DESERT BIGHORN COUNCIL

1986 TRANSACTIONS

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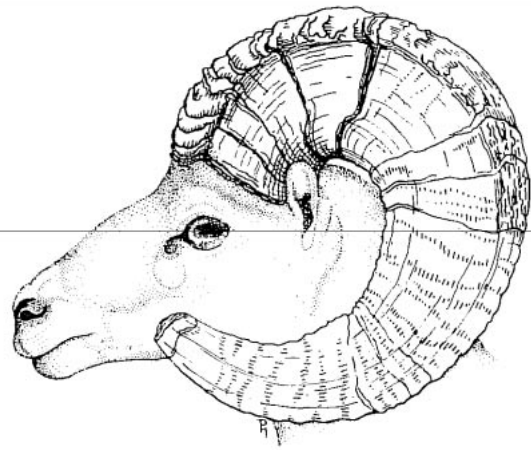
THE DESERT BIGHORN COUNCIL
awards the 1986
Honor Plaque
to

WARREN KELLY

In recognition of 30 years of service to the
Desert Bighorn Council



DESERT BIGHORN COUNCIL AWARD RECIPIENTS

BIGHORN TROPHY:

1960	Ralph and Florence Welles, U.S. National Park Service, Death Valley California
1962	Oscar V. Deming, U.S. Bureau Sports Fisheries and Wildlife, Lakeview, Oregon
1965	John P. Russo, Arizona Game and Fish Department, Phoenix, Arizona
1966	Charles Hansen, U.S. Bureau Sport Fisheries and Wildlife, Las Vegas, Nevada
1968	Steve James, Jr., Fraternity of the Desert Bighorn, Las Vegas, Nevada
1969	M. Clair Aldoux, U.S. Bureau Sport Fisheries and Wildlife, Fallon, Nevada
1974	The Arizona Desert Bighorn Sheep Society, Inc.
1978	Fauna-Silvestre. Mexico City, Mexico
1979	Robert P. McQuivey, Nevada Dept. of Fish and Game, Las Vegas, Nevada
1983	Charles L. Douglas, U.S. National Park Service, UNLV, Las Vegas, Nevada
	David M. Leslie, Jr., Oregon State University, Corvallis, Oregon
1984	George Welsh, Arizona Game and Fish Department
1986	Richard Weaver, California Department of Fish and Game

HONOR PLAQUE:

1968	Nevada Operations Office, Atomic Energy Commission, Las Vegas, Nevada
1969	Pat Hansen, Bighorn Illustrator Specialist, Death Valley, California
1972	Inyo National Forest, Bishop, California
1973	Lydia Berry, Clerk-Stenographer, Desert National Wildlife Range, Las Vegas, Nevada
1979	Jim Blaisdell, U.S. National Park Service, Seattle, Washington
1980	Society for the Conservation of Bighorn Sheep. Upland, California
1981	Dr. Thomas D. Bunch, Dept. Animal, Dairy, and Veterinary Science, Utah State Univ., Logan
	New Mexico Dept. of Game and Fish
	Dr. Grant Kinzer, New Mexico State University
1982	Maurice 'Bud' Getty, California State Parks, Sacramento, CA
1983	DBC Ewes
1985	Naval Weapons Center, China Lake, California
1986	Warren Kelly, U.S. Forest Service. Retired

AWARD OF EXCELLENCE:

1975	Gale Monson, Desert Museum, Tucson, Arizona
	Lowell Sumner, Glenwood, New Mexico
1986	Charles L. Douglas, U.S. National Park Service, Univ. Nevada, Las Vegas, Nevada.

IN MEMORY OF

JAMES C. BICKET

and

DON LANDELLS

who died surveying bighorn sheep in California

6 October 1986

PREGNANCY DIAGNOSIS IN FREE RANGING NELSON'S DESERT BIGHORN EWES

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Abstract: Ten desert bighorn (Ovis *canadensis nelsoni)* ewes (2 9 month-old lambs, 2 2.5 year-olds, and 6 ewes ≥4 years-of-age) were live captured from 29 January to 1 February 1986 at the Island-in-the-sky District of Canyonlands National Park, Moab, Utah to evaluate their reproductive status. Pregnancy diagnosis was determined in ewes ≥2.5 years with real-time ultrasound. Seven of 8 ewes were pregnant. The lambs were not scanned. Blood progesterone levels were correlated with ultrasound confirmed pregnancies. Pregnant ewes averaged 8.52 ng/ml progesterone (range = 5.19-11.64 ng/ml). The nonpregnant 2.5 year old had a serum progesterone level of 1.28 ng/ml. The ewe lambs had progesterone levels of 0.73 and 5.88 ng/ml. Progesterone levels are a positive test for pregnancy in the desert bighorn ewe, providing samples are collected at a time when the rut is over and most ewes are either pregnant or anestrus. Real-time ultrasound is 100% accurate in pregnancy diagnosis at ≥ 35 days gestation.

The lamb:ewe ratio (lambs/100 ewes) is a measure of reproductive performance in populations of desert bighorn sheep. This ratio varies considerably from area to area and from year to year. At the Desert Game Range in Nevada the lamb:ewe ratio reached a high of 81:100 in 1949 (Turner and Hansen 1980). Most populations rarely achieve this level of reproductive success and the lamb:ewe ratio is usually 50-60:100. At Canyonlands National Park the lamb:ewe ratio for 1979 to 1985 was 52, 36, 50, 77, 52, 19, 59, respectively (unpublished data). Thorne et al. (1983) observed that 38% of Rocky Mountain bighorn (*O. c. canadensis*) in Wyoming were without lambs in 1981. Simmons et al. (1984) estimated a 75% birthrate in Dall's sheep (*O. dalli*) in the Mackenzie Mountains, Northwest Territories, Canada from 1966–1973. Heimer (1978) observed an alternate year reproduction phenomena in a population of Dall's sheep. Alternate-year-reproduction has not been reported in Rocky Mountain or desert bighorn sheep.

The reproductive potential in desert bighorn sheep populations is an important component in understanding population dynamics. These data are usually unavailable and estimates have been based upon lamb counts. Counts are usually made after the early postnatal period during which significant mortality may have already occurred. As a consequence there is little information on the incidence of prenatal failures. The purpose of this study was to determine the reproductive status of captured desert bighorn ewes by real-time ultrasound and to assess the use of blood progesterone levels as a test for pregnancy diagnosis.

This project was funded in part by the Foundation for North American Wild Sheep.

METHODS

Ten Nelson's desert bighorn ewes were captured from 29 January to 1 February 1986 by a drive net or net gun at the Island-in-the-sky District of Canyonlands National Park, Moab, Utah. The ewes were transported in body bags to a base camp where they were examined for pregnancy (except the lambs) with a Model 2150 ADR Real-time ultrasound scanner and 5.0 MHz transducer (ADR, 2224 S. Priest Drive, Tempe, AZ 85282). The ewes were placed on their back and the bare area of skin adjacent to the udder was coated with mineral oil. The transducer was then placed in contact with the skin and the status of pregnancy was based upon the presence or absence of cotyledons and/or a fetus. A region of the abdomen anterior to the udder 6-7 cm wide and 20-25 cm long was clipped of hair in the adult ewes to photograph the fetus in greater detail. This procedure was not necessary to verify pregnancy.

Blood samples were collected from the jugular vein, cooled to 5-6°C, and then centrifuged. Serum samples were frozen at -20°C until analyzed for progesterone. Progesterone levels were determined by radioimmunoassay (Gibori et al. 1977).

RESULTS

Two lambs, 2 2.5 year-olds, and 6 ewes ≥4 years-of-age were captured. Seven of the 8 ewes ≥ 2.5 years of age were confirmed pregnant with real-time ultrasound (Table 1). A 2.5 year-old was not pregnant. This ewe was the size and weight of the captured ewe lambs (approximately 23 kg).

Progesterone levels (Table 1) in confirmed pregnant Nelson's bighorn ewes averaged 8.52 ng/ml (range = 5.19-11.64). The 2 lambs had levels of 0.73 and 5.88 ng/ml.

Table 1. Ultrasound readings (– = nonpregnant, + = pregnant) and progesterone values for Nelson's desert bighorn ewes captured in Canyonlands National Park, Utah, 29 January–1 February, 1986.

Ewe#	Age	Ultrasound (±)	Progesterone (ng/ml)
6	Lamb[a]		0.73
10	Lamb		5.88
4	2.5	–	1.28
14	2.5	+	10.99
9	24.0	+	11.19
11	24.0	+	11.64
13	24.0	+	5.19
15	24.0	+	6.51
16	≥4.0	+	5.91
18	24.0	+	8.91

"Lambs were not scanned with ultrasound.

DISCUSSION

There are 4 techniques (progesterone assay, rectal abdominal palpation, ultrasonic sound and vaginal biopsy) being used to detect pregnancy in domestic sheep (Bearden and Fuquay 1984). Of these, progesterone assay and ultrasonic sound have been used in North American wild sheep (Ramsay and Sadleir 1979, Whitehead and McEwan 1980, Harper 1984, Simmons et al., 1984, Thorne et al. 1984,

Harper and Cohen 1985). Ultrasonic sound equipment consists of 2 basic types. One type (vector or linear array) detects a difference in acoustical impedance between tissues or structures contained within the body. The less expensive types (A-mode) present the amplitude of the acoustical impedance as a series of lines on the y-axis and the time between echoes on the X-axis. Some models that have been developed for pregnancy detection use a sound or light to indicate whether the animal is pregnant or not. Real-time ultrasound scanners (B-mode) transpose the acoustical impedance into an actual gray scale image. The image is viewed on a television monitor. The advantage of the B-mode scanner is that tissue and structure can be visually observed.

The other type of ultrasonic technique is the Doppler. Positive diagnosis is based upon detecting a fetal pulse and swishing of the umbilical cord. The Doppler was reported by Harper (1984) and Harper and Cohen (1985) to be highly accurate for determining pregnancy in bighorn sheep. They estimated an overall accuracy of 90%. Ewes were scanned between 94 to 150 days gestation and diagnosis took 30 seconds to 10 minutes. Accuracy of the Doppler in domestic sheep (1,396 ewes) has been reported to increase from 80 to 97% as pregnancy advances from 31 to 120 days.

Based upon our own personal experience with domestic sheep. about the earliest pregnancy can be determined in the ewe using real-time ultrasound is ≥ 35 days gestation. At 35 days, the fetus is an embryonic vesicle within a gestational sac. By 60 days gestation the fetus is entirely formed with a head, body, and legs. Cotyledons are well defined structures at 35-40 days of pregnancy. At Canyonlands National Park, the rut begins in late October and lasts to mid-December. The ewes in this sample were scanned the end of January, which if pregnant, would be at a stage of development that is readily detectable with real-time ultrasound. All fetuses observed were estimated to be 45-60 days of age (Figs. 1, 2).

Cotyledons were the most prominent feature in determining pregnancy in desen bighom ewes. They appeared as donut shaped structures aligning the uterine cavity and were highlighted in darkened background of fetal fluid (Fig. 3). Cotyledons are points of nutrient exchange and occur where the placentae develop opposite the uterine endometrial surface. In pregnant ewes, they were observed the instant the transducer came into contact with the ewe's abdominal wall. The fetus then could be observed with a little searching once the cotyledons were observed. In 50% of the ewes, the cotyledons and fetus were observed simultaneously.

Pregnancy rate in Nelson's desert bighom at Canyonlands National Park as determined by real-time ultrasound was 100% in adult ewes. Only 1 of the 2 2.5 year-olds was pregnant.

Ultrasound confirmed pregnancies were 100% correlated with progesterone levels ≥ 5.0 ngiml. Pregnant ewes averaged 8.5 ng/ml. Progesterone levels are usually negligible at estrus in domestic sheep and then rise to 1.0 nglml at about 4 days after ovulation (Hecker 1983). Serum samples taken in domestic sheep at 18 days postbreeding average 4.8 1 ng/ml for pregnant and 1.41 ngiml for nonpregnant ewes (Bearden and Fuquay 1984). The accuracy in using progesterone analysis in diagnosing pregnancy in domestic sheep is 85% for pregnant ewes and approaches 100% for nonpregnant ewes. Thorne et al. (1984) round that false diagnosis in bighom sheep may occur at progesterone levels <6.0 ng/ml during the first third of gestation and that a threshold of 2.0 nglml progesterone during the latter 2 thirds of gestation was adeauate for pregnancy diagnosis. Ramsay and Sadleir (1979) also reported that progesterone levels between 2.0-3.0 nglml during the latter 2 thirds of gestation could be used as a threshold for pregnancy diagnosis in bighom sheep. Whitehead and McEwan (1980) reported that progesterone levels increased to 8.5 nglml during the first 50 days of pregnancy in bighorn ewes. From 50-80 days gestation, progesterone levels decreased and then peaked at 13.3-23.2 ngiml. They observed that 18-month-old ewes had silent beats with oeak progesterone levels of 1.0-2.2 ngiml. The ewes sampled in this study were in the mid to latter third of gestation. Based on the pregnancy

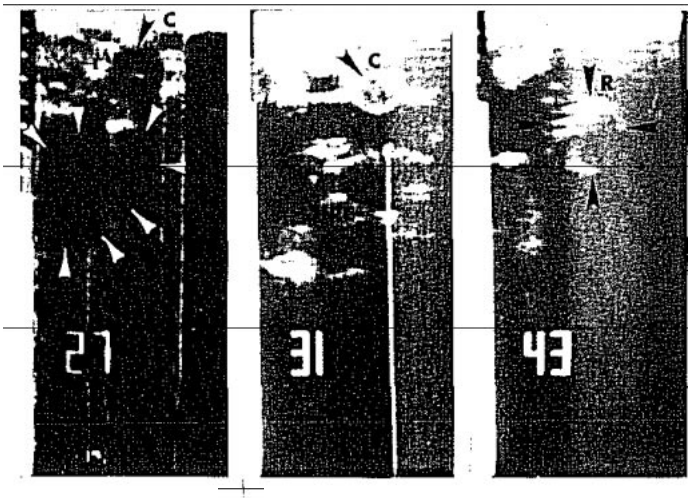


Fig. 1a. The large dark cavity (white arrows) within the uterus is the amnion filled with fluid. Cotyledons (C) can be observed above the cavity. 1b. The rib cage (RC) width of this desert bighorn fetus is 31 mm. Cotyledons are observed above the fetus. The fetus is immersed in amniotic fluid. lc. The ribs (R) of this desert bighorn fetus are very prominent.

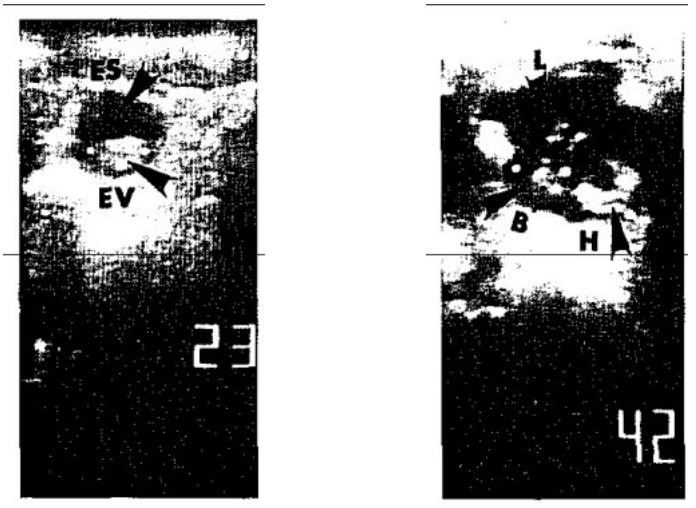


Fig. 2a. Thirty-five to 40 day pregnancy. Embryonic vesicle (EV) is surrounded by an embryonic sac (ES). The fetus is very active at this stage of development. 2b. Sixty-day fetus. Head (H), body (B) and legs (L) are very prominent.

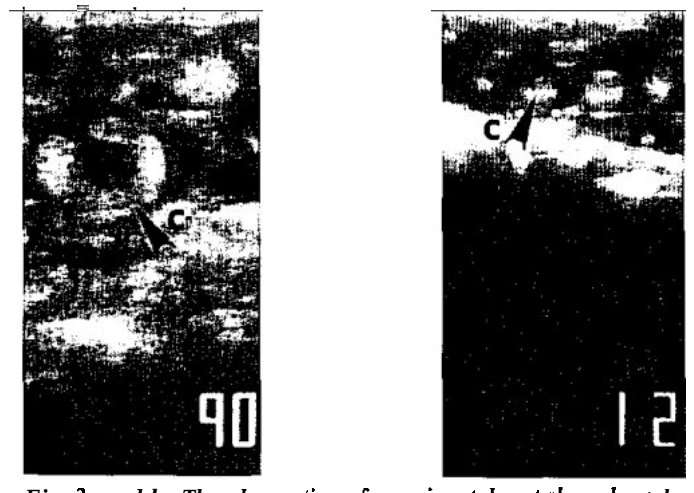
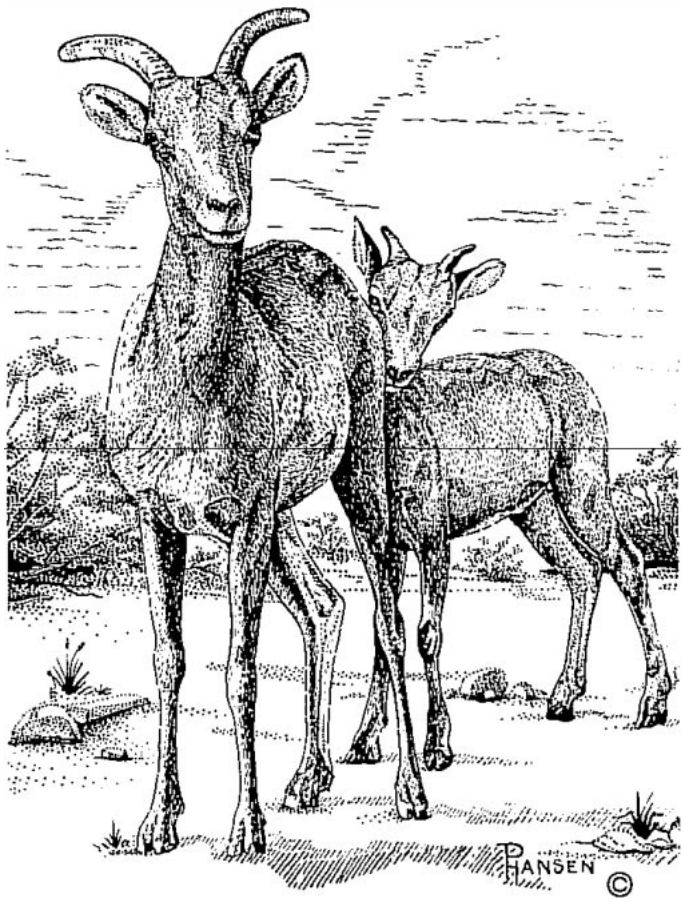


Fig. 3a and b. The observation of prominent donut shaped cotyledons (C) are indicative of pregnancy.

threshold level of ≥ 6.0 ngiml progesterone as suggested by Thorne et al. (1984), 2 of the 7 ewes confirmed pregnant with ultrasound. would not have been considered pregnant. One of the 2 lambs sampled in this study had a progesterone level of 5.88 ngiml. She was not scanned with ultrasound and there is no way of knowing whether she was pregnant. However, desert bighorn ewes usually do not breed until approximately 1.5 years of age. If she was in the luteal phase of an estrous cycle, her progesterone level was considerably higher than the peak values of 1.0 to 2.2 ngiml as observed by Whitehead and McEwan (1980) for 18-month-old bighorn ewes having silent heats. If indeed she was in the luteal phase of an estrous cycle, then her progesterone level supports the value of ≥ 6.0 ng/ml progesterone as set forth by Thorne et al. (1984) for diagnosing pregnancy during the first third of pregnancy.

In summary, progesterone analysis is a fairly accurate and inexpensive test to determine pregnancy rates in free-ranging populations of bighorn, particularly if serum samples are collected during the latter third of gestation. The Doppler as reported by Harper (1984) and Harper and Cohen (1985) is also very accurate and can be used as a supportive method to progesterone analysis. Real-time ultrasound provides an actual image of the reproductive tract and therefore allows for immediate diagnosis of pregnancy. This method can be used singularly beginning at about 5 weeks gestation. Pregnancy rate in Nelson's bighorn at Canyonlands National Park was 100% wh excluding the 2.5;ear-old that appeared to be physically underdeveloped. This high reproductive rate is similar to the rate reported by Harper (1984) where he observed a 100% pregnancy in bighorn ewes.



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DESERT BIGHORN SHEEP—RIVERBOAT INTERACTIONS IN CATARACT CANYON, UTAH

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Abstract: The precipitous slopes of Cataract Canyon adjacent to the Colorado River provide important habitat for desert bighorn sheep (Ovis *canadensis nelsoni*). The effects of riverboat use in Cataract Canyon on movement and behavior of 5 radio-collared ewes and associated animals were studied in 1985. Desert bighorn sheep behavior in spring prior to riverboat use of the area was compared with behavior during summer riverboat use. No significant differences were found. For the desert bighorn sheep observed, 58% showed no response, 39% showed a minor response, and 3% showed a moderate response to riverboats. No long term detrimental effects of riverboats were observed.

The majority of public lands inhabited by desert bighorn sheep in San Juan County, Utah are administered by either the U.S. Bureau of Land Management (BLM) or the National Park Service (NPS). Portions of desert bighorn sheep habitat, such as the slopes and canyons adjacent to the Colorado River, are more accessible and frequently receive high recreational pressure. Increasing recreational use of these areas (M.M. King, and G.W. Workman, unpubl. rep., U.S. Bureau of Land Management, Moab, Ut., 1981, 1982, 1983) poses additional problems for desert bighorn sheep. Recently, the most common human activities in southeast Utah are recreation (including hunting), low flying aircraft, and some changes in habitat due to resource development.

Human-related activities are variable in origin, magnitude and impact. Responses of desert bighorn sheep to human activities range from habituation and little impact to abandonment of habitat (Welles and Welles 1961, McQuivey 1978, Purdy and Shaw 1981). Disturbances to Rocky Mountain bighorn sheep (*O.* c. *canadensis*) in the John Muir Wilderness Area, California were dependent on the relative position of mountain sheep to backpackers, herd size, and herd composition (Hicks and Elder 1979). King and Workman (1983) observed responses of desert bighorn sheep when riverboat passengers approached, landed near, or pursued them.

Deforge (1981) pointed out that because desert bighorn sheep are usually quite sensitive to environmental disturbances, their ability to survive is maximized when the environment is stable and predictable. Stressful situations are expected to occur if environmental degradation alters desert bighorn sheep behavior and physiology. Continuous disturbance could result in desert bighorn sheep abandoning an established home range. Geist (1971b) observed that mountain sheep were slow to disperse into new areas. Desert bighorn sheep learn their habitat use patterns from older animals in the group and do not readily expand their range into new areas. Abandoned bighorn sheep ranges are not readily reoccupied unless the previous herd returns (Geist 1971b). Therefore, disturbances having the potential to displace bighorn sheep populations or cause undue stress need to be evaluated to determine the nature and extent of impacts.

The objective of this study is to evaluate desert bighorn sheep responses to rafting disturbances. The BLM provided financial assistance, and the Utah Division of Wildlife Resources furnished living quarters and provided fixed-wing aircraft flights. In addition, Canyonland National Park officials provided valuable data on rafting pressure in Cataract Canyon.

STUDY AREA AND METHODS

The study area is located in southeastern Utah in the Cataract Canyon area of the Colorado River (Fig. 1). Desert bighorn sheep groups occupying 5 home ranges in 3 side canyons (Dark, Sheep, and Gypsum) of Cataract Canyon were studied from April to September, 1985 (Fig. 1). Recreational use of the Colorado River is

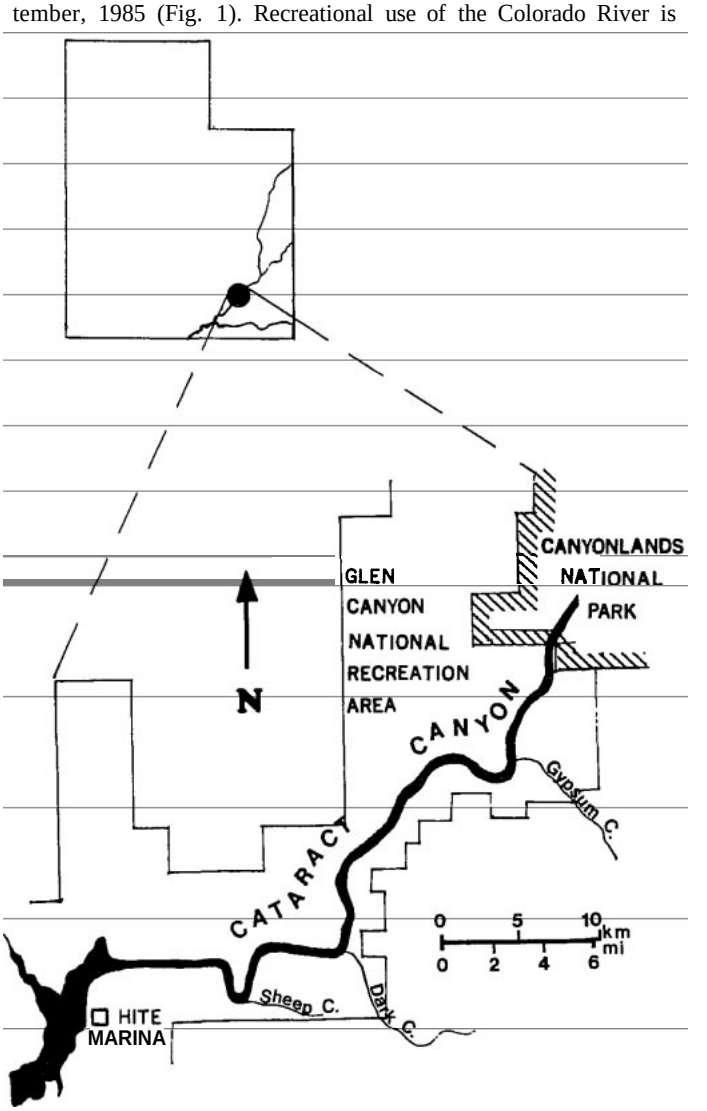


Fig. 1. Desert bighorn sheep-riverboat interactions study area in Cataract Canyon, Utah, 1985.

regulated by Canyonlands National Park and varied seasonally. Rafting, backpacking, hiking, and boating increased significantly in late spring. Only 7% of the yearly rafting trips occurred prior to 24 May. Driftwood prevented most upstream travel by powerboats and water skiers until late June. Therefore, the riverboat season was comprised of the late May through September period. Rafters alone accounted for 336 trips made by 4,234 persons in 1985.

Ground locations and bimonthly fixed-wing telemetry flights were used to locate 5 mature, radio-collared desert bighorn ewes from a previous study (King and Workman 1983). Classification and observation of animals were accomplished using a 15-60X spotting scope from an opposing canyon slope or rim. Locations and movements of collared animals were recorded on 1:62,500 U.S. Geological Survey topographic maps. Only ewe groups with lambs and young rams 3 years old or younger were observed. Focal sampling to determine diurnal movement and behavior patterns was done by continually monitoring the behavior of an individual animal. Approximately 20 different ewes and young rams were monitored. Observations usually began with a radio-collared ewe as the focal animal and the next day a new focal animal was chosen. In addition, desert bighorn groups were scan sampled every 5 minutes. Activities of all animals in view were then recorded. Activities were classified as lying, standing, foraging, walking, running, or playing. Attention behavior observed during any of these behavior types was also recorded. Behavior of animals during the riverboat season (with and without boats present) and the non-riverboat season was compared. Rafts and powerboats were considered present when they were within 0.8 km or less of the desert bighorn sheep group. Responses to the presence of riverboats were catagorized as: 0 = no response or evidence of interaction; 1 = minor responses, stare, attention, or alarm posture without movement; 2 = moderate response, walking away from disturbance or group huddle; and 3 = major response, rapid directional flight.

RESULTS

Relocation and behavior data for 5 radio-collared desert bighorn sheep ewes and associated animals were collected during 45 days from April to September. These groups included lambs and immature rams, but no ram or mixed group data were collected as rams >3-years-old were seldom observed. Group classification usually did not change from day to day.

Ewe groups displayed very little deviation from the established home range determined by King and Workman (1983) in a previous study. Of the 118 relocations of 5 ewe groups, 108 were found on steep talus slopes ≤0.8 km from the Colorado River or mouths of adjoining canyons accessible to riverboats. The maximum distance a relocation was found outside a home range was 2.4 km.

Desert bighorn sheep were observed watering on 10 separate days; once at a tank 0.8 km from Sheep Canyon Bay, and 9 times at the river. These observations were made over 22 different days between 14 June and 15 August with some use of the river as a water source by different members of the same group on consecutive days. Ewe groups watered at the river primarily before 1030 or after 1730 with only 1 observation in the interim period. Nearly 80% of the riverboats were observed between 1000 and 1800.

Desert bighorn sheep focal animals were observed for 54.3 hours prior to, and 102.1 hours during the riverboat season, respectively. Focal animal behavior was recorded for 5.8 hours while riverboats were within 0.8 km. Comparison of behavior of focal animals before and during the riverboat seasons was done with a randomized block design (Kirk 1982) for analysis of variance. Behavior categories were used as relatively homogeneous blocks with the riverboat seasons as different treatment levels. Because running and playing were observed <0.3% of the time, they were not used in the analysis. There was no significant difference in desert bighorn sheep behavior between pre-riverboat and riverboat seasons ($F=5.07$, $df=1.3$, $P>0.10$). Percent time desert bighorn sheep spent in different behavior types was similar for the pre-riverboat, riverboat, and riverboat present time periods (Fig. 2).

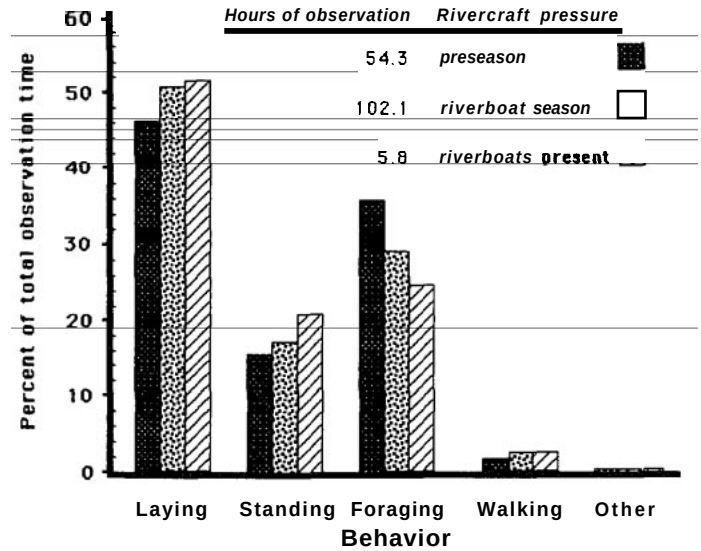


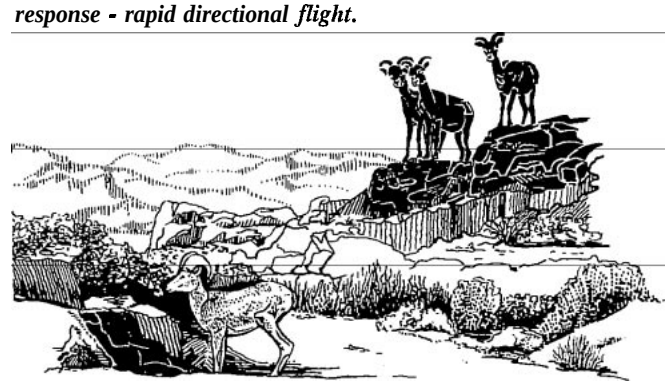
Fig. 2. Percentage of total observed time spent laying, standing, foraging, and walking for desert bighorn sheep focal data, Cataract Canyon, Utah, 1985.

Responses of ewe and ewe-lamb groups to riverboats were generally minor or absent (Table 1). Sharp turns made nearby, fast moving powerboats, and sudden noises such as the splash of swimmers or skiers entering the water caused minor disturbances. Moderate disturbances were observed when rafters turned, approached the shore and whistled, or drifted close to photograph. A few minor responses were observed when a sonic boom occurred or low flying helicopter followed the river channel. However, no major responses due to riverboating activities were observed.

Table 1. Response levels of ewe, and ewe-lamb groups to riverboats in Cataract Canyon, Utah, from April through September 1985. Numbers in parentheses indicate % of row total.

	Response level"				
Source	0	1	2	3	Total
Motorboats	39 (58)	26 (39)	2 (3)	0 (0)	67
Raft	14 (56)	10 (40)	1 (4)	0 (0)	25
Total	53 (58)	36 (39)	3 (3)	0 (0)	92

"Response levels: 0 = no response; 1 = minor response - attention or alarm posture without movement; 2 = moderate response - walking away from disturbance or group huddle; and 3 = major response - rapid directional flight.



DISCUSSION

The presence of people in riverboats in Cataract Canyon did not preclude desert bighorn sheep from using the area for daily activities. The slopes of Cataract Canyon are used by desert bighorn sheep throughout the year including the breeding and lambing seasons (King and Workman 1982). The ewes monitored in this study seldom traveled far from Cataract Canyon. New areas used outside of home ranges were usually along the river. All were observed drinking from the river at least once. Gypsum and Dark canyons had year round water flows in 1985. It is unknown if animals on Cataract Canyon slopes between Gypsum, Dark, and Sheep canyons would have adequate free water if disturbance levels or frequency increased to prevent desert bighorn sheep use. Desert bighorn sheep access to the Colorado River is limited to areas where the canyon slopes do not enter the water vertically. These areas were easily visible and accessible from the river. Use of the river as a free water source occurred in the morning and evening when riverboat pressure was minimal. Similarly, Hamilton et al. (1982) determined that desert bighorn sheep avoided using mineral licks when hikers were present, although they would return to the lick if no disturbances occurred for an hour or more.

Differences in the proportion in lying and foraging were probably due to decreased seasonal foraging and increased seasonal lying during warm summer days (Fig. 2). Scan behavior data indicated a higher than expected lying and lower than expected feeding time during midday. Activity was high in morning and evening. Krausman et al. (1985) described the decrease in diurnal activity of 2 desert bighorn sheep ewes (*O. c. mexicana*) as temperature increased in the Little Harquahala Mountains, Arizona. Cataract Canyon ewes displayed similar diurnal activity patterns.

In each case of a moderate response, the ewe group was close to shore (<100 m) while persons in boats were aware of the animals, moved toward them, and attempted to view or photograph the group. These observations were similar to the observations of Dean (1977) and Graham (1980) who reported that boat disturbances were minimal as long as boats continued moving and people did not go ashore. Normally, desert bighorn sheep lay or stood motionless while people in the rafts passed by when velocity, direction (parallel to shore), and motor noise were consistent. Stimuli which apparently drew attention included fast motorboats when animals were close to shore, starting or stopping by water skiers, human voices, whistling, and laughter.

Responses to stimuli are reinforced by the resulting experience. Ungulate responses to humans are a result of how man behaves toward them (Geist 1971a, 1978). Habituation, aversion, or attraction will result as the stimuli continue. Desert bighorn sheep continued to use the rugged slopes of Cataract Canyon despite present levels of riverboat pressure. There was little evidence of long lasting detrimental impacts by riverboats to the ewe groups studied even though there were short interruptions of behavior. Disturbances were minimized when riverboats continued moving in a predictable manner. Providing information about habitat use and potential disturbances of desert bighorn sheep to conscientious boaters and commercial rafting outfitters may enrich the recreational experience and avoid some disturbances to desert bighorn sheep.

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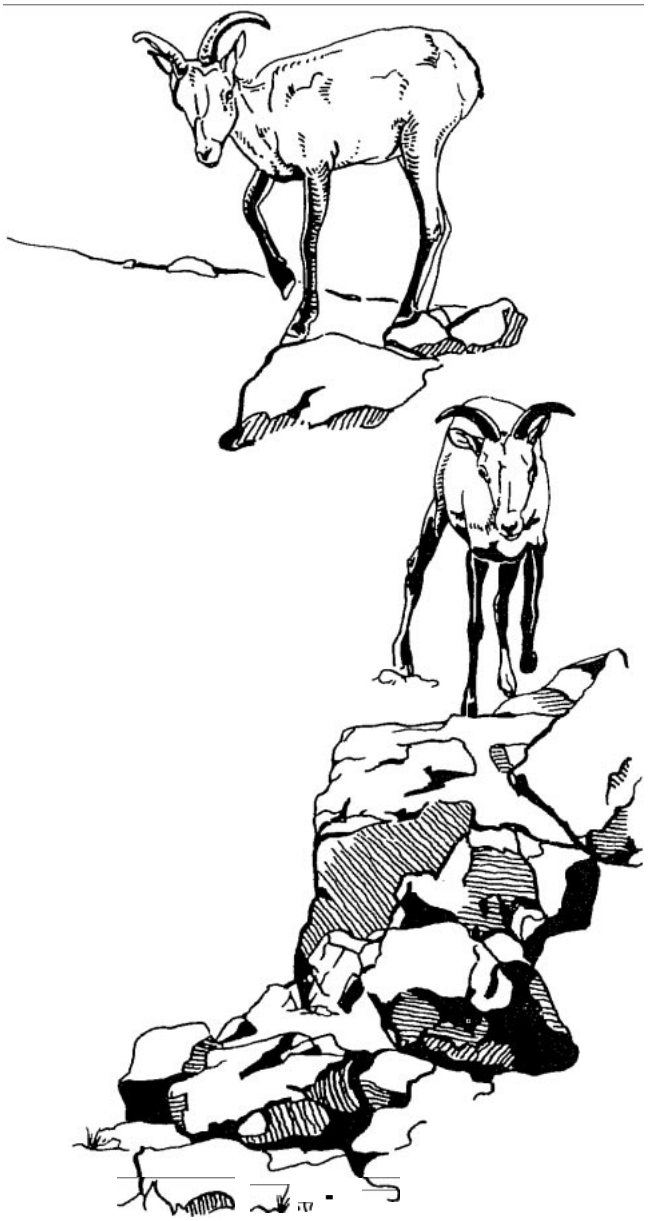

CATTLE GRAZING INFLUENCES ON VEGETATION OF A SYMPATRIC DESERT BIGHORN RANGE IN ARIZONA

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Abstract: Vegetation was sampled in a 45 ha bighorn sheep (Ovis *canadensis mexicana*) enclosure ungrazed by cattle for 26 years and a comparable grazed area to assess vegetation differences attributable to cattle grazing. Sampling was stratified by slope: level, moderate, and steep. Specific differences in grass and shrub composition were assessed. Significant differences with cattle grazing in perennial grass, annual grass, forb, total vegetation, and bare ground cover were detected on level slope only. Cattle favored level slopes while bighorn predominately used steep slopes. Direct correlations between observed cattle use by slope and vegetation cover differences (excluding shrubs) were significant ($P \leq 0.05$). Cattle fed primarily on grasses while bighorn used a wide variety of shrubs. Direct correlation between the cattle diet and the observed vegetation cover differences (excluding shrubs) was also significant.

Overgrazing of desert ranges in the southwest by domestic livestock has been cited as 1 of several factors that acted to reduce bighorn sheep distribution and abundance (Russo 1956, Buechner 1960, Gallizioli 1977, Jones 1980). Cattle grazing and its impacts on desert bighorn populations is a controversial topic, partly due to the continued widespread occurrence of cattle on desert ranges. Relatively little empirical data exist documenting impacts of cattle grazing practices on bighorn populations and forage resources, especially where the 2 exhibit high levels of sympatry. Buechner (1960) stressed the need to examine the relationships of bighorn to vegetation, particularly when assessing and understanding competition with other ungulates.

Aravaipa Canyon, Arizona, because of its high degree of sympatry between bighorn sheep and cattle, provided an excellent opportunity to document the effects of cattle grazing on vegetation within bighorn range. This was possible due to the existence of a 45 ha enclosure constructed in 1957 to re-establish bighorn. The enclosure remains cattle free and provides an opportunity to assess differences in vegetation attributable to 26 years of cattle exclusion.

The objectives of this study were to explore the effects of grazing by cattle on vegetation and to discuss relationships between vegetation differences and observed habitat and forage use.

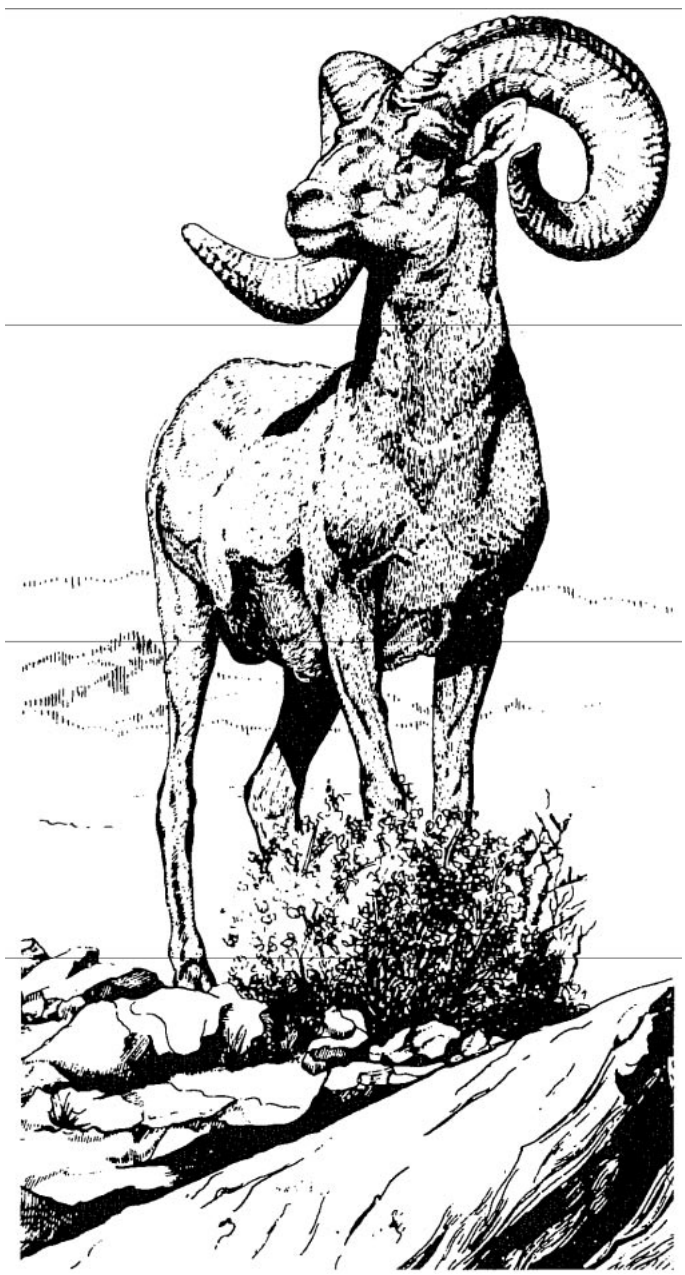
The assistance of R. Ockenfels in sampling vegetation is greatly appreciated. Bighorn sheep research at Aravaipa Canyon was conducted under Federal Aid in Wildlife Restoration Project W-78-R-27.

STUDY AREA

Aravaipa Canyon lies on the northern slopes of the Galiuro Mountains in Pinal and Graham counties, approximately 100 km southeast of Phoenix (Fig. 1). It is a steep walled canyon with vertical cliffs >250 m. Adjacent terrain is characterized by a mosiac of flat mesa tops, low buttes and broken canyon rims. Elevations range from 750 to 1,220 m. Temperatures range from winter lows near −5° C to summer highs of 35° C. Precipitation averages 35 cm annually, occurring predominantly during late summer and winter.

The area lies within the Lower and Upper Sonoran life zones and encompasses a wide range of communities (P. L. Warren, and L. S. Anderson, unpubl. rep., George Whittell Wildlife Preserve. Tucson. Ariz., 1980.) Interior canyon vegetation was characterized by desert scrub communities dominated by palo verde (*Cercidium* spp.), saguaro (*Carnegia gigantea*) and jojoba (*Simmondsia chinensis*). Areas adjacent to canyons were vegetated by semi-desert grassland communities in which white-thorn acacia (Acacia *constricta*), mesquite (Prosopis *glandulosa*), yucca (Yucca spp.) and prickly pear (*Opuntia phaecantha*) are interspersed with sideoats grama (*Bouteloua curtipendula*) and curly mesquite (*Hilaria belangeri*).

Efforts to re-establish bighorn sheep at Aravaipa Canyon were initiated in 1957 with the construction of a 45 ha enclosure in upper Horse Camp Canyon. Between 1958 and 1972, 16 bighorn were relocated to the enclosure from western Arizona (Weaver 1973). By 1973 the herd increased to 22 animals and was released from the



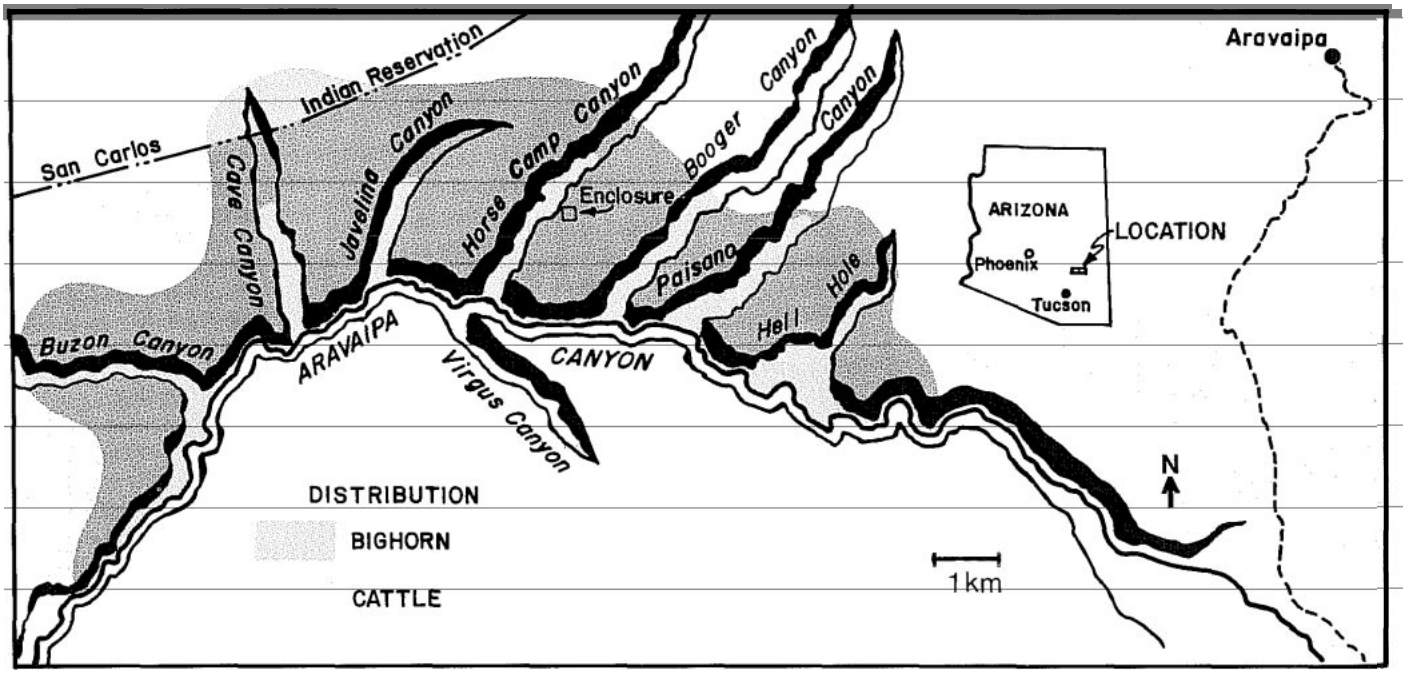


Fig. 1. Location of Aravaipa Canyon, Arizona study area, showing distribution of desert bighorn sheep and cattle. Dark shaded region corresponds to the area of sympatric distribution.

enclosure to disperse into surrounding habitat. In 1986 Aravaipa Canyon supported approximately 100 bighorn sheep. The enclosure has been maintained since 1973 as a range reference site (Turner et al. 1980) and continues to exclude cattle. Bighorn continue to use the enclosure, particuarly for lambing in spring. The enclosure lies within the semi-desert grassland community with desert scrub vegetation on steeper slopes.

Cattle grazing in bighorn habitat at Aravaipa occurs on 2 allotments accounting for 450 AUM's. Both permittees use yearlong cow-calf operations. Cattle concentrate on gentle terrain and near permanent water.

Cattle distribution overlaps 80% of the current bighorn range at Aravaipa, excluding outlying areas used only seasonally by rams (Fig. 1). Aravaipa Canyon and its side canyons are inaccessible to cattle and account almost entirely for the cattle-free portion of the bighorn range.

METHODS

Assessment of Vegetation Impacts

Measurements of vegetation in and adjacent to the bighorn enclosure were used to evaluate differences between vegetation protected from cattle grazing for 26 years and that which was not. Five 30.8 m line intercept transects (Canfield 1941) were located randomly within each of 3 slope classes for ungrazed and grazed treatments, yielding 6 treatments, each with 5 replications. Slope classes included level (0–30%), moderate (31–60%) and steep (5.61%). Percent ground or crown cover was determined for annual grass, perennial grass, forb, shrub and cacti, total vegetation, and bare ground.

Percent shrub and cacti composition was determined directly from line intercept cover data. Percentage perennial and annual grass composition was determined at each site on the basis of 100 "hits" along a pace transect (Levy and Madden 1933). Specific forb composition was not determined as forbs had dried and cured prior to sampling, making identification difficult. Vegetation sampling was conducted from July to August 1982.

The experimental design employed to assess vegetation differences was a randomized block design with 2 factors (slope and grazing), yielding 6 treatments. Factorial analysis of variance (Steele and Torrie 1980) was used to test for significance of grazing impacts between various treatments for each of the 5 vegetation classes and bare ground. Simple correlation analysis was used to assess the degree of association between vegetation and bare ground cover differences attributable to cattle grazing and cattle use by slope and diet. All statistical tests were performed at the $P<0.05$ level of significance.

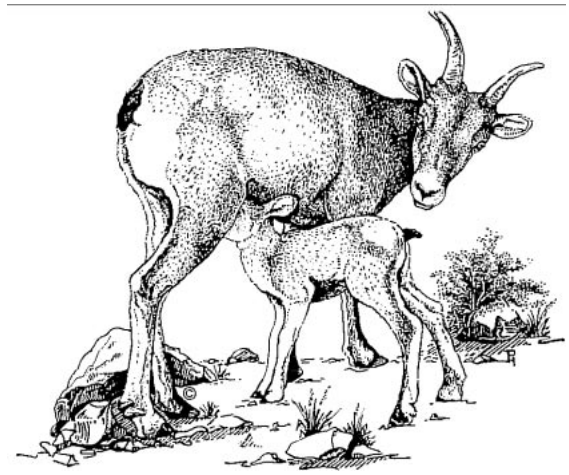
Habitat Use by Slope Class

Between December 1980 and June 1983, bighorn and cattle habitat use patterns were determined by direct ground observation. Observations of bighorn sheep were facilitated by the presence of 14 sheep (10 ewes, 4 rams) fitted with radio collars. Sightings of sheep and cattle were recorded by slope category.

Diets of Bighorn and Cattle

Diets of cattle and bighorn sheep at Aravaipa Canyon were determined through microhistological identification of plant fragments in fecal samples (Sparks and Malechek 1968, Free et al. 1970). Fresh fecal samples were collected monthly during 1981 and 1982 on the sympatric portion of the range, providing 429 bighorn and 295 cattle samples. Samples were composited by month and 20 fields were read on each of 5 slides at the Texas Tech University Food Habits Laboratory, Lubbock. Dietary overlap between bighorn and cattle was determined using methods described by Anthony and Smith (1977).

To help relate vegetation differences to grazing, diet data were summarized to correspond with the same vegetation classes measured on line intercept transects, and were combined for both years.



RESULTS

Vegetation Differences

On level slopes perennial grass cover was significantly greater on ungrazed transects compared to grazed transects. Annual grass cover was also significantly greater on ungrazed transects. Forb cover was significantly greater on grazed level slopes. Shrub and cacti cover was virtually identical inside and out of the enclosure. Total vegetation cover differed significantly on level-gentle slope, 31% higher on ungrazed, while mean percentage bare ground was 27% higher on grazed transects (Table 1). At moderate and steep slopes, no significant differences were detected between grazed and ungrazed transects for any of the vegetation classes or bare ground.

The most readily apparent difference between shrub composition at various slopes was that of increased species diversity with increasing slope, from 9 on level to 15 species on steep slope (Table 2). Grasses showed marked differences in species composition both between slopes and grazing treatments (Table 3).

Habitat Use by Slope Class

On the basis of 196 group sightings of bighorn accounting for 1,509 sheep, and 3,049 of cattle in 366 groups, patterns of slope use indicated bighorn preferred steep slopes while cattle predominantly used level terrain (Table 4). Only 1 cattle sighting was made on steep slope while 73% of the observations of bighorn occurred there. Conversely, 79% of the cattle and only 16% of the bighorn observations were made on level terrain. Use of moderate slopes by bighorn and cattle was comparable.

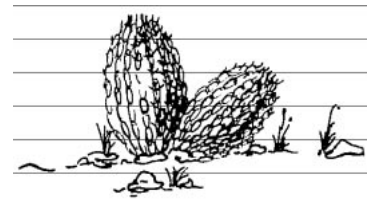


Table 1. Mean cover by category, determined from line intercept transects, for ungrazed arid grazed sites at level, moderate, and steep slope, Aravaipa Canyon, Arizona, 1982.

	Mean cover (%)								
	Level slope			Moderate slope			Steep slope		
Vegetation cover category	Ungrazed	Grazed	Diff.	Ungrazed	Grazed	Diff.	Ungrazed	Grazed	Diff.
Perennial grass	48.1	4.4	43.7**	13.2	12.8	0.4	12.6	15.1	2.5
Annual grass	13.7	5.0	8.7**	37.1	36.5	0.6	15.6	21.9	6.3
Forbs	8.0	29.7	21.7**	8.0	16.5	8.5	3.9	2.0	1.9
Shrubs and cacti	17.6	17.4	0.2	22.6	9.2	13.4	25.7	24.5	1.2
Total vegetation	87.4	56.5	30.9**	80.9	75.0	5.9	57.8	63.5	5.7
Bare ground	23.0	49.6	26.6**	26.1	31.5	5.4	46.5	41.9	4.6

Significant at P≤0.05.

Table 2. Percentage of total vegetation and total shrub (in parenthesis) cover for shrub and cacti species, determined by line intercept transects at Aravaipa Canyon, Arizona, 1982.

	Level slope		Moderate slope		Steep slope	
Shrub and cacti species	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
Acacia constricta	4.9(27.8)	1.4 (8.0)	11.9(56.7)	4.3(46.7)	4.3(16.7)	10.0(40.9)
Acacia greggii	1.5 (8.5)		0.2 (0.9)		4.7(18.3)	0.4 (1.6)
Agave chrysantha	1.6 (9.2)		1.0 (4.4)		1.0 (4.0)	1.2 (4.9)
Calliandra eriophylla			0.2 (0.9)	0.3 (3.3)	2.4 (9.4)	0.6 (2.4)
Eriogonum wrightii	2.2(11.4)	3.0(17.2)	0.8 (3.5)		1.7 (6.6)	5.5(21.3)
Krameria parviflora			1.2 (5.3)		0.5 (1.9)	
Mimosa biuncifera				0.6 (6.5)	0.8 (3.1)	
Opuntia phaecantha	0.2 (1.1)	0.2 (1.2)	6.0(26.6)	2.1(22.8)	2.9(11.3)	5.4(22.1)
Opuntia spinosior			0.1 (0.4)		0.5 (1.9)	0.2 (0.8)
Prosopis glandulosa	1.3 (7.4)	6.3(36.2)			0.1 (0.4)	0.3 (1.2)
Simmondsia chinensis				1.8(19.6)	1.6 (6.2)	
Sphaeralcea laxa	0.3 (1.7)					0.2 (0.8)
Xanthocephalum sarothrae	5.3(30.1)	4.0(23.0)	0.2 (0.9)		2.4 (9.4)	0.2 (0.8)
Zizyphus obtusifolia	0.5 (2.8)	0.9 (5.2)				
OTHER (10 species)		1.6 (9.2)	1.0 (4.4)	0.1 (1.1)	2.8(10.8)	0.8 (3.2)
TOTALS	17.6(100)	17.4(100)	22.6(100)	9.2(100)	25.7(100)	24.5(100)

Table 3. Percentage grass species composition determined by pace transect at each site at Aravaipa Canyon, Arizona, 1982.

	Level slope		Moderate slope		Steep slope	
Grass species	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
Aristida arizonica	5.0		2.0	4.0	4.0	6.0
Bouteloua curtipendula	12.0	2.0	37.0	14.0	31.0	31.0
Bouteloua chondrosoides			5.0	8.0	4.0	7.0
Bouteloua eriopoda				9.0		1.0
Bouteloua hirsuta	22.0					
Bromus rubens	19.0	34.0	37.0	21.0	37.0	30.0
Digitaria californica			6.0		6.0	6.0
Festuca octoflora		11.0			5.0	1.0
Hilaria belangeri	37.0	49.0	7.0	35.0	3.0	3.0
Leptockloa dubia			6.0	1.0	8.0	5.0
Muhlenburgia porteri				1.0	1.0	4.0
OTHER (8 species)	6.0	4.0		6.0	1.0	4.0

Table 4. Bighorn sheep and cattle use by slope class at Aravaipa Canyon, Arizona, 1980–1983.

	Observed use			
	Bighorn sheep		Cattle	
Slope class (%)	N	% total	N	%total
Level (0–30)	221	14.7	2,723	89.3
Moderate (31–60)	125	8.3	326	10.7
Steep (<61)	1,155	77.0	1	>O. 1
TOTALS	1,501	100.0	3,049	100.0

Diets of Bighorn and Cattle

Shrubs and cacti dominated the bighorn fecal samples (Table 5). Forbs accounted for 27%, perennial grass 14%, and annual grass only 1% of the bighorn diet. The single most heavily used forage item was jojoba.

Cattle predominantly used perennial grasses (Table 5). The most prevalent item in the cattle diet was sideoats grama, followed closely by curly mesquite.

Percentage yearlong dietary overlap between bighorn and cattle averaged 35% for the 2 years with a seasonal range of 34 to 36% (Dodd, unpubl. data), indicating that their diets are quite dissimilar.

Table 5. Summary of diets for bighorn sheep and cattle, determined by microhistological analysis of fecal samples collected at Aravaipa Canyon, Arizona, 1981–1982.

	Diet composition (%)	
Forage class	Bighorn sheep	Cattle
Perennial grass	14.5	56.2
Annual grass	1.3	8.0
Forbs	27.0	13.7
Shrubs and cacti	57.2	22.1

DISCUSSION

Vegetation Differences

Changes in vegetation composition and cover attributable to grazing impacts by cattle on desert grassland ranges have been well documented (Brown 1950, Martin 1975, Smith and Schmutz 1975, Smeins et al. 1976). The most frequently reported changes associated with cattle grazing have been a reduction in perennial grass cover with a concomitant increase in the shrub component. The perennial grasses absent on grazed level slopes at Aravaipa were palatable species such as sideoats grama, hairy grama, and three-awns *(Aristida* spp.) The higher incidence of curly mesquite on grazed level and moderate slopes points to the ability of this stoloniferous grass to withstand moderate grazing pressure and increase as more palatable species decline. Similar responses of these grasses to grazing have been reported by Cable (1979), Martin (1975), Smeins et al. (1976) and Waldrip (1965).

No significant differences between grazed and ungrazed shrub and cacti cover were noted at any slope. Nor does the composition data reveal any clear pattern of shrub response to protection from grazing. This does not rule out the possibility that long term changes in shrub composition occurred prior to construction of the bighorn enclosure. Smeins et al. (1976) noted that once established, shrubs increased even on ungrazed ranges before reaching a point of stabilization.

Annual grass cover was signficantly lower on level slopes while relative percent composition was higher. Despite the lower cover, the relative dominance of annual grasses on grazed level sites increased, particularly in light of the reduced influence of perennials. Annual grass abundance is tied closely to seasonal precipitation, more so than perennials and shrubs (Martin 1975), and this may strongly influence their response to cattle grazing.

Forbs showed a significant difference between grazed and ungrazed level slopes, being the greatest contributor to vegetation cover on grazed transects. This possibly reflects a response to lowered grass cover which favors forb establishment. Forb cover on other desert grassland ranges, grazed or ungrazed, was negligible (Smith and Schmutz 1975, Smeins et al. 1976) while at Aravaipaforbs constituted 53% of the total vegetation cover on level grazed transects.

Bare ground was significantly more prevalent on grazed than ungrazed level slopes. The long term implications of decreased vegetation and litter cover are serious due to the increased potential for soil loss through erosion.

Habitat Use by Slope Class

The predominant use of level slopes, minimal use of moderate slopes, and avoidance of steep slopes by cattle at Aravaipa Canyon closely follows results of previous studies. Glendening (1944) and

Mueggler (1965) both found strong relationships between grazing by cattle and the combined influence of slope steepness and distance from base of slopes in mountainous terrain. Julander and Jeffery (1964) reported that cattle typically used slopes <10% steep. Cook's (1966) analysis using 21 variables accounted for only 55% of the variability in describing cattle use of slopes. At Aravaipa Canyon, slope steepness alone accounted for 81% ($r = -0.901$) of the variation in slope use by cattle. Slope length is of minor importance in influencing use of slopes by cattle at Aravaipa Canyon. Slopes here are typically associated with low buttes (<150 m) and lengths seldom exceed 400 m.

Desert bighorn are an animal closely associated with steep, rugged terrain of southwestern mountain ranges (Russo 1956, Leslie and Douglas 1980, Seegmiller and Ohmart 1981). Slope steepness at Aravaipa Canyon accounted for 71% ($r = 0.845$) of the variation in observed use of slopes by bighorn.

Significant correlations were found between cattle use of slopes and vegetation cover differences for perennial grass, forb, total vegetation, and bare ground categories (Table 6). This suggests a direct association between observed cattle use of slopes and the vegetation differences on such slopes.

Table 6. Correlations made between independent variables of cattle slope use and diet and vegetation cover differences with cattle grazing at Aravaipa Canyon, Arizona, 1982.

Correlation			*r*
Use by Slope	*vs.*	% Cover difference with grazing for:	
		Total vegetation cover	0.986**
		Perennial grass cover	0.988**
		Annual grass cover	0.649
		Forb cover	0.975**
		Shrub and cacti cover	−0.464
		Bare ground	0.997**
Diet	*vs.*	% Total absolute difference in plant cover with grazing	0.798
		% Total absolute difference in plant cover, excluding shrubs, with grazing	0.899**

***Significant at $P \leq 0.05$.

Diets of Bighorn and Cattle

Due to a combination of dissimilarity in diets and the distinct spatial segregation based on slope steepness, exploitative competition between bighorn and cattle appears to be low at Aravaipa Canyon. The relatively low (35%) dietary overlap was not enough evidence to rule out competition (Colwell and Futuyma 1971), especially in the absence of detailed forage availability data.

Several factors contribute to differences in forage selection by bighorn and cattle, including morphological parameters and nutritional basis of forage items in the area. Impacts on vegetation in the vicinity of the enclosure reflect foraging and dietary differences between cattle and bighorn. The correlation between total cattle diet and the percentage total absolute difference in corresponding plant cover with grazing was not significant. However, when the shrub category was deleted from the analysis (the only cover category not showing significant difference at level slope) the results explain 81% ($r = 0.899$) of the variation in observed vegetation differences (Table 6). Foraging by cattle at Aravaipa Canyon therefore, has a direct influence on vegetation composition and cover.

Management Implications

Intensified range management programs were recently initiated on both cattle grazing allotments within bighorn range at Aravaipa. The goal of the range improvement programs is to improve cattle distribution, ultimately resulting in improved range condition and trend. These programs strive to reduce cattle concentrations around permanent waters while increasing use of previously lightly used or unused range. Attempts to accomplish these changes will be made by fencing existing waters, creating additional waters, fencing new pastures, salting, and herding.

The plan for improving cattle distribution at Aravaipa involves increasing use of moderate slopes. Achieving increased use of these slopes seems feasible, particularly in light of reports by Glendening (1944) and Mueggler (1965). Both found that slope use by cattle was highly dependent on slope length and steepness. Considerable use of moderate slopes (30–50%) was noted where slope distances were relatively short (<400 m). Mueggler (1965) found that 50% of the accumulative cattle use occurred at the base of moderate (40%) slopes, 60% within 150 m of the base, 75% within 300 m and 85% within 400 m. Thus, for moderate slopes of relatively short length, 35% of the accumulated cattle use occurred above the base of the slopes and within 400 m. Similar slopes at Aravaipa currently receive cattle use of only 11%. The potential exists for increased cattle use of moderate slopes under intensified management.

Two factors must be considered in attempting to increase cattle use of moderate slopes at Aravaipa Canyon: differential vegetation impacts of cattle grazing and spacial segregation from bighorn sheep. Increased vegetation impacts could be expected on moderate slopes compared to level slopes receiving an equal increment of grazing pressure due to shallower and less productive soils. At moderate slope, a 34% difference was detected between grazed and ungrazed transects in palatable grass composition, even though moderate slopes received only 11% relative use by cattle. Increased cattle grazing on moderate slopes might therefore have a greater impact on these grasses than grazing on level slopes.

Factors influencing the high degree of spatial segregation between bighorn and cattle at Aravaipa are not fully understood. The inherent preferences of each species for a particular slope certainly play a major role. But other factors, such as behavioral avoidance of cattle by bighorn, may also play a part. Irvine (1969) and Wilson (1969) reported on spatial competition and avoidance of cattle by desert bighorn in Utah. Active avoidance behavior has not been documented at Aravaipa and the 2 species were frequently seen in close proximity. This does not rule out the possibility that spatial segregation based on slope and other factors act as a subtle form of cattle avoidance by bighorn. For this reason, heavy cattle use of moderate slopes and any use of steep slopes by cattle should be discouraged when implementing intensified management practices. A realistic and desirable increase of approximately 20% in cattle use of moderate slopes with intensified management would minimally impact bighorn while substantially reducing grazing damage to gentle slope vegetation.

The common practice of salting ridge and butte tops in an attempt to draw cattle upslope to moderate slopes should be avoided at Aravaipa. Upslope areas constitute preferred habitat of bighorn and spatial separation from cattle should be maintained. Cattle use of ridges and butte tops for grazing and resting sites currently occurs to low degree and increased use could adversely affect bighorn sheep. Salting at these sites might cause cattle to graze down through steep terrain to reach gentler slopes below, rather than feeding up onto moderate slopes from below, as described by Glendening (1944). Therefore, any improvements such as salting or water development aimed at increasing cattle use of moderate slopes would impact bighorn least if implemented on moderate slopes accessible to cattle from below.

Bighorn sheep and cattle exhibit the ability to coexist at Aravaipa Canyon. Measures to improve cattle distribution could potentially disrupt the spatial segregation of bighorn and cattle. Thus, a dilemma is presented in managing for a healthy bighorn population and im-

proved range condition. Through compromise between managing for improved cattle distribution and maintaining spatial segregation, the ability of bighorn sheep and cattle to coexist at Aravaipa Canyon need not change.

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ASPECTS OF THE ECOLOGY OF DESERT BIGHORN SHEEP IN CARRIZO CANYON, CALIFORNIA

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Abstract: Desert habitat use by peninsular bighorn sheep (Ovis *canadensis cremnobates*) in Carrizo Canyon, California was studied from December 1978 to September 1979. Bighorn diet was 57% shrubs, 32% forbs, 8% cacti, and 2% grasses. Ditaxis (*Argythamnia neomexicana*), globemallow (Sphaeralcea spp.), and jojoba (*Simmondsi chinensis*) dominated bighorn diets. Cattle diet was 61% shrubs, 15% grasses, 18% forbs, 4% cacti, and 0.2% sedges; curl-leaf ceanothus (*Ceanothus* greggii) received the heaviest use (30%). Bighorn sheep and cattle are not sympatric and use 2 different vegetation types. Potential for dietary competition exists, especially if cattle are reintroduced on bighorn range. Sheep preferred southwest and west-facing steep slopes (>100%) and were usually found in rocky desert scrub vegetation at elevations ranging from 305–610 m. Sheep preferred the Jacumba Mountains over the In-Ko-Pah Mountains when water was not limited. A minimum density of 1.5 sheep/km^2 was calculated. The intensively used area was approximately 52 km^2.

Peninsular bighorn sheep were once distributed over a wide area in southeastern San Diego County, California. A small remnant population is now confined to Carrizo Canyon. Information on peninsular bighorn sheep in Carrizo Canyon is limited. Summer surveys were conducted in the area from 1972 to 1975 by Jorgenson and Turner (1974). Russi and Monroe (1976) examined the population for parasites, and Olech (1978) studied bighorn behavior. Waterhole counts of bighorn from 1975 to 1978 indicated that the population of 80–100 animals was declining and that reproduction was low (L. L. Hicks, unpubl. rep., U.S. Bureau of Land Management, El Centro, Calif., 1978). Only 15 lambs were seen in 1975, and no lambs were observed in 1978. Data from waterhole counts prior to 1975 are lacking. Explanations proposed for the decline were: (1) a 20-year drought eliminated crucial water sources; (2) human intrusion (particularly, use of off-road vehicles [ORV's]); (3) poaching may have removed as many as 30 animals; and (4) competition with domestic livestock (U.S. Bureau of Land Management, unpubl. rep., Riverside, Calif., 1978).

We investigated the ecology of bighorn sheep in and around Carrizo Canyon to determine causes of population decline. Objectives were to determine the extent of dietary overlap between cattle and bighorn sheep, quantify the habitat type used by desert bighorn sheep, and provide estimates of population parameters, including age and sex ratios, natality, mortality, and population trends. We present the results of our study to provide a management plan for stabilizing the population and make recommendations for possible habitat expansion.

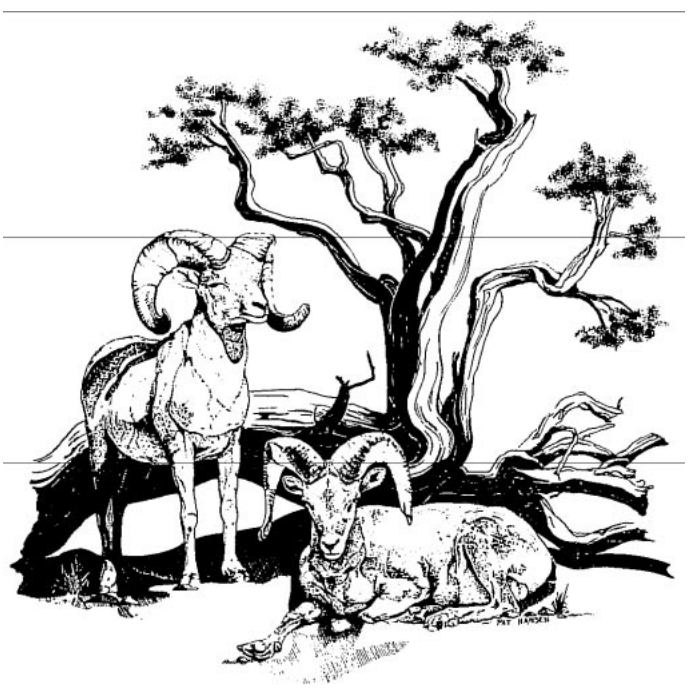
STUDY AREA

Carrizo Canyon is located in southeastern San Diego County, California, approximately 135 km east of San Diego. The canyon begins about 5 km north of the Mexican-American boundary and extends north for approximately 21 km, bisecting 2 mountain ranges. The In-Ko-Pah Mountains lie to the west and are managed by the Bureau of Land Management. The Jacumba Mountains, east of Carrizo Canyon, are under the jurisdiction of Anza-Borrego Desert State Park. The terrain is steep, with elevations ranging from 279 m at the mouth of Carrizo Canyon to 1,372 m at Jacumba Peak. Numerous rocky and sandy washes are found throughout the area. The In-Ko-Pah Mountains consist of undivided granitic rocks containing quartz-diorite and small amounts of granodiorite and granite. The Jacumba Mountains are composed of metasedimentary rocks consisting of slate, argillite, quartzite, schist, limestone, and dolomite (J. Aardahl, unpubl. rep., U.S. Bureau of Land Management, El Centro, Calif., 1973).

Precipitation averages slightly more than 10 cm/year; most occurs in early winter, with a few summer thunderstorms in late July and August. Temperatures range from below freezing in winter to more than 45°C in summer.

Four vegetation communities (U.S. Bureau of Land Management, unpubl. rep., El Centro, Calif., 1977) occur in the study area: desert wash, dominated by cheesebush (*Hymenoclea* spp.) and mesquite (Prosopis spp.), enriched rocky desert scrub, dominated by brittlebush (*Encelia farinosa*) and burrobush (Ambrosia *dumosa*), semi-desert chaparral, dominated by buckwheat (*Eriogonum fasciculatum*) and mountain mahogany (Cercocarpus spp.), and California chaparral, dominated by scrub oak (Quercus *dumosa*) and curl-leaf ceanothus. The latter is found only in the In-Ko-Pah Mountains and rarely occurs below 853 m. Enriched rocky desert scrub is the most common vegetation type in the study area and is found on both steep and gentle slopes at elevations ranging from 305 to 914 m.

Areas of human use completely surround the canyon. Anza-Borrego Desert State Park's Dos Cabezas Campground is on the east side of the Jacumba Mountains, adjacent to 2 springs. McCain Valley has a network of vehicle trails overlooking Carrizo Canyon, which are currently closed to all recreational vehicle traffic. One road leads into Carrizo Canyon and extends south for about 12 km. The San Diego and Arizona Eastern Railroad tracks run for approximately 20 km through the gorge.



METHODS AND MATERIALS

We spent 4 to 5 days/week in the study area between 5 December 1978 and 28 September 1979. A Bushnell 32X scope and 7X35 binoculars were used to observe bighorn sheep. Different geographical areas were visited each week. Three methods were used to search for bighorn, with seasonal use and time expenditure differing among methods. The first involved hiking predetermined cross-country routes in washes and on ridgelines, stopping often to scan surrounding terrain. This method was used predominantly during winter and after summer rainstorms to determine sheep dispersal and seasonal ranges. Second, the Carrizo Canyon jeep trail was searched for tracks and sheep 1–2 times/week. Third, sheep were counted from concealment at different waterholes from May to September 1979, allowing assessment of use and relative importance of each spring. Feces were removed and tracks obliterated to help determine amount of use between each observation period.

Relative habitat use was determined from direct observations. The following characteristics were recorded on each sighting: slope, aspect, elevation, terrain, vegetation type (dominant species), distance to permanent water, herd composition, time of use in area, distance from escape terrain (slope >80%), and distance from human influences. Degree of slope was measured with a Brunton compass. Elevations, distances, and aspects were determined from 7.5-minute topographic maps. Cattle on the McCain Valley allotment primarily grazed on the higher flats about 3-6 km from bighorn habitat.

Because of summer rains, bighorn sheep were difficult to find, so adequate sample size was a problem in computing sex ratios. Population size was estimated from a combination of direct counts of animals (both recognizable and unrecognizable individuals) and the amount of droppings and tracks over the 10-month period. Caughley (1977) stated that an informed guess by a reliable observer was acceptable and may in fact be superior to an objective estimator.

Age ratios of bighorn sheep were documented throughout the year. Age of rams was determined using criteria developed by Geist (197154) and Bleich (unpubl. data). We did not attempt to age ewes because of the inherent difficulties pointed out by Geist (1971:55).

Diets

Diets of bighorn sheep and cattle were quantified from microscopic analysis of fecal material (Free et al. 1970). We attempted to collect 20 bighorn and 10 cattle fecal samples monthly from September 1978 to August 1979. Bighorn pellets were usually collected shortly after defecation. When this was not possible, collections of reasonably fresh samples (within 2 to 3 days) were made in areas where sheep were recently observed grazing. Cattle fecal samples were collected in areas as near sheep habitat as possible (0-4 km).

Twenty random fields of view were read on each fecal slide preparation, yielding 400 readings/month. A valid field consisted of ≥2 identifiable plant fragments. Frequency of occurrence of fragments was converted to particle density/field (Fracker and Brischle 1944). The particle density of each plant species divided by the total number of particles of all species yielded percentage relative density for each monthly sample.

Index of overlap in diets of cattle and bighorn was calculated by summing percentage use in common (Y) for each plant species i during that year; where n equals the total number of forage species eaten (Anthony and Smith 1977). A value of 100 would indicate

$$\sum_{i=1}^{n} Y_i$$

that cattle and sheep used all the same plant species in the same proportions, and a value of 0 indicated that there was no forage species in common.

Vegetation Analysis

Randomly located point-intercept transects (Phillips 1959) were used in estimating relative frequency, density, and cover of perennial plant species. Seven 50-m lines (45 points) were used in each sampling stratum. Annuals were not recorded due to difficulty in identifying species during late summer. Plant sampling was selected on the basis of animal use. Sampling of bighorn habitat was made in the Jacumba Jim drainage where extensive bighorn and no cattle use occurred. Vegetation characteristics of cattle habitat were determined in flat areas in McCain Valley where no sheep sign was found.

RESULTS

Diet

Bighorn Sheep

Thirty-five plant species (17 shrubs, 10 forbs, 5 grasses, 1 cactus, 1 fern, and 1 unknown) were detected in fecal samples of bighorn sheep from the Carrizo Canyon area. Shrubs were the major component of the annual diet (57%), followed by forbs (32%) (Table 1). Grasses (3%) in diets were minimal, although grasses were preferred by sheep in other studies (McQuivey 1978, Browning and Monson 1980). This is probably due to the paucity of grasses on the range in our study area. Common ditaxis was the most heavily used species (18%), followed by globemallow (13%), jojoba (10%), desert lavender (*Hyptis emoryi*) (8%), cholla (*Opuntia* spp.) (7%), and wooly plaintain (Plantago insularis) (5%).

Shrubs dominated bighorn diets in all seasons except winter. Common ditaxis was used heavily through summer, autumn, and winter but received little use during spring. Ditaxis, jojoba, and globemallow made up 53% of the summer diet, and ditaxis, cholla, and mesquite composed 67% of the autumn diet. Major components (58%) of the winter diet were desert lavender, ditaxis, globemallow. and burrowbush. Wooly plantain and globemallow were eaten predominantly during spring.

Not only were preferences for different species noted, but also different parts of the plants were selected. Sheep preferred the inflorescences of burrobush and brittlebush but rarely ate other parts of the plants. Pawing for roots was frequently observed during summer. Sheep also climbed rocks to graze the uppermost leaves on ocotillo (*Fouquieria* splendens).

One bias of the fecal analysis was the lack of brittlebush in the fecal material. From observation, brittlebush was heavily grazed in winter and spring, however, in microscopic analysis it represented only 3% of the diet. In March, sheep were observed grazing on brittlebush flowers 68 times in sessions ranging from 5 to 72 seconds. At the first lambing area, few flowers remained on brittlebush plants and some were browsed to the point where all leaves had been taken. Yet, analysis of 20 pellet groups in March showed no trace of brittlebush in the pellets. Possibly the brittlebush flowers are almost totally digestible. Conversely, jojoba was recorded as comprising 20% of the summer diet, but few jojoba shrubs are located in the study area. These disparities between field and microscopic determinations underscore the importance of using both data sets from an area to determine herbivore food habits.

Cattle

Cattle used 38 plant species (20 shrubs, 13 forbs, 2 grasses, 2 sedges, and 1 cactus) (Table 1). Components of the total diet of cattle consisted of shrubs (61%), forbs (18%), grasses (15%), cacti (4%), and sedges (0.2%). Curl-leaf ceanothus was the most heavily used (30%), followed by brome grass (*Bromus rubens*) (14%), filaree (*Erodium* cicutarium) (9%), mountain mahogany (8%), globemallow (6%), and desert sunflower (*Viguiera* deltoidea) (5%). These 6 species comprised 72% of the diet.

Although shrubs dominated diets during all seasons, cattle also showed a seasonal preference for different species. Brome grass and California mistletoe (*Phoradendron californicum*) accounted for 27% of the summer diet. The major components of the autumn diet were curl-leaf ceanothus (35.6%) and desert sunflower (17.8%), and during winter, curl-leaf ceanothus (38.1%) and cholla (12%) made

Table 1. General plant types (%) found in fecal samples of bighorn sheep and cattle, Carrizo Canyon, California, December 1978–September 1979.

Season	Seasonal overlap	Plant type					
		Grasses	Forbs	Browse	Sedges	Ferns	Cacti
Summer	(May-Sep)						
Bighorn		2.06	22.93	66.08		0.31	7.49
	12.0						
Cattle		25.58	17.10	52.54			0.93
Autumn	(Oct-Nov)						
Bighorn		1.65	48.54	33.03		0.10	16.67
	18.2						
Cattle		8.83	26.03	61.88	0.05		3.08
Winter	(Dec-Feb)						
Bighorn		1.59	33.46	58.08		0.61	6.25
	16.8						
Cattle		4.79	13.04	69.37	0.64		11.95
Spring	(Mar-Apr)						
Bighorn		5.96	34.39	54.66		0.38	2.76
	18.2						
Cattle		12.51	19.13	67.98	0.05		0.21
Overall average							
Bighorn		2.52	31.74	56.66		0.36	7.92
	15.4						
Cattle		15.41	17.89	60.82	0.17		3.97

up 50% of the diet. Brome grass (22.7%), globemallow (11.8%), filaree (17.1%), curl-leaf ceanothus (30%), and mountain mahogany (11.7%) were the major components (83%) in the spring diet.

Bighorn-Cattle Overlap

Dietary overlap between cattle and bighorn during 1979 in the Carrizo Canyon area was low (15.4%). Seasonal overlap was highest in autumn and spring (18.2%) and lowest in summer (12%) (Table 1). Because cattle and sheep occupied 2 different vegetation types (Fig. 1), plant species heavily used by bighorn were rarely used by cattle. Bighorn were found in enriched rocky desert scrub, whereas cattle were primarily found in mixed chaparral. Differences in vegetation of the 2 habitats were quite obvious (Table 2). Range overlap between cattle and sheep rarely occurred in this study area, although there were no fences to impede animal movements.

Only during May and June 1979 was a small sample of cattle feces collected in bighorn range. The exact number of cattle on the range was unknown but sign indicated only 2 to 3. A minimal diet overlap of cattle and bighorns occured in May, when brittlebush was used to a degree by both species (11.8%). Sign indicated that cattle foraged primarily in the canyon bottoms, whereas sheep foraged predominantly on steep slopes.

Table 2. Vegetation characteristics of 2 sites used by bighorn and cattle, Carrizo Canyon, California, 1979.

Species	Relative frequency (%)	Relative density (%)	Relative cover (%)	Importance value
Site 1: Location: T16S R7E SE1/4 SEC. 14				
Bighorn - Rocky desert scrub				
Encelia farinosa	36.6	18.8	13.8	69.2
Ambrosia dumosa	24.3	18.6	6.9	49.8
Opuntia echinocarpa	18.3	6.1	10.3	34.7
Hyptis emoryi	4.3		20.7	25.0
Aristida spp.	2.1	16.0	3.4	21.5
Krameria grayii	2.1	2.8	13.8	18.7
Lotus scoparius	2.1	2.3	13.8	18.2
Echinocereus engelmannii	8.1	2.8	6.9	17.8
Trixis californica	2.1		10.3	12.4
Site 2: Location: T16S R6E NE1/4 SEC. 14				
Cattle - Mixed Chaparral				
Adenostoma fasciculatum	47.8	75.6	46.7	170.2
Ceanothus greggii	44.9	18.5	44.9	108.4
Quercus dumosa	2.9		5.9	8.7
Arctostaphylos pungens	1.5	2.5	2.5	6.4

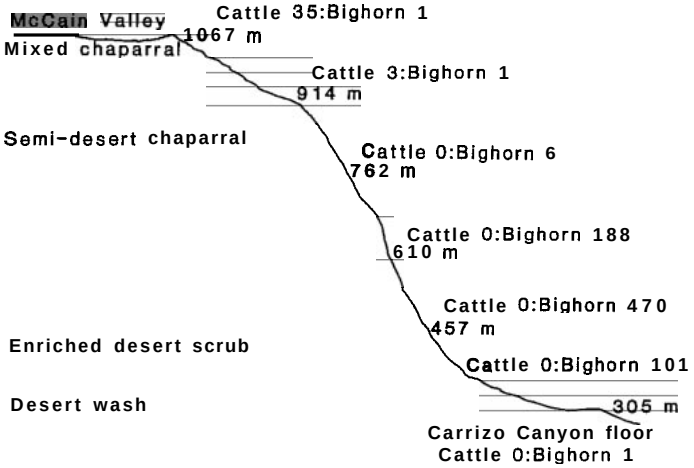


Figure 1. Distribution of cattle and desert bighorn sheep sightings by vegetation type and elevation, Carrizo Canyon, California, 1979. Numbers indicate individual animals observed during the study period.

Habitat Use

From 5 December 1978 to 6 September 1979, 126 bighorn groups (N=804 individuals) were sighted ($\bar{x}$=6.4 sheep/band/sighting). We estimated a population of 80 to 100 animals, similar to Hicks (1978). The ram:ewe:yearling:lamb ratio for bighorn in Carrizo Canyon was 29:100:1.59. Hicks (1978) estimated 40:100:0.6:1.3.

Includng winter and summer ranges, 52 km' of habitat were actively used by bighorn. The Jacumba Mountains were preferred by ewes and lambs but were not used heavily in the summer (Table 3). In contrast, bighorn use of the 4 active springs in the In-Ko-Pah Mountains and the surrounding area was far heavier in summer than in winter. Bighorn distribution was focused around springs in summer; sheep were rarely seen >2 km from water (Table 4) despite unusually high rainfall in 1979.

Bighorns were found predominantly on steep slopes (>100%), particularly in spring after lambing (Table 5). Directional aspect of slopes used varied among seasons. Sheep selected lower elevations in all seasons with summer low elevation use reflecting water availability, because this is where the springs are located. Reproduction and lamb rearing occurred on extremely steep slopes. Small caves and overhanging rocks were common and supplied ample thermal cover.

Table. 3 Number of bighorn sheep seen in and hours spent observing in the Jacumba and In-Ko-Pah Mountains, California, 1979.

	In-Ko-Pah Mountains			Jacumba Mountains		
	N bighorn	Nhours observed	Sheepl hour	N bighorn	Nhours observed	Sheepl hour
December	30	69	0.43	0	31	0.00
January	1	22	0.05	25	48	0.52
February	1	28	0.04	48	85	0.56
March	0	2	0.00	246	110	2.24
April	0	61	0.00	241	84	2.87
May 1-May 15	0	34	0.00	39	38	1.03
May 30	10	80	0.13	50	34	1.47
June	9	56	0.16	0	16	0.00
July	28	107	0.26	15	13	1.15
August	18	56	0.32	15	44	0.34
September	17	16	1.06	2	4	0.50

Table 4. Comparisons of distances (km) sheep were found from known water in winter and summer, Carrizo Canyon, California, 1979. Numbers in parentheses indicate percentage of bighorn sheep seen at designated distances.

Distances from known wnter	Winter			Summer		
	N bighorn	Hoursof observation	Sheep/ hour	N bighorn	Hoursof observution	Sheep/ hour
0-0.25	0	89	0.00	19	193	0.09
0.25-0.5	0	111	0.00	31	207	0.15
0.5-1.0	0	162	0.00	15	217	0.07
1.0-1.5	10 (1.5)	139	0.07	60	183	0.33
1.5-2.0	129 (20.4)	130	1.02	0	109	0.00
2.0-2.5	240 (37.9)	114	2.1	13	106	0.12
>2.5	254 (40.2)	289	0.87	12	118	0.10

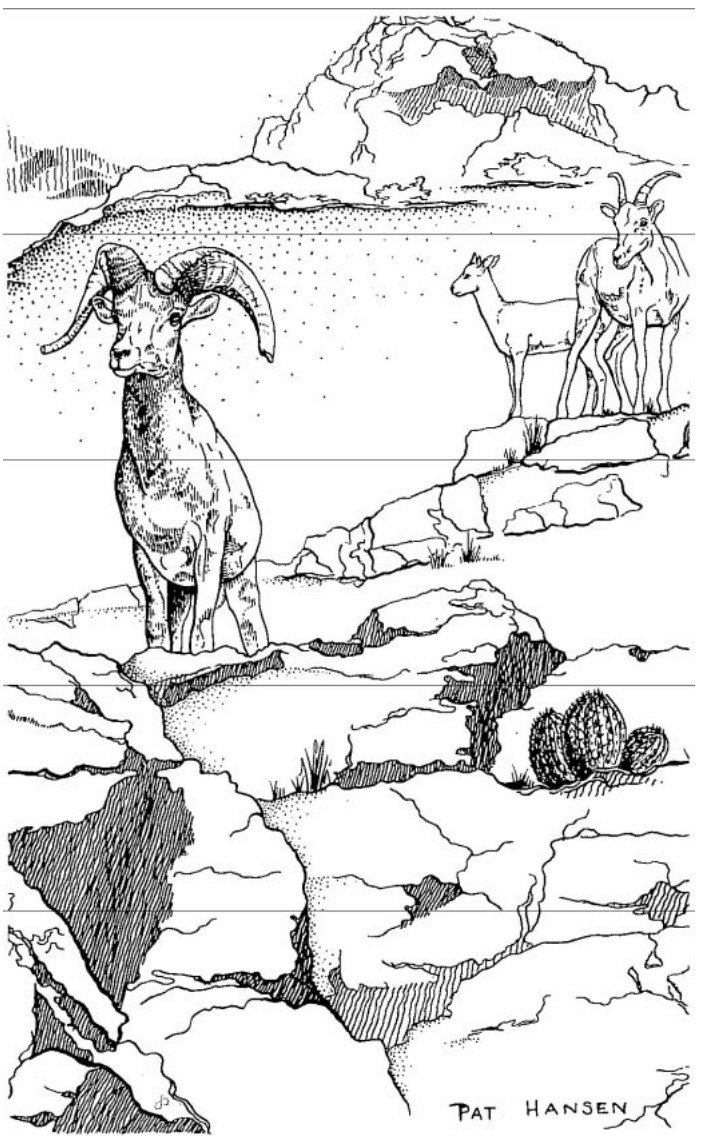


Table 5. Summary of topographic information as obtained from sightings of bighorn in Carrizo Canyon, California, 1979. N = number of bighorn sheep. Numbers in parentheses are percentages of bighorns seen in designated habitat during the different seasons.

	Winter		Spring		Summer		Total	
	N	(%)	*N*	(%)	*N*	(%)	*N*	(%)
Slope								
0–40%	7	(6.8)	4	(0.8)	17	(9.0)	28	(4.0)
40–80%	36	(35.3)			34	(18.1)	70	(9.0)
80–100%	16	(15.6)	35	(7.2)	4	(2.1)	55	(7.0)
>100%	43	(42.2)	446	(91.9)	133	(70.7)	622	(80.0)
Aspect								
East	46	(41.8)	1	(0.2)	7	(4.1)	54	(7.0)
Southeast					3	(1.8)	3	(0.3)
Southwest	11	(10.0)	312	(64.2)	11	(6.4)	333	(43.5)
Northeast	1	(0.9)					1	(0.1)
Northwest					19	(11.1)	19	(2.5)
North	12	(10.9)	3	(0.6)	27	(15.7)	42	(5.5)
South	4	(3.6)	131	(26.9)	14	(8.2)	149	(19.5)
West	36	(32.7)	39	(8.0)	90	(52.6)	165	(21.5)
Elevation (m)								
<305	1	(0.9)					1	(0.1)
305–458	63	(60.0)	5	(1.0)	33	(17.7)	101	(13.1)
459–610	40	(38.1)	305	(64.1)	125	(67.2)	470	(61.3)
611–763			166	(34.8)	22	(11.8)	188	(24.5)
764–915	1	(0.9)			5	(2.7)	6	(0.7)
916–1,068					1	(0.5)	1	(0.1)
>1,068								
Habitat type								
1-soil or rocky covered	3	(2.8)	1	(0.2)	3	(1.6)	7	(8.0)
2-flat canyon wash	5	(4.8)	3	(0.6)	14	(7.5)	22	(2.8)
3-cliff	2	(1.9)			1	(0.5)	3	(0.4)
4-rocky slope	49	(47.1)	103	(21.1)	122	(65.2)	274	(35.0)
5-soil covered slope					12	(6.4)	12	(1.5)
6-talus slope					1	(0.5)	1	(0.1)
7-ridge top	45	(43.3)	380	(78.0)	35	(18.7)	460	(59.0)

DISCUSSION

Bighorn-Cattle Dietary Overlap

The 5 plant species that made up 63% of the bighorn diet were only 13% of the cattle diet (Fig. 2). These diet differences and minimal range overlap indicated that forage competition between the 2 species was low. However, competition could become important if cattle were reintroduced into bighorn use areas. Twenty-seven (77%) of the plant genera used by bighorns were also used by cattle. Reintroduction of cattle into bighorn range could increase forage competition, particularly in the areas near important bighorn waterholes. Also, dietary overlap could become severe in dry years when availability of annuals is low. Up to 1,000 cattle/year grazed in Carrizo Canyon (in sheep habitat) until World War II. The effect of this grazing is unknown since records were not kept and "relict areas" were not found.

Human activities in the Jacumba Mountains and McCain Valley have led to a decline in available bighorn habitat (Hicks 1978, Olech 1978, Cunningham 1981). Also, a decrease in precipitation over the past few decades has led to a decline in the number of springs. Many springs have dried up in the last 20 years (Dick McCain, pers. comm.). Several palm groves and mesquite thickets, which are usually associated with springs, occur in the absence of surface water. The loss of waterholes could be creating (or has already created) a serious problem for the Carrizo Canyon bighorn herd.

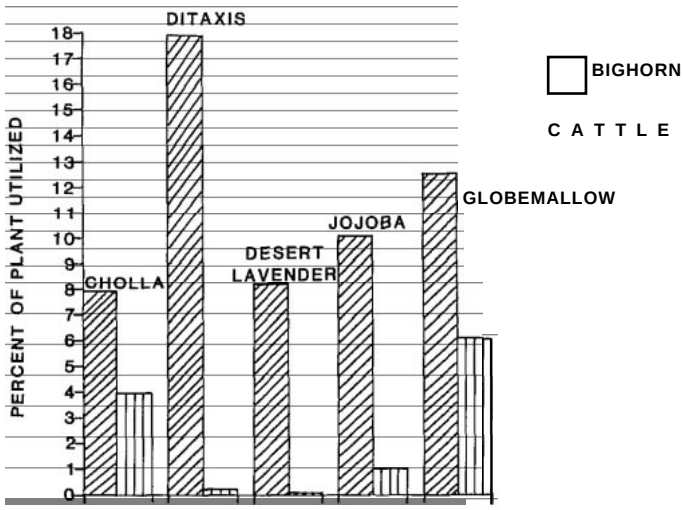


Figure 2. Comparison of cattle and desert bighorn sheep use of 5 plant species in Carrizo Canyon, California, 1979.

Similar to other bighorn populations in the southwest (Blong and Pollard 1968, Leslie and Douglas 1979), bighorn in Carrizo Canyon are restricted to within a 2-km radius of springs during summer (Table 4). Considering the location of springs and an assumed restriction on travel, the largest possible summer range in Carrizo Canyon is 32 km^2. Using the lower population estimate of 80 sheep, density is $2.5/km^2$ during summer. If the Jacumba Mountains' springs were still used, the possible summer range would be doubled to $60.1/km^2$. Cattle and human use, or springs drying up, are believed responsible for sheep ceasing to use Sombrero Peak, Palm, Macho, Grapevine, Rockhouse, Longwalk, and Redondo springs. If sheep still used these springs, the total possible summer range would be 104 km^2 (Fig. 3).

Hansen (1971) hypothesized that loss of habitat because of the loss of springs and their summer habitat could cause overcrowding and result in a decline in bighorn numbers. His major concerns were stress, inbreeding, and disease transmission. We believe that loss of springs could also result in overgrazing at remaining springs because of increased density of bighorns. If springs are lost, habitat and forage surrounding the springs are also lost. This places more pressure on forage near remaining springs in summer, when forage quantity and quality are lowest. This effect could be further compounded because summer is the time when sheep are attempting to breed.

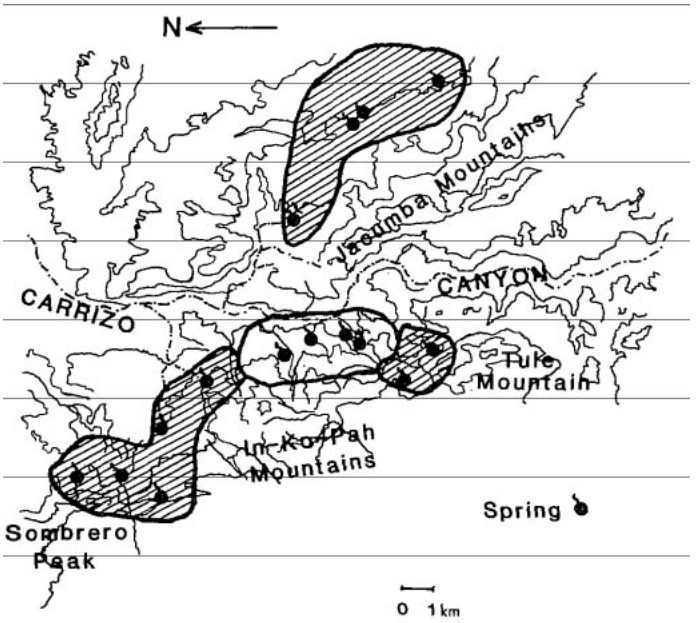


Figure 3. Distribution of springs in Carrizo Canyon, California, 1979. Open outlined area indicates current bighorn sheep summer distribution. Shaded outlined areas indicate possible summer distribution if springs in this area were used.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This study provides data on the dietary intake of bighorn in Carrizo Canyon. However, adequate data on the quality and quantity of available forage are lacking. Common ditaxis was the most preferred plant by bighorn, yet it and other preferred species were heavily grazed throughout the range. Desert bighorn sheep consume a wide variety of plant species, seeming to adapt to the available vegetation. Demming (1962) theorized that bighorn sheep may be a relict species that is trying to adapt to changes in vegetation because of a 100-year drought. Little qualitative and no quantitative literature exist on the effects of range condition on desert bighorns. In this paper, we have implicated the importance of preserving forage conditions around the remaining springs during summer. We simply do not know what the effects of reintroducing cattle on the bighorn range will be in these areas, however, the effects of cattle are well documented (see McQuivey 1978 for review). Although Dodd (pers. comm.) found that 2 sympatric populations of bighorns and cattle often used different microhabitat sites for grazing (steep versus gentle slopes) in Aravaipa Canyon, Arizona, limited water sources (springs) were not a problem there. Therefore, we believe that desert bighorn researchers and managers should be more concerned with range conditions. Stelfox (1976) provides a good outline of procedures to be used, and these can be modified for a desert environment.

One of the management recommendations of the McCain Valley Wildlife Habitat Mangement Plan was to re-establish bighorns on their former range, not through transplants but by dispersal of resident bighorn. This may be difficult because bighorn rarely disperse to other suitable habitats (Geist 1967). However, through redevelopment of dried springs and development of new water sources re-establishment of bighorns may be possible.

Horizontal wells as described by Coombes and Bleich (1979) and Blich et al. (1982) have been successfully used in the Santa Rosa Mountains. Numerous palm groves and mesquite thickets were found where there was no surface water. It is possible that these areas were once springs. Horizontal wells might produce water at these areas and provide bighorn with more watering sites which would disperse bighorn over larger foraging areas. Also, alleviation of current human use in the Jacumba and In-Koh-Pah mountains would be beneficial to bighorn sheep.

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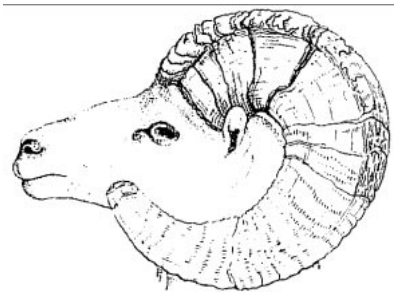

STATUS OF BIGHORN SHEEP IN ARIZONA, 1986

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SURVEYS AND HARVEST

Bighorn surveys are conducted during the fall from helicopters and limited ground observation. In 1985 2,065 bighorn were classified: 604 rams, 1,003 ewes, 292 lambs, 129 yearlings and 37 unclassified animals. Yearlings were not separated out in all surveys and the number in the sample may not be representative of the actual population structure. These data provide rams:ewes:lambs ratios of 60:100:29.

A conservative bighorn sheep harvest program was maintained but the definition of a legal ram was changed to "any ram" from "mature ram". The curl and horn length criteria previously used to define a legal ram were eliminated. The decision to make this change was based on the results of an analysis of data for 3 game management units that were open to any ram hunting from 1982 through 1984. No significant change in average age or score of harvested rams was observed over the 3-year period. Data from the 1985 any ram hunts have not been evaluated completely; preliminary analyses indicate a statewide average green Boone and Crockett score of 156% (range= 117–177%) and an average age of 7.6 years (range = 3–12 years).

Bighorn sheep were hunted in 22 hunt areas. Permit numbers in each area ranged from 1 to 8. Of 2,451 first choice applications submitted, 54 bighorn sheep hunt permits were allocated ($\bar{x} = 45.4$ applicantslpermit). All permit holders participated in the hunts, harvesting 52 rams (93% hunt success).

Two special hunting permits were authorized in 1985 in addition to the 54 traditional permits. Both were offered to the Arizona Desert Bighorn Sheep Society to generate revenue for bighorn management in Arizona. One permit was offered in a raffle and 1 was auctioned. The money generated by these 2 permits was $103,864. Both hunters holding the special permits harvested rams.

No major changes are anticipated for the 1986 bighorn sheep hunts. A single permit is being recommended for Game Management Unit 22 in central Arizona. The bighorn sheep in this unit are from transplants in the vicinity of Apache Lake during 1980 and 1981. The herd has grown to an estimated 80-100 animals and includes several mature rams.

TRANSPLANTING PROGRAMS

A very active and successful bighorn transplant program continued through 1985. Three reintroductions and 2 supplemental transplants were accomplished during 1985. Two types of sheep capture techniques were used in Arizona, with equal success. During the summer in northwestern Arizona, bighorn concentrate around the shores of Lakes Mead and Mohave. Sheep can be further concentrated using an apple pomace bait and captured using a drop net (Wilson et al. 1982). In southwestern Arizona, baiting has met with limited success, therefore bighorn are captured using helicopters, capture rifles and tranquilizing drugs as described by deVos and Remington (1981).

In mid-July, 1985, 41 bighorn were captured at 3 different locations along the south shore of Lake Mead. Two rams were released at the capture site after being marked with visibility collars and/or ear tags. Thirty sheep were transported across Lake Mead by boat, transferred to trailers and delivered to 2 release sites in northern Arizona southwest of Lake Powell. Twenty-four of the sheep were released in Hack's Canyon as a new reintroduction. Fifteen sheep were released in Paria Canyon as a supplement to a release accomplished in 1984.

No mortalities occurred during the capture and release operations. Mortality has been noted in these releases over the past 2 years. Three of the 4 mortalities appeared to be the result of falls from ice covered ledges. The cause of the fourth mortality has not been determined. Since 1982, 149 sheep have been captured using the drop net. Only one ewe has died as a direct result of capture.

During 1985, 52 bighorn were also captured in the west Kofa and Castle Dome Mountains using helicopters and tranquilizer guns. Twenty sheep were released into the Mazatzal Mountains in central Arizona, 21 were released in the Black Mountains of west-central Arizona, and 8 were used to supplement an existing herd in the Buckskin Mountains in western Arizona. Three sheep died during capture and one radio-collared ewe died 3 weeks after capture on Lion Mountain.

The Lion Mountain and Black Mountain release required specialized transportation equipment because both of the release sites were inaccessible by ground vehicles. The Lion Mountain release site was located 2 km inside the Mazatzal Wilderness Area. To minimize handling and reduce stress on the sheep, 8 individual flight boxes were built and designed to be placed on a flatbed trailer. Each box was large enough to contain 4-5 animals and outfitted with cables so that the entire box could be carried by sling into the release site by a helicopter. Once all of the flight boxes had been flown into the release location, all of the animals were free-released simultaneously. Using this technique, it was only necessary to physically handle the sheep during the initial capture.

The success of the 3 November transplants has varied. The Buckskin Mountain transplant appears successful, with all 8 sheep remaining within 5 km of the release site. The Black Mountain transplant has failed. Mountain lion predation began soon after the release and has accounted for all 4 of the known mortalities. Because of this predation, all of the radio-collared sheep may have dispersed from the release site into adjacent mountain ranges. Bighorn have moved as far as 145 km west-northwest of the release site. Monitoring has been difficult because of the large distances involved, and dispersal has occurred in several directions.

At least 4 of the original 20 bighorn sheep released on Lion Mountain have moved from the release site. Two known mortalities have occurred. The first was probably a result of internal injuries sustained by the animal during capture. The second mortality was a lion kill that occurred a month after the release. The balance of the Lion Mountain herd appears to be staying in the vicinity of the release site although only 3 working radio collars remain on sheep on the mountain.

Thirteen transplanted bighorn herds, not including supplemental transplants, are being monitored in Arizona. To standardize data collection and consolidate the existing monitoring data, a transplant biologist position was created by the Arizona Game and Fish Department in 1986. This position was designed as a contract and funded by monies donated by the Arizona Desert Bighorn Sheep Society.

In 1986 transplanting activities should remain constant. Efforts are being directed at supplementing existing transplants. All of the transplants proposed for 1986 will be designed to-augment existing herds.

RESEARCH

Since 1982 the Arizona Game and Fish Department's Research Branch has evaluated movements, reproduction, and mortality in 3 transplanted desert bighorn sheep herds. More specifically, these parameters were compared for free releases vs. releases where animals are kept in an enclsoure for a period of time prior to release. The results of this study, which was completed in 1985, do not indicate any discernable difference in relative success between these 2 types of releases (Shaw 1985).

During 1985 a management study to determine the effectiveness of fall helicopter surveys was performed on the Kofa National Wildlife Refuge. This study, conducted jointly by the Arizona Game and Fish Department and the U.S. Fish and Wildlife Service, consisted of a cellular double count made with 2 Bell Jet Ranger helicopters. Upon completion of data analysis, accurate observation rates for bighorn ranges, giving more accurate population estimates, may be available (R. R. Remington, pers. comm.).

PLANNING

Opportunities exist in Arizona to continue to expand bighorn distribution through transplants and habitat improvements. The 1986–1990 Draft Big Game Strategic Plans (Ariz. Game and Fish Dep., Phoenix, 1985) are in the final review stages at present. The draft bighorn sheep plan identifies a number of opportunities and actions designed to improve bighorn sheep habitat, provide additional recreation for both hunters and nonconsumptive users, and continue to expand the bighorn sheep's range in Arizona.

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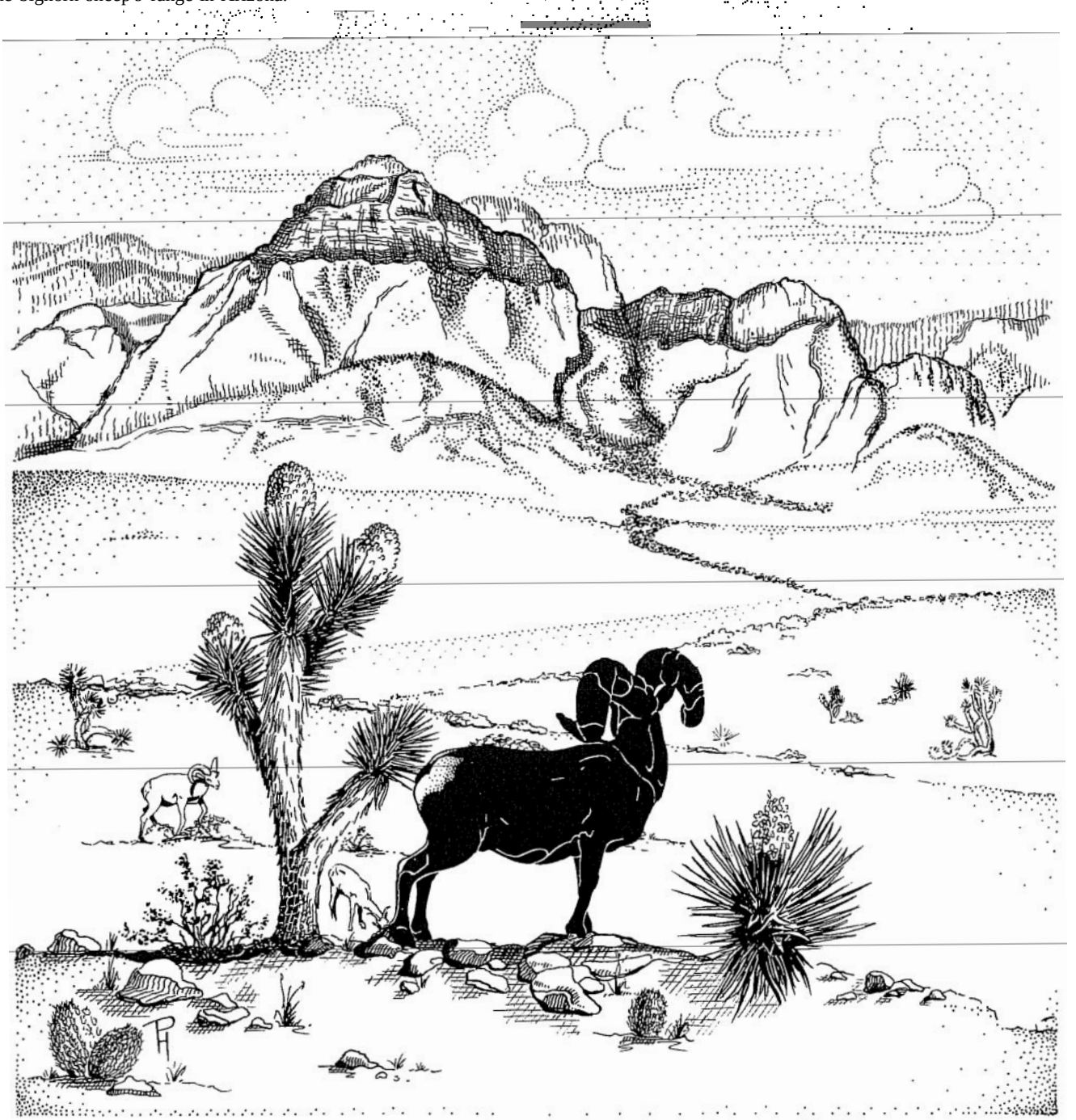

STATUS OF BIGHORN SHEEP IN COLORADO, 1985

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Nevada transplanted 21 desert bighorn sheep to Colorado in July and August, 1985. Seventy-seven desert bighorn sheep have been successfully transported to Colorado since 1979. Two populations have been established in western Colorado. Thirty-six sheep were released into Colorado National Monument and adjacent Devil's Canyon in November 1979, January 1980 and November 1981. The second population was established in Dominguez Canyon on the east side of the Uncompahgre Plateau, west of Delta, Colorado. Forty-one sheep were released on 4 dates: August 1983, July 1984, July and August 1985 (Table 1).

The Dominguez population includes about 50 sheep (Table 1). During the spring 1985, 18 sheep were classified: 4 males, 8 females and 6 lambs. This herd has been monitored by southwest regional personnel of the Colorado Division of Wildlife (CDOW).

Table 1. Desert bighorn sheep transplants in western Colorado, 1979–1985.

Date	State of origin	Colorado release site	N sheep
9 Nov 1979	Arizona	Devil's Canyon	11
19 Jan 1980	Nevada	Colorado Nat'l Mon.	16
19 Nov 1981	Arizona	Devil's Canyon	9
2 Aug 1983	Arizona	Big Dominguez	10
16 Jul 1984	Arizona	Big Dominguez	10
24 Jul 1985	Nevada	Dry Fork, Big Dominguez	13
2 Aug 1985	Nevada	Dry Fork, Big Dominguez	8

The Devil's Canyon population was estimated at 60 in November, 1985. Natality rates of 71 and 75% in 1982 and 1983, respectively, and a 70% survival rate for lambs to 1 year of age were reported. Adult mortality rates of 8 and 10% were observed in 1982 and 1983, respectively (Creeden 1986).

Management objectives are to increase both populations of sheep to 10 and prepare management plans in cooperation with the Bureau of Land Management (BLM) and the National Park Service (NPS). The plans will attempt to assess the impact of desert bighorn on the habitats they're using, determine if they present conflicts to other uses of the public lands, and establish herd objectives. In addition to limited hunting, CDOW may use both populations as donors for other transplant operations.

CDOW has an approved release site on the Dolores River between Slick Rock and Dove Creek (U.S. Bureau Land Management, unpubl. rep., Durango, Colo., 1985). Also, the Uncompahgre Resource Management Plan calls for introduction of desert sheep in Roubidoeu Canyon which is south of Dominguez Canyon. Figure 1 shows the established populations and the 2 areas proposed for future releases.

CDOW will continue to monitor radio-collared animals to determine the overall distribution of the transplanted populations. There are 5 active collars on sheep in the Devil's Canyon population of the 25 put on sheep during the 3 releases. The CDOW and BLM plan to capture and radio-collar 10 additional sheep in 1986. In conjunction with the BLM, the CDOW is considering developing water sources to encourage expansion of sheep into available habitat.

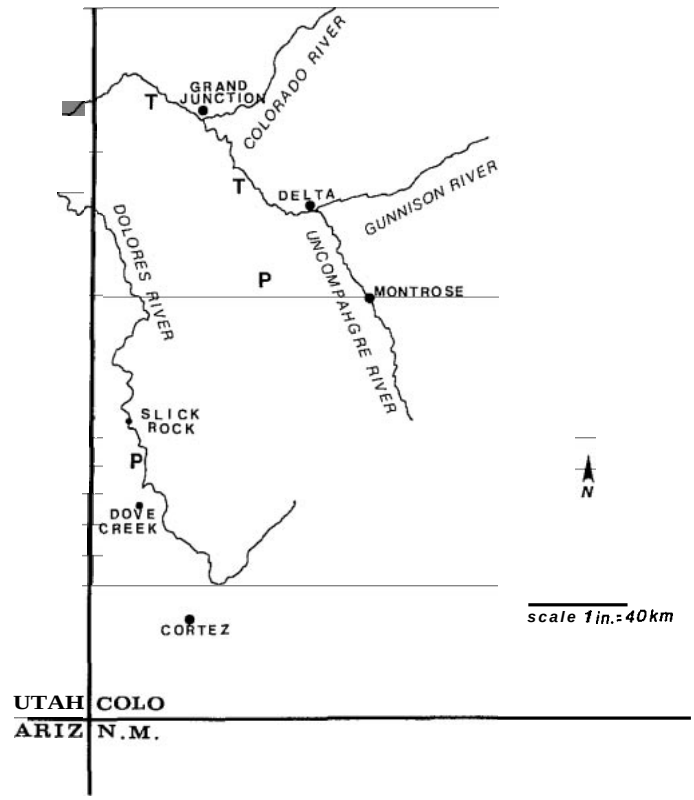

Figure 1. Locations of transplanted (T) desert bighorn sheep populations and proposed release sites (P) in Western Colorado.

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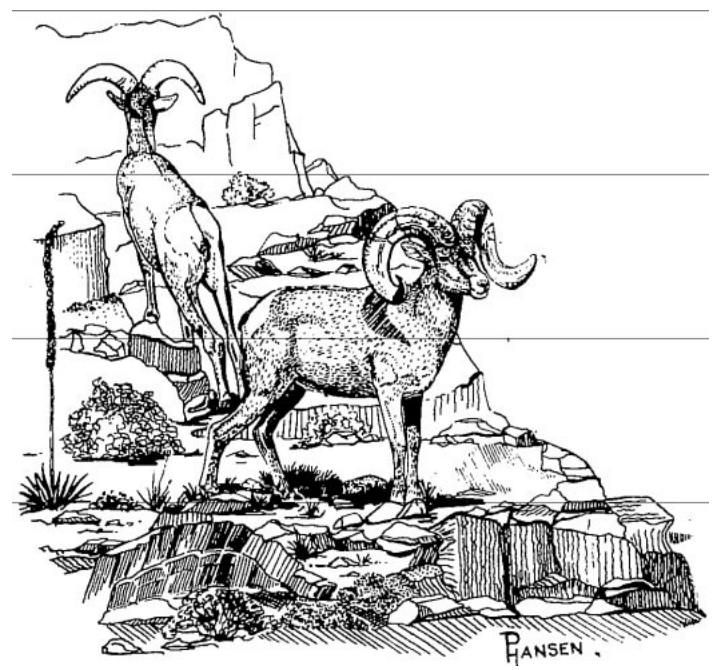

FERAL BURRO REPORT, 1986

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Management of feral burros (Equus *asinus*) by the U.S. Bureau of Land Management (BLM), National Park Service (NF'S), and the U.S. Navy is reviewed.

NEW MEXICO

Bandelier National Monument has been free of feral burros since 1984. The New Mexico Game and Fish Department reports that the State is now free of feral burros.

NEVADA

There has been no change in the status of feral burros in Nevada since 1985. Round-ups of feral burros and feral horses (E. *caballus* did occur during 1985; none of the round-ups, or feral burro or horse bands, occurred in areas inhabited by bighorn sheep (Ovis *canadensis*).

ARIZONA

The BLM captured 841 feral burros in 1985. The goal for 1986 is to remove 550 burros from the western half of the state; approximately 100 have been caught to date. Burros continue to be removed from the Black Mountains.

Overall the state-wide population is estimated, via various census techniques, at 2,600 feral burros; management goals are for a state-wide population of ≤1,500 burros. The BLM does not expect any budget cuts in their 1987 wild horse and burro program. The BLM plans to reach their management levels by the end of 1987; additionally, 6 of the 8 herd management plans have been completed.

CALIFORNIA

The BLM plans on removing ≥250 feral burros from their lands adjoining Death Valley National Monument in 1986; 90 burros have been caught to date. These captures are being concentrated in the Saline and Panamint Valleys. The BLM hopes to remove ≥250 feral burros in 1987 from various areas in the Mohave Desert. Other plans include a feral burro census of the California Desert Conservation Area (CDCA) during summer, 1986. The census should create a solid base of data on the remaining numbers and distributions of feral burros within the CDCA. The BLM does not expect to receive any budget cuts in their wild horse and burro program in the upcoming fiscal year.

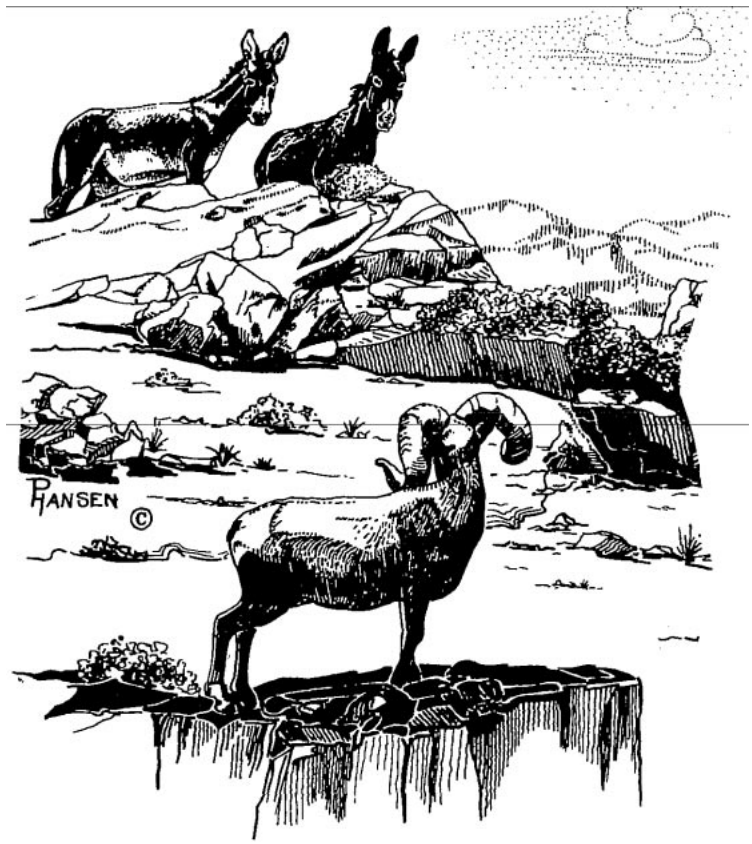
Death Valley National Monument is in the final year of their planned 3-year live capture effort. Four mules, 1,391 feral burros, and 88 feral horses have been captured in 1986. In 3 years 5,685 feral burros have been removed from the monument. A helicopter census in March 1986 in the monument counted 229 feral burros; the goals of the last capture effort, scheduled for April 1986, are to capture ≥115 burros. The next phase of the live capture effort will allow any humane group to capture any burro it can (with certain restrictions). The NPS will not provide any funding for these efforts.

The small band (approximately 15 head) of feral burros occupying Joshua Tree National Monument remains despite trapping efforts by the NFS. This is the same band of feral burros wearing BLM brands that was reported to the Council in 1984. Local NFS resource managers have not been allowed to implement direct reduction efforts.

The Navy is continuing low level (i.e., maintenance), live capture efforts following the large scale removal efforts which ended in 1984. During 1985, 80 feral burros were removed; another 195 were removed in 1986. The majority of these captures have occurred in the vicinity of the Eagle Crag Mountains and near Death Valley National Monument.

An increasng feral burro population has been reported on the Army's Fort Irwin Desert Training Center (south of Death Valley National Monument). The Army has no plans to remove these animals.

The California Department of Fish and Game reported an increasing feral burro population in the Whipple Mountains. Bighorn sheep were consistently observed in the Whipple Wash area in 1985; however, use of this area by feral burros has increased substantially in 1986. A concomitant decrease in bighorn sheep use has also taken place.



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