4/27/78

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DEPARTMENT OF ZOOLOGY

27 April 1978

Mr. Milton Frei
Bureau of Land Management
Building 50
Denver Federal Center
Denver, CO 80225

re: Contract No. 52500-CT4-270

Dear Mr. Frei:

Enclosed please find the original copy of the final report for feral burros.

The additional 24 copies are being sent in a separate box via third class parcel post.

If we can be of further assistance, please do not hesitate to call.

Sincerely yours,

Robert D Ohmart

Robert D. Ohmart, Ph.D.
Associate Professor of Zoology

pd

Enclosure

P. S. Other materials requested by BLM will follow.

THE PEREGRINATIONS AND BEHAVIOR OF FERAL BURROS (*EQUUS ASINUS*) WHICH AFFECT THEIR DISTRIBUTION AREA AND POPULATION SIZE IN THE HAVASU RESOURCE AREA, COLORADO RIVER VALLEY, CALIFORNIA - ARIZONA

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SELECTED ECOLOGICAL RELATIONSHIPS OF FERAL BURROS, DESERT BIGHORN SHEEP, DOMESTIC CATTLE, AND DESERT MULE DEER IN THE BLACK MOUNTAINS, ARIZONA

ABSTRACT

The primary objective of this study was to examine selected ecological relationships between feral burros (Equus asinus) and desert bighorn sheep (Ovis canadensis nelsoni) in the Black Mountains, Arizona; concomitantly data were gathered on cattle (Bos bos) and desert mule deer (Odocoileus hemionus). A total of 15 months were spent collecting field data between June 1976 through September 1977. A population estimate of 450 burros was derived by use of the Lincoln Index, while direct counts of bighorn sheep from helicopter flights indicated approximately 35 sheep in the study area.

Seasonal distributions of burros always exceeded those of sheep. Sheep and burro distributions during the cooler months (October through May) exceeded those during the warmer months (June through September). Burros, sheep and deer moved farther from permanent water during the cooler months than during the warmer months.

Burros predominantly used foothills during all seasons except winter (December through February 1977), whereas sheep predominantly used butte slopes during all seasons except summer (June through August 1976). In areas of sympatry, greatest overlap in habitat use occurred during the winter months (December through February 1977) and spring (March through May 1977) on butte slopes. Division of the study area into specific habitat types revealed that burros used low, gentle terrain (below 2,200 feet elevation and less than 40 percent slope), while sheep used high, steep terrain (above 2,200 feet and greater than 40 percent slope). Deer were observed using washes most often (48 percent) during the summer months and mesa tops most often (64 percent) during the winter months. Temperature, amount of precipitation and habitats proximal to permanent water sources were factors which strongly influenced seasonal habitat use by all four species.

Of the 59 plant species utilized by burros, 45 (76 percent) were also used by sheep, 37 (63 percent) by cattle, and 14 (24 percent) by deer. Woolly plantain (Plantago insularis), globe mallow (Sphaeralcea sp.), California buckwheat (Eriogonum fasciculatum), and red brome (Bromus rubens) were the plant species most commonly taken among the four vertebrate species. Burro diets were found to consist of 14 percent grasses, 47 percent forbs, and 37 percent browse; sheep diets consisted of 8 percent grasses, 43 percent forbs, and 49 percent browse; cattle diets consisted of 10 percent grasses, 53 percent forbs, and 37 percent browse; while deer diets consisted of zero

percent grasses, 2 percent forbs, and 96 percent browse.

Burro-bighorn-cattle-deer aggression at permanent watering sites was not observed during the period of study. Simultaneous water hole visits by burro and bighorn and burro and deer were observed, but no indications of inter-specific aggression were observed.

Of the five permanent water sources studied, only in one instance was water fouling observed. Burros were apparently responsible for this since no other animal species was observed using this water source to any degree before, during or after fouling was observed. The water source remained foul for two to four weeks and water quality improved as spring flow increased.

Percent of saturation of dissolved oxygen was the parameter measured monthly to indicate differences of water quality at three permanent water sources. Two of these water sources showed a decrease in water quality from May 1977 to August 1977. The major factor involved in lowered monthly water qualities was the rate of water flow at the spring heads.

These data indicate substantial ecological overlap between burros and sheep, moderate dietary overlap between cattle and burros and low dietary overlap between burros and deer. Reliable forage production data and burro utilization data are needed to determine burro carrying capacity for areas where sheep and burro distributions overlap. Carrying capacities combined with ecological overlap information in this study would give the Bureau of Land Management the information necessary to intelligently manage large mammal populations

found within the Black Mountains, Arizona.

INTRODUCTION

The feral burro (Equus asinus), a native of northeastern Africa, was first domesticated by early Egyptians sometime before 3500 B.C. It was introduced into North America in the 1530's by the Spanish and become widespread in southwestern United States sometime during the latter half of the 19th century. Escapes from prospectors and mining operations supplemented the feral population, and later many were set free when mines were abandoned. Burros were well adapted to the arid environment of the Southwest and established reproducing herds. By 1957 it was estimated that there were from 5,500 to 13,000 burros in the Southwest (McKnight 1958). The major concentrations were along or near the Colorado River in California, Nevada and Arizona.

The effect of feral burros on native habitat and wildlife has long been a source of controversy. Many people believe feral burros are disrupting the balance of the desert ecosystem and recommend stringent controls or extirpation, whereas others consider burros to be of significant aesthetic value and favor their preservation. This controversy has often been specifically concerned with the competitive relationships of feral burros and bighorn sheep.

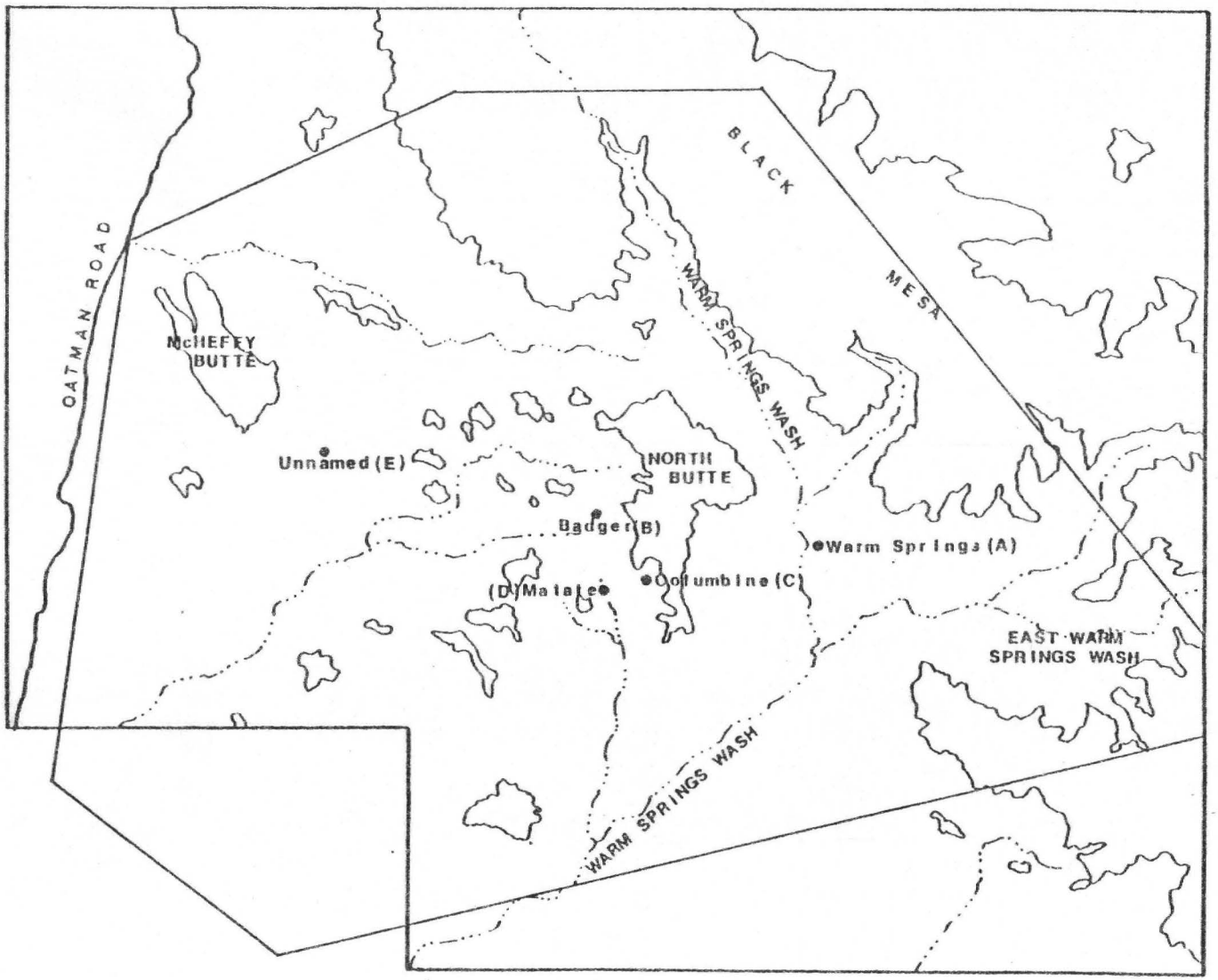
This controversy prompted the Bureau of Land Management to fund this study to examine ecological relationships of feral burros and desert bighorn sheep (Ovis canadensis nelsoni) in an area of the Black Mountains, Arizona. Specific objectives

include the collection of data regarding distribution and movement patterns, food habits and competitive behavior of feral burros and desert bighorn sheep in an area which only contained point source watering sites. Dietary data were also collected on desert mule deer (Odocoileus hemionus) and domestic cattle (Bos bos). Field observations were also recorded on these two species when possible, but the former occurred in very low numbers, and the latter was only present on the northwest extreme of the study area.

STUDY AREA

The study area is located at the southern end of the Black Mountains, approximately 17 miles northeast of Topock, Arizona. Topock lies 38 miles south of Bullhead City, Arizona and 30 miles north of Lake Havasu City, Arizona. The study area incorporates approximately 66 square miles (Map 1).

The Black Mountains are of volcanic origin, mostly basalt, and are characterized by having large mesas and ridges, steep cliffs, numerous talus slopes, rocky foothills, alluvial fans and sandy washes. The study area ranges in elevation from 1,200 to 3,857 feet above sea level (Plate 1). The only sources of permanent water are Warm Springs, comprised of a series of three artesian springs, and three other seeps within the foothills west of Warm Springs. The area receives approximately 4 to 6 inches of precipitation annually, and temperatures range from approximately 25 degrees Fahrenheit in the winter to approximately 120 degrees Fahrenheit



MAP 1. Study area with associated water sources.

PLATE 1: View of Black Mountain study area looking west from the top of South Butte. Photograph by M. T. Walker.

in the summer. Plant species found within the study area are a mix of the Lower Sonoran and Mohave deserts. In addition, some phreatophytes, such as willow (Salix gooddingii), honey mesquite (Prosopis juliflora), seep-willow (Baccharis sergiloides) and others, are associated with the moist conditions around the springs and seeps.

MATERIALS AND METHODS

Capturing, Measuring and Marking

Four sheep and 28 burros were captured within the study area (Table 1) using darts containing the drug M99 (etorphine), a derivative of the opium alkaloid thebaine, combined with the tranquilizing agent azaperone. Dosages used for burros consisted of 2.25 mg to 3.00 mg M99 mixed with 30.0 mg azaperone. Sheep dosages consisted of 2.00 mg M99, 20 mg azaperone, and 2.3 mg atripene. All animals were darted with a Cap-chur CO_2 rifle.

Seven of the 28 captured burros and the four sheep were marked with colored radio-transmitter collars manufactured by Telonics in Mesa, Arizona. Animals not fitted with radio-transmitters were marked with nylon color collars and/or plastic ear tags (Table 1). Ear tags only were placed on small colts. Data concerning standard measurements, condition, age and associated animals were recorded for captured animals. Ages of captured burros were estimated according to dentition patterns of eruption, replacement and wear (Davis 1966).

TABLE 1. Burros captured in the study area, Black Mountains, Arizona.

Ear Tag Number	Collar	Sex	Est.Age	Date of Capture
111	Blue/Yellow(Horizontal)	M	9 yrs.	06-16-76
115	Black Radio (9B)	F	2 1/2 yrs.	03-11-77
16	Blue	F	1+ yrs.	10-20-76
117	Red Radio (2A)	F	6-8 yrs.	03-12-77
118	Green Radio (1A)	F	5 yrs.	03-12-77
119	---	F	4 wks.	03-12-77
120	Red	M	5 yrs.	03-12-77
121	Orange Radio (7A)	M	≈1 yr.	03-12-77
122	---	M	2-4 mo.	03-12-77
123	Pink Radio (8A)	F	8 yrs.	03-12-77
124	Dark Yellow Radio (3A)	F	3 1/2 yrs.	03-12-77
125	---	M	6-9 mo.	03-12-77
126	Light Yellow (1A)	M	1-2 yrs.	03-12-77
127	White/Red	M	4-5 yrs.	03-12-77
128	Red/White	M	7-8 yrs.	03-12-77
129	Yellow	F	≈1 yr.	03-12-77
130	Yellow/Red	F	≈1 yr.	03-12-77
131	Red/Yellow	M	1+ yrs.	03-12-77
132	Blue	F	4 1/2 yrs.	03-12-77
133	Blue/Red	M	2 yrs.	03-13-77
134	White	M	≈1 yr.	03-13-77
135	Red/Blue	M	5 yrs.	03-13-77
136	White/Blue	M	2 1/2 yrs.	03-13-77
137	Yellow/Red(Horizontal)	F	4 1/2 yrs.	03-13-77
138	White/Blue(Horizontal)	F	8 1/2 yrs.	03-13-77
139	Red/White(Horizontal)	M	4 yrs.	03-16-77
140	Red/Blue(Horizontal)	M	8 yrs.	05-21-77
141	Yellow/Blue(Horizontal)	M	4 yrs.	06/29/77

Recognition of animals which were not marked was minimal since only one animal was continuously recognizable--an adult jack with a broken leg.

Field Observations

Full-time field observations were initiated in June 1976 and extended to September 1977. Ground observations were conducted continuously during this interval by camping within the study area for two to six consecutive days. A four-wheel drive vehicle and a two-wheel drive motorcycle allowed primary ground access into the study area, while walking facilitated secondary access. Ground observations were conducted while walking predetermined routes, usually at consistently timed intervals. Both binoculars (7x 35 mm) and a spotting scope (30x) aided in ground observations.

In addition to ground surveys, five helicopter and two fixed-wing surveys contributed to data collection. On 10 November 1976, February 1977, June 1977, and September 1977, eight hours each were utilized conducting helicopter surveys. On 2 May 1977 an additional three hours helicopter time was spent, courtesy of the Arizona Game and Fish Department. Approximately 12 hours of fixed-wing flight was conducted, six hours in September 1976 and six hours in May 1977. All helicopter survey methods were either of grid or contour fashions, while fixed-wing surveys were conducted by randomly searching for radio-transmitter fitted animals.

Data concerning herd size, age composition, sex

composition, color ratios, collar channel, habitat use and distribution were recorded for animals observed as well as temperatures and weather conditions.

Estimation of Numbers

Estimations of animal numbers were obtained by direct counts (via helicopter surveys) and by use of a Lincoln Index.

Direct counts of burros from four helicopter surveys were obtained by assuming that only a portion of such animals are observable from the air. Hinkes (1977) indicated helicopter observations accounted for only 60 percent of the actual burro population. Sheep were more easily observed during helicopter surveys than burros and were counted directly without incorporating the 60 percent correction factor. A total of three sheep counts was conducted (Table 2).

The 60 percent method used for burros (Hinkes 1977) is highly subjective. Therefore, an additional technique involving the use of a time specific Lincoln Index was employed. On 3 September 1977, 195 burros were marked with an orange dye expelled from a CO_2 charged pistol. On 10 September 1977, eight hours of helicopter time was utilized to survey the study area for both marked (223) and unmarked animals. These data were used to compute a population estimate (Lincoln Index) with the following formula:

$$N = \frac{Mn}{m}$$

N = Estimate of population number

M = Total number of marked animals

TABLE 2. Helicopter survey direct count estimation in the Black Mountains, Arizona.

Date	Burro				Bighorn Sheep		
	Direct Count	Est	Area mi^2	Density	Direct Count	Area mi^2	Density
Nov 1976 (Fall)	116	193	46.37	4.16	38	7.56	5.03
Feb 1977 (Winter)	82	137	45.97	2.98	30	7.56	3.97
Jun 1977 (Summer)	98	163	34.88	4.67	--	2.93	--
Sep 1977 (Fall)	233	388	59.06	6.57	35	7.56	4.63
Average	132	220	46.57	4.60	34.3	7.56	4.54

10 September 1977 - Lincoln Index

Burro

Date	Est	Area mi^2	Density
Sep 1977 (Fall)	456	59.06	7.72

Confidence limits (95 percent)

$N_L = 379.30$

$N_U = 550.77$

n = Total number of animals in sample

m = Number of marked animals in sample

with confidence limits calculated by:

$$N_L, N_U = M_n \frac{(m+2) \pm 2\sqrt{m+1}}{M^2}$$

Mortality

Estimation of mortality, per se, using the "Time Specific Life Table" was not possible because an insufficient number of animals were marked and observed in the various age classes. Specific incidences of observed mortality were described.

Sex Ratios

Sex ratios of burros were obtained by utilizing both ground observations and capture data. Aerial surveys did not allow sex determination of burros. Sexing of sheep was easily determined from helicopter surveys and hence both ground and aerial observations were utilized to derive sex ratios of sheep. Sex ratios of both burros and sheep were derived from the number of males per females observed and expressed as a percent for each age class.

Age Ratios

Both burros and sheep were aged as adults, yearlings (between one and two years of age), or young (less than one year old). Ground and aerial observations were used for both species. The sample of burros (28) was not used to calculate a population age ratio as animals less than one year were usually not captured. Also an age ratio, based

on tooth replacement and wear, could not be established for sheep due to the small sample (N=3).

Distribution and Movements

Habitat Preference

Seven major habitat types were delineated within the study area. These were washes, bajadas, foothills, extensive slopes (mesa and butte), and major formation tops (mesa and butte). Habitat types were delineated by the following criteria:

I. Washes - drainage systems, usually having sandy or coarse soils and dominated by blue palo verde (Cercidium floridum), catclaw (Acacia greggii) and desert lavender (Hyptis emoryi).

II. Bajadas - extensive formations of volcanic alluvium, gently sloping (1-16 percent) without any abrupt uplifting in topography and dominated by brittle bush (Encelia farinosa) and creosote (Larrea sp.) with varying amounts of cholla (Opuntia sp.) and ocotillo (Fouquieria splendens).

III. Foothills - areas created by topographic uplift which are generally higher in elevation than washes and bajadas but below extensive slopes. They are characterized by igneous alluvium and volcanic talus. Creosote, cholla and brittle bush predominated with varying amounts of California buckwheat (Eriogonum fasciculatum).

IV. Extensive slopes (butte and mesa) - Long (usually

steep) slopes leading up to major formation tops, with one or more changes in slope and characterized by volcanic talus. Joint fir (Ephedra fasciculata), brittle bush and California buckwheat predominate.

V. Mesa tops - major flat or gently sloped formations caused by uplifts, characterized by having extensive slopes on all sides, and above 2,200 feet in elevation. They were dominated by joint fir, yucca (Yucca sp.) and black brush (Coleogyne ramosissima).

VI. Butte tops - major formations caused by uplift and characterized by having extensive slopes on all sides and generally having rough, irregular tops above 2,200 feet elevation. They were dominated by cholla, yucca (Yucca baccata) and white ratany (Krameria parvifolia).

Supplementary to the general habitat types, 28 specific habitat types were determined by incorporating the degree of slope and elevation (Table 3). These specific types were determined in an effort to evaluate species' habitat preference in terms of the specific physical parameters mentioned and in an attempt to identify any possible source of misinterpretations arising from the general habitat preference data.

In addition to the above criteria, additional specific information concerning forage utilization and production in each general habitat type were to have been obtained via

TABLE 3. Specific habitat types and criteria used in classification.

Abbrv.	Description	Height (ft)	Slope (%)
WHS	Washes, high, steep	>2,200	>20
WHG	Washes, high, gentle	>2,200	<20
WLS	Washes, low, steep	<2,200	>20
WLG	Washes, low, gentle	<2,200	<20
BHS	Bajada, high, steep	>2,200	>40
BHG	Bajada, high, gentle	>2,200	<40
BLS	Bajada, low, steep	<2,200	>40
BLG	Bajada, low, gentle	<2,200	<40
FHS	Foothills, high, steep	>2,200	>40
FHG	Foothills, high, gentle	>2,200	<40
FLS	Foothills, low, steep	<2,200	>40
FLG	Foothills, low, gentle	<2,200	<40
For Both Butte and Mesa Slopes			
SHS	Slopes, high, steep	>2,200	>40
SHG	Slopes, high, gentle	>2,200	<40
SLS	Slopes, low, steep	<2,200	>40
SLG	Slopes, low, gentle	<2,200	<40
BTHS	Butte-tops, high, steep	>2,200	>40
BTHG	Butte-tops, high, gentle	>2,200	<40
BTLS	Butte-tops, low, steep	<2,200	>40
BTLG	Butte-tops, low, gentle	<2,200	<40
MTHS	Mesa-tops, high, steep	>2,200	>40
MTHG	Mesa-tops, high, gentle	>2,200	<40
MTLS	Mesa-tops, low, steep	<2,200	>40
MTLG	Mesa-tops, low, gentle	<2,200	<40

a range-oriented study conducted by Ferdanand Notah (ASU Range Department) in 1976. Notah's study was concerned, in part, with the determination and evaluation of various range types in the alkali and warm springs areas and was directed toward providing information which would complement this study and vice versa. Notah's data, however, were not available for incorporation in this report because we have no knowledge of where he is or where his data can be obtained.

Territoriality

Activities, which may be related to territorial behavior, were observed for but not quantified since instances of such behavior were rare.

Seasonal Distributions and Movements

Seasonal movements were obtained for burros and sheep via seasonal distribution data obtained from both ground and aerial observations. All observations were plotted on topographic maps. Sporadic (daily or non-seasonal) burro and sheep movements are also discussed. Data concerning seasonal movements for known (marked) animals were insufficient to warrant discussion, primarily due to inadequate sample sizes and/or insufficient study duration. Adequate burro numbers were not marked until March 1977, while marked sheep only numbered four, and deer and cattle were not marked at all.

Habitat - Meteorological Correlations

Statistical correlation analyses were conducted by comparing mean daily temperatures (degrees Fahrenheit) and

total monthly rainfall, with the total number of corresponding burro, sheep, and deer observations obtained in each habitat type. Meteorological data were obtained from maximum-minimum thermometers and from the Needles F.A.A. Airport, Needles, California. Habitat use data were obtained from both ground and aerial surveys for all species except cattle.

Competition and Behavioral Responses

Food Habits

Quantification of the amounts and diversity of consumed plant species by the four herbivorous species was acquired through microscopic fecal analysis (Free et al. 1970). This technique involves microscopic examination of discernible plant fragments such as trichomes, pollen grains, silica cells, epidermal cells, etc., in collected fecal samples. The frequency of occurrence of fragments of each plant species was converted to relative density. Sparks and Malechek (1968), using only epidermal fragments as evidence for the presence of a plant species, found relative density to approximate percent dry weight. A reference collection was made of all the plant species found within the study area. Plant analysis was conducted at Arizona State University.

An attempt was made to collect 20 burro, sheep, and cattle fecal samples per month. Cattle samples for June, July and August 1976 and sheep samples for August 1976 were not obtained. Fecal samples for deer were only obtained for June and July 1977 due to scarcity of deer and confusion of old deer pellets with old sheep pellets, in which case none were collected. Most fecal samples were usually obtained within

one hour following elimination.

Comparison of fecal analysis data for burros, sheep, cattle, and deer (when obtained) were made by comparing the 15 most utilized plant species and by comparing the utilization of different plant types (i.e., grasses, forbs, browse) on a seasonal and overall basis.

Observation of Water Sources

Water hole observations were made periodically (several times per each water source per month). All observations (for all species except cattle, at all water sources) were described. Instances of different animal species simultaneously using the same water source were described and specific signs of direct interaction or aggressive behavior were looked for but never observed. All observations were qualitatively described. Seasonal distances of burros and sheep from the various water sources were determined.

Water Source Fouling

Water sources were inspected several times per month for signs of fouling. Detailed descriptions of observed instances were made.

Water Analysis

Monthly analysis of samples from water sources B, C and D (Map 1) were obtained from May to September 1977. Free acidity, total acidity, alkalinity, carbon dioxide, total hardness, dissolved oxygen and pH were measured by using a

Model AL-36B Water Analysis Kit (Hach Chemical Company, Ames, Iowa). Additional parameters were not obtained because of the complexity, weight, size and cost of testing equipment. Of the parameters obtained, dissolved oxygen was used as an index to describe water quality.

RESULTS AND DISCUSSION

Estimation of Numbers

Burros

An estimated population of 456 burros was computed from a Lincoln Index during the helicopter survey on 10 September 1977. Of the 223 burros marked, 114 (51 percent) were observed during the survey. Burro distribution at this time (59.06 square miles) produced a density of 7.72 burros per square mile.

Seasonal population estimates were computed from the helicopter observations by incorporating the previously discussed 60 percent factor and ranged from 137 in February 1977 to 388 in September 1977 (Table 2). The apparent variation associated with these seasonal estimates (involving the 60 percent factor) suggests either periodic mass burro movement into and out of the study area, or that error exists in the method itself. It is believed that these variations are a product of the method itself and not a result of periodic burro movement for the following reasons:

1. Periodic aerial reconnaissance surveys rarely revealed marked burros using areas outside of the

66 square-mile study area;

2. The direct count (60 percent method) has never been substantiated, particularly for use in terrain types associated with this particular study area.

It is felt that the 60 percent burro observance factor is too high, and a 40 to 45 percent factor is more realistic for similar terrain types since the September Lincoln Index estimate of 456 exceeds the September direct count of 388 (Table 2). The seasonal direct count (60 percent estimates reported in this report) is therefore, best interpreted as a minimum population estimate.

Sheep

Seasonal estimates of sheep populations via direct counts were fairly consistent (Table 2). The higher estimates of 35 and 38 (10 September 1977 and 10 November 1976, respectively) were congruous with the observed increase in sheep using the study area at these times since adult rams were present. The February estimate of 30 represents only adult ewes, yearlings, and lambs.

Unfortunately, no sheep were observed on the 10 June 1977 helicopter survey because the survey was made late in the day. The disturbances produced from the helicopter while making the earlier (from 7:00 A.M. to 4:00 P.M.) burro survey caused the sheep to conceal themselves in areas which did not allow observation. It is recommended that all future sheep surveys via helicopters be conducted without

such disturbances. Since sheep are easily observed from helicopters when not previously disturbed, the estimations obtained appear to nearly represent actual numbers. This was, however, a result of the specific nature of sheep habitat (generally isolated and open buttes) found within the study area and therefore, not inferred to be an acceptable method to estimate sheep populations in all areas in general.

Seasonal sheep densities were found to range from 3.97 to 5.03 with an average of 4.54 animals per square mile.

Mortality

Burros

Carcasses of four burros, which had been shot, were found in the study area. Only one case of natural mortality was observed. The cause of death in this instance was due to malnutrition resulting from a broken rear leg. An eight year old jack was observed alive but in an extremely languid condition near Warm Springs on 15 August 1977 (Plate 2). He was lying down and unable to get up and died before the end of the day. Another burro having a broken front leg was frequently observed. It, however, survived through the study. Broken legs can be a cause, however slight, of natural mortality in the burro population of the Black Mountains, Arizona.

Sheep

Hunting accounted for the only known sheep mortality during this study (an adult ram was harvested during the 1976 sheep hunt). Other causes of desert bighorn mortality

PLATE 2: An eight year old jack with broken right rear leg near Warm Springs on 15 August 1977. Photograph by M. T. Walker.

such as predation, disease and accidents have been observed during previous studies (Russo 1952; Russo 1956; Kennedy 1948; and others) and are therefore also assumed to account for sheep mortality in the Black Mountains. Bobcats (Lynx rufus) were frequently observed within the study area and may prey on lambs. During the November helicopter survey an adult bobcat was observed stalking a small group of adult ewes and lambs which were foraging on an isolated butte slope. The helicopter, however, frightened both species, making the stalk unsuccessful.

Sex Ratios

Burros

The overall mean sex ratio (15-month period) for the total populations of burros was 55 percent males and 45 percent females (1.22:1)(Table 4). A similar sex ratio of 57 percent males and 43 percent females (1.33:1) was observed in the 28 collared burros. The sex ratios for each age class (adults, yearlings, and young) all showed a predominance of males, being most pronounced in the young age class. Woodward (1976) and McMichael (1964) also showed a preponderance of males (1.33:1 and 2:1, respectively), while Seegmiller (1977) and Morgart and Ohmart (1976) showed a preponderance of females (0.9:1 and 0.8:1, respectively). Moehlman (1974) reported an adult sex ratio of 1:1. The discrepancy between McMichael's 1964 sex ratio and that of this study (both in the same general area) is due to either biased data, or a

TABLE 4. Total and seasonal average estimates of age and sex ratios of feral burros in the Black Mountain study area using ground and aerial direct count observations.

Season	Observed Numbers	% Sex Ratio Male:Female	% Age Ratio Adult:Yearl:Colt
TOTAL POPULATION			
Jun-Aug 1976	N=227	62:38	80: 4:16
Sep-Nov 1976	N=268	47:53	70: 7:23
Dec 1976-Feb 1977	N=336	51:49	76: 5:19
Mar-May 1977	N=487	57:43	70:10:20
Jun-Aug 1977	N=680	56:44	66:12:22
Annual Average (12 month)			74: 7:19
Average (15 month)	N=399.6	55:45	72: 8:20
ADULTS			
Jun-Aug 1976	N=159	64:36	
Sep-Nov 1976	N=132	45:55	
Dec 1976-Feb 1977	N=172	52:48	
Mar-May 1977	N=255	53:47	
Jun-Aug 1977	N=355	50:50	
Average (15 month)	N=214.6	52.8:47.2	
YEARLINGS			
Jun-Aug 1976	N= 10	30:70	
Sep-Nov 1976	N= 11	55:45	
Dec 1976-Feb 1977	N= 3	67:33	
Mar-May 1977	N= 44	77:23	
Jun-Aug 1977	N= 55	65:35	
Average (15 month)	N= 24.6	58.8:41.2	
COLTS			
Jun-Aug 1976	N= 4	100: 0	
Sep-Nov 1976	N= 3	100: 0	
Dec 1976-Feb 1977	N= 12	33:67	
Mar-May 1977	N= 35	60:40	
Jun-Aug 1977	N= 30	60:40	
Average (15 month)	N= 16.8	70.6:29.4	

significant decline in the number of males during the past 12 years. Sample sizes were not indicated in McMichael's thesis, thus it can only be assumed his sample was small.

Sheep

The overall mean adult and yearling sex ratio (15-month period) was 31 percent males and 69 percent females (0.45:1) (Table 5). The sex ratio during the period when the distribution of rams and ewes overlap (July - December 1976 and July - August 1977) was 40 percent males and 60 percent females (0.67:1). The November 1976 helicopter survey yielded an adult sex ratio of 1:1. However, this ratio may be erroneous due to the possibility of having doubly counted three rams. The sex ratio of 0.52:1 was obtained in the same general area in May of 1977 by the Arizona Game and Fish Department (G. Welsh, pers. comm.), which approximated our estimations. Seegmiller's (1977) 0.8:1 sex ratio of sheep in the Bill Williams Mountains indicates the Black Mountain sheep population (study area only) has fewer adult males. McMichael reported an observed sex ratio of 0.83:1 in the Warm Springs area in 1964 (again, total sample size was not given in McMichael's thesis).

Age Ratios

Burros

Age ratios were calculated from direct observations for each season (Table 4). Burro age ratios were divided into adults, yearlings (between one and two years old), and young

TABLE 5. Total and seasonal average estimates of sex and age ratios of bighorn sheep in the Black Mountain study area using ground and aerial direct count observations.

Season	% Sex Ratios (Male:Female)				% Age Ratios
	Total Population M:F	Adults M:F	Yearlings M:F	Lambs M:F	Adult:Yearl:Lamb
Jun-Aug 1976	30:70	19: 81	75:25	100: 0	57:11:32
Sep-Nov 1976	47:53	47: 53	57:43	0:100	63:09:28
Dec 1976-Feb 1977	16:84	16: 84	0: 0	0: 0	58:04:38
Mar-May 1977	1:99	0:100	9:91	0: 0	58:12:30
Jun-Aug 1977	26:74	27: 93	18:82	100: 0	53:20:27
Annual Average (12 months)					59: 9:32
Average (15 months)	24:76	22: 78	40:60	67: 33	58:11:31
Jul-Dec 1976 + Jul-Aug 1977 (1)		37:63	40:60	43:57	62:10:28*
Jun 1976 + Jan-Jun 1977 (2)					52:14:34**
Nov 1976 Helicopter Survey					63:08:29

* N=335 (1) Ram included observations
** N=321 (2) Ram excluded observations

(colts less than one year old). Seasonal variation in age ratios was small and mostly a result of increased yearling observations as the study progressed. Yearlings were difficult to differentiate, especially when they were not in the presence of adults. With experience it became easier to distinguish between yearlings and adults. Even with experience, the yearling age class was frequently difficult, and the obtained yearling estimate was probably below the true value.

By calculating mean values a reliable age ratio of 72 percent adults, 8 percent yearlings and 20 percent colts (3.6:0.4:1) was obtained (Table 4). Slightly younger age structures have been reported by Seegmiller (1977) and Woodward (1976).

Sheep

A sheep age ratio was first obtained by calculating mean values for 15 months of observations. The ratio of 58 percent adults, 11 percent yearlings and 31 percent lambs (1.9:0.35:1) was obtained by using both aerial and ground observations (Table 5). This ratio, when compared with Seegmiller's (1977) ratio of 3.6:1:1 and Russo's (1956) 4.6:0.4:1 ratio, shows the Black Mountain sheep population consists of fewer adults and yearlings per lamb. When using this overall (15-month period) average, it should be noted that it includes observations for months when adult rams were known not to inhabit the study area (January 1977 - June 1977). In an attempt to correct for this error, the

percent ratio of 62:10:28 (2.23:0.36:1) was calculated from observations obtained only during the period when ram-ewe distributions overlap (July - December 1976 and July - August 1977), furthermore, the percent ratio of 63:8:29 (2.14:0.27:1) was calculated from the November 1976 helicopter survey which was also during a period of ram-ewe distributional overlap (Table 5). These ratios show a larger number of adults per lamb than the overall mean ratio and represent a more reliable estimation of the actual age ratios.

The spring (March 1977 - May 1977) lamb to adult ewe ratio was 0.52:1 (51.7 lambs per 100 ewes), which compared favorably with the Arizona Game and Fish (May 1977) ratio of 0.45:1 (45.2 lambs per 100 ewes)(G. Welsh, pers. comm.).

Habitat Preference

Burros

Observed trends in seasonal burro use of the general habitat types were:

1. Increased use of foothills during the warmer months and
2. Increased use of mesa tops and bajadas during the cooler months.

Burro use of foothills ranged from a high of 75 percent during the 1976 summer months to a low of 20 percent during the 1976-77 winter months. Burro use of mesa tops increased from a low of 3 percent during the summer of 1976 to a high of 37 percent during the 1976-77 winter months. Similarly, burro use of bajadas increased from a low of 5 percent during

the 1976 summer to a high of 27 percent during the 1977 spring (Table 6).

These apparent trends are mostly a result of:

1. Increased burro water stress during the hotter months and the increased use of habitat types associated with permanent water sources (i.e., burros used habitat types, mostly foothills, near permanent water sources during hotter months when frequent watering needs precluded traveling to areas removed from water sources); and
2. Greater production of available forage in areas outside the summer burro range, predominantly mesa tops and bajadas, thus attracting burros into these areas during the cooler months.

Although general trends were apparent, it should be noted that ephemeral use of habitat removed from water were recorded whenever meteorological conditions permitted. Burros were observed using mesa tops (habitat type normally restricted to cool season use) during the hotter months when a decrease in temperatures or precipitation occurred.

Dividing general habitat types into specific habitat types illustrates burro use of low, gentle foothills most often, high gentle mesa tops second, and low gentle bajadas third (Table 7).

In general, burros were observed most often in low, gentle habitat types as compared to high, steep types (Table 8). Predominant burro use of gentle habitat types with slopes

TABLE 6. Percent frequency of burro and sheep sightings in general habitat types over their entire range.

	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977	Average of all Seasons
Foothills						
Burro	75	49	20	36	56	47.2
Bighorn Sheep	50	1	7	5	36	19.8
Washes						
Burro	12	6	5	8	9	8.0
Bighorn Sheep	0	0	0	0	3	0.6
Mesa Tops						
Burro	3	31	37	17	15	20.6
Bighorn Sheep	0	2	2	2	0	1.2
Butte Tops						
Burro	0	0	0	0	0	0.0
Bighorn Sheep	3	30	23	42	11	21.8
Bajada						
Burro	5	8	25	27	8	14.6
Bighorn Sheep	0	0	0	0	0	0.0
Butte slopes						
Burro	3	6	11	6	8	6.8
Bighorn Sheep	47	67	68	51	50	56.6
Mesa Slopes						
Burro	2	0	2	6	4	2.8
Bighorn Sheep	0	0	0	0	0	0.0
TOTAL						
Burro	100	100	100	100	100	100.0
Bighorn Sheep	100	100	100	100	100	100.0
NUMBER OF OBSERVATIONS						
Burro	312	281	345	526	838	460.4
Bighorn Sheep	113	128	121	175	190	145.4

TABLE 7. Percent of monthly and average seasonal burro observations in specific habitat types.

Months and Seasonal Averages	N	Specific Habitat Types															
		FHS	FHG	FLS	FLG	BHG	BLS	BLG	SHS	SHG	SLS	SLG	WHG	WLG	MTHS	MTHG	TOTAL
Jun '76	35				69									31			100
Jul '76	146	2	26	6	47				6					13			100
Aug '76	131	8	22	5	34	5		8	1	5				4		8	100
Average		3	16	4	50	1		3	2	2				16		3	100
Sep '76	70	2	7	4	67			2	7	1				10			100
Oct '76	21	14		5	52								29				100
Nov '76	190	8	1	2	23		1	11	4		2			2		46	100
Average		8	3	4	47		T	4	4	T	1		10	4		15	100
Dec '76	134	3	3		4			18	23	4				4		41	100
Jan '77	82	2	12		10			2	9					14		51	100
Feb '77	129	2	15		9			47			3					24	100
Average		2	10		8			22	11	1	1			6		39	100
Mar '77	134		14	8	15			33	4	4				4		18	100
Apr '77	187		9	2	28	3		24	6	8		1		12		7	100
May '77	205	9	7	2	12	3		22	12				5	2		26	100
Average		3	10	4	18	2		26	8	4		T	2	6		17	100
Jun '77	426	2	13	1	28	1		14	10	3	1		1	9		17	100
Jul '77	254	7	13		44			7	11	1			5	3	2	7	100
Aug '77	158		16	1	41	3			9	3			2	5		20	100
Average		3	14	T	38	1		7	10	2	T		3	6	T	15	100
Overall Average		4	11	2	32	1	T	13	7	2	T	T	3	7	T	18	100

TABLE 8 Percent of monthly, average seasonal, and average overall burro and sheep observations in high, low, steep, and gentle terrain types.

	MONTHS AND SEASONS																				
	(A)				(B)				(C)					(D)				(E)			
	Jun '76	Jul '76	Aug '76	Average	Sep '76	Oct '76	Nov '76	Average	Dec '76	Jan '77	Feb '77	Average	Mar '77	Apr '77	May '77	Average	Jun '77	Jul '77	Aug '77	Average	Overall Averages
ELEVATIONAL TYPES																					
High																					
Burro	0	34	49	27.7	17	43	59	39.7	74	74	41	63.0	39	33	62	44.7	47	46	53	48.7	45.0
Sheep	10	100	96	68.7	100	100	97	99.0	100	100	100	100.0	62	100	100	87.3	69	92	90	83.7	88.0
Low																					
Burro	100	66	51	72.3	83	57	41	60.3	26	26	59	37.0	61	67	38	55.3	53	54	47	51.3	55.0
Sheep	90	0	4	31.3	0	0	3	1.0	0	0	0	0.0	38	0	0	12.7	31	8	10	16.3	12.0
Total																					
Burro	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sheep	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
SLOPE TYPES																					
Steep																					
Burro	0	14	14	9.3	13	19	17	16.3	26	11	5	14.0	11	8	23	14.0	14	20	10	14.7	13.7
Sheep	100	70	57	75.7	96	100	50	82.0	80	86	95	87.0	62	49	76	62.3	36	60	76	57.3	72.8
Gentle																					
Burro	100	86	86	90.7	87	81	83	83.7	74	89	95	86.0	89	92	77	86.0	86	80	90	85.3	86.3
Sheep	0	30	43	24.3	4	0	50	18.0	20	14	5	13.0	38	51	24	37.7	64	40	24	42.7	27.2
Total																					
Burro	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sheep	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

(A) N = 312 Burros
N = 97 Sheep

(B) N = 281 Burros
N = 128 Sheep

(C) N = 345 Burros
N = 129 Sheep

(D) N = 526 Burros
N = 175 Sheep

(E) N = 838 Burros
N = 190 Sheep

less than 40 percent was observed for all months studied with an overall 15-month average of 86.3 percent. Although burros were observed to be capable of movement in all but the most extreme (greater than approximately 120 percent slope) habitat types, they used those areas which required the least amount of effort. Prominent burro trails in all habitat types were nearly always observed as being located in areas of least resistance.

Burro preference for low habitat types was observed for 10 of the 15 months studied and for each season except winter (Table 8). It was not felt that burros were selecting habitat types specifically with regard to elevation but rather for other attributes, such as proximity of water sources, abundance of forage and accessibility, which may or may not be related to elevation.

Sheep

Sightings of bighorn sheep were most frequent in butte slopes for all seasons (except summer 1976) with the greatest use during the winter and fall months (68 and 67 percent, respectively). Significant use of foothills was limited to the summer months (50 percent during summer 1976 and 36 percent during summer 1977). Percent use of butte tops increases during the cooler months, reaching a maximum of 42 percent during the spring 1977. Sheep were seldom observed in washes or mesa tops (15-month averages of 0.6 percent and 1.2 percent, respectively) and never observed on mesa slopes or bajadas (Table 6).

Consistently high year-round use of butte slopes was observed because this habitat type offers both adequate escape terrain and adequate year-round available forage supplies and was proximal enough to a permanent water source to permit use, regardless of season. As with burros, the relatively high percentage of sheep sightings in foothills during the warmer months was also primarily due to increased water requirements, which restricts their use to areas (hence, habitat types, i.e., foothills) near permanent water sources. Possible explanations for the greater use of butte tops during the cooler months were as follows:

1. Sheep may be attracted to butte tops while seeking new food supplies, which are generally present in these areas during the cooler months.
2. Decreased summer use of butte tops due to an increased need for shade by sheep during the summer months. Butte tops are flat and/or barren and do not provide much usable shade, hence are undesirable to sheep during the hotter months. Sheep were always observed in shaded areas during the hottest part of the day throughout the summer months. Butte top areas offer very little usable shade during the midday hours (Plate 3). This lack of shade is a result of the general physical characteristics found throughout this habitat type.
3. Increased winter use of butte tops due to an increase in use by lambing ewes. It has been

PLATE 3: Example of the relatively barren and shadeless characteristics of butte top habitat types. Photograph by M. T. Walker.

> documented that adult ewes seek the most secure, hence the most inaccessible areas, shortly before, during and after the lambing season--usually during the months from February to May (Russo 1956). Butte tops were determined to be the most inaccessible, therefore the most secure, habitat types found within the study area, primarily due to the fact that all are surrounded by steep, rugged slopes. Sheep sightings were highest (42 percent) in butte tops, which coincided with the primary months (March through May) of lambing activity.

Specific habitat types most used by sheep were high, steep butte slopes (15-month period mean of 55 percent), second were high, gentle butte tops (11 percent) and third were high, gentle foothills (7.3 percent)(Table 9).

In general, bighorn sheep preferred high, steep terrain types (88 and 73 percent, respectively) over low, gentle terrain (12 and 27 percent, respectively)(Table 8). Preferred forage availability and innate behavioral characteristics appear most responsible for these observed preferences. Sheep are known to avoid areas which do not offer an elevational advantage over intruders or adequate escape terrain in general (Hicks 1977). In addition, the preferred forage supplies in the lower and more gentle terrain types have been reduced considerably through heavy burro use; hence, sheep prefer the higher, steeper terrain types which are not used heavily (relatively) by burros.

TABLE 9. Percent of monthly, average seasonal, and average overall sheep observations in specific habitat types over entire range.

Months and Seasonal Averages	N	Specific Habitat Types												TOTAL
		FHS	FHG	FLS	FLG	SHS	SHG	SLS	WLG	MTHG	MTLG	BTHS	BTHG	
Jun 1976	26			90		10								100
Jul 1976	64	34	14			36	16							100
Aug 1976	23	4	26		4	53							13	100
Average		13	13	30	1	33	6						4	100
Sep 1976	44	2				80						14	4	100
Oct 1976	18					100								100
Nov 1976	66					47		3		5			45	100
Average		1				75		1		2		5	16	100
Dec 1976	48		13			67						13	7	100
Jan 1977	42	7				79				7			7	100
Feb 1977	39					54	5					41		100
Average		2	4			67	2			2		18	5	100
Mar 1977	55					38					38	24		100
Apr 1977	51					49							51	100
May 1977	69		13			64				4		12	7	100
Average			4			51				1	13	12	19	100
Jun 1977	83		6	7	24	29							34	100
Jul 1977	86	11	23			49	9		8					100
Aug 1977	21	14	14		10	62								100
Average		8	14	2	11	47	3		3				12	100
Overall Average		5	7	6	3	55	2	T*	T	1	3	7	11	100

T*= Trace

Overlap

Spatial and temporal overlap between burros and sheep were measured by monitoring their seasonal use of various types of habitat within areas of sympatry (Table 10). Overlap occurred on butte slopes during winter months (52 percent burros, 68 percent sheep), spring months (77 percent burros, 51 percent sheep), and summer months 1976 (75 percent burros, 47 percent sheep). Other habitat overlap occurred in foothills during summer 1976 (25 percent burros, 50 percent sheep) and during summer 1977 (86 percent burros, 36 percent sheep). Only slight overlap was observed in washes during summer 1977 and in mesa tops during the fall, winter and spring months.

The degree of spatial overlap as observed in general habitat types (Table 10) may not represent the best measure of overlap since burros and bighorn sheep prefer different terrain types within the general habitat types (Table 11).

For example, Table 12 shows the maximum degree of overlap as observed in general foothill habitat type during the 1976 summer was 25 to 50 percent (percent burro to sheep use, respectively). Yet only a 25 to 1 maximum degree of overlap was observed when habitat use was represented in terms of the corresponding specific foothill habitat types (FHS, FHG, FLS and FLG).

Deer

Paucity of deer observations (N = 45 for total 15-month period) did not allow reliable data on habitat use. In general,

TABLE 10. Percent frequency of burro and sheep sightings in general habitat types within area of range overlap.

	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977	Average of all Seasons
Foothills						
Burro	25	58	32	0	86	40.2
Sheep	50	1	7	5	36	19.8
Washes						
Burro	0	16	0	0	6	4.4
Sheep	0	0	0	0	3	0.6
Mesa Tops						
Burro	0	10	16	23	0	9.8
Sheep	0	2	2	2	0	1.2
Butte Tops						
Burro	0	0	0	0	0	0.0
Sheep	3	30	23	42	15	22.6
Bajada						
Burro	0	0	0	0	0	0.0
Sheep	0	0	0	0	0	0.0
Butte Slopes						
Burro	75	16	52	77	8	45.6
Sheep	47	67	68	51	46	55.8
Mesa Slopes						
Burro	0	0	0	0	0	0.0
Sheep	0	0	0	0	0	0.0
TOTAL						
Burro	100	100	100	100	100	100.0
Sheep	100	100	100	100	100	100.0
NUMBER OF OBSERVATIONS						
Burro	4	50	83	22	190	69.8
Sheep	97	128	129	175	190	143.8

TABLE 11. Percent frequency of burro and sheep sightings in specific habitat types within area of range overlap.

Specific Habitat Type		Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977	Average of all Seasons
FHS	Burro	0	20	7	0	11	7.6
	Sheep	24	1	2	0	6	6.6
FHG	Burro	0	12	25	0	16	10.6
	Sheep	16	0	5	5	15	8.2
FLS	Burro	0	6	0	0	2	1.6
	Sheep	9	0	0	0	3	2.4
FLG	Burro	25	20	0	0	57	20.4
	Sheep	1	0	0	0	12	2.6
SHS (butte)	Burro	75	14	41	50	7	37.4
	Sheep	37	66	67	51	42	52.6
SHG	Burro	0	2	6	27	1	7.2
	Sheep	10	0	1	0	4	3.0
SLS	Burro	0	0	5	0	0	1.0
	Sheep	0	1	0	0	0	0.2
WLG	Burro	0	16	0	0	6	4.4
	Sheep	0	0	0	0	3	0.6
MTHG	Burro	0	10	16	23	0	9.8
	Sheep	0	2	2	2	0	1.2
MTLG	Burro	0	0	0	0	0	0.0
	Sheep	0	0	0	0	0	0.0
BTHS	Burro	0	0	0	0	0	0.0
	Sheep	0	5	5	17	0	5.4
BTHG	Burro	0	0	0	0	0	0.0
	Sheep	3	25	18	25	15	17.2
TOTAL							
	Burro	100	100	100	100	100	100.0
	Sheep	100	100	100	100	100	100.0
NUMBER OF OBSERVATIONS							
	Burro	4	50	83	22	190	69.8
	Sheep	97	128	129	175	190	143.8

TABLE 12. Percent frequency of burro and sheep sightings in general and specific butte slopes and foothill type habitats.

	Butte Slopes					Foothills				
		Specific					Specific			
	General	SHS	SHG	SLS	SLG	General	FHS	FHG	FLS	FLG
Summer 1976										
Burro	75	75	0	0	0	25	0	0	0	25
Sheep	47	37	10	0	0	50	24	16	9	1
Fall 1976										
Burro	16	14	2	0	0	58	20	12	6	20
Sheep	67	66	0	1	0	1	1	0	0	0
Winter 1976-77										
Burro	52	41	6	5	0	32	7	25	0	0
Sheep	68	67	1	0	0	7	2	5	0	0
Spring 1977										
Burro	77	50	27	0	0	0	0	0	0	0
Sheep	51	51	0	0	0	5	0	5	0	0
Summer 1977										
Burro	8	7	1	0	0	86	11	16	2	57
Sheep	46	42	4	0	0	36	6	15	3	12

deer were most often observed using washes (48 percent of observations) and foothills (19 percent) during the summer months and mesa tops (64 percent) during the cooler months.

Territoriality

Burros

Frequency of territorial behavior expressed by burros was low. Adequate data to support or refute the existence of territories were not obtained. The few observations which suggested slight tendencies toward territoriality were infrequent and inconclusive.

Limited insight regarding possible territorial tendencies in burros was obtained for Jack #111. In six observations during the months of June through September 1976, Jack #111 (a nine-year-old male) was found to occupy an area of approximately 0.3 square miles, but conclusive evidence of this area being a territory was not obtained. He was never observed preventing other jacks from entering the area, but on one occasion there was a fight involving #111 and other adult males (involving an estrous female). He did not attempt to expel the other jacks from the area.

Throughout the remainder of the study, he was occasionally observed in the 0.3 square miles (twice with estrous females) but did not consistently use this area. Periods of noninhabitance were frequent and on two occasions he was absent more than 30 days at a time.

The only other instance of possible territoriality was observed when an unmarked jack was noted chasing four

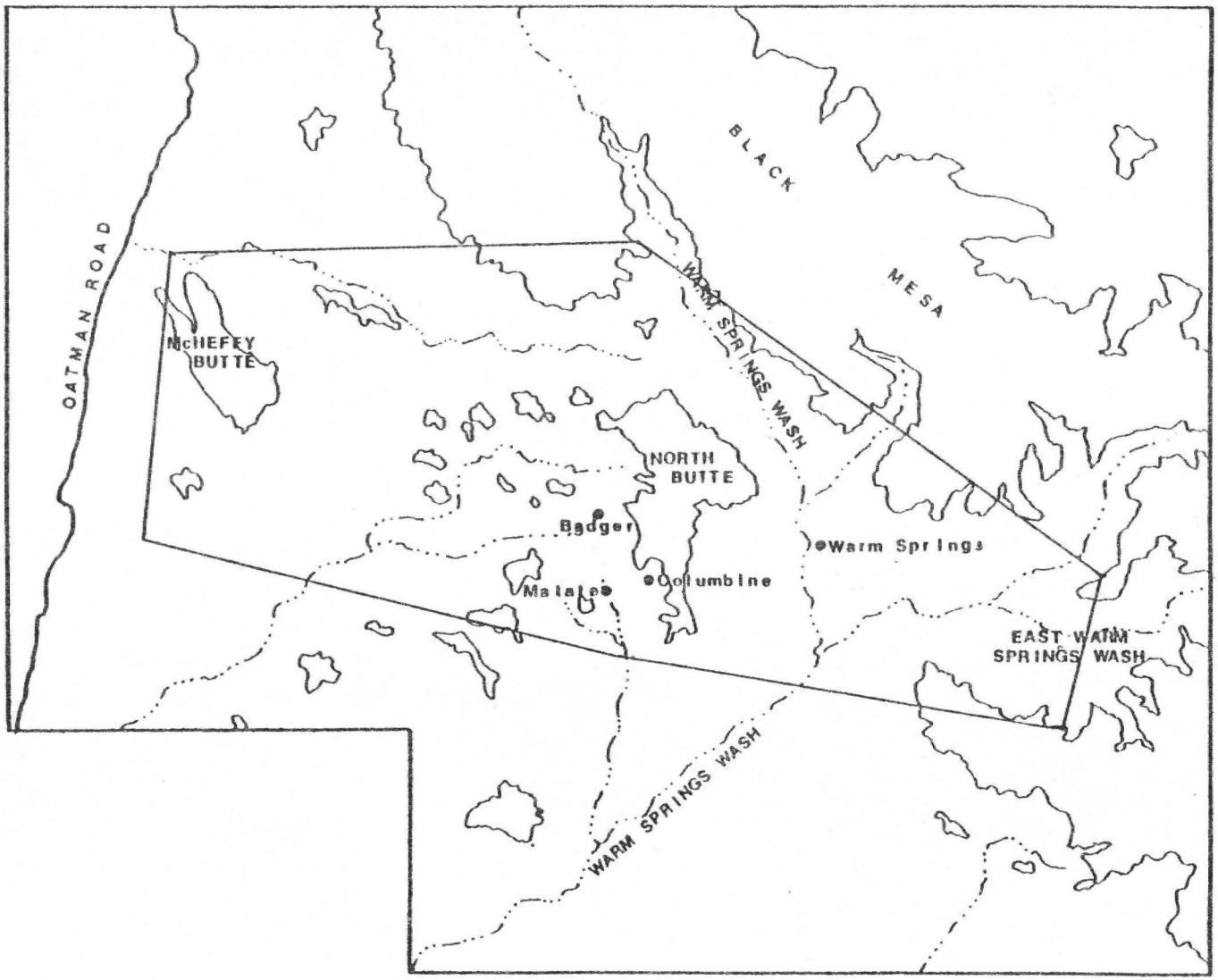
adult burros (unsexed) from Matate Seep on 21 June 1976. This behavior was only observed once.

Conclusions were that territoriality was nonexistent in this population or that conditions were not adequate for territoriality to be fully expressed.

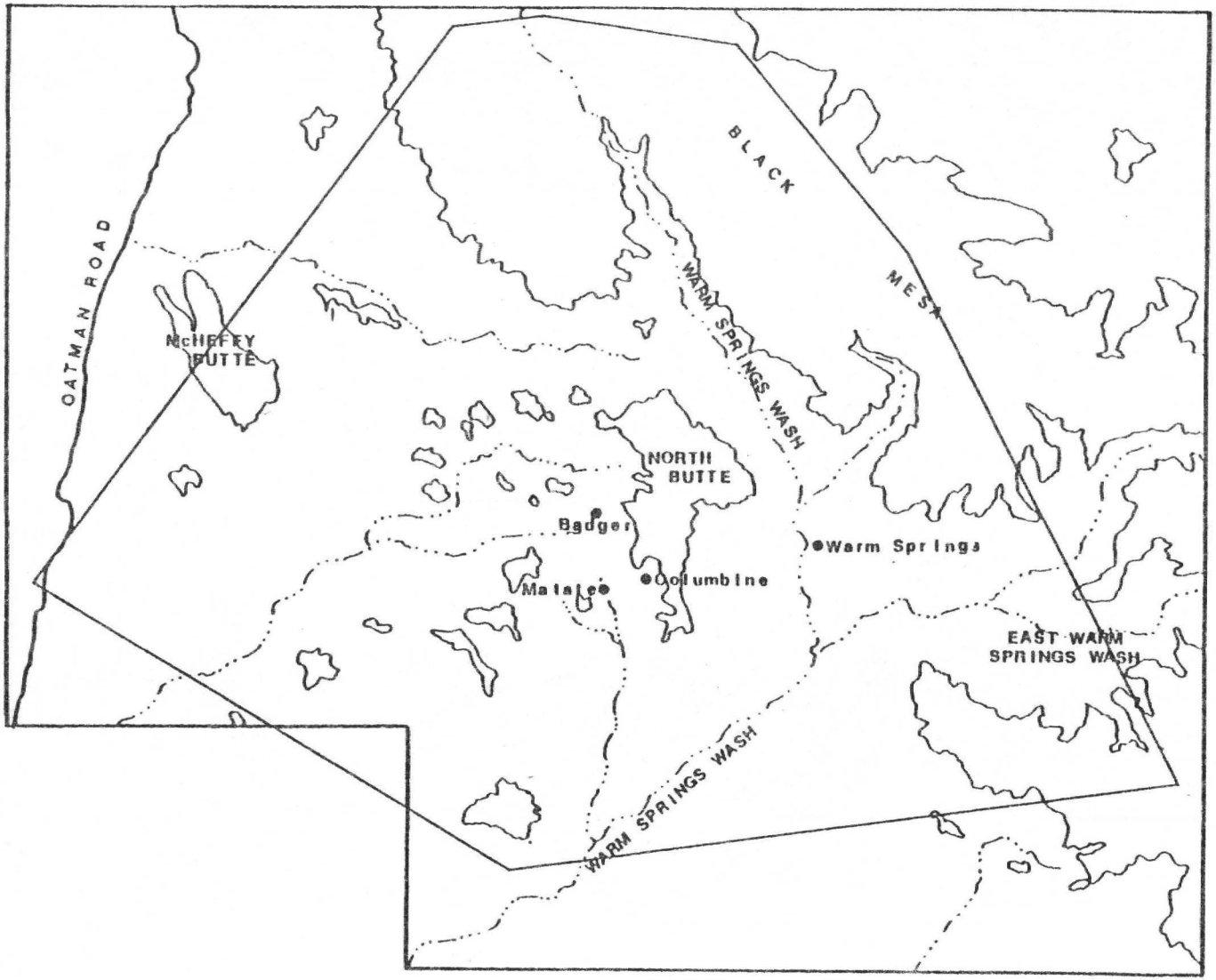
Seasonal Movements

Burros

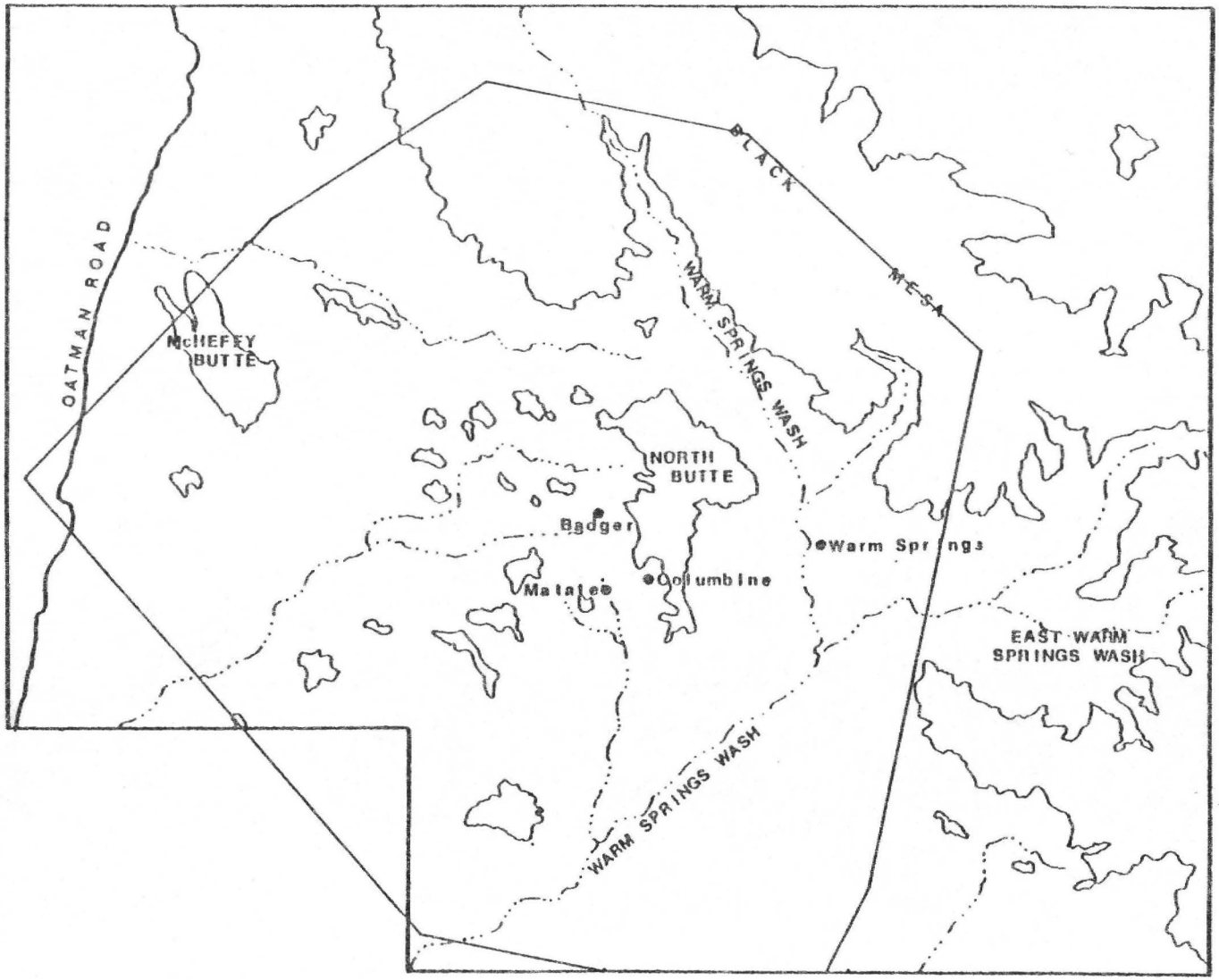
General seasonal distributions of burros are shown on Maps 2, 3, 4, 5, and 6. Area of seasonal distribution increased with decreasing temperatures. Decreased temperatures allow movement away from permanent water sources into areas containing a greater abundance of forage. Burros were found to inhabit isolated areas of mesa tops and bajadas at distances up to five miles from permanent water sources during the coolest months of the year (Table 13). In addition to cooler temperatures, an increase in precipitation also resulted in movement away from water. Maps 3, 4, and 5 show the spring, fall, and winter seasons as having the greatest areal extent of burro distribution. The months associated with these seasons, September - November, December - February, and March - May, respectively, were characterized as having either substantial rainfall and/or cool temperatures. Burros would soon move into the more isolated areas (bajadas and mesa tops) following local precipitation or after a large temperature decline, regardless of the season. Area of summer distribution was one-half or less the area of the other seasons. Although high temperatures during the summer



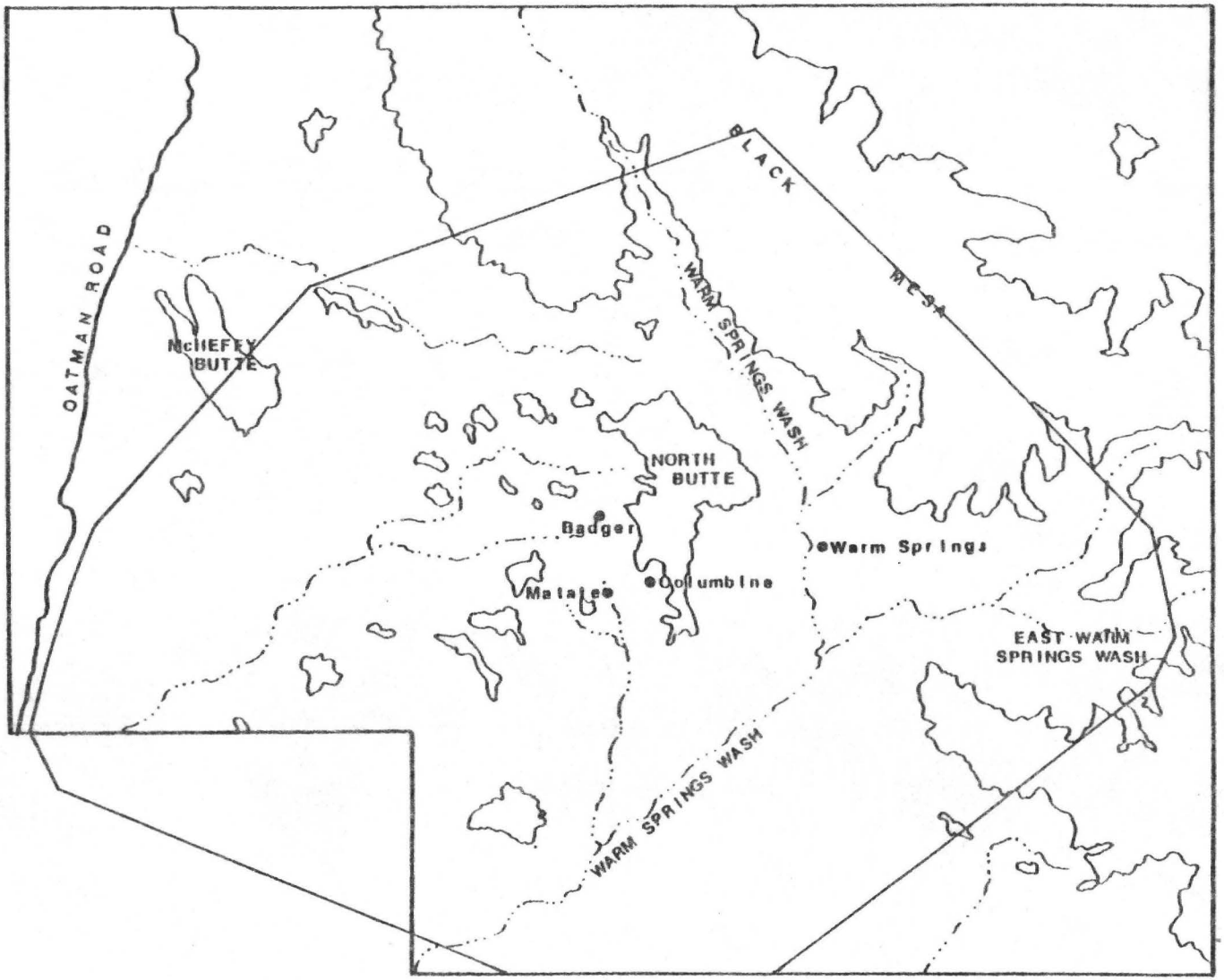
MAP 2. Summer distribution of burros (1976). Area = 23.15 sq mi



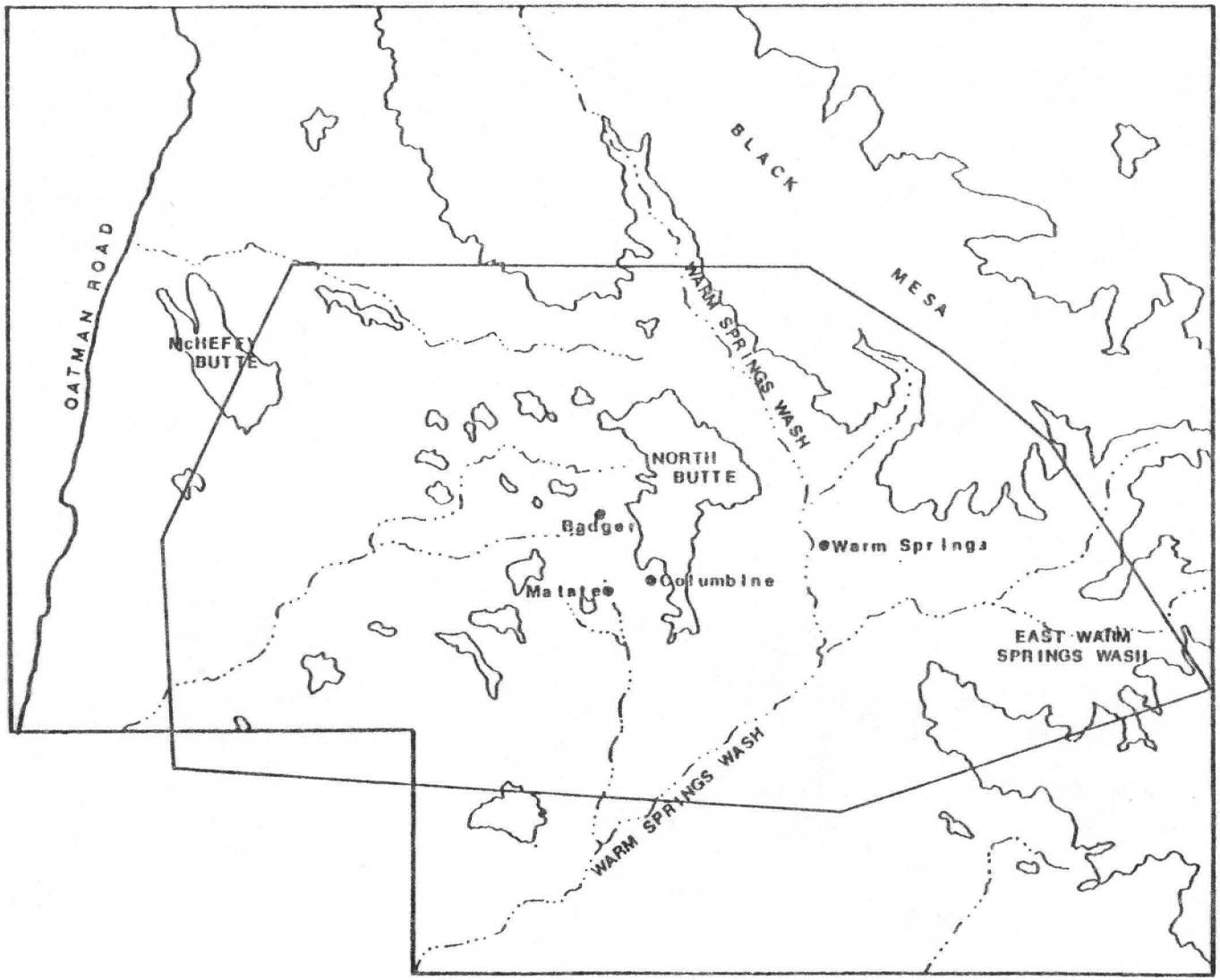
MAP 3. Fall distribution of burros (1976). Area = 46.37 sq mi



MAP 4. Winter distribution of burros ('76-'77). Area = 45.97 sq mi



MAP 5. Spring distribution of burros (1977). Area = 52.71 sq mi



MAP 6. Summer distribution of burros (1977). Area = 34.88 sq mi

TABLE 13. Seasonal percentages of burro and sheep observations at selected distances from permanent water sources. (Distance in miles)

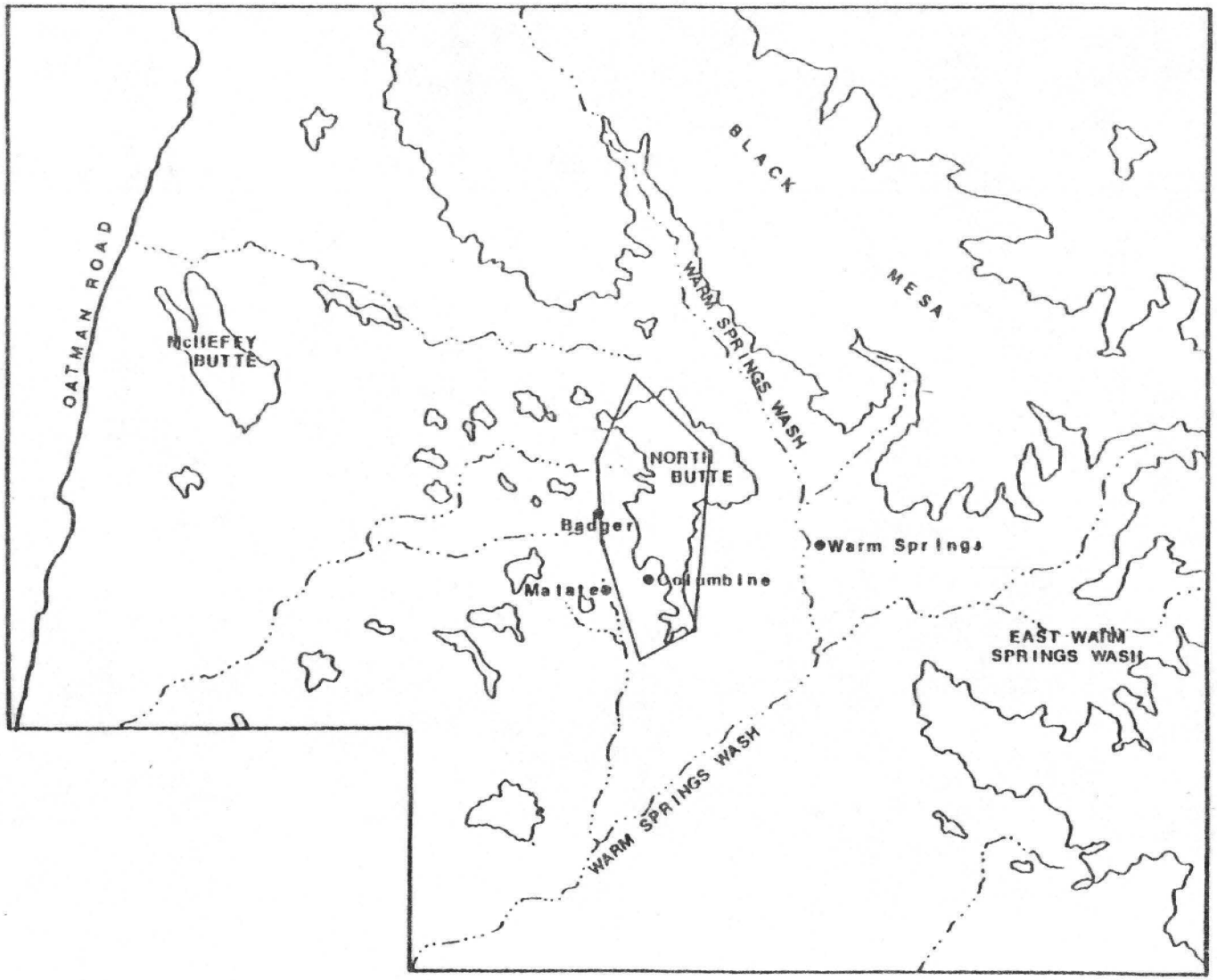
	0-½	½-1	1-1½	1½-2	2+	Total	Number of Observations
Summer '76							
Burro	58	11	9	10	12	100	312
Sheep	76	5	19	0	0	100	99
Fall '76							
Burro	21	15	9	19	36	100	277
Sheep	22	31	41	2	4	100	131
Winter '76-'77							
Burro	7	4	14	23	52	100	333
Sheep	29	34	27	2	8	100	130
Spring '77							
Burro	38	13	9	14	26	100	519
Sheep	14	48	30	8	0	100	175
Summer '77							
Burro	56	16	18	7	3	100	740
Sheep	61	32	7	0	0	100	190
Average							
Burro	36	12	12	15	25	100	2,181
Sheep	40	30	25	2	3	100	725

months restricted burro movements, burros have been observed using isolated areas (away from water) immediately following local summer rain. Movement distances were not as great at these times as was observed during the cooler months. The rapid dessication of the area due to the return of high ambient temperatures appeared to be the reason for these shorter distance movements.

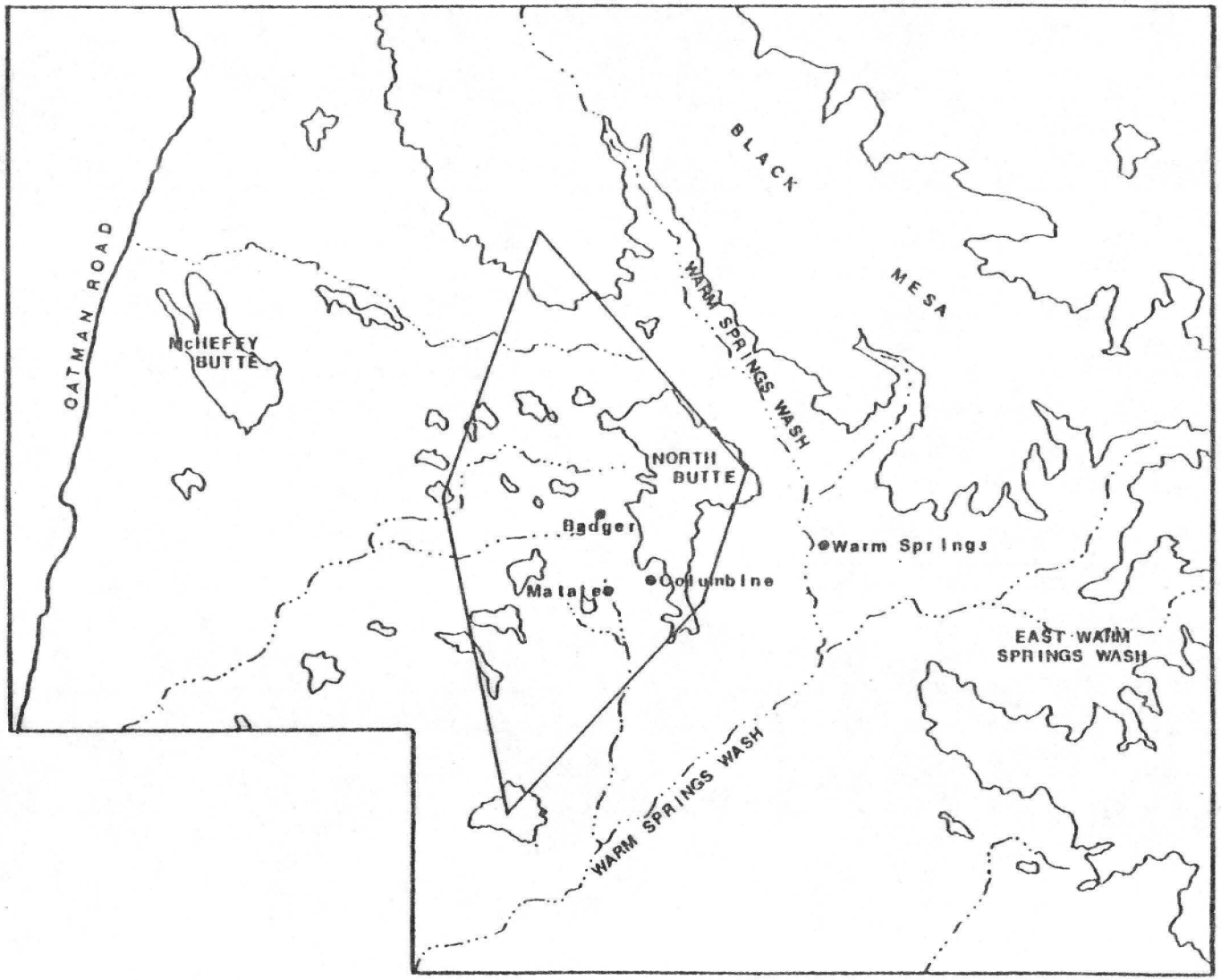
Nearly all general seasonal movements appeared to be a result of either water restrictions during summer months or forage availability during winter months.

Sheep

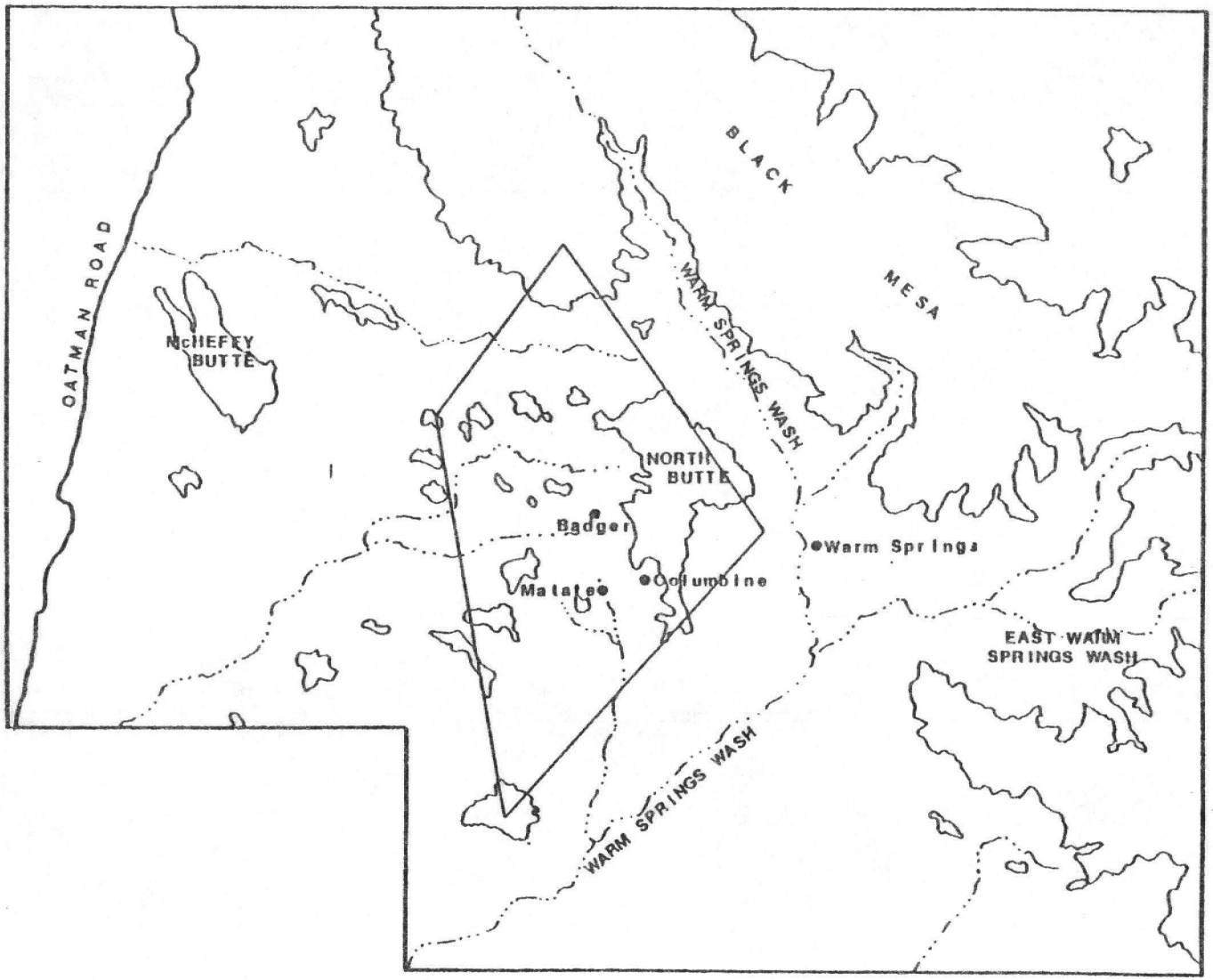
Sheep movements appeared to be more complex than those of burros. The same basic relationship between temperature and rainfall and area of seasonal distributions were apparent in sheep as observed in burros (Maps 7, 8, 9, 10, 11). In addition, at least two other factors were observed to be responsible for seasonal distributions and movements of sheep. Ram migrations into and out of the study area may have had some effect on fall distributions, as it was during this period that adult rams were observed the greatest distance from permanent water sources. Rams left the study area during the latter part of December and did not return until mid-July, with the onset of the breeding season. Observations of rams during times of migrational movement could easily account for an increase in overall area of distribution. Winter ranges for adult rams could not be determined and, therefore, were not included in seasonal distributions.



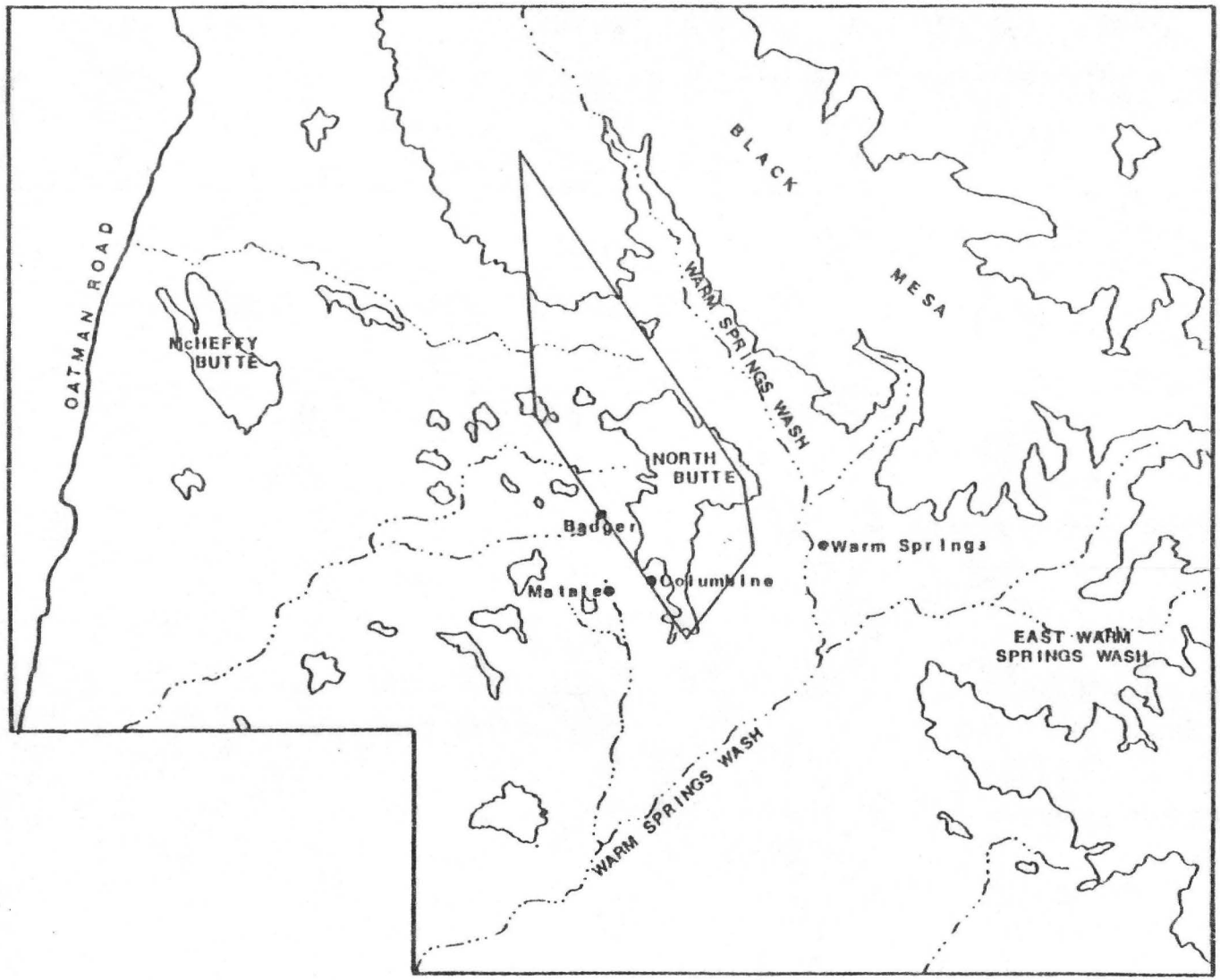
MAP 7. Summer distribution of sheep (1976). Area = 1.51 sq mi



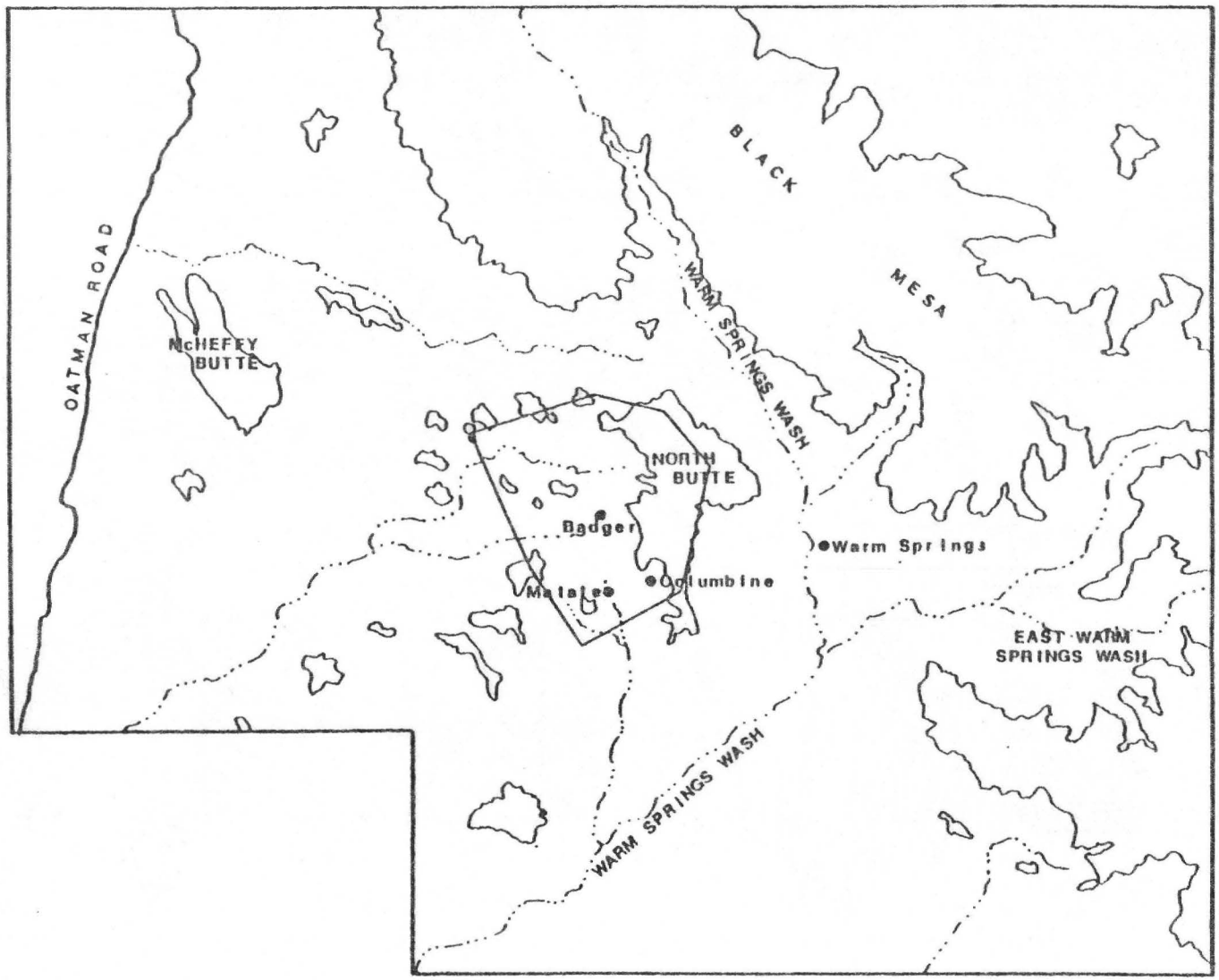
MAP 8. Fall distribution of sheep (1976). Area = 7.56 sq mi



MAP 9. Winter distribution of sheep ('76-'77). Area = 7.56 sq mi



MAP 10. Spring distribution of sheep (1977). Area = 3.42 sq mi



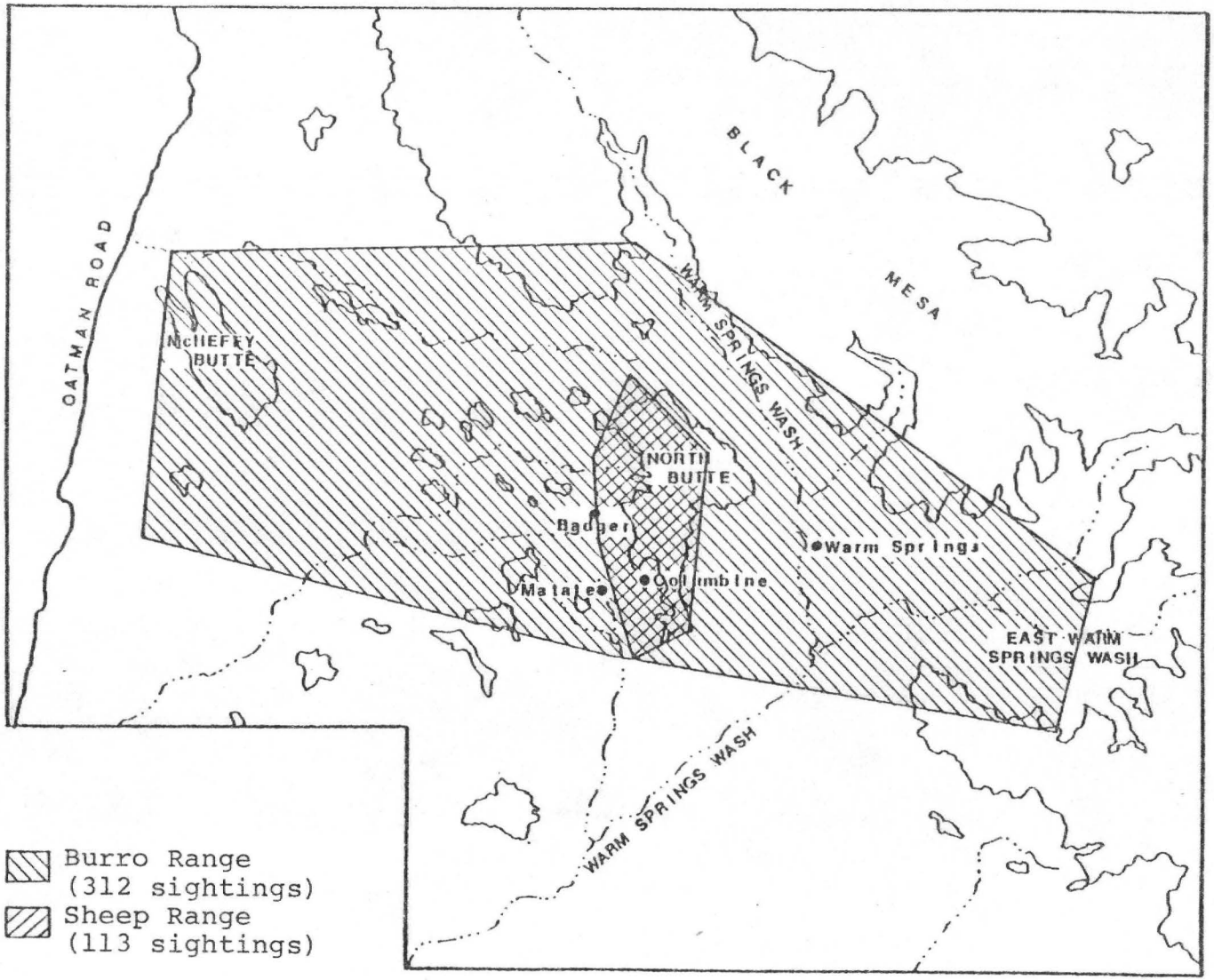
MAP 11. Summer distribution of sheep (1977). Area = 2.93 sq mi

The second factor was the adult ewe behavior during the spring months (March - May) being partly responsible for the restricted spring distribution (Map 10). During these months adult ewes were getting ready to lamb and restricted their habitat use to the most inaccessible types for a short period before, during and after lambing. This behavior restricted the area of spring distribution. Meteorological conditions would have been favorable for an increase in distributional area (as was apparent for burros) at this time, but instead spring ewe distribution was relatively small.

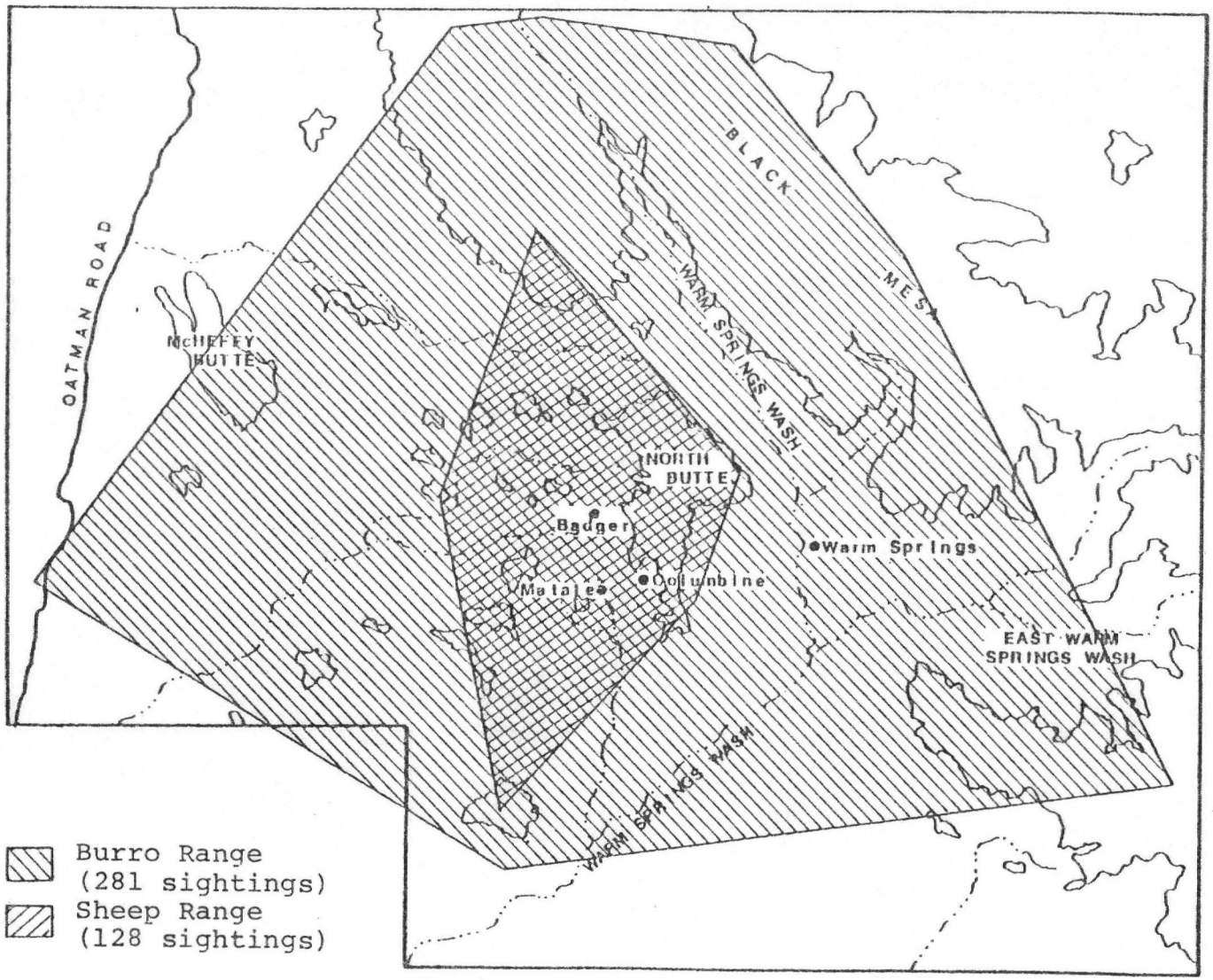
Overlap

By comparing burro-sheep distributions, it was evident that burro distributions not only exceeded but also completely surrounded sheep distributions for all seasons (Maps 12, 13, 14, 15, 16). Sheep prefer areas characterized by ruggedness and inaccessibility. Nearly all of the sheep observations, for example, were restricted to areas which were in close proximity to the rugged butte slopes found within the study area. This species characteristic suggests that sheep distributions may be more consistent and restricted than burros on a seasonal basis, regardless of meteorological conditions. Furthermore, since this preferred type of sheep habitat was comparatively isolated or disassociated from other areas of similar habitat, this complete overlap by the seasonal burro distributions was not totally unexpected.

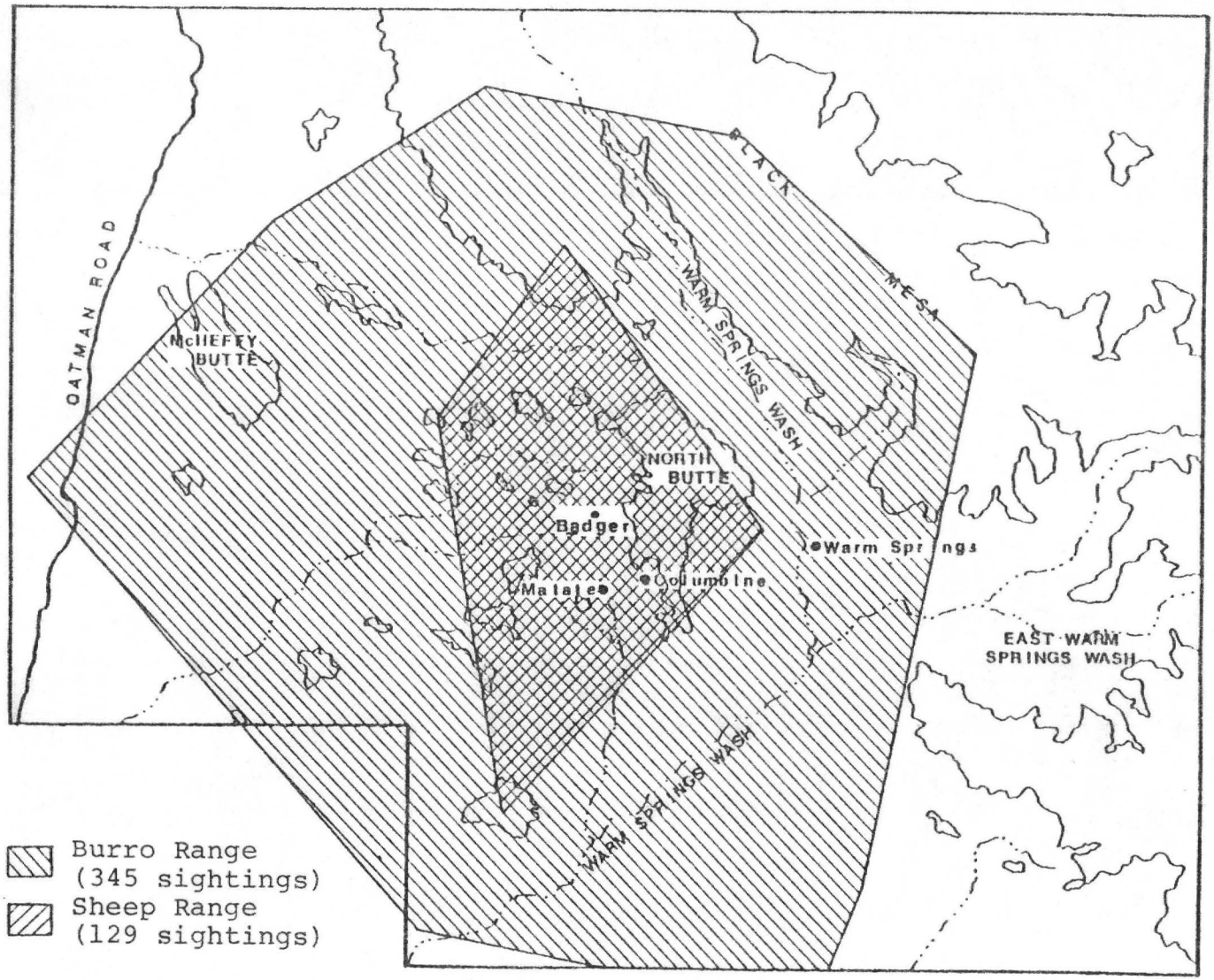
Overlap of distributions for sheep and burros shows that for every season burro distributions completely surround those



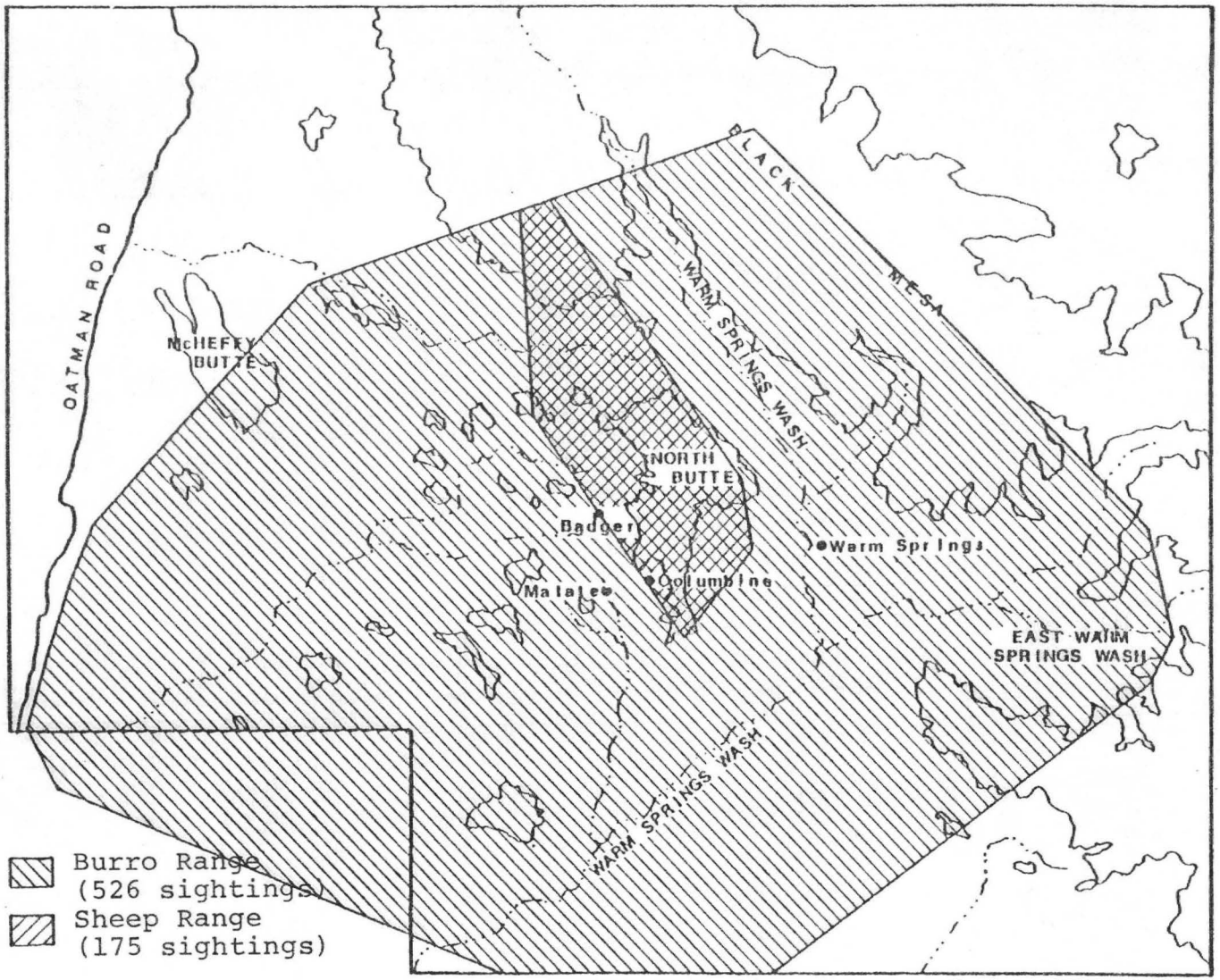
MAP 12. Summer burro-sheep distributional overlap, June-August, 1976.



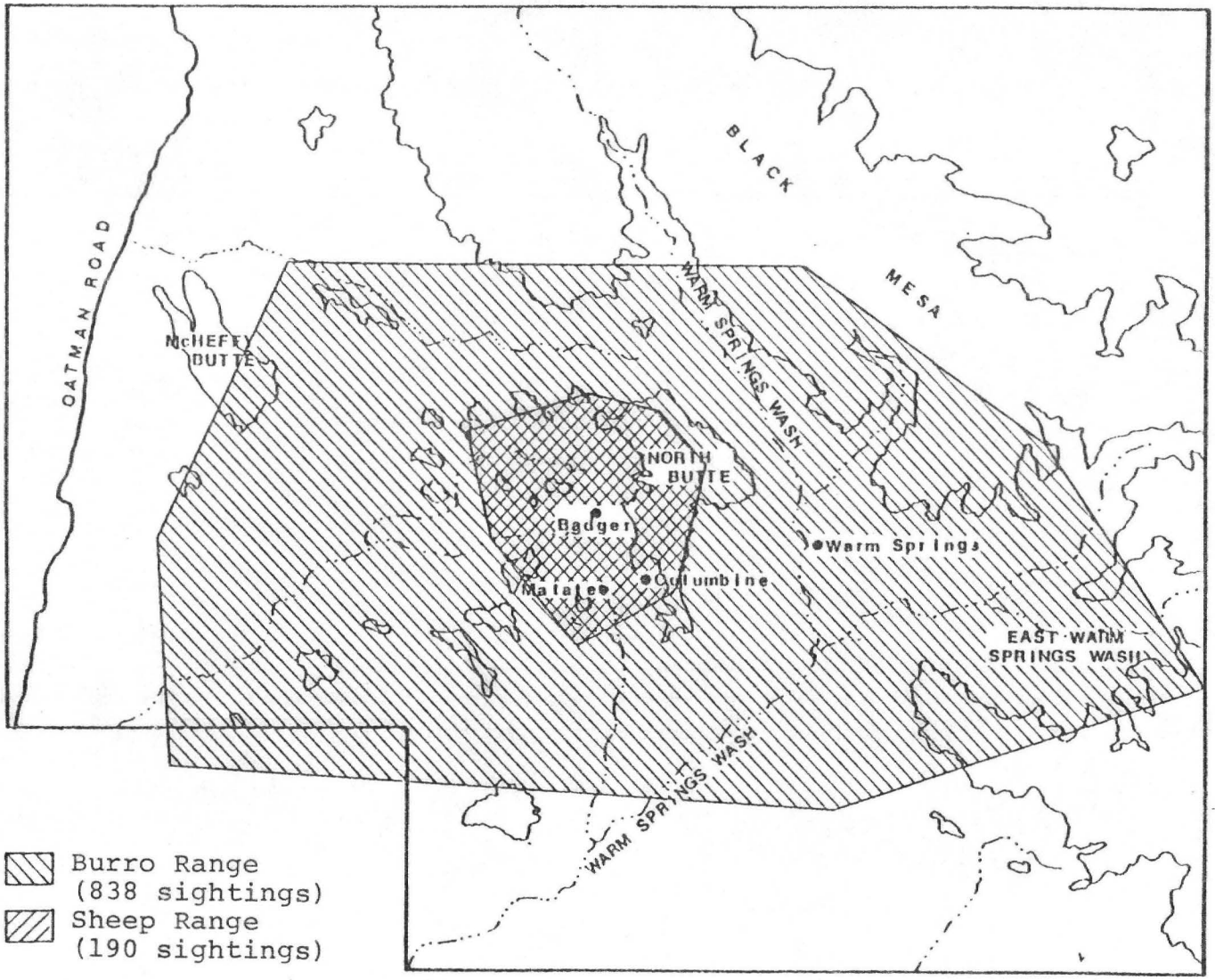
MAP 13. Fall burro-sheep distributional overlap, September-November, 1976.



MAP 14. Winter burro-sheep distributional overlap, December 1976-February 1977.



MAP 15. Spring burro-sheep distributional overlap, March-May 1977.



MAP 16. Summer burro-sheep distributional overlap, June-August 1977.

of the sheep. Burros were observed using every habitat type found within the area of sheep distributions except for butte tops where only fecal material of burros was observed, which indicated periodic use of butte tops by burros.

Daily Movements

Burros

Greatest frequency of watering during summer months occurred in evenings or after dark. They usually spent the night near the vicinity of the water source. In mid-morning (9:00 A.M. - 11:00 A.M.) burros usually moved into the outlying washes, foothills or slopes and then returned to a water source during the following evening or night. Winter watering habits were less predictable as use of the permanent water sources was minimal.

Sheep

Sheep were observed watering most often in mid-morning hours (7:00 A.M. - 10:00 A.M.) during the summer months. After watering most sheep bedded in the shade, either at the watering site or close proximity. Foraging resumed around 3:00 or 4:00 P.M., with the animals moving in the direction of the higher slopes or buttes for nighttime bedding.

Deer and cattle observations were too few to determine distributions or movements. Deer were, however, most often observed during the summer months, near permanent water sources. Most of the winter deer observations were in areas without permanent water sources, such as mesa tops.

Habitat-Meteorological Correlations

Correlations between habitat use and mean daily temperatures were statistically significant ($p = 0.05$) only for burros using foothill type habitat ($N = 118$, $R = 0.3464$ and $p<0.001$). No other significant correlations were obtained. Subjective relationships regarding burro use of mesa tops and bajadas with temperatures as well as sheep use of foothills and butte tops with temperatures were made. Burros were found to generally increase their use of foothills and decrease mesa top and bajada use during times of increased temperatures. Sheep were generally observed to increase their use of foothills and decrease their use of butte tops during periods of warmer temperatures. Explanations regarding these relationships are described in the "Habitat Preference" discussion.

All correlations regarding animal use of the various habitat types and monthly amounts of precipitation were not significant. Subjective relationships concerning increased burro use of mesa tops and bajadas and decreased foothill use with increased precipitation were observed. In addition, decreased sheep use of foothills and increased use of butte tops were observed during periods having increased precipitation amounts (explanations under "Habitat Preference" discussion).

Data concerning deer and cattle were insufficient to derive any habitat use-meteorological condition correlations.

Fecal Analysis

Burro

During the 15-month period from June 1976 to August 1977, fecal analysis revealed that burros utilized 59 plant species (Table 14, includes four unknowns). Woolly plantain (Plantago insularis), red brome (Bromus rubens), and California buckwheat (Eriogonum fasciculatum) were the three most common species (27.92, 9.74, and 8.27 percent, respectively). These combined with desert ratany (Krameria sp.)(7.05 percent) and globe mallow (Sphaeralcea sp.)(5.63 percent) comprised 58.61 percent of the total burro diet (15-month period).

Overall burro diets were found to consist of 13.63 percent grasses, 47.17 percent forbs, and 36.96 percent browse (Table 15).

Burros were found to consume forbs more than any other forage type, for all seasons studied, with the greatest amount (51.66 percent) occurring during the spring months of 1977. Apparently forbs were more actively sought than other plant types and were thought to be the biotic stimulus most responsible for initiating fall burro movement into bajada and mesa top habitat types. It was during cool and/or wet periods, when forb production was greatest and burro water stress reduced, that the predominant use of these habitats by burros was observed. Woolly plantain (27.92 percent) was, by far, the most consumed forb, with cloak fern (Notholaena parryi) second (3.82 percent) and camis (Camissonia sp.) third (3.43 percent).

Seasonal browse consumption by burros was nearly commensurate with forb consumption, browse being consumed most often during the 1977 summer months (40.92 percent) and

TABLE 14* and 14A. The average percent relative densities of plant species found in the seasonal diets of burros.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
TABLE 14:							
Woolly Plaintain (Plantago insularis)	27.92	100	23.60	28.79	29.48	29.08	28.63
Red Brome (Bromus rubens)	9.74	100	13.17	8.00	9.68	12.98	4.86
California Buckwheat (Eriogonum fasciculatum)	8.27	100	15.69	5.96	11.85	5.94	1.91
Desert Ratany (Krameria grayi)	7.05	93	4.34	8.74	3.02	5.91	13.22
Globe Mallow (Sphaeralcea sp.)	5.63	93	7.84	1.02	0.42	4.53	14.34
Cloak Fern (Notholaena parryi)	3.82	60	9.68	5.45	2.96	--	1.02
Camis (Camissonia sp.)	3.43	67	0.04	0.14	6.30	10.64	0.03
Blue Palo Verde (Cercidium floridum)	3.34	100	5.54	3.34	2.28	2.24	3.30
White Bur Sage (Ambrosia dumosa)	2.45	93	1.76	3.21	5.36	1.48	0.43
Joint Fir (Ephedra fasciculata)	2.30	67	0.40	--	2.40	3.67	5.02
Bebbia's Rush (Bebbia juncea)	2.30	47	0.14	3.79	4.27	2.88	0.43
Big Galleta (Hilaria rigida)	2.27	80	0.47	4.17	1.19	1.52	4.01
Burro Brush (Hymenoclea sp.)	1.54	67	--	3.07	2.14	0.83	1.64
Tidestromia (Tidestromia oblongifolia)	1.46	53	3.93	3.08	0.04	0.03	0.23
Ocotillo (Fouquieria splendens)	1.36	67	0.25	0.03	1.02	4.80	0.67
TOTAL	82.88		86.85	78.79	82.41	86.53	79.74

*Table 14 pertains to the 15 plant species most used.

TABLE 14 and 14A. Continued.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
TABLE 14A:							
Beavertail Cactus (Opuntia basilaris)	1.27	20	--	--	--	0.36	6.01
Bladder Stem (Eriogonum inflatum)	1.20	67	0.14	2.21	2.96	0.39	0.31
Mistletoe (Phoradendron californicum)	1.14	73	0.47	4.30	0.21	0.07	0.64
Borage (Amsinckia/Cryptantha spp.)	1.11	80	1.55	1.22	0.37	2.07	0.35
Blue Stem (Andropogon sp.)	1.10	80	0.07	2.83	0.70	0.39	1.50
Lupine (Lupinus sparsiflorus)	1.06	87	0.98	1.03	0.97	2.13	0.21
Creosote (Larrea sp.)	0.97	80	1.81	1.72	0.95	0.28	0.10
Opuntia (Opuntia sp.)	0.96	73	1.00	2.53	0.54	0.14	0.61
Chaenactis (Chaenactis sp.)	0.86	27	2.86	1.43	--	--	--
Argythamnia (Argythamnia neomexicana)	0.72	67	0.11	0.54	0.75	0.07	2.13
Deer Vetch (Lotus rigidus)	0.69	33	0.88	--	0.74	1.05	0.78
Bladder Sage (Salazaria mexicana)	0.46	33	--	--	--	0.80	1.51
Honey Mesquite (Prosopis juliflora)	0.44	67	0.40	0.73	0.65	0.21	0.19
Aster (Aster abatus)	0.36	13	--	--	1.69	0.11	--
Brittle Bush (Encelia farinosa)	0.30	7	--	--	1.50	--	--
Desert Lavender (Hyptis emoryi)	0.26	67	0.43	0.04	--	0.10	0.73
Bedstraw (Galium stellatum)	0.26	20	--	--	--	0.47	0.84
Unknown G	0.24	20	--	--	0.74	0.46	--
Arrowweed (Tessaria sericea)	0.22	27	0.60	--	0.49	--	--
Golden Eye (Viguiera deltoidea)	0.21	40	--	0.38	0.03	0.32	0.32
Deer Vetch (Lotus salsuginosus)	0.21	20	--	0.53	--	0.54	--

TABLE 14A. Continued.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
Polypogon (Polypogon interruptus)	0.21	20	--	--	0.04	--	0.99
Black Brush (Coleogyne ramosissima)	0.21	20	--	--	0.97	--	0.10
Unknown C	0.18	33	--	0.19	0.62	0.07	--
Aster (Machaeranthera tortifolia)	0.18	7	--	--	0.89	--	--
Brickellia (Brickellia coulteri)	0.17	27	0.11	0.19	0.49	--	0.07
Pepper Grass (Lepidium lasiocarpum)	0.16	27	0.19	--	--	0.32	0.29
Jackass Clover (Wislizenia refracta)	0.15	13	--	0.31	--	--	0.45
Rock Nettle (Eucnide urens)	0.01	7	0.04	--	--	--	--
Three Awn (Aristida sp.)	0.13	13	--	--	0.11	0.55	--
Fluff Grass (Erioneuron pulchellus)	0.13	7	--	--	--	--	0.66
Unknown F	0.12	13	--	--	0.40	0.18	--
Catclaw (Acacia greggii)	0.09	13	--	--	--	0.14	0.30
Bear Grass (Nolina bigelovii)	0.09	13	--	--	0.03	--	0.42
Coldenia (Coldenia canescens)	0.05	7	--	--	--	--	0.23
Bowlesia (Bowlesia incana)	0.04	13	--	0.06	--	--	0.14
Tobacco (Nicotiana trigonophylla)	0.03	13	0.04	0.12	--	--	--
Needle and Thread (Stipa comata)	0.03	7	--	--	--	--	0.14
Sandpaper Plant (Perityle emoryi)	0.03	7	--	--	0.16	--	--
Bladder Pod (Lesquerella arizonica)	0.01	7	--	--	0.10	--	--
Unknown A	0.01	7	0.04	--	--	--	--
Trixis (Trixis californica)	0.01	7	--	0.06	--	--	--
Triangle Bur Sage (Ambrosia deltoidea)	0.01	7	--	--	--	--	0.04
Milk Vetch (Astragalus wootoni)	0.01	7	--	--	--	--	0.04

TABLE 15. Percentages of the general plant types found in burro, sheep, and cattle seasonal diets.

		Plant Type				
		Grasses	Forbs	Browse	Unknowns	Total
Summer 1976	Burro	13.76	47.90	34.30	4.04	100.00
	Bighorn Sheep	5.29	45.22	49.49	-	100.00
	Cattle	-	-	-	-	-
Fall 1976	Burro	15.01	42.33	39.03	3.63	100.00
	Bighorn Sheep	7.66	23.28	67.11	1.95	100.00
	Cattle	15.60	47.66	36.31	0.43	100.00
Winter 1976-77	Burro	11.73	47.07	38.90	2.30	100.00
	Bighorn Sheep	6.51	62.06	31.06	0.37	100.00
	Cattle	15.88	64.21	19.91	-	100.00
Spring 1977	Burro	15.47	51.66	31.66	1.21	100.00
	Bighorn Sheep	8.55	45.81	45.25	0.39	100.00
	Cattle	7.30	56.92	35.67	0.11	100.00
Summer 1977	Burro	12.18	46.90	40.92	-	100.00
	Bighorn Sheep	9.26	40.70	49.93	0.11	100.00
	Cattle	2.44	42.67	54.89	-	100.00
Average Overall June '76 - August '77	Burro	13.63	47.17	36.96	2.24	100.00
	Bighorn Sheep	7.61	43.29	48.50	0.60	100.00
	Cattle*	10.30	52.86	36.70	0.14	100.00
	Deer**	-	2.00	96.00	2.00	100.00

* Cattle dates are from September 1976-August 1977.
** Deer dates are June and July 1977 only.

least during the 1977 spring months (31.66 percent)(Table 16). California buckwheat and desert ratany were the browse species most consumed (8.27 and 7.05 percent, respectively). Browse consumption related to forb consumption in that as forb use decreased, from one season to another, browse use increased, and vice versa.

Seasonal grass consumption by burros was consistently low, ranging from a low of 11.73 percent during winter months to a high of only 15.47 percent during the spring months. Apparently grass species in the area were not a suitable substitute for either browse or forbs.

Increased water requirements during the summer months resulted in increased densities of burros in areas around permanent water sources which, when combined with other animal use, then resulted in the overutilization of available forage. Available forb and browse were quickly reduced in these areas with the onset of warmer weather. Considerable damage to the browse species was apparent. Ocotillo and bur-sage in areas adjacent to permanent water sources showed signs of extreme overuse. Although overutilization ranged from heavy to light with increasing distance from the water source, severe hedging of ocotillo was still observed at distances greater than three miles from water sources. A similar relationship between browse utilization and distance from available water was also observed by Hanley and Brady (1977) while studying feral burros in the Havasu Resource Area, lower Colorado River Valley, California-Arizona.

TABLE 16* and 16A. The average percent relative densities of the plant species found in the seasonal diets of sheep.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
TABLE 16							
Globe Mallow (Sphaeralcea sp.)	15.33	100	20.89	11.23	7.98	16.49	21.93
California Buckwheat (Eriogonum fasciculatum)	11.73	100	3.70	14.86	15.51	15.07	6.82
Woolly Plantain (Plantago insularis)	11.63	100	3.12	5.63	19.71	14.13	12.76
Bebbia's Rush (Bebbia juncea)	6.53	93	2.87	16.49	3.43	4.16	4.46
Golden Eye (Viguiera deltoidea)	5.36	93	3.26	7.83	2.02	3.30	9.69
Desert Lavender (Hyptis emoryi)	5.33	79	14.48	10.17	0.03	2.49	2.53
White Bur Sage (Ambrosia dumosa)	4.21	86	3.59	6.47	3.07	7.45	0.30
Desert Ratany (Krameria grayi)	4.19	100	4.87	3.53	1.72	2.71	8.34
Red Brome (Bromus rubens)	4.14	79	5.00	3.32	4.88	7.69	0.11
Blue Palo Verde (Cercidium floridum)	4.06	100	12.44	1.94	1.04	4.18	3.48
Lupine (Lupinus sparsiflorus)	3.51	71	4.80	0.14	10.97	1.19	0.90
Bladder Stem (Eriogonum inflatum)	2.83	71	--	1.07	6.32	4.63	1.20
Borage (Amsinkia/Cryptantha spp.)	2.61	57	--	0.37	9.66	2.11	0.04
Stick Leaf (Mentzelia sp.)	2.42	50	8.32	--	0.04	3.73	1.98
Burro Brush (Hymenoclea sp.)	1.49	71	--	3.74	1.28	1.17	0.85
TOTAL	85.37		87.29	86.69	87.66	90.50	75.39

*Table 16 pertains to the 15 plant species most used.

TABLE 16 and 16A. Continued.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
TABLE 16A:							
Blue Stem (Andropogon sp.)	1.44	86	0.23	2.59	0.88	0.39	2.72
Catclaw (Acacia greggii)	1.44	29	--	--	--	0.84	5.89
Big Galleta (Hilaria rigida)	1.32	71	0.06	1.75	0.74	0.42	3.23
Mistletoe (Phoradendron californicum)	0.99	50	--	1.29	0.25	--	3.06
Cloak Fern (Notholaena parryi)	0.97	43	2.66	--	2.06	--	0.04
Camissonia (Camissonia sp.)	0.75	57	0.04	0.03	1.69	1.45	0.30
Argythamnia (Argythamnia neomexicana)	0.71	50	--	1.09	0.37	--	1.84
Polypogon (Polypogon interruptus)	0.63	7	--	--	--	--	2.93
Sandpaper Plant (Perityle emoryi)	0.59	43	--	2.19	0.37	0.17	--
Honey Mesquite (Prosopis juliflora)	0.50	29	2.93	0.26	--	--	0.15
Bowlesia (Bowlesia incana)	0.47	50	0.12	1.30	0.29	0.53	--
Aster (Machaeranthera tortifolia)	0.44	21	3.00	--	--	--	0.03
Deer Vetch (Lotus rigidus)	0.42	50	1.25	0.07	0.60	0.45	--
Black Brush (Coleogyne ramosissima)	0.41	14	--	--	1.89	--	--
Bedstraw (Galium stellatum)	0.31	21	--	--	--	1.39	0.07
Shrub Oak (Quercus sp.)	0.28	21	--	--	0.62	0.68	--
Creosote (Larrea sp.)	0.25	21	1.31	0.24	0.03	--	--
Tidestromia (Tidestromia oblongifolia)	0.24	35	--	0.37	--	--	0.76
Chaenactis (Chaenactis sp.)	0.23	21	--	0.51	0.55	--	--
Joint Fir (Ephedra fasciculata)	0.23	29	--	--	0.07	0.87	0.11
Monoptilon (Monoptilon bellioides)	0.22	29	--	0.63	--	--	0.40
Pepper Grass (Lepidium lasiocarpum)	0.20	14	--	--	0.60	--	0.33

TABLE 16A. Continued

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
Bladder Sage (Salazaria mexicana)	0.15	21	--	--	--	0.47	0.22
Rock Nettle (Eucnide urens)	0.14	14	--	--	0.04	0.60	--
Ironwood (Olneya tesota)	0.13	21	--	--	--	0.03	0.57
Milk Vetch (Astragalus wootoni)	0.13	7	--	--	--	--	0.60
Bear Grass (Nolina bigelovii)	0.11	21	--	--	0.33	0.07	0.12
Unknown E	0.10	7	--	0.48	--	--	--
Deer Vetch (Lotus salsuginosus)	0.09	14	--	--	0.33	0.07	--
Bladder Pod (Lesquerella arizonica)	0.09	14	--	--	0.40	--	--
Brickellia (Brickellia coulteri)	0.09	35	0.06	0.22	--	0.07	0.11
Unknown H	0.08	7	--	--	--	0.39	--
Fishhook (Mammillaria sp.)	0.08	14	--	--	--	--	0.36
Spike Rush (Eleocharis sp.)	0.05	14	--	--	--	--	0.25
Blue Dicks (Dichelostemma pulchellum)	0.05	14	--	--	0.02	0.21	--
Water Leaf (Hydrophyllaceae)	0.03	14	--	0.04	0.11	--	--
Unknown A	0.03	14	--	0.11	0.04	--	--
Unknown I	0.02	7	--	--	--	--	0.11
Beavertail Cactus (Opuntia basilaris)	0.02	14	--	--	--	--	0.11
Figwort (Mohavea breviflora)	0.02	7	--	--	--	--	0.07
Tobacco (Nicotiana trigonophylla)	0.01	7	--	--	0.04	--	--
Cruciferae	0.01	7	--	0.04	--	--	--
Ocotillo (Fouquieria splendens)	0.01	7	--	--	--	0.04	--
Bermuda (Cynodon dactylon)	0.01	7	--	--	--	0.03	--

Seegmiller (1977) and Woodward (1976) both found overall higher percentages in browse consumption by burros (39.7 and 61.0 percent, respectively) than was found in this study (36.96 percent). Reasons for these differences were probably due to differences in plant species composition between the study areas.

Sheep

Sheep used a total of 59 (4 unknowns included) different plant species. Highest consumption values were for globe mallow (15.33 percent), California buckwheat (11.73 percent) and woolly plantain (11.63 percent) (Table 16). California buckwheat and woolly plantain were consumed by sheep most during the winter and spring months (which corresponded to their growing season), while globe mallow was consumed heavily during all seasons (except winter), with primary consumption during the dry summer months, which also corresponds with its growing season (Table 16).

Sheep consumed 7.61 percent grasses, 43.29 percent forbs, 48.50 percent browse and 0.6 percent unknowns (Table 15). Browse was consumed primarily during the summer and fall months, while forbs received heaviest use during the winter and spring months. Use of grasses was low throughout each season. As with burros, sheep seemed to prefer forbs whenever available (winter and spring months) and substituted browse when forbs were unavailable (summer and fall months). Grasses did not appear to be preferred over other forage types.

Forage data in this study were similar to those reported

by Seegmiller (1977) of 7.6 percent grasses, 31 percent forbs, 54 percent browse, and 7.4 percent unknowns. Both data sets differ from those reported by McMichaels (1964) of 33 percent grasses, 28 percent forbs, and 39 percent shrubs. McMichaels' data were from the analysis of eight sheep stomachs, all of which were collected during the month of December 1964.

Cattle

A total of 40 plant species, including two unknowns, were found to be consumed by cattle. No data were obtained for the months of June, July and August 1976 (Table 17). The three plant species most consumed by cattle were globe mallow (23.90 percent), California buckwheat (10.45 percent), and red brome (10.10 percent). Globe mallow received heaviest consumption during the summer (June - August 1977), while California buckwheat and red brome were taken primarily during the winter (December 1976 - February 1977).

Cattle consumed 10.30 percent grasses, 52.86 percent forbs, and 36.70 percent browse. Forbs were the primary component in the diet during every season except summer (June - August 1977). Grasses were used mostly during the winter and fall months (Table 15). In the Black Mountains cattle appear to prefer forbs when available and secondarily use browse. Grasses were probably used when available but even then total values did not exceed other forage types (Table 15).

Deer

Fecal samples of deer were obtained for only two months (June and July 1977). The limited data shows desert ratany

TABLE 17* and 17A. The average percent relative densities of the plant species found in the seasonal diets of cattle.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
TABLE 17:							
Globe Mallow (Sphaeralcea sp.)	23.90	100	--	17.38	18.17	26.62	33.41
Woolly Plantain (Plantago insularis)	10.45	100	--	9.59	14.75	13.67	3.78
Red Brome (Bromus rubens)	10.10	92	--	15.58	15.88	7.22	1.72
Joint Fir (Ephedra fasciculata)	9.63	100	--	13.10	9.18	9.36	6.90
Camis (Camissonia sp.)	7.41	75	--	10.88	7.65	7.23	3.89
Blue Palo Verde (Cercidium floridum)	5.49	83	--	3.07	1.19	9.50	8.21
Bladder Sage (Salazaria mexicana)	5.27	92	--	12.38	1.67	4.14	2.91
Lupine (Lupinus sparsiflorus)	4.16	58	--	5.90	7.21	3.51	--
Catclaw (Acacia greggii)	4.10	33	--	--	--	1.71	14.69
Desert Ratany (Krameria grayi)	3.62	50	--	0.04	--	4.61	9.84
California Buckwheat (Eriogonum fasciculatum)	2.91	92	--	1.88	4.64	3.31	1.83
White Bur Sage (Ambrosia dumosa)	1.92	75	--	5.32	1.45	0.11	0.79
Bladder Stem (Eriogonum inflatum)	1.90	100	--	2.60	2.71	1.42	0.87
Borage (Amsinkia/Cryptantha spp.)	1.64	67	--	1.56	2.52	2.45	0.04
Mistletoe (Phoradendron californicum)	1.24	67	--	0.26	0.12	0.85	3.75
TOTAL	93.74			99.54	87.14	95.71	92.63

*Table 17 pertains to the 15 plant species most used.

TABLE 17 and 17A. Continued

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
TABLE 17A:							
Deer Vetch (Lotus rigidus)	1.22	33	--	--	3.91	0.97	--
Chaenactis (Chaenactis sp.)	1.20	33	--	2.97	1.14	0.71	--
Aster (Machaeranthera tortifolia)	1.06	8	--	--	4.24	--	--
Schrub Oak (Quercus sp.)	1.05	33	--	--	0.20	0.97	3.04
Burro Brush (Hymenoclea sp.)	0.66	50	--	0.04	0.85	0.11	1.64
Deer Vetch (Lotus salsuginosus)	0.25	17	--	--	0.91	--	0.11
Cloak Fern (Notholaena parryi)	0.23	8	--	--	0.91	--	--
Honey Mesquite (Prosopis juliflora)	0.22	17	--	--	--	0.04	0.84
Big Galleta (Hilaria rigida)	0.20	25	--	--	--	0.07	0.72
Golden Eye (Viguiera deltoidea)	0.20	33	--	--	--	0.15	0.64
Ocotillo (Fouquieria splendens)	0.13	8	--	--	--	0.53	--
Pepper Grass (Lepidium lasiocarpum)	0.12	25	--	--	--	0.23	0.26
Unknown F	0.07	33	--	0.24	--	0.04	--
Coldenia (Coldenia canescens)	0.06	8	--	--	--	--	0.23
Bebbia's Rush (Bebbia juncea)	0.06	25	--	--	0.03	0.23	--
Argythamnia (Argythamnia neomexicana)	0.05	17	--	--	--	0.07	0.11
Brickellia (Brickellia coulteri)	0.03	17	--	0.14	--	--	--
Desert Lavender (Hyptis emoryi)	0.03	17	--	0.03	0.09	--	--
Tidestromia (Tidestromia oblongifolia)	0.03	8	--	0.11	--	--	--
Bladder Pod (Lesquerella arizonica)	0.02	17	--	0.07	--	--	--
Unknown G	0.02	8	--	0.07	--	--	--

TABLE 17 and 17A. - Continued.

Plant Species	Ave. % Relative Density	% Frequency	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977
Alfalfa (Medicago sativa)	0.02	8	--	--	--	0.07	--
Opuntia (Opuntia sp.)	0.02	17	--	0.04	--	0.04	--
Bowlesia (Bowlesia incana)	0.01	8	--	--	--	--	0.04
Mustard (Cruciferae)	0.01	8	--	--	0.03	--	--

(34.39 percent), mistletoe (Phoradendron californicum) (27.70 percent), and blue palo verde (Cercidium floridum) (11.81 percent) as being the three species most commonly taken out of a total of 18. These three shrub species along with California buckwheat represent 85.4 percent of the total diet (Table 18). Deer consumed 96.0 percent browse, 2.0 percent forbs, zero percent grasses and 20 percent unknowns. Deer were primarily browsers, at least for the summer months (June and July 1977) (Table 19).

Comparisons

Of the 59 species of plants utilized by burros, 45 (76 percent) were also consumed by sheep, 37 (63 percent) by cattle, and 14 (24 percent) by deer. Woolly plantain, globe mallow, California buckwheat, and red brome were the species most heavily shared by these four large herbivores (Table 20). Woolly plantain, California buckwheat, and red brome were shared most often by burros, sheep, and cattle during the winter (December 1976 - February 1977) and/or spring months (March - May 1977), while globe mallow and desert ratany were most often shared during the summer months (June - August 1977 (Table 21).

In general, deer and sheep found in the study area tended to be browsers while burro and cattle tended to prefer forbs. Sheep also show a tendency to utilize large amounts of forbs (43.3 percent) when available. Grasses were the least utilized of the forage types by all four species; probably because grasses are scarce in the study area.

TABLE 18. Average percent relative density of the plant species found in deer diets.

Plant Species	Ave. % Relative Density June 1977 & July 1977 Only
Desert Ratany (*Krameria grayi*)	34.39
Mistletoe (*Phoradendron californicum*)	27.70
Blue Palo Verde (*Cercidium floridum*)	11.81
California Buckwheat (*Eriogonum fasciculatum*)	11.51
Smoke Tree (*Dalea* sp.)	2.83
Bladder Stem (*Eriogonum inflatum*)	2.55
Unknown J	2.13
Ironwood (*Olneya tesota*)	1.98
Woolly Plantain (*Plantago insularis*)	1.49
Bebbia's Rush (*Bebbia juncea*)	0.83
Catclaw (*Acacia greggii*)	0.72
Honey Mesquite (*Prosopis juliflora*)	0.72
Argythamnia (*Argythamnia neomexicana*)	0.50
Pepper Grass (*Lepidium lasiocarpum*)	0.27
Penstemon (*Penstemon antirrhinoides*)	0.22
Desert Lavender (*Hyptis emoryi*)	0.16
Globe Mallow (*Sphaeralcea* sp.)	0.11
Aster (*Machaeranthera tortifolia*)	0.05

TABLE 19. Average percent of the general plant types found in deer diets.

Plant Type	Ave. % Use June 1977 & July 1977 Only
Grasses	0.00
Forbs	2.00
Browse	96.00
Unknowns,	2.00
TOTAL	100.00

TABLE 20. Overall comparison of the five plant species most heavily shared by burros, sheep, cattle, and deer.

Plant Species	Average % Relative Density*			
	Burro	Sheep	Cattle	Deer
Woolly Plantain (*Plantago insularis*)	27.92	11.63	10.45	1.49
Globe Mallow (*Sphaeralcea* sp.)	5.63	15.33	23.90	0.11
California Buckwheat (*Eriogonum fasciculatum*)	8.27	11.73	2.91	11.51
Red Brome (*Bromus rubens*)	9.74	4.14	10.10	--
Desert Ratany (*Krameria grayi*)	7.05	4.19	3.62	34.39
TOTAL	58.61	47.02	50.98	47.50

*Average of all seasonal data obtained.

TABLE 21. Seasonal comparison of the five plant species most shared by burros, sheep, and cattle.

Ave. % of Seasonal Relative Densities	Summer 1976	Fall 1976	Winter 1976-77	Spring 1977	Summer 1977	Total Time
Woolly Plantain (*Plantago insularis*)						
Burro	23.60	28.79	29.48	29.08	28.63	27.92
Bighorn Sheep	3.12	5.63	19.71	14.13	12.76	11.63
Cattle	--	9.59	14.75	13.67	3.78	10.45
Globe Mallow (*Sphaeralcea* sp.)						
Burro	7.84	1.02	0.42	4.53	14.34	5.63
Bighorn Sheep	20.89	11.23	7.98	16.49	21.93	15.33
Cattle	--	17.38	18.17	26.62	33.41	23.90
California Buckwheat (*Eriogonum fasciculatum*)						
Burro	15.69	5.96	11.85	5.94	1.91	8.27
Bighorn Sheep	3.70	14.86	15.51	15.07	6.82	11.73
Cattle	--	1.88	4.64	3.31	1.83	2.91
Red Brome (*Bromus rubens*)						
Burro	13.17	8.00	9.68	12.98	4.86	9.74
Bighorn Sheep	5.00	3.32	4.88	7.69	0.11	4.14
Cattle	--	15.58	15.88	7.22	1.72	10.10
Desert Ratany (*Krameria grayi*)						
Burro	4.34	8.74	3.02	5.91	13.22	7.05
Bighorn Sheep	4.87	3.53	1.72	2.71	8.34	4.19
Cattle	--	0.04	--	4.61	9.84	3.62

Water Hole Observation

Of the permanent water sources monitored via ground observations (see Map 1), burros were observed utilizing waters A, B, C, D, and E; sheep were observed utilizing B, C, and D; and deer were observed using A and D. The only combination of these vertebrates simultaneously using the same water sites were sheep and burros at B and D, and deer and burros at A. The combination involving burros and sheep was observed in two instances. On 22 July 1976, 26 sheep were observed at water hole B (Plate 4). Sheep not drinking were bedded in shaded areas approximately 40 yards from the water source. Five sheep were at the water hole when three adult burros approached. The sheep near the water hole casually moved to the bedding area as the burros reached a distance of approximately 30 yards. While the burros drank (approximately 15 minutes) the sheep continued to remain in the vicinity of the bedding area but did not appear alarmed by the presence of the burros other than occasionally glancing in the burros' direction. After the burros had completed watering, they moved approximately 25 yards from the water source and stood in the shade of a mesquite tree for approximately 1.5 hours. During this time, the sheep intermittently returned to the water source to drink and browse, showing only initial signs of nervousness which was followed by a complete lack of interest in the burros. In July 1977 burros and sheep were again observed in close proximity at water source D. Both species obtained water but at slightly different times, both species remained a distance of approximately

PLATE 4: Observation of feral burros and desert bighorn sheep simultaneously using water source B (Badger Seep).
Photograph by M. T. Walker.

75 yards from each other, and neither showed interest or concern for the other.

Deer have been observed utilizing water in the presence of burros at Warm Springs (source A) during the summer months. Deer and burros were always observed at greater distances from each other (greater than 100 yards) than were sheep and burros and showed no concern toward each other.

Direct competition or aggressive behavior between any combination of the four species was never observed during this study. These types of behavior could, however, develop provided that conditions of extreme aridity were present.

Burros were observed using Warm Springs most often, Matate Seep secondly (except for winter months), and Badger Springs thirdly; whereas sheep were observed using Badger Springs most, Columbine secondly, and Matate thirdly. Deer were observed only using Warm Springs.

Seasonal percentages of burro and sheep observations at selected distances from permanent water sources are illustrated in Table 13. Burros, sheep, and deer were most frequently observed at or very near (0.0-0.5 mi) permanent water sources during the summer months. Animal observations were at greater distances during cooler months. Sheep were seldom observed at distances greater than 1.5 miles from water regardless of season, while burros were often observed at distances of two plus miles during the fall, winter and spring months.

Water Source Fouling

Evidence of water fouling was subjectively observed at source D. During the period from approximately 1 August to 1 September 1976 water source D was observed containing large quantities of algae, burro feces, and was malodorous (Plate 5). Prior to fouling, water hole D received very high burro use. As water quality decreased so did burro use. Animal species other than burros were never observed using this water source prior to or during the period of degraded water quality (tracks of either sheep and/or deer were, however, observed prior to fouling). After clearing in September 1976, this water source remained unadulterated and never again showed signs of fouling even though comparable burro use and similar ambient temperatures were observed during the summer months of 1977. Sheep were observed utilizing this water source throughout the 1977 summer months while unadulterated. Whether or not the 1977 summer appearance of sheep at water source D was a factor of water quality could not be determined. Fouling of water sources other than water source D was not observed. Possible reasons for this single instance of water degradation may be explained in terms of water flow rates, pooled water volumes, animal use and/or temperature (see "Water Analysis" discussion).

Water Analysis

Water analysis data are listed in Table 22. Testing was initiated in May 1977, and continued through the summer months. Data obtained for these months indicate that of the

PLATE 5: Observation of water source D (Matate Seep) containing large quantities of algae, burro feces and other debris during the period from approximately 1 August to 1 September 1976. Photograph by M. T. Walker.

TABLE 22. Monthly comparison of the water analysis data obtained for water sources B, C, and D.

	MATATE (D)				BADGER (B)				COLUMBINE (C)			
	5/25/77	6/25/77	7/31/77	8/77	5/25/77	6/25/77	7/31/77	8/77	5/25/77	6/25/77	7/31/77	8/77
Free Acidity												
High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Acidity												
High (gr/gal)	0.00	0.66	0.66	0.67	0.00	0.33	1.00	1.30	0.00	1.00	1.00	1.00
Low (gr/gal)	0.00	0.53	1.07	1.07	0.00	0.53	2.00	2.40	0.00	1.60	1.80	2.00
Alkalinity												
High (gr/gal)	1.00	9.00	9.00	9.00	1.00	9.00	12.00	12.80	15.00	16.00	14.00	14.00
Low (gr/gal)	0.60	8.00	8.40	8.30	0.80	7.60	10.80	11.00	12.80	16.00	13.20	13.60
Carbon Dioxide (mg/l)	17.00	15.00	10.00	10.40	10.00	10.00	20.00	20.00	40.00	35.00	25.00	27.00
Total Hardness (gr/gal)	8.00	9.00	9.00	9.00	7.00	9.00	11.00	11.00	16.00	16.00	14.00	15.00
Dissolved Oxygen (mg/l)	11.00	10.00	11.00	11.00	13.00	7.00	3.20	3.40	10.00	8.00	3.80	3.90
Percent Saturated* (%)	140	127	140	140	165	89	41	43	127	102	48	50
pH	9.00	8.00	8.00	8.00	9.00	9.00	8.50	9.00	8.00	8.00	8.00	8.00

*$\frac{8.57}{1.09}$ = 7.86 mg/l = 100% @ 700 m and @ 23° C.

various parameters (eight total), only dissolved oxygen appeared to be relevant to fouling. Past studies have indicated this is the best overall index to water quality (Cole 1977, pers. comm.).

The percent of oxygen saturation was calculated by using factors which corrected for temperature and elevation: 8.57 and 1.09, respectively (Cole 1975). A constant of 23° C temperature correction factor was used. This temperature was relatively stable for each water source during the period in which water samples were taken. The assumptions regarding the interpretation of the obtained percentages were:

1. That values of 100 percent or more represent high quality water;
2. Any decrease in water quality was probably the result of an increase in organic matter, including fecal material but not exclusively so; and
3. Any decrease in the monthly percentages subsequently represents a decrease in quality (Cole 1975; Cole 1977, pers. comm.).

Of the water sources sampled, source D (Matate Seep) was found to have the best quality of water throughout the 1977 summer, May excluded (Table 22). This was surprising since during the summer of 1976 this water source was subjectively observed as being very poor (see "Water Source Fouling"). There appeared to be a decided difference in flow rates at Matate Seep during the 1976 and 1977 summers.

Although quantified flow rate data were not obtained, estimates made during numerous monthly trips to the spring indicate that this was the case. The observed flow rates during the 1976 summer months were greater than those observed during the 1977 summer months. Consequently the volume of pooled water during the 1976 summer months was adequate (measuring approximately 4.5 x 45.0 x 70.0 cm) and a sufficient quantity of organic matter accumulated which decomposed, resulting in the apparent "fouled" state during summer 1976. The volume of pooled water during the 1977 summer was, however, small enough (measuring approximately 1.3 x 15.2 x 30.5 cm) to prevent sufficient organic matter accumulation necessary for detectable decomposition. These phenomena concerning flow rates and pooled water volumes are probably also responsible for the discrepancies obtained when comparing Matate Seep with the other two sampled seeps. Both Columbine (site C) and Badger (site B) seeps had greater flow rates and pooled water volumes than did Matate, and both were large enough (approximately 60 x 80 x 100 cm) to allow considerable organic matter accumulation. Therefore, both had lower percentages of saturated oxygen than did Matate. The only water available for collection at Matate during the 1977 summer was that which had immediately seeped to the surface; additional collecting sites were nonexistent due to the high evaporation and reabsorption rates associated with the sandy substrate at Matate. These characteristics did not exist at Columbine or Badger. Water sample collection sites at these sources were characterized as being stagnate,

nonmoving pools at least 80 cm in depth and formed by solid rock basins.

Monthly variations (of percent oxygen saturation) was observed for sources B and C. Water source D did not show any monthly variation as all values obtained were consistent and all indicated a relatively high quality of water.

Water sources B and C showed similar monthly characteristics. Water source B showed a substantial decrease in saturated oxygen (165 percent to 89 percent) from May to June. A similar decrease was observed for source C (127 percent to 102 percent) which also occurred from May to June. In addition, water source B showed a substantial decrease from June to July (89 percent to 41 percent) and a slight increase from July to August (41 percent to 43 percent); similarly, water source C showed a decrease from June to July of 102 percent to 48 percent, respectively. From July to August there was an increase of 48 percent to 50 percent, respectively. The fact that these two water sources have proportionately similar monthly water qualities was not surprising since they also had similar overflow rates, volumes of pooled water, habitat and substrate associations, and similar amounts of animal use.

Although these data may provide information useful in predicting trends, relationships and/or peculiarities that were associated with various water sources, they do not, however, indicate absolute water quality values nor interpret water suitability for animal use (Cole 1975). If, for example, a water source was determined to be 100 percent (oxygen) saturated and therefore labeled high quality (relative to other sampled sources), it would not necessarily indicate "clean" water; furthermore, water found to be 40 percent

saturated and labeled poor would not necessarily indicate that it was unsuitable for animal consumption. No relationships between the degree of monthly animal use and the monthly percentage of saturated oxygen were apparent for any of the sampled water sources.

CONCLUSIONS AND RECOMMENDATIONS

This study indicates that there is considerable overlap in burro and bighorn sheep distributions, habitat preferences, and diets. The impacts or environmental consequences of these overlap values cannot be fully understood or quantitatively determined without obtaining additional information on minimum range carrying capacities. Data from this study supports current ecological theory that when there is extensive overlap between niches of two species that it will result in the reduction or extinction of one of the two populations, especially in a resource-limited environment such as the arid and poorly vegetated desert habitats that exist in the Black Mountains.

The vegetation in the overlapping summer range (mainly in foothills and butte slopes) shows definite signs of overuse, especially near the permanent water sources (Plate 6). The intensified summer use of foothills by both species because of the increased need and location of summer water sources has produced an obvious gradient of utilization ranging from extreme to light with increasing distance (up to 3.5 miles) from permanent water sources. This overuse will continue

PLATE 6: Typical degree of overuse of ocotillo near Warm Springs water source. Photograph by M. T. Walker.

as long as existing burro numbers continue to remain in the area. If summer utilization of these restricted areas exceeds normal winter-spring forage production, or if winter-spring forage production is reduced as a consequence of extreme drought conditions, then a decrease in the present number of animals using this area would be expected. Management programs should consider the reduction of burro numbers in areas having only point water sources when overutilization of the summer range is apparent.

Additional Recommendations

1. Prohibit burro access to all existing water sources located in areas where burros and bighorn sheep overlap in distribution (regardless of season or habitat type) and discourage all future water developments which do not exclude burros from these areas.
2. Develop and fence new water sources in butte tops which would be expected to result in:
   a. Increased summer use of butte tops by sheep;
   b. A decrease in sheep dependence on forage around existing water sources during summer months.
3. Estimate burro numbers (seasonally) via a time specific Lincoln Index. Incorporate the use of helicopters to obtain reliable sample sizes. Mark animals with color dyes expelled from CO_2 charged pistols.

4. Discourage the excessive use of helicopters in sheep habitat during the lambing season (approximately February - May).
5. Avoid helicopter use in sheep habitats prior to making actual sheep counts (see results for the estimation of sheep numbers).
6. Develop and fence new water sources in mesa top areas, where, at present, the absence of permanent water discourages year-round sheep use, thus increasing the area of total year-round sheep habitat.
7. Reduce overall burro population via yearly round-up and/or eradication methods until the apparent range condition around existing water sources improves.
8. Obtain reliable information as soon as possible concerning net primary production, forage utilization and quality via a continuing range study.
9. When developing new water sources, allow ample circulation of fresh water in pooled portions and take measures to prevent unnecessary accumulation of organic matter in pooled segments.
10. Continue monitoring ecological relationships of feral burros and bighorn sheep with an emphasis on seasonal food habits in specific habitats.

11. Future investigators working in comparable rocky habitat should be aware that broken legs are a potential source of burro natural mortality, however slight.
12. Future capturing activities should take place during the summer months while burros are concentrated in close proximity to the permanent water sources.

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