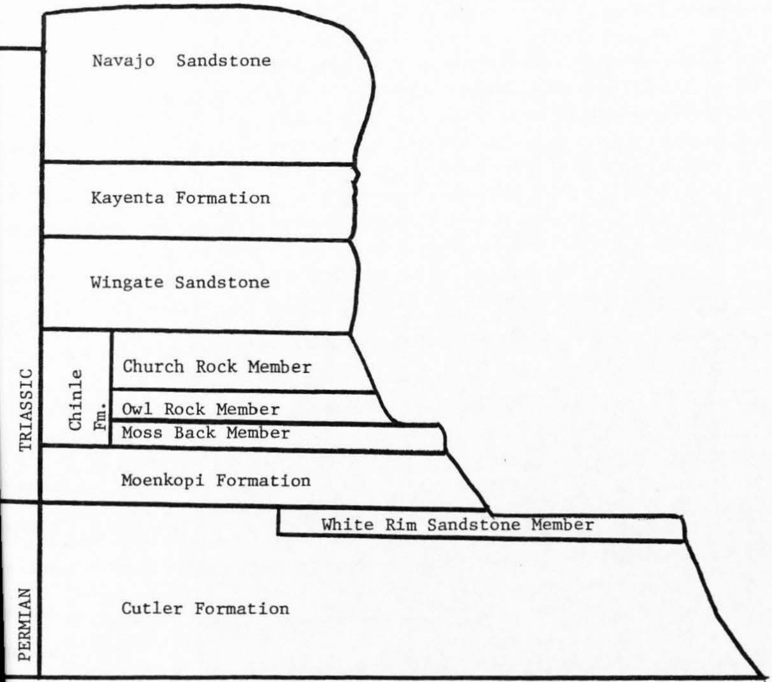

Figure 3. Profile of the geological formations in the Island in the Sky District in Canyonlands National Park, Utah (modified from Hintze, 1973).

The Kayenta Formation, of the late Triassic Period, is a thin cliff-forming unit. In the Park it is less than 75 m thick and composed of red and reddish-purple, very fine- to medium-grained sandstone.

The Wingate Sandstone, of the late Triassic Period, forms massive, vertical cliffs which support the mesas and plateaus surrounding the Park and in the Island in the Sky District. This formation is approximately 100 m thick and consists of pale orange and light brown fine-grained sandstone. Desert varnish often gives the Wingate a dark red color.

The Chinle Formation, of the late Triassic Period, ranges from 100 to 200 m in thickness, and weathers to form ledgy slopes. The Chinle in the Park consists of the Owl Rock, Church Rock and Moss Back members. The Moss Back is the most recognizable member, being a cliff-forming unit about 15 m thick. It consists of gray to pale orange, fine- to medium-grained sandstone. Most of the uranium mining which has occurred in Canyonlands was concentrated in the Moss Back Member.

The Moenkopi Formation, of the early Triassic Period, is exposed in the Island of the Sky District and the eastern and western boundaries of the Maze and Needles districts. The Moenkopi, which generally is about 100 m thick, forms ledgy slopes and consists of reddish brown, fine-grained sandstone.

The Cutler Formation, of the lower Permian Period, is a complex interfingering of quartz sands, arkosic sands, and limestone. The uppermost member, the White Rim, is a cliff-forming formation, which varies from 5 m to 40 m in thickness. This formation is located only in the Island in the Sky and Maze districts. The less resistant members of the Cutler form numerous small benches. In the southern sections of the Park, a colorful banding has resulted from the interfingering of red and white sandstones.

The Honaker Trail Formation of the Hermosa Group, of the Pennsylvanian Period, is composed of interbedded gray limestones, sandstones, and shales. In the Park this formation is exposed only in Cataract Canyon.

Their relative resistances to erosion and the subsequent manner in which these formations weather have a profound effect upon the flora and fauna of Canyonlands National Park.

Wildlife

Since Canyonlands is a desert habitat, most of the mammals found there are nocturnal. The most commonly observed mammals are the antelope ground squirrel *(Ammospemophilus leucurus)*, rock squirrel *(Spermophilus variegatus)*, and chipmunk *(Eutamias minimus)*. Cottontail rabbits *(Sylvilagus auduboni)* are seen occasionally, while the black-tailed jackrabbit *(Lepus californicus)* is seen infrequently.

Two native ungulates, the desert bighorn sheep *(Ovis canadensis)*, and the mule deer *(Odocoileus hemionus)*, inhabit the Park throughout the year. Female deer frequently were observed on the river bottoms and adjoining broad washes. Both sexes are observed on the higher grasslands throughout the year. Deer are much less common in the canyons and benches between the rivers and the high grasslands.

Armstrong (1972) reported that Canyonlands is within the range of the coyote *(Canis latrans)*, gray fox *(Urocyon cinereoargenteus)*, bobcat *(Lynx rufus)*, and mountain lion *(Felis concolor)*. Coyotes and gray foxes are seen occasionally, but bobcats and mountain lions rarely.

The most common large avian predators in Canyonlands are the raven *(Corrus corax)*, red-tailed hawk *(Buteo borealis)*, golden eagle *(Aquila chrysaetos)*, prairie falcon *(Falco mexicanus)*, western horned owl *(Buba virginianus)*, and Cooper's hawk *(Buteo borealis)*.

Vegetation

The following information was taken primarily from Walter Loope's unpublished dissertation (1977).

At elevations of approximately 1933 m, terraced areas with deep soils are occupied by a grass-dominated plant community with a total ground cover of approximately 20-30 percent. Major grasses are galleta grass *(Hilaria jamesii)*, Indian ricegrass *(Oryzopsis hymenoides)*, blue grama *(Bouteloua gracilis)*, sand dropseed *(Sporobolus cryptandrus)*, and needle and thread *(Stipa comata)*. Major shrubs are Mormon tea *(Ephedra viridis)*, four-winged saltbush *(Atriplex canescens)* and blackbrush *(Coleogyne ramosissima)*. Pinyon pine *(Pinus edulus)* and juniper *(Juniperus osteosperma)* comprise variable portions of another plant community type occurring mostly on shallower soils.

The tight clay soils of the Chinle Formation support little vegetation. Here, plant cover ranges from almost no vegetal cover on south-facing slopes to as much as 10 percent cover on north-facing slopes. Garrett saltbush *(Atriplex garretii)*, squawbush *(Rhus trilobata)* and prince's plume *(Stanlyea pinnata)* are present on such slopes. Galleta grass and Indian ricegrass also are found occasionally.

The terraces of the Moss Back Member of the Chinle Formation supports a blackbrush dominated community. Total vascular plant cover varies between 10-20 percent and consists primarily of the blackbrush, Mormon tea *(Ephedra viridis* and *E. torreyana)*, and galleta grass. Serviceberry *(Amelanchier utahensis)*, cliffrose *(Cowania mexicana)*, junipers, and pinyons occur at patches of very shallow soil.

The terrace of the White Rim supports a blackbrush-galleta grass community, which has a total vegetal cover of 10-20 percent. Indian rice-grass, globemallow *(Sphaeralcea coccinea)*, snakeweed *(Gutierrezia* sp.), mojave aster *(Machaeranthera venusta)*, yucca *(Yucca harrimaniae)*, and *Ephedra torreyana* are represented sporadically in this community.

Near the edges of the White Rim Sandstone, blowing sand has filled joint cracks. Better moisture conditions exist in these cracks, due to the collection of runoff water from the surrounding slickrock. Such situations are found in all of the slickrock areas of the Park. Characteristic plants in such areas are juniper, pinyon pine, cliff-rose, squawbush, cliffrose, mountain mahogany *(Cercocarpus intricatus)*, single-leaf ash *(Fraxinus anomola)* and Fremont barberry *(Berberis fremontii)*. Percent ground cover varies greatly.

The Cutler Formation in the Island in the Sky District is covered by a plant community which has a varied species composition and which is determined by slope, exposure, drainage patterns and soil types. On well-drained north-facing slopes, serviceberry, squawbush, and Bigelow sagebrush *(Artemesia bigelovii)* are common. Total vascular plant cover on such slopes approximates 20 percent. Throughout this varied slope community, desert trumpet *(Eriogonum inflatum)*, Mormon tea *(Ephedra torreyana)*, rabbitbrush *(Chrysothamnus nauseosus)*, prince's plume, mojave aster, single-leaf ash, shadscale, galleta grass, and Indian ricegrass occur. In general, plant cover totals approximately 5-10 percent. On lower elevations and benches, shadscale *(Atriplex confertifolia)* predominates. Sides of washes in this formation have a 20-30 percent plant cover which consists of rabbitbrush, gumweed *(Grindelia aphanactis)*, brickle bush *(Brickellia longifolia)*, tamarisk *(Tamarix pentandra)*, sandbar willow *(Salix exigua)*, Fremont cottonwood *(Populus fremontii)*, saltgrass *(Distichlis stricta)*, common reed *(Phragmites communis)* and *Oxytenia acerosa.*

Along the river bottoms, plant cover often is 100 percent and composed of tamarisk, common reed, Fremont cottonwood, sandbar willow, saltgrass, Salina wild rye grass *(Elymus salinus)*, hackberry *(Celtis reticulata)*, *Forestiera neomexicana*, and *Baccharis emoryi.*

In many areas throughout the Park, heavy use by livestock and roadbuilding activities have resulted in the appearance of cheatgrass *(Bromus tectorum)*, Halogeton *(Halogeton glomeratus)*, and Russian thistle *(Salsola kali)*.

Land Use

Hunting

The earliest evidence of human encroachment upon the bighorn sheep's habitat in the Park area dates back to the Fremont and Anazazi peoples, who inhabited southeastern Utah from approximately 200 AD to 1300 AD (Jennings, 1966). In archeological sites in the Glen Canyon area, south of Canyonlands National Park, bighorn sheep bones outnumber deer bones by a ration of 7:1 (Jennings, 1966). This ratio, consistent regardless of the elevation of the archaelogical site, is cited as evidence that bighorn sheep were hunted by these early Indians. This ratio does not indicate necessarily the relative densities of deer and bighorn sheep.

Livestock grazing

Domestic livestock grazing in Canyonlands National Park began in the 1880's. Topographical barriers prevented large cattle operators from utilizing the Island in the Sky and Maze districts. However, they used the Needles District, which has easy access for cattle. As a result, much of the vegetation was severely depleted (Olsen, 1941). Smaller, local cattlemen began to use the Island in the Sky and Maze districts during the 1920's (Walker, 1964). Livestock grazing in the Park has been continuous up until the present. Grazing within the 1964 boundaries of the Park was terminated in 1975. Lands added to the Park in 1971 will be grazed by livestock until 1981.

Mining

Most mining activities in Canyonlands National Park occurred in the Island in the Sky District, where the uranium and vadmium bearing Chinle Formation is exposed. Two types of encroachment, roadbuilding and poaching, were associated with mining activities. Miners often were flown into isolated areas with only light provisions. Thus, they used bighorn sheep for a food source. Bates Wilson, former Park superintendent, observed bighorn sheep hides in a miner's camp on the White Rim during the late 1950's (Wilson, personal communication, 1974).

Tourism

There are four modes of visitor use in the Park today. During the spring, summer, and early fall, large numbers of commercial boat tours travel the Colorado River and to a lesser extent the Green River. As many as three groups per day are not uncommon between May and September on the Colorado River. Most river trips are completed in three days, which limits the impact of such visitors upon the canyons adjacent to the rivers. Vehicular travel in much of the Park is limited to four-wheel drive vehicles. The only paved entrance into the Park is Utah 211, which enters the Needles District. This road presently ends at Big Spring Canyon. A proposed extension of Utah 211 will enable visitors to drive two-wheel drive vehicles to the confluence of the Green and Colorado rivers, which is within the present range of the bighorn. The Needles District receives about 40,000 visitors annually with 8,000 using the numerous backcountry roads and hiking trails. The Maze

District is entered only by four-wheel drive vehicles or by hikers. Total visitation in the district is approximately 2,000 persons per year. A gravel road, suitable for two-wheel drive vehicles, provides entrance into the Island in the Sky District. Approximately 20,000 people visit this district each year. Approximately 1,000 people travel the White Rim Road which is restricted to four-wheel drive vehicles and backpacking. A small percentage of visitors choose to see the Park from small aircraft.

PROCEDURES

The investigator spent October 1974 through December 1974 and March 1975 through December 1975 in the field. A four-wheel drive vehicle was used when possible. However the rugged topography dictated that most of the actual survey be conducted on foot. Canyons were surveyed by hiking through them and by scanning them from the rims with binoculars and a 15-60 x spotting scope. Time was spent in each district of the Park, although the Island in the Sky District was surveyed most intensively.

Canyons in the Island in the Sky District were divided into four categories. Canyon type I was defined as having vertical cliffs, steep slopes and a broad level floor at the same level as the river (Figures 4 and 6). Canyon type II was characterized by vertical cliffs, steep slopes, a broad level area, and access to the river restricted by a vertical jump (Figures 5 and 7). Canyon type III was characterized by vertical cliffs, steep slopes, benches, and access to the rivers restricted by a vertical jump (Figures 8 and 10). Benches include the small level areas and steep slopes separating them. Canyon type IV was characterized by vertical cliffs, steep slopes, benches, and an unrestricted access to the river (Figures 9 and 11).

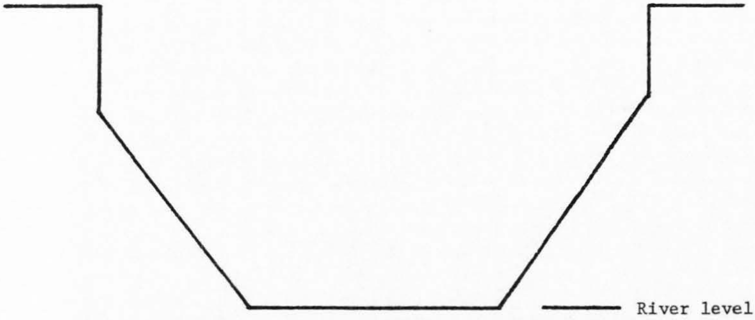

Figure 4. Canyon type I is characterized by vertical cliffs, steep slopes, and a broad floor at the same elevation as the river.

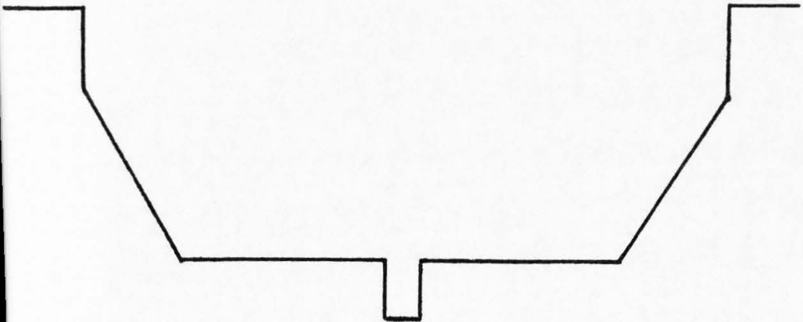

Figure 5. Canyon type II is characterized by vertical cliffs, steep slopes, a broad level area, and restricted access to the river.

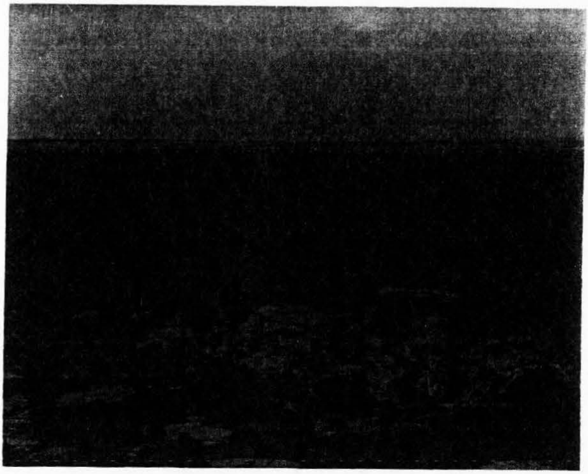

Figure 6. Taylor and Upheaval canyons, typical type I canyons in Canyonlands National Park, Utah.

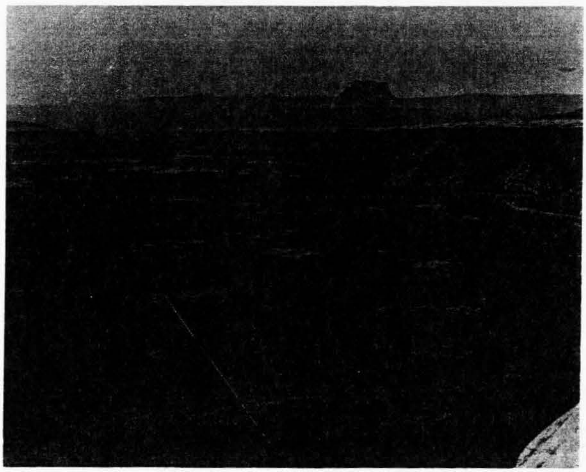

Figure 7. Junction Pocket, a typical type II canyon in Canyonlands National Park, Utah.

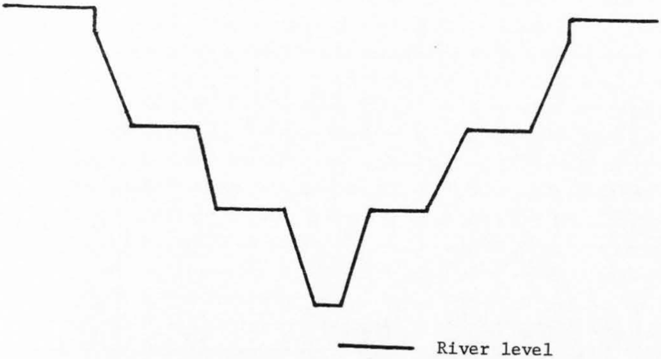

Figure 8. Canyon type III is characterized by vertical cliffs, benches, and restricted access to the river.

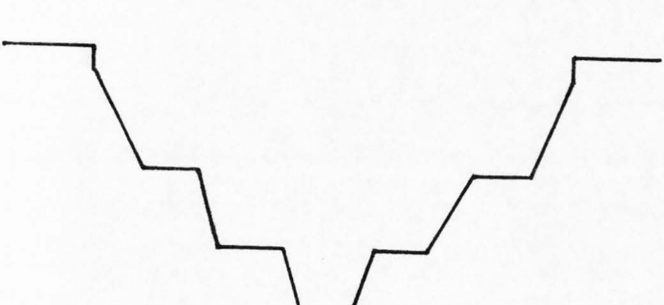

Figure 9. Canyon type IV is characterized by vertical cliffs, benches, and an unrestricted access to the river.

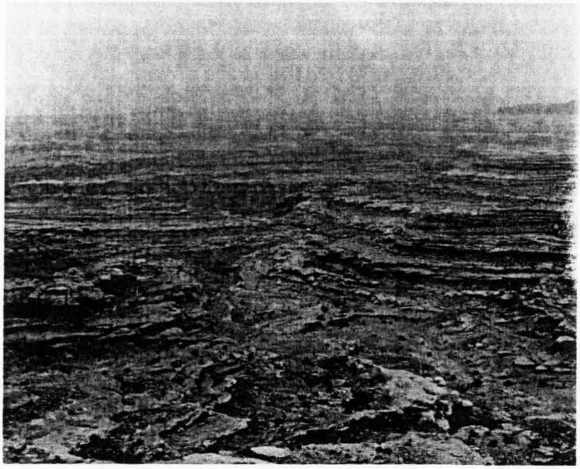

Figure 10. White Crack, a typical type III canyon in Canyonlands National Park.

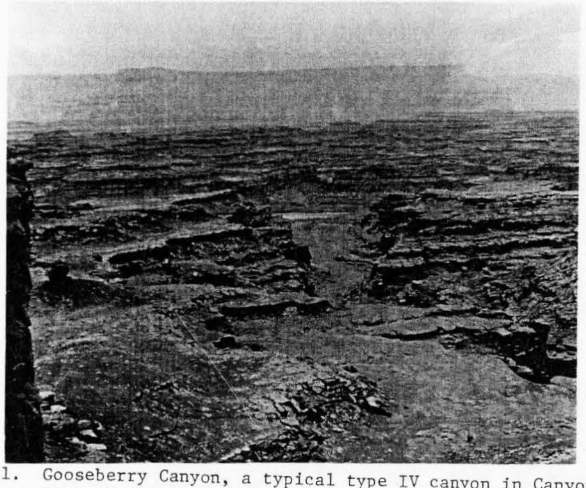

Figure 11. Gooseberry Canyon, a typical type IV canyon in Canyonlands National Park.

Walter L. Loope, a doctoral candidate in the Department of Range Science at Utah State University, currently conducting a study of the vegetation in Canyonlands National Park, assisted with the description of the vegetation and land forms of the canyons. A topographical map was shaded to approximate the area occupied by various plant communities and landforms. A dot grid was used to determine the percentage each community type or landform occupied. A minimum of two canyons for each canyon type was surveyed by this method.

Representative canyons of each type were surveyed periodically throughout the study. Water sources, bedding areas, indications of livestock grazing, and wildlife observations were recorded. Skulls, horn sheaths or antlers were recorded as definite indications of bighorn sheep or deer use. Locations and numbers of deer observed were recorded.

When bighorn sheep were observed, number, sex, estimated age, location (including geological formation and topography of the immediate area) were recorded. Bighorn sheep reactions to human disturbance (planes, hikers, and four-wheeldrive vehicles) were noted. Behavior was recorded for qualitative purposes. Each observation of two rams or a ram and a ewe was termed one interaction. Bighorn sheep sightings by Park employees, visitors and tour operators were used solely for distribution purposes.

In November 1974, personnel from the Utah Division of Wildlife Resources (UDWR) helped place transmitters on three rams and two ewes in the Park. A helicopter was used to locate bighorn sheep.

Then the bighorn sheep were captured by tranquilization with a dart containing M-99. While the bighorn sheep were immobilized, blood, feces, hair, nose swabs, and ear scrapings were collected to investigate the presence of parasites and pathogens. Dr. R. A. Smart of the Veterinary Science Department at Utah State University analyzed the samples and performed two necropsies.

UDWR personnel made radio telemetry flights at two-week intervals to monitor the movements of the transmitter-equipped animals. Defective transmitters limited the effectiveness of the radio telemetry work.

During the capture work, numbers and sex of bighorn sheep were recorded. This census was supplemented with bighorn sheep observations from the ground. Each fall, every major drainage on the Island in the Sky District was surveyed within two-week periods and the numbers of identifiable individuals recorded.

RESULTS

Bighorn Sheep Distribution and Abundance

The Maze District apparently has no resident bighorn sheep. Only one sighting (two rams, one ewe, and one lamb in 1973) on the northern edge of the District has been reported during recent years. Canyons in the Maze consist of steep or vertical slickrock walls and relatively narrow level floors (100-600 m wide). Deer frequently have been observed on the canyon floors, which have a pinyon-juniper-blackbrush type cover (Table 2).

The northern half of the Needles District also has no resident bighorn sheep, although rams move along the talus slopes adjacent to the Colorado River during the summer. Eight rams were observed at the confluence of the Green and Colorado rivers in July of 1974. Park personnel and visitors also reported two bighorn sheep sightings (two rams in 1975 and one ram in 1974) at the confluence and two sightings (one ram in 1973 and two rams in 1974) in the Graben section of the Needles District. However, bighorn sheep reside in the isolated canyons in the southern portion of the Needles District. During the 1974 aerial census, six rams, seven ewes, and five lambs were observed in Cross Canyon. Three rams also were observed in Y-Canyon, just north of Cross Canyon during the fall of 1974, and Y-Canyon has physical and botanical characteristics similar to Cross Canyon. During the

Table 2. Plant community and rock cover types in various canyons in Canyonlands National Park, Utah

Maze District													
Jasper	2.25	00.0	0.00	00.0	0.00	00.0	0.00	30.0	0.68	00.0	0.00	70.0	1.58
Water	1.60	00.0	0.00	00.0	0.00	00.0	0.00	30.0	0.48	00.0	0.00	70.0	1.12
Needles District													
Cross	2.64	60.0	1.58	00.0	0.00	00.0	0.00	25.0	0.66	00.0	0.00	15.0	0.40
Y-	1.65	65.0	1.07	00.0	0.00	00.0	0.00	30.0	0.50	00.0	0.00	15.0	0.08
Island in the Sky													
Taylor and Upheaval	24.35	00.0	0.00	65.0	15.83	00.0	0.00	00.0	0.00	25.0	6.09	10.0	2.44
Fake Junction Pocket	6.22	42.0	2.61	25.0	1.56	00.0	0.00	00.0	0.00	28.0	1.74	5.0	0.31
Junction Pocket	5.65	54.0	3.05	2.0	0.01	00.0	0.00	6.0	0.34	30.0	1.70	8.0	0.45
White Crack	6.74	25.0	1.69	00.0	0.00	00.0	0.00	00.0	0.00	15.0	0.39	60.0	4.04
Monument Basin	5.52	14.0	0.77	30.0	1.66	8.0	0.44	00.0	0.00	47.0	2.59	4.0	0.22
Gooseberry	4.07	00.0	0.00	7.0	0.28	00.0	0.00	00.0	0.00	67.0	2.73	26.0	1.06
Buck	7.77	00.0	0.00	20.0	1.55	00.0	0.00	00.0	0.00	20.0	1.55	60.0	4.66
Lathrop	4.66	00.0	0.00	50.0	2.33	00.0	0.00	00.0	0.00	15.0	0.70	35.0	1.63
Little Bridges	2.07	00.0	0.00	32.0	0.83	00.0	0.00	00.0	0.00	25.0	0.52	35.0	0.72
Mussleman Arch	3.37	20.0	0.67	00.0	0.00	00.0	0.00	00.0	0.00	25.0	0.85	55.0	1.85

1975 aerial census, six rams, twelve ewes, and nine lambs were observed in these canyons. The rams sighted at the confluence probably were from this herd. The total canyon areas consists of 95 percent steep talus slopes, 5 percent wash, and a blackbrush community with 10-15 percent vegetal cover occupying 60 percent of the canyon area. A pinyon-juniper community, with 20-25 percent vegetal cover also occupies 25 percent of the canyon area and exposed rock the remaining 15 percent (Tables 2 and 3). Deer were observed in all areas of the Needles District.

The Island in the Sky District has more bighorn sheep than the other two districts. Consequently, bighorn sheep distribution in this district was examined closely. Canyon type I included Taylor and Upheaval canyons (Figure 4). Vertical cliffs in this type usually are of Wingate Sandstone, they occupy 10 percent of the total area and have no vegetal cover. Steep slopes, comprised of the Chinle and Moenkopi formations, occupy 40 percent of the total canyon area. A broad level canyon floor at the same elevation as that of the river occupies 50 percent of the total canyon area. The shadscale community is the most prevalent plant community type, occupying 65 percent of this kind of canyon, Vegetal cover within the shadscale community is approximately 10 percent (Tables 2 and 3). The slope community occupies 25 percent of the canyon. On the Chinle Formation, vegetal cover in the slope community is 0-10 percent and is composed of Garrett saltbush, squawbush, prince's plume, galleta grass, and Indian ricegrass (Tables 2 and 3). Both canyons have perennial springs.

Table 3. The landform types of various canyons in Canyonlands National Park, Utah

Canyon	Total area (km^2)	Vertical cliffs		Slopes		Single level area		Benches	
		%	km^2	%	km^2	%	km^2	%	km^2
Maze District									
Jasper	2.25	70.0	1.58	00.0	0.00	30.0	0.68	00.0	0.00
Water	1.60	70.0	1.12	00.0	0.00	30.0	0.48	00.0	0.00
Needles District									
Cross	2.64	5.0	0.13	95.0	2.51	00.0	0.00	00.0	0.00
Y-	1.65	5.0	0.08	95.0	1.57	00.0	0.00	00.0	0.00
Island in the Sky District									
Taylor and Upheaval	24.35	10.0	2.44	40.0	9.74	50.0	12.17	00.0	0.00
Fake Junction Pocket	6.22	5.0	0.31	35.0	2.18	60.0	3.73	00.0	0.00
Junction Pocket	5.65	5.0	0.28	35.0	1.98	60.0	3.39	00.0	0.00
White Crack	6.74	5.0	0.34	15.0	1.01	00.0	0.00	80.0	5.39
Monument Basin	5.52	5.0	0.28	25.0	1.38	00.0	0.00	70.0	3.86
Gooseberry	4.07	5.0	0.20	15.0	0.61	00.0	0.00	80.0	3.26
Buck	7.77	5.0	0.39	15.0	1.17	00.0	0.00	80.0	6.22
Lathrop	4.66	5.0	0.23	15.0	0.70	00.0	0.00	80.0	3.73
Little Bridges	2.07	5.0	0.10	15.0	0.11	00.0	0.00	80.0	1.66
Mussleman Arch	3.37	5.0	0.17	15.0	0.51	00.0	0.00	80.0	2.70

No bighorn sheep were observed in canyon type I, although a reliable sighting (one ram, two ewes, and two lambs) was reported by a park visitor in Taylor Canyon in October 1974. Deer were observed frequently in the river bottoms adjoining and within these canyons. The level canyon floors allow deer to move easily to and from the river.

Canyon type II included Fake Junction Pocket and Junction Pocket (Figure 5). Vertical cliffs occupy the upper 5 percent, steep slopes 40 percent, and the level area 55 percent of the total area. The entire canyon is in the Cutler Formation, and there is no vegetal cover on the vertical cliffs. The steep slopes occupy an average of 29 percent of the total canyon area. Vegetal cover on this landform is 5-10 percent. Blackbrush dominated vegetation occupies an average of 48 percent of the canyon area. Cover within this community is 10 percent, composed primarily of blackbrush, galleta grass, and Indian ricegrass (Tables 2 and 3). There were no permanent springs in either canyon in canyon type II. Nineteen bighorn sheep sightings (40 rams, 10 ewes, and one lamb) were recorded in the two canyons (Tables 4 and 5), but no deer.

Canyon type III included White Crack, the Loop area, and Monument Basin (Figure 8). Canyons of this type are in the Cutler Formation. The vertical cliffs occupy the upper 5 percent, and the benches (including the level areas and the steep or vertical slopes) 80 percent of the canyon. Steep slopes above the first level of benches occupy

Table 4. Bighorn sheep sightings and group composition recorded during 1974-1975 according to canyon type and season in Canyonlands National Park, Utah

Canyon type (I-IV)	No. of sightings	Rams	Ewes	Lambs	No. of sightings	Rams	Ewes	Lambs
	Fall 1974				Spring 1975			
Taylor Canyon (I)	0	0	0	0	0	0	0	0
Fake Junction Pocket (II)	1	1	0	0	1	7	0	0
Junction Pocket (II)	2	2	2	0	5	21	4	0
White Crack (III)	2	2	0	0	1	4	0	0
Loop area (III)	3	14	4	0	0	0	0	0
Monument Basin (III)	8	4	12	4	2	1	1	0
Buck Canyon (IV)	1	1	0	0	1	1	2	0
On White Rim between Buck and Lathrop canyons	0	0	0	0	1	0	7	0
Gooseberry and Dogleg canyona (IV)	0	0	0	0	0	0	0	0
Musselman Arch and Little Bridges canyons (IV)	0	0	0	0	0	0	0	0
	Summer 1975				Fall 1975			
Taylor Canyon (I)	0	0	0	0	0	0	0	0
Fake Junction Pocket (II)	1	2	0	0	1	0	1	0
Junction Pocket (II)	3	4	0	0	5	3	3	1
White Crack (III)	0	0	0	0	3	3	3	2
Loop area (III)	0	0	0	0	3	7	3	1
Monument Basin (III)	5	0	10	6	4	2	4	0
Buck Canyon (IV)	2	1	3	3	2	1	2	1
On White Rim between Buck and Lathrop canyons	1	0	4	3	2	1	2	2
Gooseberry and Dogleg canyons (IV)	1	0	2	2	4	3	2	0
Mussleman Arch and Little Bridges canyons (IV)	0	0	0	0	2	2	1	1

Table 5. Bighorn sheep sightings in relation to total area of canyon types in Canyonlands National Park, Utah during 1974-1975

Canyon type	Total area occupied by canyons in each type (km^2)	Number of bighorn sightings	Bighorn sheep observed (km^{-1})
I	24.35	0	0.0
II	11.87	19	4.3
III	19.00	31	4.6
IV	24.94	17	1.9

15 percent of the total canyon area. Vegetation in White Crack and the Loop area is similar, with a blackbrush community occupying 25 percent, steep slopes 15 percent, and exposed rock 60 percent of the canyon. In Monument Basin, steep slopes occupies 47 percent, the shadscale community 30 percent, the blackbrush community 14 percent, grass 8 percent, and exposed rock 4 percent of the total area (Tables 2 and 3). Vegetal cover within these plant communities is approximately 10 percent, and permanent water is available in each canyon of this type. In type III, 31 bighorn sheep sightings (37 rams, 37 ewes, and 13 lambs) were recorded (Tables 4 and 5). Although deer were observed on the White Rim above such canyons, they were not observed in the canyons proper.

Canyon type IV included Buck, Gooseberry, Dogleg, Lathrop, Little Bridges, and Mussleman Arch canyons (Figure 9). The vertical cliffs occupy less than 5 percent, benches 80 percent and the steep slopes above the first bench 15 percent of the total area. The canyons are in the Cutler Formation. The percent cover of plant community types in the first five canyons is 27 percent for the shadscale community, 32 percent for the slope community, and 39 percent exposed rock. In Mussleman Arch Canyon, the blackbrush community occupies 20 percent, the slope community 25 percent, and exposed rock 55 percent. Small permanent springs or seeps are present in each canyon in type IV. A total of 17 bighorn sheep sightings (10 rams, 25 ewes, and 12 lambs) were recorded in type IV canyons (Tables 4 and 5). Deer were observed both in the washes of these canyons and on the White Rim above them. Only once were deer seen on the benches in canyons of this type.

It is estimated that there are 60-100 bighorn sheep in the Island in the Sky District. This estimate was derived from an aerial census and ground counts. During the aerial census, ten rams, nine ewes, and four lambs were counted in six hours of flying time. The Nevada Fish and Game makes extensive annual aerial censuses and estimates that only 30 percent of a given bighorn sheep population is counted (Robert McQuivey, personal communication, 1975). By employing their correction factor to the Canyonlands aerial census, a population estimate of 77 bighorn sheep in the Island in the Sky District is derived. Considering the limited flying time during this study, the proper correction factor would be 25 percent at most, resulting in an estimate of 92 animals. An absolute minimum of 37 bighorn (21 rams, 10 ewes, and 2 lambs) were observed from the ground during the fall of 1974. During the fall of 1975, a minimum of 34 bighorn (12 rams, 16 ewes, and 6 lambs) were observed from the ground. These totals probably represent between 40-60 percent of the actual population. These figures result in estimates of between 62 and 93 for 1974 and 57 and 85 for 1975. The population composition for the 1974 aerial census was 1.1 rams:1.0 ewes:0.4 lambs. Composition for the 1974 ground estimates was 2.1:1.0:0.2 and for the 1975 ground estimate, it was 0.75:1.0:0.6.

Human Encroachment

Livestock grazing

Domestic sheep and cattle grazing has been widespread in the Maze District. As recently as 1969, 1600 domestic sheep wintered in the Maze (National Park Service records). Weathered horns of domestic rams were found in the Maze, indicating that grazing has occurred here for many years. The topography of the canyons in the Maze District permits animals to graze only the canyon floors and the ridges above the canyons.

Unrestricted access to the Needles District enabled cattle operators to exploit the grasslands there continuously since the 1880's (Olsen, 1941). Cattle have utilized all but the most inaccessible canyons, such as Y and Cross canyons.

Limited access to the Island in the Sky District, as in the Maze District, discouraged large cattle operators from moving into this district. Local cattlemen with small herds began to use this district during the 1920's (Allred, personal communication, 1975). Bureau of

Land Management records indicate that livestock use has been constant since the 1940's. The National Park Service records for 1966 indicate that 4755 domestic sheep wintered on the White Rim and 43 cattle grazed Gary's pasture throughout 1966. Most grazing has been confined to the level areas on top of the Island in the Sky District and on the White Rim (Figure 12).

Of the four canyon types, type I received the heaviest livestock grazing pressure. The topography of such canyons allowed herders to move their livestock throughout the canyon. Only the sparse vegetation on the Chinle Formation escaped heavy pressure. The accessibility of the river and permanent springs in the eastern portion of the canyons permitted livestock to remain in these canyons for extended periods.

Livestock have never grazed in the type II canyons because the White Rim Sandstone cliffs prohibited livestock from entering such canyons.

Of the type III canyons, the Loop area and Monument Basin escaped livestock grazing because of the White Rim cliffs. However, a road was built through the White Rim into the White Crack area prior to 1952, and in 1952, a local cattle operator moved approximately 100 cattle into the canyon and onto the plateau south of White Crack. Many of the cattle perished during the summer (Allred, personal communication, 1975). This was the only known attempt to graze livestock in this canyon.

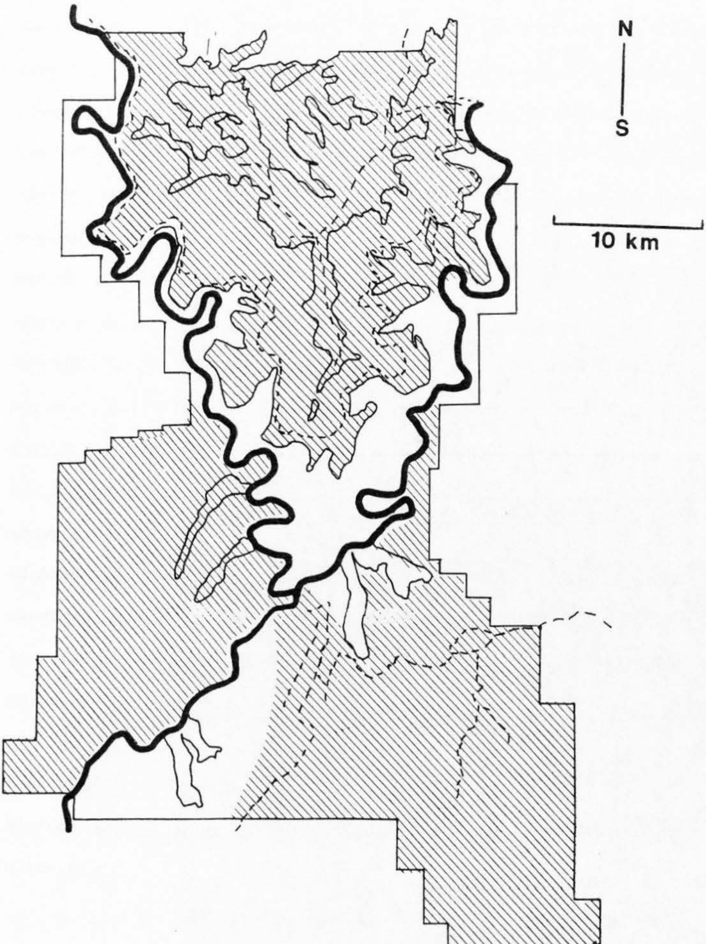

Figure 12. Areas grazed by domestic livestock in Canyonlands National Park, Utah.

Of the type IV canyons, Gooseberry, Dogleg, and Little Bridges have escaped livestock grazing pressure. The White Rim Sandstone above Buck Canyon has weathered enough to allow herders to bring their livestock into the north fork and graze the length of the canyon. A road dynamited through the White Rim also has enabled herders to move livestock into Lathrop Canyon. As recently as 1974, 12 cows were placed in both Buck and Lathrop canyons, where topography restricts cattle to washes. Steep or vertical cliffs separate the benches from these washes. During the 1974 aerial census, bighorn sheep (three rams, one ewe, and one lamb) were observed on the benches in Buck Canyon, while cows were observed grazing in the wash. The presence of weathered cattle and horse bones in the wash of Buck Canyon indicates that livestock grazing has occurred there for many years. However, bighorn sheep are seen on the benches in Buck Canyon throughout the year. Nine bighorn sheep sightings (four rams, eighteen ewes, and ten lambs) were recorded in the Buck and Lathrop canyon areas. Five of these sightings (one ram, fourteen ewes, and six lambs) were observed on the White Rim between Buck and Lathrop canyons.

The blackbrush-galleta grass community type on the White Rim has been grazed continuously by domestic livestock since the 1920's. Sixteen sightings (11 rams, 21 ewes, and 9 lambs) were recorded on the White Rim.

Mining

Mining activities in Canyonlands National Park were located primarily on the Chinle formation in the Island in the Sky District. Very little mining has taken place in the Maze and Needles districts. The White Rim jeep road, several spurs and two airstrips were constructed on the White Rim during the late 1940's and early 1950's. There have been obvious modifications of the vegetation in these areas, but these are limited to actual construction sites. The most detrimental effect of these roads was the opening up of country previously accessible only on horseback. Miners surveyed much of the Chinle Formation during the 1950's (Follows, 1969). It is possible then that miners played a major role in the reduction of bighorn sheep populations. However, the numbers and distribution of bighorn sheep declined considerably prior to mining activities during the 1930's (Allred, personal communication, 1975). Since rams continue to use the Chinle Formation today and probably did so at that time, a conflict was inevitable. One prospector used bighorn sheep for camp meat (Wilson, personal communication, 1974). It is probable that other miners also exploited the bighorn. One role mining might have played would be to maintain the restricted distribution of bighorn sheep that had previously resulted from livestock grazing.

Vehicles

The White Rim four-wheel drive road is the only road passing through the bighorn sheep range in the Park. The Park Service records vehicle use of the road with two automatic counters located at the Park boundaries. It is not known positively how many people make the entire circuit. Table 6 expresses the relative use of the White Rim road and demonstrates the increased visitation during April, May and June. The percentage of visitors driving to Mussleman Arch and Lathrop canyons, rather than making the entire trip, is greatest during these months (exceeding 50 percent at times). The impact of these visitors is confined to the presence of their vehicles and campsites, since most people do not hike on the White Rim.

Table 6. Visitor use of the White Rim Road in Canyonlands National Park during 1973. Information was derived from automatic counters placed where the road crosses the Park boundary.

Months	Number of visitors	Number of vehicles
January	21	8
February	28	11
March	77	26
April	164	66
May	246	82
June	398	133
July	42	14
August	39	13
September	32	18
October	23	10
November	21	9
December	8	4
Total	1,099	394

Thirteen interactions between bighorn sheep and vehicles were witnessed (Table 7). In seven of these interactions, the bighorn sheep initially assumed an alarm posture, with feet slightly spread and head held high and pointed in the direction of the disturbance.

Table 7. Observed bighorn sheep and vehicle interactions in Canyonlands National Park, Utah during 1974-1975

Group composition	Distance from bighorn sheep to vehicle	Topographical relationship	Bighorn sheep's reaction
1 ram	0.03km	same level, no barriers	alarm posture, fled when approached
1 ram	0.03km	same level, no barriers	alarm posture, fled when approached
1 ram	0.04km	same level, no barriers	ran immediately
1 ram	0.05km	same level, no barriers	alarm posture, fled before approached
1 ewe	0.10km	same level, no barriers	ran immediately
1 ewe, 1 lamb	0.30km	same level, no barriers	alarm posture, fled when approached
4 ewes, 3 lambs	0.80km	same level, no barriers	alarm posture, fled when approached
7 ewes	0.80km	same level, no barriers	ran immediately
2 ewes, 2 lambs	0.30km	same level, no barriers	alarm posture, fled when approached
3 rams, 1 ewe	0.15km	sheep were above vehicle	alarm posture, then ignored vehicle
1 ram, 2 ewes	0.25km	sheep were below vehicle separated by a cliff	no reaction
7 rams	1.60km	sheep were below vehicle, separated by a cliff	no reaction
2 rams	0.25km	sheep were below vehicle, separated by cliff	no reaction

On three occasions, the bighorn sheep immediately fled. In six interactions, bighorn sheep remained attentive and ran as soon as a rider left the vehicle and approached the animals. In four instances, the rider did not approach the bighorn sheep and they remained still. In three interactions, the bighorn sheep showed no visible reaction, other than looking in the direction of the vehicle. On these occasions, the bighorn sheep were below the disturbance and separated by a vertical cliff. In the fourth interaction, the bighorn sheep were above the vehicle on a steep slope, and they continued to feed in the presence of the vehicle. The importance of topographical barriers in minimizing impact is evident from these observations. Since the White Rim Road travels through areas where escape terrain is not available, the road possibly may be limiting the expansion of the bighorn sheep range.

Table 8 expresses the average distance rams and ewe groups were from the roads when first spotted. These are airline distances to the nearest road and calculated from a map. Thus, the distances in the table would not represent the true ground distance in rugged terrain. There was a total of 74 sightings with a range of 0.3 to 4.8 km.

Lathrop Canyon is the only canyon on the east side of the White Rim which visitors are able to drive through. There is a small, but regular number of vehicles travelling this road each month, except during the spring months when traffic increases significantly. The only difference between Buck and Lathrop canyons is this road. No bighorn sheep were observed in Lathrop Canyon below the White Rim, although Park personnel and visitors have reported seeing a small ewe group in Lathrop Canyon. Six sightings (four rams, seven ewes, and four lambs) were recorded in Buck Canyon, and an additional four sightings (one ram, thirteen ewes, and five lambs) were recorded on the White Rim between Lathrop and Buck canyons. In each case, the bighorn sheep fled directly into Buck Canyon or onto the benches between Lathrop and Buck canyons.

Table 8. The average distances bighorn sheep groups were sighted from the nearest road and water resource in Canyonlands National Park, Utah

	Distance from roads (km)		Distance from water (km)	
	$\bar{X}$	sd	$\bar{X}$	sd
Rams				
summer 1975 (n=7)	1.230	1.085	2.060	1.445
fall 1974 (n=10)	2.640	1.451	0.683	0.670
fall 1975 (n=8)	1.863	0.946	0.752	0.970
spring 1975 (n=7)	1.486	0.940	0.403	0.431
Ewes				
summer 1975 (n=8)	1.388	0.844	0.525	0.681
fall 1974 (n=10)	2.120	0.598	0.566	0.410
fall 1975 (n=20)	1.790	1.029	0.571	0.769
spring 1975 (n=4)	2.000	0.462	0.463	0.395

Hikers

The reaction of bighorn sheep to hikers is extremely unpredictable. Factors affecting bighorn sheep reactions are: proximity to the hiker, topographical relationships, proximity to escape terrain, and physical barriers between the hiker and bighorn sheep. The terrain of the Park enables bighorn sheep to move out of sight by fleeing only a short distance. Therefore, measurements of bighorn sheep retreat distances were not recorded. The distances, listed in the Appendix, represent the distance between the observer and bighorn sheep when the bighorn sheep fled. Since many of these observations reflect either suitable terrain for the hiker to remain hidden or unexpected observations, predictions based on these distances would be biased. On six occasions, bighorn sheep observed the hiker and were separated from the hiker by a physical barrier.

In these interactions, the bighorn sheep immediately assumed an alarm posture and then resumed normal feeding activities. Rams appear to be more tolerant of disturbances than ewes.

Planes

When aircraft were above 500 m, they had little visible effect upon bighorn sheep. Bighorn sheep showed no reaction to 84 commercial jets and 29 private planes which created sounds in the canyons. One low-flying military jet disturbed a ram which was bedded down. He looked for the source of the extremely loud noise. The sound quickly faded and the ram remained bedded down. During the aerial census, the helicopter definitely disturbed the bighorn sheep. Apparently the animals were able to associate the noise with its source.

Boating

When questioned about the reaction of bighorn sheep to boats, boat operators invariably say the bighorn sheep remain still as the boats pass, running only when the boats are brought ashore and passengers disembark. Since bighorn sheep usually are on the talus slopes above the river, disturbance by boaters may be minimized. However, by interrupting the bighorn sheep grazing period, boats do have a detrimental impact. Bighorn sheep use of the river as a water source is limited to two areas in the Park. This may be a result of the abundance of deer on the river bottoms or possibly the heavy boat traffic (two or three boat tours/day) during the summer months.

Ewe Movements

No seasonal migrational patterns were observed for ewe groups. Their home ranges were centered in the canyons below the White Rim (Figure 13). There appear to be three overlapping units of home ranges. The southernmost range consists of Junction Pocket, White Crack and the Loop area. There are a minimum of three to six ewes which move through these canyons (Table 6). Although ewes were observed from this unit from the beginning of the study, lambs were not observed there until the fall of 1975. The ewe:lamb ratio was 1:0.44. Ewes in this unit were sighted on the White Rim only once, which also was the only time a ewe group was observed to remain on the White Rim overnight. They centered their activities on an island composed of the Moenkopi Formation while on the White Rim. The only route through the White Rim Sandstone in this area is the road to the White Crack area, which was heavily used by ewes and rams.

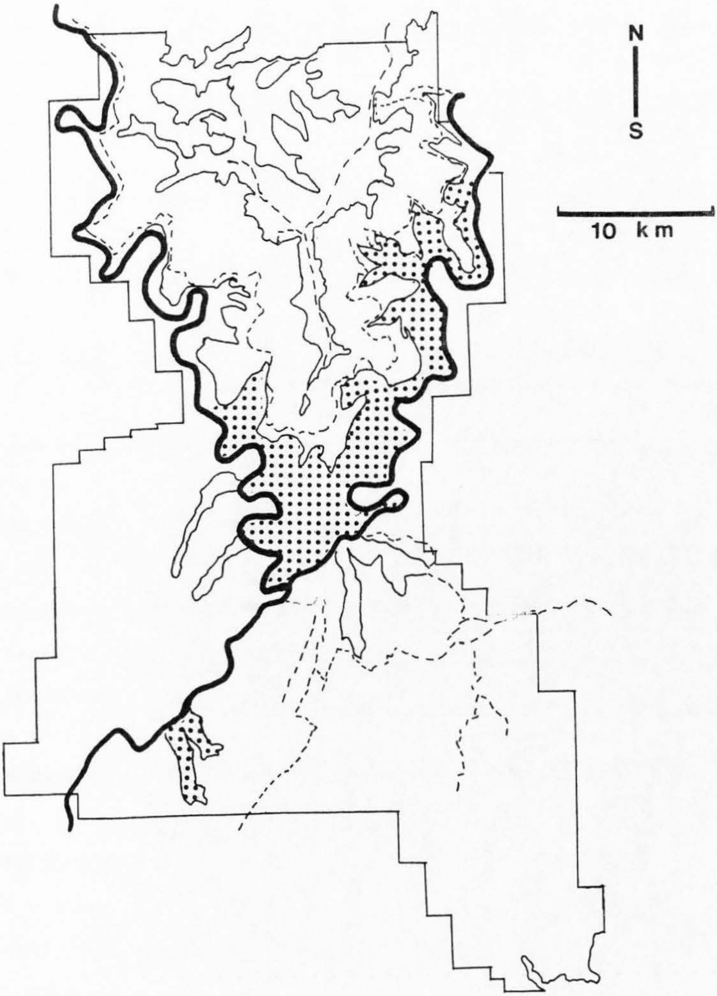

Figure 13. Distribution of bighorn sheep ewes in Canyonlands National Park, Utah.

The central unit, centered in Monument Basin, had a minimum of six ewes. On two occasions, ewes from this unit were observed on the White Rim. A single ewe had used a route through the White Rim Sandstone on the southern edge of Monument Basin. The second sighting consisted of two ewes and two lambs on the northwest edge of the Basin. When disturbed, the group's closest route was blocked and they fled 2.0 km to an alternate route through the White Rim. This movement was the greatest straightline distance ewes were observed to make in a short period. Ewe:lamb ratios for this unit were 1:0.33 during the fall of 1974, 1:0.6 during the summer of 1975, and 1:0.0 during the fall of 1975 (Table 6).

The northern unit consists of Dogleg, Gooseberry, Buck, and Lathrop canyons. Buck Canyon is the apparent center of bighorn activities in this unit. Ewe groups move onto the blackbrush flats on the White Rim in four areas in this unit. The area between Lathrop and Buck canyons is most heavily used. There are two other areas around Buck Canyon and one above Dogleg Canyon where ewe groups also move onto the blackbrush flats. Ewe:lamb ratios for this unit were 1:0.89 during the summer of 1975 and 1:0.57 during the fall of 1975 (Table 6).

Bighorn sheep use of the blackbrush flats on the White Rim is limited. Ewes never were observed west of the White Rim Road. The greatest distance ewes were observed from the White Rim Sandstone was 0.9 km at which time they were located on Moenkopi Formation slopes which provided suitable escape terrain. When ewe groups were limited to the canyons below the White Rim for escape terrain, they remained within 200 m of the White Rim Sandstone. In seven of these eight sightings, the bighorn sheep actually were on the White Rim Sandstone.

The primary purpose for bighorn sheep to move onto these flats was for the abundant supply of forage there. Also, the potholes in the slickrock provide a source of water after rains.

Ram Movements

Ram movements in the Park followed a seasonal pattern, particularly in the southern portion. During the late winter and spring, rams moved laterally through the Loop area, White Crack, Junction Pocket, and Fake Junction Pocket on a specific route (Figure 14). During this time, the rams remained at similar elevations, feeding primarily on the abundant blackbrush and grasses in these canyons. The average group size during this period was 4.7 rams (n=7, range 1-9). Group composition was variable. The range of daily movement fluctuated between 200 m and 2.0 km.

During June, rams dispersed to higher elevations, individually or in pairs. Their movements appeared not to be limited, as they were sighted on top of the Island (1900 m) and on the White Rim (1300 m). During late summer, rams had to return to springs below the White Rim for water. Apparently this did not restrict their movements, as the average map distance from water was 2.06 km (Table 8). Rams moved the greatest distance from June through October.

During October, rams descend to the canyons below the White Rim, searching for ewes. Rams usually are alone when searching for ewes,

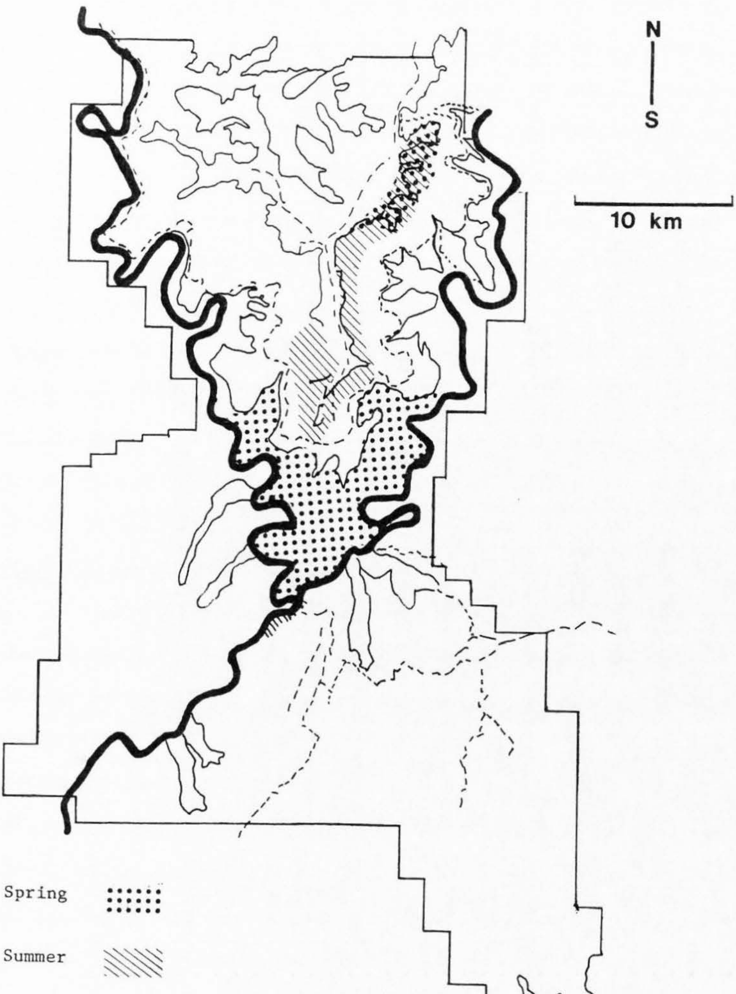

Figure 14. Distribution of bighorn sheep rams during the spring and summer in Canyonlands National Park, Utah.

but on rare occasions are found in pairs. The average group size for bachelor bands during this period was 1.3 animals (n=18, range 1-3), while the average number of rams in company with ewes was 1.9 (n=15, range 1-10).

In the central and northern units of the Island in the Sky District, ram movement was extremely variable as rams were observed or reported at all elevations in this area. Generally, though, rams move to higher elevations during the summer months and return to the canyons below the White Rim during the fall. No horizontal migration patterns were observed in Buck, Lathrop and Gooseberry canyons. This probably was due to the absence of large areas of blackbrush in the canyons in this area of the Park.

Behavior

Leadership

In order to determine leadership, undisturbed bighorn sheep must be observed. Bighorn sheep often will flee if only one animal is disturbed or runs, even if it is a lamb. Leadership appears to be related to independence, with the older animals being the most independent. Younger animals will move away from the group, but will return if not followed. Older animals will continue to move regardless of whether they are followed.

Behavioral patterns and dominance

Percentages used in this section are derived from 10 ram-ram interactions and 14 ram-ewe interactions. No attempt was made to record how many times each pattern occurred per interaction. Terminology is from Geist (1971a).

Dominant rams commonly perform the low-stretch. In this posture, the dominant ram extends his neck and lowers his head, tilting his horns to the right or left (Figure 15). The low-stretch is performed whenever a large ram moves by a subordinate ram. Rams also assume this posture when approaching ewes. The low-stretch was performed in 80 percent of the ram-ram interactions and 86 percent of the ram-ewe interactions. It was usually repeated many times during each interaction.

Rams perform a "twist" in the presence of subordinate animals (Figure 16). This was observed primarily in ram-ewe interactions. The ram stands directly behind the ewe and dips his head to either of the ewe's haunches. In one segment of a ram-ewe interaction, the ram performed the twist 30 times in less than 10 minutes. This pattern was performed in 36 percent of the ram-ewe interactions.

Rams display their horns for several minutes at a time. They remain still, with head raised and slightly turned. This occurred in 70 percent of the ram-ram interactions, and less than 1 percent of the ram-ewe interactions. This display is difficult to recognize at great distances, so the true percentage may be higher. The display is commonly performed after a clash between two rams.

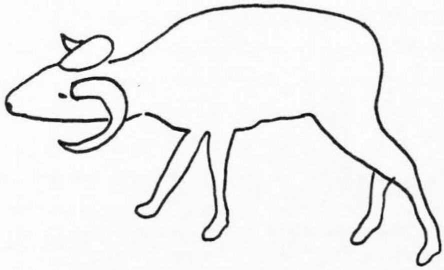

Figure 15. Bighorn sheep ram performing the low-stretch with extended neck and head tilted.

Figure 16. Bighorn sheep ram performing the twist, touching the ewe with his muzzle.

Horn-rubbing is performed only by rams. The rams stand together and rub each others horns or heads. One ram may move his rump into the other ram while jostling. This occurred in 70 percent of the ram-ram interactions.

Rams will perform a front kick to both younger rams and ewes (Figure 17). The ram kicks the subordinate with either front leg and may exhibit this behavioral pattern when both animals are standing or when one is laying down. Rams often employ this to threaten a ewe that refuses to rise. This pattern occurred in 70 percent of the ram-ram interactions and in 21 percent of the ram-ewe interactions.

A dominant animal will butt a subordinate by directing the base of its horns into the head, side, or rump of the animal. Both rams and ewes perform the butt. Ewes were observed butting other ewes and rams when competing for a specific ram's attention. This occurred in 70 percent of the ram-ram interactions and in 21 percent of the ram-ewe interactions.

The clash is the most dramatic of the dominance behavior patterns. Clashes most often occur between rams of similar rank which are unable to determine dominance through horn displays. The clash occurs when rams stand on their hind legs and charge, concentrating their blows upon the base of the horns. Occasionally a young animal will raise up and charge an older animal. The older ram remains still and catches the charge with the base of its horns, neutralizing the thrust of a young ram. A strange ram entering an established group will initiate fighting, not only between himself and a member of the group, but also between the original members of the group. The clash occurred in 40 percent of the ram-ram interactions.

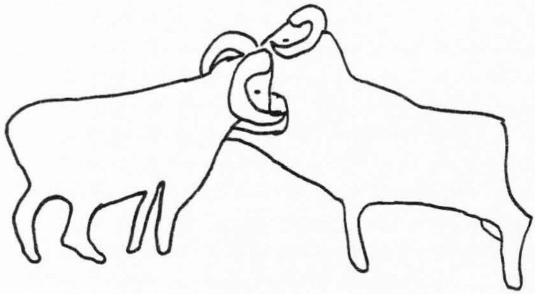

Figure 17. Bighorn sheep ram performing the front kick by lifting his front leg into the chest of the other ram.

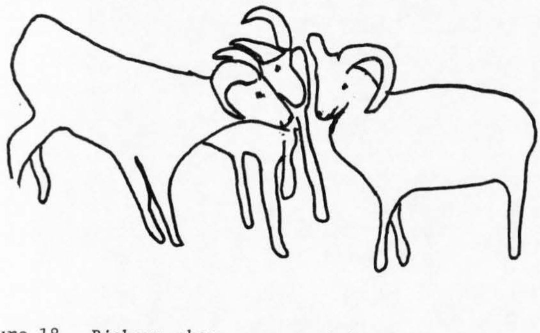

Figure 18. Bighorn sheep rams positioned in a huddle with heads together.

The threat charge resembles the initial stages of the butt. The aggressor lowers its head and takes several quick steps toward the opponent. Rams use this when herding ewes or when moving younger rams away from ewes or a shrub. Ewes demonstrate a threat charge towards other ewes, young rams, and lambs. The threat charge occurred in 60 percent of the ram-ram interactions and 29 percent of the ram-ewe interactions.

When a dominant ram approaches in a low-stretch or performs the twist, ewes usually urinate. This occurred in 70 percent of the ram-ewe interactions, but only in one ram-ram interaction. While the ewe urinates, the ram will sniff the urine and then perform a lip curl (Figure 19). He stands in a display stance with his muzzle raised and lips curled back. Rams displayed the lip curls every time a ewe urinated.

Figure 19. Bighorn sheep ram sniffing an estrous ewe.

Rams use the low-stretch and the threat charge to herd estrous ewes in order to keep them away from other rams or anestrous ewes. This was performed in 21 percent of the ram-ewe interactions, but in none of the ram-ram interactions.

Rams spontaneously mount subordinate animals, regardless of sex, although they are more persistent in mounting estrous ewes. This occurred in 50 percent of the ram-ram interactions and 36 percent of the ram-ewe interactions. Only on one occasion did a subordinate ram mount a dominant one. This occurred during a huddle of five rams (Figure 18), in which indiscriminate head butting and mounting occurred. Geist (1971a) proposed that the huddle is a learning experience in which one's horn size is evaluated.

It was evident from the observations made during this study that dominant rams treat all subordinate animals in the same manner, regardless of sex. How the above behavior patterns are exhibited and the role they play in bighorn society can be demonstrated by the following example. The group was composed of ram 1 (6-7 years old), ram 2 (4-5 years old), ram 3 (3 years old), and an adult ewe. Ram 1 guarded the ewe and continually positioned himself between the ewe and other rams. He exhibited the low stretch both when herding the ewe and when other rams approached. The subordinates quickly submitted in most cases. However, if the subordinate rams did not retreat, ram 1 would perform a threat charge. The younger animals then would immediately retreat. Ram 1 employed the front kick to force the ewe to rise, and then the twist to stimulate the ewe to urinate, after which he performed the lip curl. On three occasions, this action was followed by a mount, which caused the ewe to run. This stimulated the younger rams to enter the chase. Immediately, ram 1 would threaten the younger rams with a low-stretch or, in extreme cases, a butt. Only once was there a head-on clash between ram 1 and ram 2. After retreating, ram 2 would approach ram 3 in a low-stretch posture and perform the front kick. On two occasions, ram 2 mounted ram 3. There were no discernible differences in the reactions of the subordinates to the dominant rams. Only one noticeable difference occurred in the actions of the dominant rams. Although ram 2 would perform the twist when interacting with ram 3, he more readily jostled horns and placed his head over the back of ram 3. Ram 1 never behaved in this manner towards the ewe.

DISCUSSION

Past Bighorn Sheep Distribution and Decline

Human encroachment has been a major determinant of the present distribution of bighorn sheep in Canyonlands National Park. Thus, human encroachment and bighorn sheep distribution should be discussed as a cause and effect relationship. Bighorn sheep distribution in the Park was reduced considerably during the late 1930's. Prior to this time, bighorn sheep rams and ewes were observed commonly in Grays Pasture on top of the Island in the Sky District (Allred, personal communication, 1975). Today, ewes are never observed in this area; rams are seen only infrequently on the Kayenta Formation along the fringe of the mesa. Historical bighorn sheep range extended throughout the canyons in the western side of the District, but today there are no resident bighorn west of Murphy Hogback. A similar decline in numbers and distribution was observed in many of the western states during the late 1880's (Smith, 1954; Buechner, 1960). Buechner (1960) associates this decline with the western movement of white man's livestock throughout the West at this time. However, the Island in the Sky District of Canyonlands escaped livestock pressure until the 1920's (Walker, 1964). This perhaps explains the delayed decline of bighorn sheep in this area. Buechner (1960) implicates the introduction of the scabies mite *(Psoroptes ovis)*, space and forage competition from livestock, and excessive hunting as factors of the white man's western movement that are related to the shrinkages of sheep distribution and reduction in their populations.

Forage competition with livestock

It is probable that prior to the introduction of livestock, native herbivores in the Park were exploiting most of the available forage. With the introduction of several thousand additional herbivores, forage competition was inevitable. Stoddart, Smith, and Box (1975) describe cattle as preferring grasses and domestic sheep and deer browse. Kimball and Watkins (1951) observed that even though browse constituted only 16.9 percent of the total diet of cattle, the volume of browse consumed was sufficient to create severe competition with deer. Although forage utilization by bighorn sheep in Canyonlands National Park was not examined quantitatively, it was apparent that they utilized a wide variety of plants, with galleta grass, Indian ricegrass, and blackbrush used most often. Wilson (1968) observed a similar preference pattern in southeastern Utah. The introduction of large numbers of livestock undoubtably limited the amount of forage available to the native ungulates. Similarly, Berwick and Aderhold (1968) observed a 50 percent decline in a Montana Rocky Mountain bighorn sheep population after the introduction of 600 domestic sheep onto the bighorn sheep winter range.

Space competition with livestock

Land form preferences might have arisen to minimize forage competition. Cattle and domestic sheep prefer to graze in level areas

(Stoddard et al, 1975). In the Island District, Grays Pasture and the blackbrush flats on the White Rim were grazed most heavily by livestock. The native ungulates were forced into the canyons and the river bottoms below the White Rim and onto the rocky areas on top of the Island. This spatial separation between livestock and bighorn sheep has been observed in several studies (Welles and Welles, 1961; Barmore, 1962; Wilson, 1968; Irvine, 1969).

Deer and bighorn sheep competiton

Further diversification of land form preferences occurred between deer and bighorn sheep. Deer and bighorn sheep in Canyonlands presently occupy distinctly different habitats, oftentimes, in the same canyons. Mule deer remain in the washes and on the river bottoms where there is a relatively abundant vegetal cover, whereas bighorn sheep have retreated to the more inaccessible benches or canyons which are inaccessible or unappealing to deer or domestic livestock. Deer now are distributed throughout the district in level areas, with the exclusion of type II and III canyons which are inaccessible or unappealing to deer. Of 39 deer sightings, only one group was observed on benches within the range of bighorn sheep ewes. Lowless (1963) observed that mule deer preferred level areas and avoided talus slopes in Colorado, which corresponds to the Canyonlands situation. Deer and bighorn never were observed together in the same habitats. Similar observations were made in southeastern Utah by Wilson (1968) and Irvine (1969), in Dinosaur National Monument by Barmore (1962), and in Death Valley

National Monument by Welles and Wells (1961). Forage is sparse in desert habitats, possibly differing topographical preferences, rather than differing foraging strategies minimize competition between deer and bighorn sheep. The influx of domestic livestock may have forced deer into marginal habitats already inhabited by bighorn sheep. Welles and Welles (1961) observed deer to be aggressive competitors with bighorn. Thus, the movement of deer into bighorn habitat would be detrimental to bighorn sheep because of dietary overlap.

Diseases

Cattlemen, interviewed by Follows (1969), claimed bighorn sheep were heavily infested with the scabies mites during the periods from 1916-1922 and 1952-1956. During these periods, they also observed bighorn sheep that were in a weakened condition and with numerous head sores and missing ears. There is however, conflicting information as some cattlemen did not observe heavy scabies infestations (Allred, personal communication, 1975). The role of scabies in bighorn sheep declines in the West has been supported by Smith (1954) and Buechner (1960). Post (1962) has suggested that the decline was a result of Pasteurellosis, rather than scabies, which he believed was endemic to bighorn sheep and not introduced by livestock. Post (1962, 1971) emphasizes the precipitating role of stress in Pasteurellosis. The introduction of large numbers of livestock and the herders accompanying them perhaps stressed the bighorn sheep. If bighorn sheep were forced to concentrate in a restricted range, the mite population, might increase. This also could result in greater stress being placed upon bighorn sheep, thereby allowing Pasteurella spp., a normal inhabitant in bighorn sheep respiratory tracts, to multiply and thereby result in acute pneumonia and septicemia (Post, 1971). Herman (1969) emphasizes the role of reduced habitat preceding epizootics in deer, grouse, mice, and rabbit populations. Whether parasites or diseases are currently limiting bighorn sheep in Canyonlands is questionable. The bighorn sheep appeared to be in good health. Bighorn sheep with partially missing ears or sores on their heads were not observed. Neither were bighorn sheep observed to scratch their heads or ears excessively. Nasal swabs, ear scrapings, and feces collected from four rams and two ewes were negative for mites, internal parasite ova, and lungworm larvae. Bacterial examinations were negative for pathogens, including Pasteurella spp. (Smart, personal communcation, 1976). Dr. Smart performed necropsies on two bighorn sheep rams (aged 7.5 and 6.5 years). The only parasite observed was fringed tapeworm, Thysonsoma spp. (Smart, personal communication, 1976).

Hunting

A detrimental factor associated with livestock grazing is the presence and activities of herders. Herders killed primarily rams, whereas miners indiscriminately killed both ewes and rams.

Hansen (1970) theorized there are two tongue colors, which identify bighorn sheep with different behavioral characteristics. He described a pink-tongued phenotype, which was extremely wary and very gregarious with other bighorn sheep, and a black-tongued phenotype, which was less cautious and less inclined to flee from man, as well as less gregarious with other bighorn sheep. The high proportion of black-tongued bighorn sheep killed by Nevada hunters led Hanson to believe that heavy hunting would remove the pure black-tongued phenotype from the population. If this phenotypic or behavioral trait is expressed similarly in Canyonlands, it would follow that heavy hunting by miners and herders would result in a larger percentage of pink-tongued bighorn sheep. However, the only tongue color observed during the study was black. Although not every bighorn's tongue was observed, there were no observations of large groups of bighorn sheep. This perhaps indicates that either the bighorn sheep in Canyonlands are primarily of the black-tongued variety or that Hansen's theory is not applicable in the Park.

Hunting applied selective pressure on bighorn sheep, which likely resulted in populations becoming wary of man. This fear could be passed on to future generations through learning (Geist, 1971a), and perhaps would explain the avoidance demonstrated by bighorn for man during this study. Bighorn sheep have two behavioral responses after being disturbed by man. Initially, they assume an alarm posture, with muscles tensed, often followed by a retreat, which entails running and sometimes ascending steep or near vertical slopes. The energy expenditures involved in these responses may be costly. Table 9 depicts partial energy expenditures for a 68 kg (150 pound) bighorn sheep ram. These are speculative estimates, since the formulas were

Table 9. Energy expenditure per hour by a 68 kg (150 pound) bighorn ram for various activities[a]

Activity	Rate per hour	Metabolic cost (kcal hr-1)	Basal metabolism plus activity cost as multiple of basal metabolism
Basal metabolism	$\frac{(70)(W_{kg}^{0.75}}{24}$	69.00	1.00
Standing[b]	$(70)(W_{kg}^{0.75})\ (1.1)$	76.00	1.10
Running[b]	$\frac{(70)(W_{kg}^{0.75})\ (8)}{24}$	552.50	8.00
Walking 1 km on level[c]	$(0.59)(W_{kg})(D_{km})$	40.10	1.58
Vertical ascent of 0.1 km[c]	$(6.45)(W_{kg})(H_{km})$	43.90	1.64
Walking 1 km, 10% gradient	(Sum of rates for walking and vertical ascent)	84.00	2.22
Foraging[d]	$(0.54)(W_{kg})$	36.70	1.54
Ruminating[d]	$(0.24)(W_{kg})$	16.30	1.23
Alarm posture	$\frac{(70)(W_{kg}^{0.75})\ (1.2)}{24}$	82.90	1.20

[a]Moen, 1973.
[b]Crampton and Harris, 1969.
[c]Clapperton, 1961.
[d]Graham, 1964.

calculated from domestic sheep (Moen, 1973). Taylor et al. (1974) demonstrated that the costs of running conform to the formulas used in this table, regardless of species. Dr. James Gessaman, ecological physiologist at Utah State University, conducted experiments with red deer *(Cervus elaphus)* to determine their metabolic rates while running. When disturbed by a person to whom the deer were unaccustomed their metabolic rate increased approximately 20 percent. Since the running speed did not change, Dr. Gessaman attributed the increase to the deer tensing its muscles as a result of psychological stress (Gessaman, personal communication, 1976). Thus, a speculative formula for the energetic costs of stress was derived, incorporating the 20 percent increase. This appears to be justifiable, because bighorn sheep exhibit a similar alarm posture during which their muscles are tensed. The basic metabolic rate multiplier indicates the increased energy budget costs of the various activities (Table 9). The cost of stress would increase the costs of all activities, exaggerating the high costs of running and climbing. Consequently, bighorn sheep would attempt to minimize energetically costly activities, such as running and climbing, and to avoid stressful situations.

Ruminants under severe energy limitations are forced to consume great quantities of forage to meet their metabolic requirements. Therefore, bighorn sheep in Canyonlands National Park must spend a large part of each day foraging. If human activity disturbs a bighorn sheep, forcing it to interrupt its foraging period, its energy intake would be limited--further compounding the energy costs of stress.

Consequently, if a bighorn sheep was disturbed several times a day by man or domestic livestock, it would be unprofitable for it to reside in an area of high human encroachment, due to its decreased energy intake and increased energy output. This energy deficit particularly would be detrimental to pregnant or lactating ewes, which might explain the more restricted distribution of ewes as compared to rams in the Park.

In order to minimize competition and energy costs, bighorn sheep in Canyonlands have withdrawn to a restricted range. Bighorn sheep withdrawal as a result of human encroachment has been observed in Death Valley National Monument (Welles and Welles, 1957); in the Kofa Game Range, Arizona (Monson, 1963); in southeastern Utah (Wilson, 1969); and in southern California (Jorgenson, 1974). Withdrawals into restricted ranges often result in decreased horn growth, low disease resistance, poor maternal care, high lamb mortality, and decreased life span (Geist, 1971b; Hansen, 1971; McCarthy, 1972).

Although much of the foregoing discussion is speculative, all of these factors probably have been involved in restricting bighorn sheep distribution in Canyonlands. These factors obviously are interrelated. If forage becomes depleted, bighorn sheep would have difficulty meeting their energy requirements. If bighorn sheep were forced into more rugged habitat, the energy costs of moving would be increased. If bighorn sheep were forced to concentrate in a limited area, resulting in intraspecific competition and higher parasite populations, energy costs again would increase. No one factor can be pinpointed as the most detrimental, as it appears a combination of factors usually are responsible for the reduction of bighorn sheep populations.

Topography and the Present Bighorn Sheep Distribution

The topography of the canyons in the Island in the Sky District is closely related to the presence or absence of bighorn sheep. Canyon type I, characterized by a broad level area at the same elevation as the river, was grazed heavily by livestock. Livestock were able to utilize entire canyons of this type, as there are no physical barriers which bighorn sheep can use to isolate themselves from the livestock. Canyon type II, characterized by a broad level area and a vertical jump restricting access to the river, was not used by livestock. Physical barriers, such as vertical cliffs and a vertical jump in the wash, prevented livestock from entering these canyons. Here bighorn sheep were able to minimize disturbances and maximize their energy intake. Canyon type III, characterized by benches and restricted access to the river, has similar physical barriers which discourage livestock and deer from utilizing forage in these canyons. Canyon type IV, characterized by benches and an unrestricted access to the river, was exposed to a limited amount of grazing. However, steep slopes or cliffs prevented domestic animals from grazing most canyons of this type, whereas bighorn sheep were able to utilize 80 percent of them. In such canyons, bighorn sheep and livestock may coexist, but they are occupying distinctly different habitats. Without physical barriers, bighorn sheep are not able to isolate themselves and still have sufficient forage, space, and water to remain for long periods. The question may arise as to whether or not bighorn sheep prefer benches over washes. In canyon type II, bighorn sheep utilize the washes and the broad level areas in both canyons. In canyon type III, which has a similar topography to type IV canyons, bighorn sheep are seen frequently in the washes where the vegetation is relatively abundant. Undoubtedly, bighorn sheep would use washes and other level areas if it was free from human activities and competitors.

The relationship of bighorn sheep distribution to topography may be extrapolated to explain the absence of bighorn sheep in Maze and much of the Needles District. In the Maze, herbivores are confined to the washes and the ridges above the canyons, since the walls are composed of slickrock. When large numbers of livestock moved in, most of the available forage and space was occupied, leaving no suitable terrain for bighorn sheep. In the Needles District, only the canyons along the Colorado River in the southern end of the District escaped heavy livestock pressure, because of isolating physical barriers east of the canyons.

Ewe movements

The restricted movement of ewes reflects the impact of human encroachment. In southeastern Utah, Irvine (1969) observed ewe groups moving up to the Wingate Mesa whenever water was available. In Canyonlands, ewe groups were confined to the lower elevations, moving only as high as the White Rim. The availability of water and forage in canyons below the White Rim enables ewes to remain in an area of one or two canyons. This limited movement is most noticeable in Monument Basin, where one ewe was observed seven times in a year. Only once was she observed outside of Monument Basin, and then she was on the White Rim only 100 m from the edge of the Basin. Throughout the year, ewe groups move on top of the White Rim to graze in the blackbrush flats. Their movements are restricted by the White Rim Road and the paucity of suitable escape terrain above the White Rim. Ewes were never observed less than 200 m from the White Rim Road. Although the Chinle and Moenkopi formations provide appropriate temporary escape terrain, the White Rim Road is between the White Rim Sandstone, which borders the canyons below, and the Chinle Formation. Consequently, when ewe groups encounter vehicles on the White Rim Road, there are no physical barriers hiding the vehicle, they retreat to the canyons below the Rim. Light (1971) observed that bighorn sheep in southern California were more tolerant of human activities when suitable escape terrain was nearby.

Limited ewe home ranges centered around sources of free water are typical in desert habitats (Monson, 1964; Hansen, 1965; Denniston, 1965; Wilson, 1968; Irvine, 1969). However, the extremely limited home range for ewes in Canyonlands is atypical. Hansen (1971) observed desert bighorn sheep ewes which made 22-mile annual circuits. In Canyonlands, ewes never were observed to move more than 2.0 km. The greatest distance moved was the result of disturbance by the researcher. The greatest airline distance between two sequential sightings of a ewe group was 3.0 km. Bighorn sheep are able to move great distances, but their knowledge of routes through physical barriers and of water sources might limit their movements. Human activities above the White Rim, however, are probably the greatest restriction.

Exact locations of lambing grounds were not determined. However, ewes used the same areas which they utilize throughout the year when close to parturition in late May. Ewes possibly retreat to small portions of these canyons when they lamb in June. The addition of lambs also did not appear to alter the movements of ewe groups. Lamb mortality was highest during September and October. The ewe:lamb ratio during the summer of 1975 was 19:14 and during the fall of 1975 was 19:8. This is a fairly low mortality rate compared to the 90 percent lamb mortality observed in Death Valley National Monument (Welles and Welles, 1961). This may be due to the above average rainfall for the summer months of these two years. Lamb survival was highest in Buck Canyon, where all adult ewes observed had lambs. Lamb mortality in this area remained low throughout the summer and fall. Perhaps, a significant factor was the fact that the ewes in this area have much longer horns than those in canyons such as Monument Basin and White Crack. Geist (1971a) believes horn growth is an indicator of herd vitality. A possible explanation for higher vigor in the Buck Canyon bighorn sheep is that they foraged on the blackbrush flats above the White Rim more frequently than did other ewe groups in the District.

Ram movements

Ram movements do not appear to be as restricted by human activities as much as those of the ewes. During the summer months (June-September), rams move up to the higher elevations. However, this period of movement is associated with low visitor use on the White Rim. Also, domestic livestock historically were removed from the White Rim by June. Bighorn sheep rams travel individually or in pairs during June-September, returning to the canyons below the White Rim for water. During late October and November, rams move to the canyons below the White Rim in search of ewes. The rut begins in late October. However, most rut activity occurs in late November and early December. Ram movements during this period are erratic, as some rams remain at higher elevations, although the majority are at lower elevations. On the eastern side of the White Rim, rams disperse after the rut to higher elevations or remain in the canyons below. In the southern portion, rams form bands and move horizontally through Fake Junction Pocket, Junction Pocket, White Crack, and the Loop area. A possible explanation for this is the abundance of blackbrush in these canyons. There also appears to be a lower number of ewes utilizing these canyons. The rams remain in this series of four canyons until June, when they begin their dispersal to higher elevations. Rams do not appear to be restricted as much as ewes by the availability of water or by human encroachment. Blong and Pollard (1968) observed similar differences in distances travelled by rams and ewes.

Whether ewes will develop seasonal movements similar to those of rams, now that livestock grazing has ceased in the Park, should be studied. The seasonal migrations Geist (1971a) observed in Rocky Mountain bighorn sheep do not apply to the bighorn in Canyonlands, although his observations regarding the difficulty of rehabitation by bighorn sheep may be applicable.

Behavior

Although quantitative data were not collected, it appears that large rams are dominant in desert bighorn sheep societies. Welles and Welles (1961) were the first to state that the desert bighorn society was dominated by ewes. This probably resulted from their observations of ewes leading mixed groups. Ewes or lambs frequently are the first to flee from a disturbance. Since bighorn sheep will follow the first animal that runs, it often gives the impression that ewes are the group leaders and dominant. However, when bighorn sheep are undisturbed and allowed to interact normally, it is obvious that rams dominate ewes. Geist (1971) presented the neotenization theory, wherein he theorized that rams maximize their horn growth by extending the juvenile age when body growth is greatest. Implications of this theory are testable. For example, this hypothesis states that dominant rams treat subordinates of either sex similarly regardless of sex. Behavioral patterns such as the low-stretch were performed in 80 percent of the ram-ram interactions and 86 percent of the ram-ewe interactions. The low-stretch was described by Welles and Welles (1961) as submissive behavior. However, younger rams and ewes never exhibited this to the larger dominant rams. Differences in the percentages of behavioral patterns discussed in the results are attributable to the length of time bighorn sheep were observed. When observing bighorn sheep for several hours, almost all of the behavioral patterns discussed were observed. Only the clash was not observed during ram-ewe interactions, regardless of observation length. One difference, which probably is accurate, is that the twist is performed by rams primarily towards ewes. Possibly horn rubbing replaces the twist in ram-ram interactions.

The only time ewes were aggressive towards rams was when young rams tried to mount them or when two ewes were in competition for a particular ram. In the first case, ewes which were aggressively pursued by young rams might turn towards the ram and thrust their heads into the throat of the ram. In the latter case, if a ram was preoccupied with another ewe, an older ewe might butt the ram or the other ewe to gain the ram's attention.

Current limiting factors

An assessment of the factors currently limiting the bighorn sheep population in Canyonlands is difficult. Small water sources are available in most of the canyons. However, summer use of Fake Junction Pocket and Junction Pocket, which do not have permanent water sources, is limited. Since there are large amounts of blackbrush in these canyons, they are preferred foraging areas when water is plentiful in the spring and fall. Therefore, water might be a limiting factor in this area. Only one ewe group was observed feeding on bones and no bighorn sheep were observed eating soil. Also, dicalcium phosphate, placed in Monument Basin, was not touched by bighorn sheep. This does not rule out the possibility of mineral deficiencies, but perhaps indicates phosphorus and calcium may not be lacking. Predation also appears to be minimal. Five bighorn sheep skeletons (one 8-year old female, three yearling females, and one lamb) were found. The old ewe had worn molars and was missing a premolar and a molar, which possibly led to malnutrition. The death of the three yearlings is puzzling, since mortality, although common in young lambs, in yearlings usually is rare.

Bighorn sheep apparently are at an equilibrium with the carrying-capacity in the canyons below the White Rim. The rams' dispersal during the summer may be essential to maintain this equilibrium. Also, utilization of the White Rim by the ewe group may be essential to this equilibrium. Now that grazing has ceased, bighorn sheep possibly will expand their use of the blackbrush flats on the White Rim. Hence, it is important that man is recognized as an important factor limiting the expansion of the bighorn sheep in the Park. It is critical for the bighorn that tourist activities on the White Rim be monitored to prevent potential interference with the bighorn's well-being.

SUMMARY AND RECOMMENDATIONS

This two-year study was conducted to determine the distribution, abundance, and movement of desert bighorn sheep, and the effect of human encroachment upon such in Canyonlands National Park, Utah.

There are between 60 and 100 bighorn sheep in the Island in the Sky District. An additional 20 to 30 bighorn sheep reside in the southern canyons of the Needles District. The Maze District has no resident bighorn. Bighorn sheep distribution in the Island in the Sky has been greatly reduced since the 1920's. This decline has been associated with intensive livestock grazing. The introduction of livestock resulted in competition for forage and space, possibly resulting in increased parasitism and disease in the bighorn, and also perhaps complicating the bighorn sheep's energy regime.

Hunting by livestockmen and miners is thought to have had a detrimental influence on bighorn sheep. The selection for wary bighorn sheep perhaps has had a more permanent effect upon the bighorn sheep in Canyonlands than the actual killing of them. When bighorn sheep encounter tourists, this fear places a psychological stress upon them which may be energetically costly. This may explain the reluctance of bighorn sheep to expand their range, in spite of the cessation of livestock grazing. The importance of physical barriers in minimizing psychological and energetic stress was evident. If bighorn sheep are able to retreat to terrain which is unappealing or inaccessible to livestock or deer, they will continue to inhabit the area.

Deer and bighorn sheep were found to concurrently inhabit some canyons. However, they demonstrated a difference in habitat selection. Bighorn sheep remained on the benches, while deer occupied the washes and broad level areas. However, this does not mean that bighorn sheep prefer rugged habitat. In canyons not inhabited by deer, bighorn sheep regularly utilized washes and level areas.

The impact of tourism is minimized when bighorn sheep and the source of disturbance are separated by physical barriers and the presence of man on the White Rim may be limiting the expansion of ewe home ranges.

Ewes remain in the canyons below the White Rim throughout the year, although in some areas, particularly around Buck Canyon, they graze in the blackbrush flats on the White Rim. The White Rim road apparently restricts ewe use of the White Rim.

Rams in the southern portion of the Island in the Sky District have regular seasonal movements. During the late winter and spring, rams formed bands which moved horizontally through a series of four canyons. In June, they dispersed individually or in pairs to higher elevations. In late October, they descended individually to the canyons below the White Rim to search for ewes. The height of the rut activity was from mid-November to mid-December.

Currently, bighorn sheep in the Park appear to be at maximum numbers for the restricted range they inhabit. Further range expansion may be necessary for the population to increase.

It is recommended that the Park Service monitor tourism on the White Rim and continue to relate human use to bighorn sheep population trends. The development of water holes should be delayed. Water hole development might increase deer utilization, which might precipitate a further decline of bighorn sheep. Hiking below the White Rim should be restricted.

Since deer are abundant in the Maze District and the terrain may not be suitable to support both deer and bighorn sheep, a reintroduction should be delayed, pending refinement of reintroduction techniques and further study of deer and bighorn sheep interactions in such areas.

Studies investigating the deer population and its role in limiting bighorn sheep should be initiated. Also studies should be initiated to determine whether bighorn sheep will expand their range, now that livestock grazing in the Park has been terminated, and the role that human activities and encroachment play in regard to the bighorn sheep should be investigated.

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APPENDIX

Table 10. Bighorn sheep sightings recorded during 1974-1975 in Canyonlands National Park, Utah

Date	Number and sex			Location	Distance from		
	Rams	Ewes	Lambs		Roads (km)	Water (km)	Observer (km)
7/30/74	8	0	0	Needles side of confluence	0.80	0.05	0.02
8/3/74	1	0	0	White Rim above Junction Pocket	0.03	3.20	0.02
8/4/74	0	2	2	Monument Basin	1.60	0.05	0.04
8/4/74	0	2	0	Monument Basin	1.20	0.10	0.15
10/20/74	0	1	1	Monument Basin	1.20	1.60	0.80
10/20/74	1	0	0	Monument Basin	1.60	0.10	0.30
10/21/74	1	1	1	Monument Basin	2.40	0.25	0.10
10/22/74	0	2	0	Monument asin	2.40	1.20	0.08
10/26/74	1	0	0	White Crack	4.80	0.03	0.25
10/30/74	1	4	2	Monument Basin	2.40	0.08	0.08
10/30/74	0	1	0	Monument Basin	2.40	0.02	0.03
11/1/74	1	0	0	Buck Canyon	1.60	1.60	0.15
11/21/74	1	0	0	Loop of Colorado River	1.20	0.08	0.80
11/26/74	3	0	0	Y Canyon	4.80	1.60	0.25
12/8/74	1	0	0	Fake Junction Pocket	4.00	0.80	1.20
12/9/74	1	0	0	Junction Pocket	1.20	1.20	0.80
12/9/74	1	2	0	Junction Pocket	2.40	0.80	0.40
12/10/74	1	0	0	White Crack	3.20	1.20	0.08
12/10/74	2	0	0	Loop area	1.60	0.02	0.15
12/11/74	10	3	0	Loop area	3.20	0.02	1.60
12/12/74	1	2	0	Monument Basin	1.60	0.02	0.15
12/14/74	0	1	0	Monument Basin	1.60	0.05	0.04
12/15/74	1	0	0	Kayenta formation above Lathrop Canyon	2.40	0.20	0.04
3/24/75	0	7	0	White Rim above Lathrop Canyon	1.60	0.80	1.60
3/26/75	1	0	0	Monument Basin	1.60	0.02	1.60
4/27/75	5	0	0	Junction Pocket	2.40	0.15	1.60
4/28/75	5	0	0	Junction Pocket	0.40	0.15	0.80
4/30/75	4	0	0	White Crack	3.20	1.20	0.08
5/12/75	0	1	0	Monument Basin	2.40	0.05	0.08

Table 10. Continued

Date	Number and sex			Location	Distance from		
	Rams	Ewes	Lambs		Roads (km)	Water (km)	Observer (km)
5/13/75	0	4	0	Junction Pocket	2.40	0.80	0.04
5/13/75	9	0	0	Junction Pocket	1.60	0.20	1.60
5/14/75	2	0	0	Junction Pocket	1.60	0.30	0.07
5/21/75	7	0	0	Fake Junction Pocket	1.60	0.80	1.20
5/30/75	1	2	0	Buck Canyon	1.60	0.20	0.10
6/1/75	0	1	0	White Rim above Monument Basin	1.60	1.60	0.10
6/6/75	2	0	0	Fake Junction Pocket	1.20	0.80	0.80
6/7/75	2	0	0	Junction Pocket	1.60	3.20	1.20
6/9/75	1	0	0	Buck Canyon	3.20	0.80	0.05
7/11/75	0	3	3	Buck Canyon	3.20	0.00	0.20
7/22/75	0	4	3	White Rim between Lathrop and Buck Canyon	0.80	0.40	1.20
7/23/75	0	4	2	Monument Basin	1.20	0.40	0.80
7/24/75	1	0	0	Mossback below Junction Butte	1.60	3.20	0.20
8/7/75	0	2	2	White Rim above Monument Basin	0.30	1.60	0.30
8/7/75	10	0	0	White Rim above Junction Pocket	0.20	3.20	0.20
8/8/75	0	2	2	Dogleg Canyon	1.20	0.05	0.15
9/30/75	0	1	1	White Crack	3.20	0.40	1.20
9/30/75	2	0	0	White Crack	3.20	0.40	1.20
9/30/75	0	1	0	Junction Pocket	2.40	1.60	0.80
10/1/75	1	0	0	Junction Pocket	2.80	3.20	0.80
10/24/75	0	1	1	White Rim above Buck Canyon	0.25	0.02	0.30
10/25/75	1	2	1	White Crack	3.20	0.07	0.60
10/26.75	1	2	0	Junction Pocket	0.80	0.15	2.40
10/26/75	2	0	0	Loop area	3.20	0.05	1.20
10/27/75	2	0	0	Junction Pocket	0.25	0.25	0.20
10/27/75	0	2	0	Junction Pocket	1.00	0.25	0.50
10/28/75	0	1	0	Monument Basin	1.80	1.50	1.60

Table 10. Continued

Date	Number and sex			Location	Distance from		
	Rams	Ewes	Lambs		Roads (km)	Water (km)	Observer (km)
11/16/75	0	1	0	Fake Function Pocket	1.60	3.20	1.60
11/17/75	0	0	1	Junction Pocket	3/20	1/60	0.05
11/17/75	2	2	1	White Rim north of Loop area	1.60	0.10	1.20
11/18/75	3	1	0	Moenkopi north of White Crack	0.15	0.80	0.15
11/22/75	1	0	0	White Rim above Mussleman Arch Canyon	0.05	0.05	0.15
11/22/75	1	1	1	Cutler south of Little Bridges Canyon	2.00	0.80	2.00
11/23/75	0	1	2	White Rim between Lathrop and Buck Canyon	1.60	0.20	0.20
11/23/75	1	1	0	White Rim north side of Buck Canyon	1.00	0.03	0.20
11/23/75	1	0	0	White Rim north of Gooseberry Canyon	1.60	0.02	1.60
11/23/75	0	1	0	Gooseberry Canyon	1.60	0.10	0.30
11/23/75	1	0	0	Gooseberry Canyon	3.20	0.80	1.60
11/23/75	1	1	0	Cutler south of Buck Canyon	3.20	0.40	0.08
11/24/75	0	1	0	Gooseberry Canyon	2.40	0.20	0.80
11/24/75	1	1	0	Drainage south of Dogleg Canyon	3.20	0.20	1.60
11/24/75	1	2	0	Monument Basin	0.80	0.40	0.80
11/24/75	0	1	0	Monument Basin	0.80	0.40	0.80
11/25/75	1	0	0	White Rim north of Monument Basin	0.04	0.02	0.04

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