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Warrick, Gregory David

MOUNTAIN SHEEP FORAGING BEHAVIOR

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MOUNTAIN SHEEP FORAGING BEHAVIOR

by

Gregory David Warrick

A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN WILDLIFE AND FISHERIES SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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APPROVAL BY THESIS COMMITTEE

This thesis has been approved on the date shown below:

P. R. Krausman — 16 Dec 85
P. R. Krausman, Thesis Director
Associate Professor of Wildlife Ecology
Date

R. William Mannan — 16 Dec. 1985
R. W. Mannan
Assistant Professor of Wildlife Ecology
Date

Astrid Kodric-Brown — Dec. 11, 1985
A. Kodric-Brown
Assistant Professor of Ecology
and Evolutionary Biology
Date

ACKNOWLEDGMENTS

Particular appreciation is extended to my major advisor, Dr. Paul R. Krausman, and my graduate committee members, Drs. Astrid Kodric-Brown and R. William Mannan for their constructive comments and guidance throughout the study. Special thanks are due to Dr. Bruce D. Leopold for assistance with data analysis. I also wish to thank Arnold Kotra and Mark Brown for assisting in data collection.

Funding for this study was provided by the Bureau of Reclamation and the U.S. Fish and Wildlife Service.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

I studied foraging behavior of mountain sheep (*Ovis canadensis mexicana*) in the Harquahala and Little Harquahala Mountains, Arizona during 1984. Ewes in the poorly vegetated Little Harquahala Mountains foraged at lower topographic positions and moved more while foraging than ewes in the Harquahala Mountains. Ewes in the Harquahala Mountains devoted more time to feeding during foraging bouts. Percent time feeding by ewes increased with group size class only in the Harquahala Mountains. Ewes from both mountain ranges spent more time standing when foraging alone or in small groups than when in large groups. Seasonal variation in group sizes was evident only in the Little Harquahala Mountains; the largest group sizes were present in the fall. Sheep group sizes increased as ruggedness class decreased.

INTRODUCTION

Foraging behavior can yield insight into the relationship between an animal and its environment. Ungulates modify their foraging behavior in response to habitat differences and seasons (Novellie 1978, Owen-Smith 1979). The behavior of a herbivore may be a more sensitive indicator of forage plant quality and quantity than direct measurements of vegetation (Owen-Smith 1979, Ruyle and Dwyer 1985). Furthermore, antipredator activities while foraging may reflect the level of real or perceived risk of predation (Berger 1983, Risenhoover and Bailey 1985).

Knowledge of foraging behavior of mountain sheep is limited. Berger (1978) related group size to foraging efficiency in Rocky Mountain bighorn sheep (*O. c. canadensis*). Risenhoover and Bailey (1985) studied the effects of visibility and proximity to escape terrain on the foraging behavior of Rocky Mountain bighorn. No one has examined the foraging behavior of mountain sheep occupying a desert ecosystem.

This study investigated foraging behavior of mountain sheep in two desert mountain ranges differing in physiographic features and forage plant abundance. Objectives were to examine the effects of group size, season, and mountain range on the time sheep spend feeding and their rates of movement while feeding; the influence of group size and ruggedness on sheep vigilance; and the effects of ruggedness, season, and mountain range on group size.

STUDY AREA

I conducted the study in the Harquahala and Little Harquahala Mountains of western Arizona (Fig. 1). Although these two mountain ranges border each other, they differ in elevation, ruggedness, forage plant abundance and available water sources.

The Harquahala Mountains are essentially one large mountain mass with a northeast axis. The Harquahala Mountains range in elevation from 580 m to 1,732 m and cover 311 Km^2. Generally, the Harquahala Mountains are more rugged than the Little Harquahala Mountains. The Little Harquahala Mountains are a series of small mountain masses immediately southwest of the Harquahala Mountains. These mountains exhibit relatively low relief and are separated by extensive areas of creosote flats. The Little Harquahala Mountains encompass approximately 66 Km^2 of mountainous terrain interspersed within 113 Km^2 of creosote flats. Elevations range from 427 m to 940 m.

The Little Harquahala Mountains lie entirely within the desertscrub formation (Lowe 1964). Dominant plant species on the slopes are creosotebush (*Larrea tridentata*), brittlebush (*Encelia farinosa*), littleleaf paloverde (*Cercidium microphylum*), and white bursage (*Ambrosia dumosa*) (Krausman 1985). Blue paloverde (*Cercidium floridum*), and ironwood (*Olneya tesota*) dominate the washes. Other plants present and utilized as forage by bighorn include ocotillo (*Fouquieria splendens*), catclaw (*Acacia greggii*), ratany (*Krameria spp.*), desert lavender (*Hyptis emoryi*), mammillaria (*Mammillaria spp.*) and barrel cactus (Ferocactus wislenzii). Vegetation on the slopes is sparse and ranges between 13.2 and 20.7 percent ground cover depending on vegetative association (Krausman 1985).

The Harquahala Mountains contain both the desertscrub and chaparral formations. Dominant plants in the desertscrub formation are brittlebush, white bursage, creosotebush, flattop buckwheat (Eriogonum fasciculatum), and galletagrass (Hilaria rigida) (Krausman 1985). Less abundant plants that sheep frequently used as forage include littleleaf paloverde, ironwood, catclaw, whitethorn acacia (Acacia constricta), mormon tea (Ephedra trifurca), ocotillo, barrel cactus, and mammillaria. Dominant plants within the upper elevation chapparal formation include mountain mahogany (Cercocarpus montanus), turbinella oak (Quercus turbinella), snakeweed (Gutierrezia spp.) and sumac (Rhus ovata) (Krausman 1985). The Harquahala Mountains offer a greater diversity and density of forage plants than the Little Harquahala Mountains. Ground cover averaged 27 % in the Harquahala Mountains (Krausman unpubl. data).

Weather data recorded 21 Km NW of Harquahala Mountain in Aguila, Arizona indicate that average daily maximum temperatures range from 17^{o} C in January to 39^{o} C in July and average daily minimim temperatures range from 1^{o} C in January to 21^{o} in July (Sellers, Hill, and Sanderson-Rae, 1985). Precipitation occurs primarily in late summer and winter and averages 22 cm annually (Sellers et. al. 1985).

There are potholes in both mountain ranges that hold water after rains and may provide a temporary source of water to sheep. Water is available to sheep at permanent springs in the higher elevations of the Harquahala Mountains. There is no permanent water available to sheep in the Little Harquahala Mountains.

There are approximately 20-30 sheep in each mountain range. Lamb survival has been low since 1979 and sheep numbers have declined at least in the Harquahala Mountains (Krausman unpublished data).

METHODS

I collected behavioral data mainly from radio-collared sheep. I collected data only from ewes because few rams had collars at the beginning of this study. Functional radio collars were on 6 ewes in the Little Harquahala Mountains and 4 ewes in the Harquahala Mountains at the beginning of the study. Four additional ewes in the Little Harquahala Mountains and 3 additional ewes in the Harquahala Mountains were radio-collared in 1984. Due to transmitter failures and mortalities, the number of ewes with functional radio collars varied from 10 to 15 during this study. I located each collared ewe at least once every two weeks.

When locating sheep, care was taken to remain undetected and to get into positions where sheep could be observed for long periods of time. Most observations were within 300 to 800 m of sheep. Only observations of undisturbed sheep were used in analyses.

Once I located a group of sheep I observed them with a spotting scope until one or more of the ewes initiated feeding. One animal was selected from the feeding ewes and her activities were recorded for 15 minutes using a tape recorder. If the ewe fed for at least 6 minutes during the 15 minute period and did not bed down, the observation was considered a foraging bout. This was done to restrict observations to ewes intent on feeding. Other studies have shown that ungulates spend as little as 50 to 60 percent of a foraging period actually feeding (Berger 1978, Owen-Smith 1979, Trudell and White 1981).

The cuttoff point selected for a foraging bout was set below these levels in anticipation of desert sheep having to commit more time to searching and moving between relatively scarce food items. Foraging bouts were collected for as long as ewes stayed in view and continued to forage.

I identified 3 main activities associated with foraging bouts: feeding, moving, and standing. I defined feeding as gathering, chewing, and swallowing food items. Moving was defined as movement without feeding. Sheep were considered standing when they remained stationary and surveyed their surroundings.

I measured the time spent feeding, moving, and standing to the nearest second from the recordings. Number of steps taken, forage plants eaten, group size, group composition, topographic position, exposure, and location also were recorded. I recorded an index to ruggedness for each location. The index was similar to that described by Beasom, Wiggers, and Giardino (1983). Briefly, I placed a grid with 44 uniformly spaced dots representing a 20 hectare area over each location which was plotted on a 7.5 minute topographic map. The number of dot-contour line intersections was used to index 4 classes of ruggedness: 10-20, 21-30, 31-40, and 41-50. These classes represented gently rolling, moderately rugged, rugged, and very rugged terrain, respectively. Group sizes used in analyses were counts of adult animals only. Four classes of group sizes were delineated: (1), (2-3), (4-6), (7+). I defined 5 topographic positions: mountaintop, upper slope, mid slope, lower slope, and base of the mountain. I recorded plants consumed by sheep when possible. These data provided information on general seasonal changes in forage plant use.

I delineated seasons using average temperature and precipitation data recorded at the Aguila station during 1984 (Fig. 2) (U.S. Weather Bureau 1984). Total precipitation for the year was 20.6 cm. Winter (January-March) was a cool dry season with an average temperature of 13.2^{o} C and .5 cm of precipitation. Early summer (April-June) was a hot dry season with a mean temperature of 22.1^{o} C and 1.1 cm of precipation. Late summer (July-September) was hot and wet with an average temperature of 28.4^{o} C and 8.8 cm of rainfall. Fall (October-December) was cool and wet with a mean temperature of 12.2^{o} C and 10.2 cm of precipitation.

Foraging bouts were judged to be independent observations based on a serial correlation test (Zar 1984) and a runs up and down test ($p>.05$) (Gibbons 1976) on all sequences (9) of 6 or more bouts. To meet the normality assumption, a square root transformation was used on group size and an arcsin-square root transformation was used on percent time feeding, percent time standing, and movement rate (Zar 1984). Differences in percent time feeding and movement rate for mountain range, group size class, and season were determined using analysis of variance (Zar 1984). Analysis of variance was also used to evaluate the effects of mountain range, season, and ruggedness class on group size and to determine the effects of group size class and ruggedness class on percent time standing. A significance level of .05 was used for all statistical tests. All confidence intervals were calculated based on the GT-2 method. This method of computing confidence intervals is preferred when sample sizes are very unequal (Sokal and Rohlf 1969).

RESULTS

I collected information on 483 foraging bouts from 185 groups of sheep during 1984. During 47 of these bouts the ewe fed on barrel cactus. Sheep behave quite differently when feeding on barrel cactus than when feeding on other forage plants. Sheep feeding on barrel cactus typically fed on no other forage plants and showed little or no movement. Sheep fought frequently trying to gain access to an opened cactus and often waited long periods of time for an opportunity to return to the cactus. Therefore, these 47 bouts were excluded from the analyses.

There was a significant 3-way interaction (P=.003) between mountain range, group size class, and season for movement rate. The effect of group size class on rate of movement was only significant for late summer (Fig. 3). Movement rate increased with group size class during late summer in ewes from the Little Harquahala Mountains. During this season, Little Harquahala ewes in groups of 4-6 had higher movement rates than ewes in the Harquahala Mountains. During the other 3 seasons, group size class had no significant effect on movement rate for either mountain range. Therefore, the 2-way interaction (P=.021) between mountain range and season was graphed (Fig. 4). Movement rate was higher during late summer than in winter for Harquahala ewes. There were no significant seasonal differences in movement rates for ewes in the Little Harquahala Mountains. Ewes from the Little Harquahala Mountains had higher movement rates while feeding than ewes from the

Harquahala Mountains during winter and fall.

Percent time standing decreased significantly (P=.002) with group size class in both mountain ranges (Fig 5).

Mountain range and group size class had a 2-way interaction (P=.041) for percent time feeding (Fig. 6). Percent time feeding per bout increased with group size class in the Harquahala Mountains but had no significant increase with group size class in the Little Harquahala Mountains (Fig.6). Harquahala ewes in group sizes of 7 or more sheep fed more during foraging bouts than Little Harquahala ewes in all group sizes. Ewes from the Harquahala Mountains foraging in groups of 4-6 spent more time feeding per bout than ewes from the Little Harquahala Mountains with the exception of group size class 2-3 (Fig. 6).

There was a 2-way interaction (P=.006) between mountain range and season for group size (Fig. 7). Ewes in the Little Harquahala Mountains formed larger group sizes during the fall than during other seasons. Harquahala ewes showed no significant differences in group size between seasons. No significant differences in group size occured between mountain ranges. Group sizes in both mountain ranges increased as ruggedness class decreased (P=.0003) (Fig. 8).

DISCUSSION

Several factors may influence the movement rates of foraging sheep. The higher movement rates by ewes foraging in the Little Harquahala Mountains probably reflect the relative scarcity and patchiness of food items within this mountain range. A greater number of steps were required by ewes to consume the widely dispersed food items within this range. The seasonal differences in sheep movement rates appear to be more complicated. Despite a greater abundance and diversity of forage plants after the onset of summer rains, sheep movement rates remained as high or higher than dry season movement rates. Owen-Smith and Novellie (1982) found that movement rates for kudu (Tragelaphus strepsiceros) decreased during the wet season. However, they found that kudu became more selective and ate only higher quality food items during this season. While sheep foraged on many of the same plants throughout the year (Figs. 9 and 10), they selected for the more nutritious new growth during the wet seasons. This was especially evident during late summer when sheep primarily fed on the highly nutritious leaves (Krausman unpub. data) and new growth of ocotillo (Figs. 9 and 10). This apparent increased selectivity may have contributed to the high movement rates seen during late summer. Sheep typically fed on individual ocotillo for a short period of time before moving to another plant suggesting that available leaves were depleted rapidly (Charnov 1976). This depletion would be amplified when sheep formed larger group sizes explaining the increase in movement rate with group size class seen in the Little Harquahala Mountains.

Although courting rams frequently chased foraging ewes during September and October, this didn't significantly influence movement rates of foraging ewes. Movement rates were as high as mixed groups when ewe groups were analyzed separately.

An inverse relationship between movement rate while foraging and habitat patch quality has been suggested (Berger 1983). It seems reasonable that sheep in the Little Harquahala Mountains are exploiting lower quality food patches. However, this concept doesn't seem to apply to seasonal data from this study. This idea would suggest that habitat patch quality remains stable or decreases for ewes during the wet season. Desert plants respond quickly to rainfall by producing nutritious new growth. The addition of this new growth should provide sheep with higher quality forage. I suggest that desert sheep become more selective foragers during wet seasons and therefore their movement rates remain stable or increase during these seasons despite the greater abundance and quality of forage plants.

A decrease in vigilance with group size has been documented for bighorn sheep and other ungulates (Berger 1978, Underwood 1982, Risenhoover and Bailey 1985). There is evidence that animals foraging in large groups are more apt to detect predators and are therefore less susceptable to predation. Several studies of birds have shown that they detect predators earlier when in larger groups (Powell 1974, Siegfried and Underhill 1975, Kenward 1978). Bighorn sheep may also detect predators earlier because they have a greater combined number of alert postures when foraging in large groups (Risenhoover and Bailey 1985).

Also, individual sheep within larger groups would have a smaller chance of becoming a victim during a predator attack. This benefit could be negated however, if predators detect and attack large groups more frequently. Predators are most successful when hunting single individuals or prey in small groups (Schaller 1972, Van Orsdol 1984.) The decrease in sheep vigilance with larger group sizes may have resulted from sheep being less vulnerable to predation in large groups.

Because individual sheep within large groups spend less time surveying for predators they are able to convert more time to feeding. This relationship has been documented for mountain sheep (Berger 1978) and other ungulates (Berger 1983). Similar results were found for ewes in the Harquahala Mountains. However, percent time feeding did not increase with group size class in ewes from the Little Harquahala Mountains. This was caused by two factors. As group size class increased, percent time standing tended to level off (Fig. 5) and percent time moving tended to increase for ewes in this mountain range. The combination of these two effects allow no increase in percent time feeding with group size class. These two effects also explain why the difference in percent time feeding between mountain ranges is only significant for the larger group size classes. Ewes in the Little Harquahala Mountains benefit less in terms of foraging efficiency by forming larger groups than ewes in the Harquahala Mountains.

A sheep foraging during the wet season might be expected to increase its feeding time due to a greater availability of forage plants. However, bighorn ewes from both mountain ranges had no significant change in percent time feeding with season. Owen-Smith and

Novellie (1982) also found little seasonal variation in the percent time kudu spend feeding per bout despite a four-fold increase in density of forage plants. Even though patches had a great deal more forage, kudu accepted a much lower fraction of this forage during the wet season than during dry seasons. Bighorn sheep may be reacting similarly and may benefit more by increasing the quality of their diet than by increasing their forage intake during wet seasons. Ewes did include more nutritious food items (Krausman unpub. data) such as ocotillo and acacia in their diets during the wet seasons (Figs. 9, 10). However, sheep may adjust their forage intakes seasonally by varying the proportion of a day spent feeding.

Rugged terrain is important as escape cover for mountain sheep (Wishart 1978, Hanson 1980, Tilton and Willard 1982). When mountain sheep exploit less rugged areas they may be more vulnerable to predation (Murie 1944). Sheep foraging in larger group sizes as discussed before may be less vulnerable to predation. Therefore, the larger groups formed by sheep in the less rugged areas may compensate for being in less secure escape terrain. My data support Risenhoover and Bailey's (1985) contention that forming large groups enable sheep to forage in less secure areas.

The inverse relationship between ruggedness and group size predicts larger group sizes in the Little Harquahala Mountains. Although sheep in the Little Harquahala Mountains did not form statistically larger group sizes than Harquahala sheep during 1984 (Fig. 7) they have in previous years (Chilelli and Krausman 1981, Krausman unpub. data). Large group sizes may be particularly important to sheep in the Little Harquahala Mountains because they forage more often in the less rugged lower topographic positions (Table 1). Sheep in the Little Harquahala Mountains were seen on several occasions to enter the washes in the flats and forage on blue paloverde and ironwood. Mountain sheep in the Little Harquahala Mountains may need to exploit resources in these relatively lush lower topographic positions in order to supplement the limited forage available on the slopes.

Simmons (1980) suggested that larger group sizes in sheep indicate better quality habitat. However, sheep in the Little Harquahala Mountains form as large or larger group sizes despite being in a seemingly lower quality habitat than Harquahala sheep. Any relationship between bighorn sheep group size and habitat quality may be confounded by physiographic features that affect vulnerability to predation such as ruggedness.

The seasonal variation in group size seen in the Little Harquahala Mountains may be due to a combination of factors. During the fall, sheep in the Little Harquahala Mountains used less rugged terrain. Also, high quality forage may have been more available because of high rainfall previous to and during this season. The large group sizes seen in the Little Harquahala Mountains in the fall may be in response to good forage conditions and their use of less rugged areas during this season.

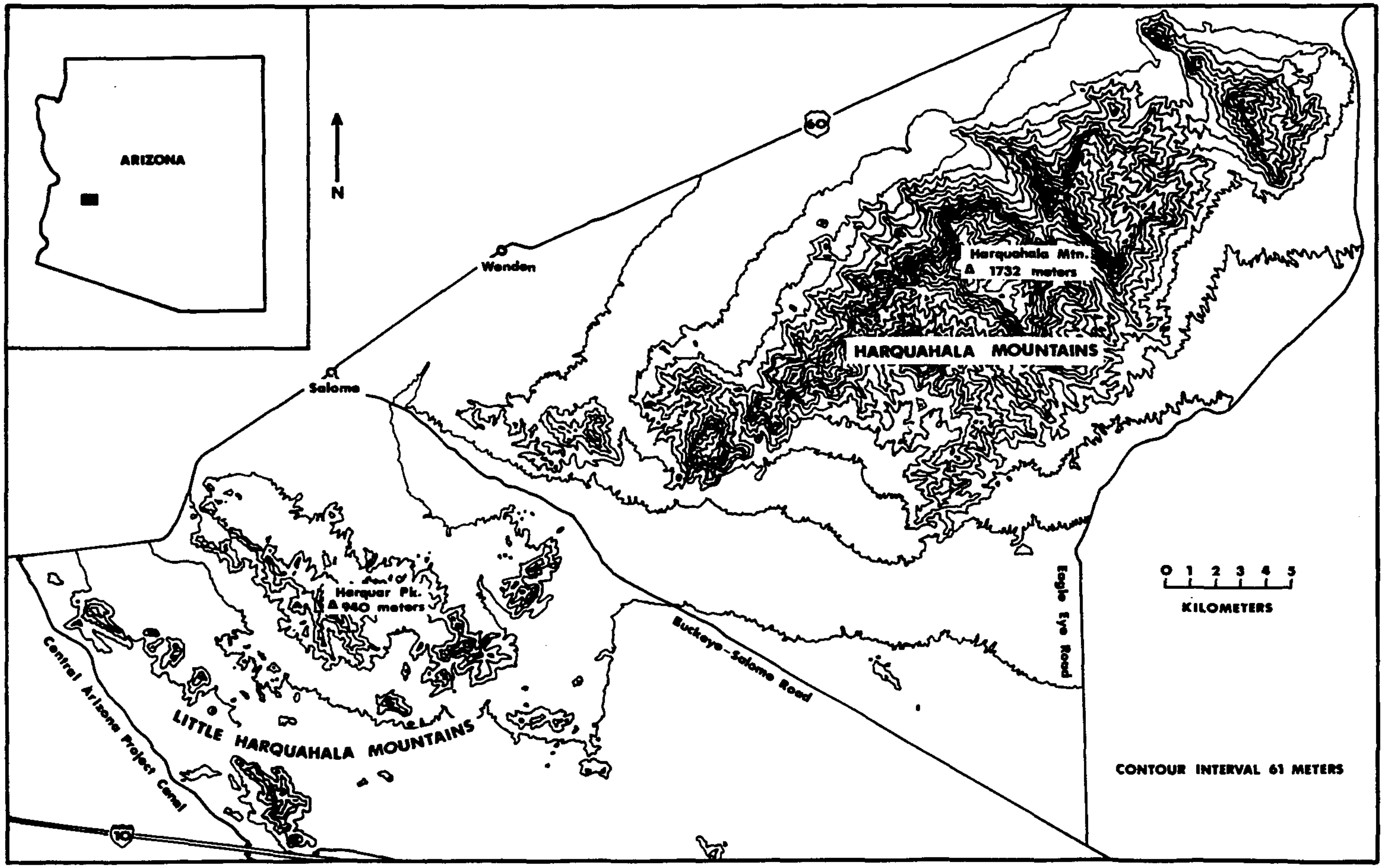

Figure 1. Topographic map of the Harquahala and Little Harquahala mountains, Arizona, 1984.

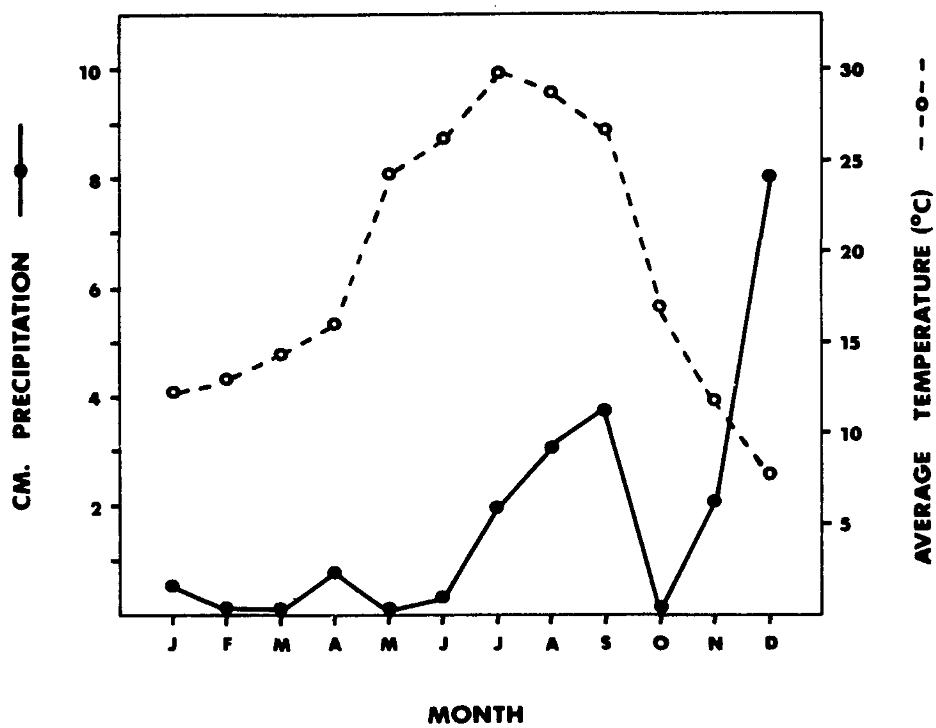

Figure 2. Average temperature and precipitation data collected at the Aguila station, Arizona for 1984.

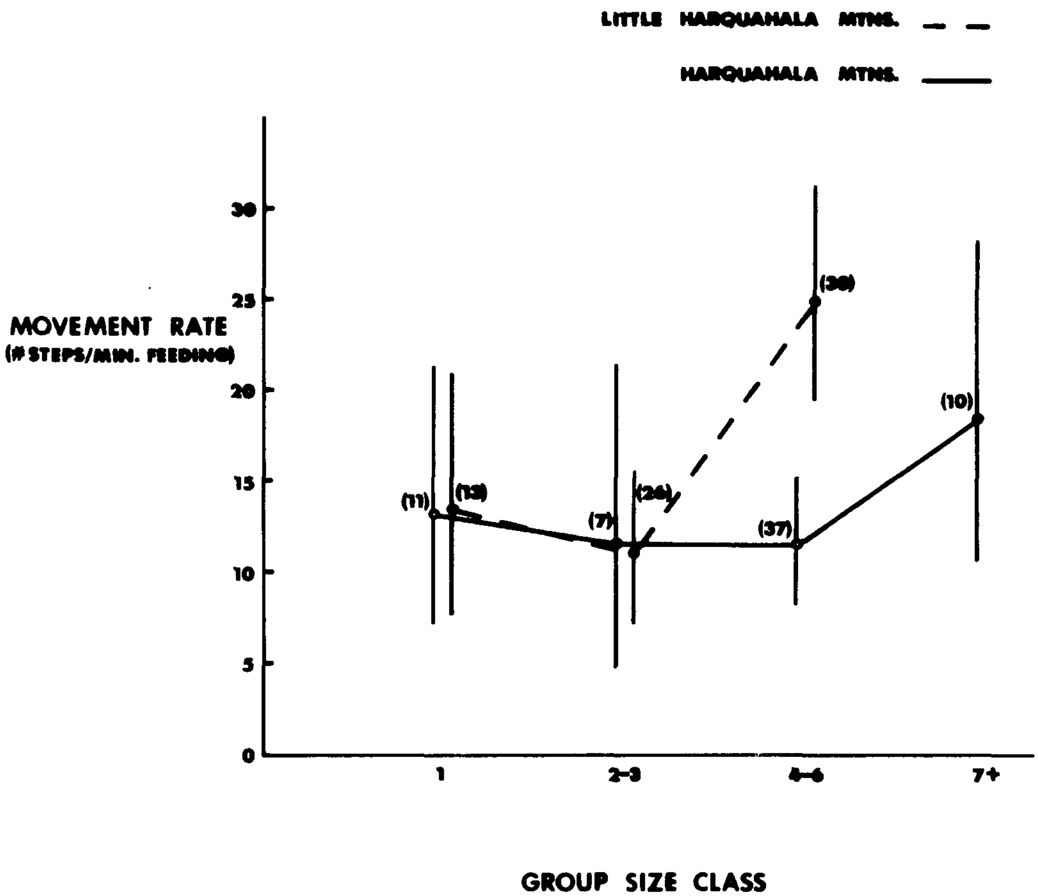

Figure 3. Average movement rates for ewes in relation to group size class during late summer in the Little Harquahala and Harquahala Mountains, Arizona, 1984. Vertical bars represent 95% confidence intervals and sample sizes are in parentheses.

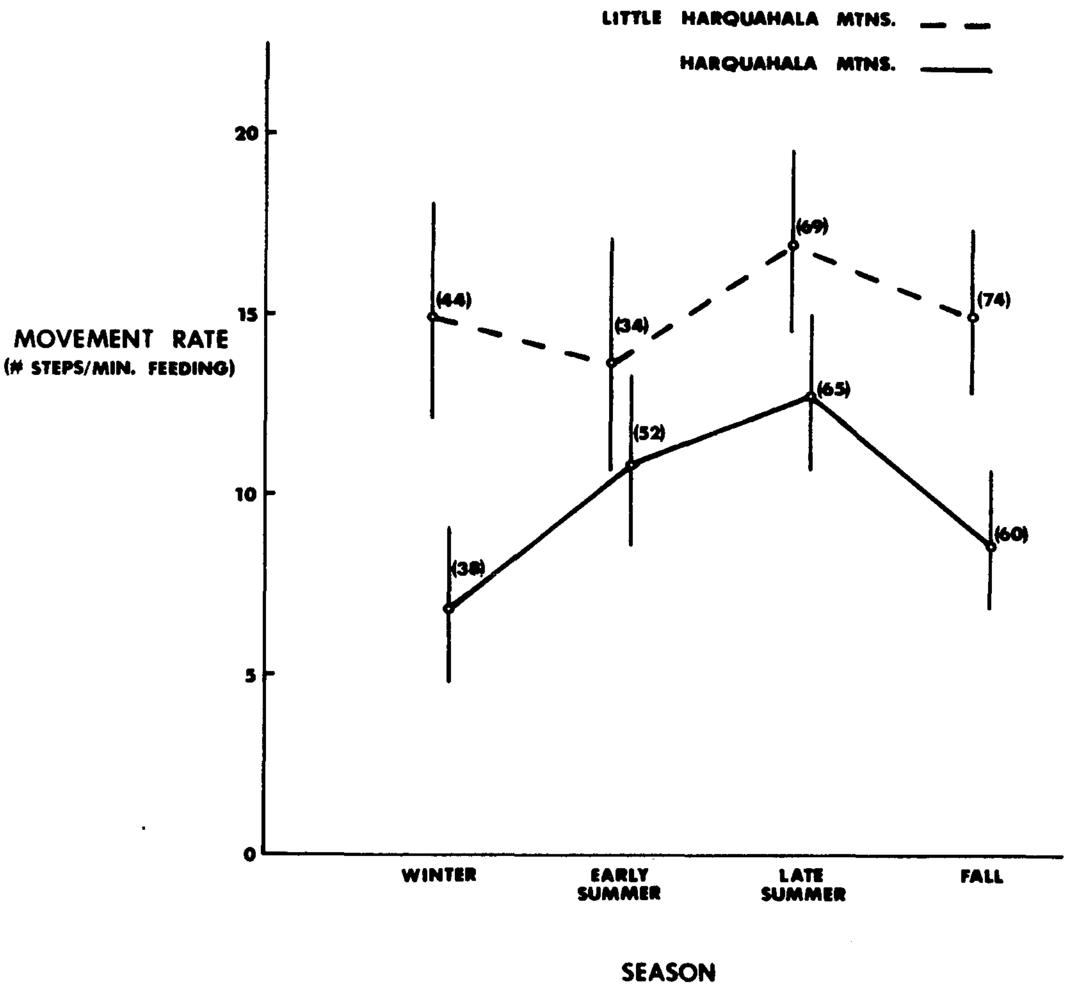

Figure 4. Seasonal movement rates for ewes in the Harquahala and Little Harquahala Mountains, Arizona, 1984. Sample sizes and 95% confidence intervals denoted by parentheses and vertical bars.

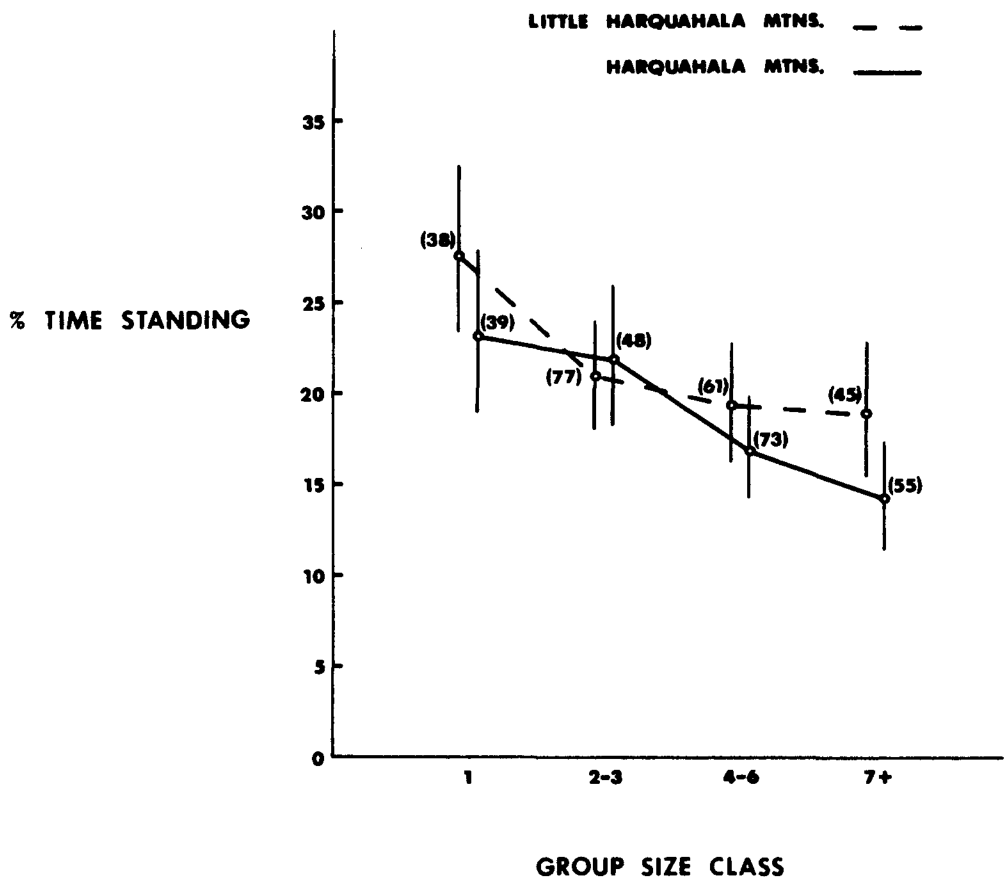

Figure 5. Relationship between percent time standing and group size class of ewes in the Harquahala and Little Harquahala Mountains, Arizona, 1984. Parentheses indicate sample sizes and vertical bars represent 95% confidence intervals.

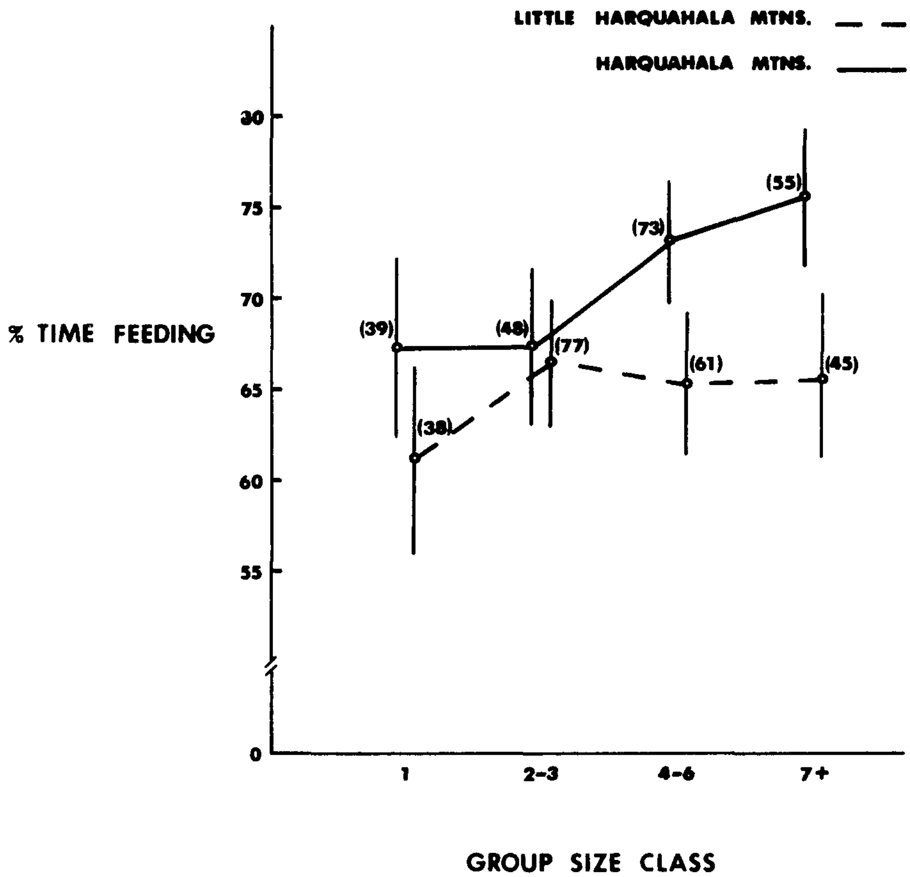

Figure 6. Effect of group size class on percent time ewes spend feeding per foraging bout in the Harquahala and Little Harquahala Mountains, Arizona, 1984. Confidence intervals (95%) are represented by vertical bars and sample sizes are in parentheses.

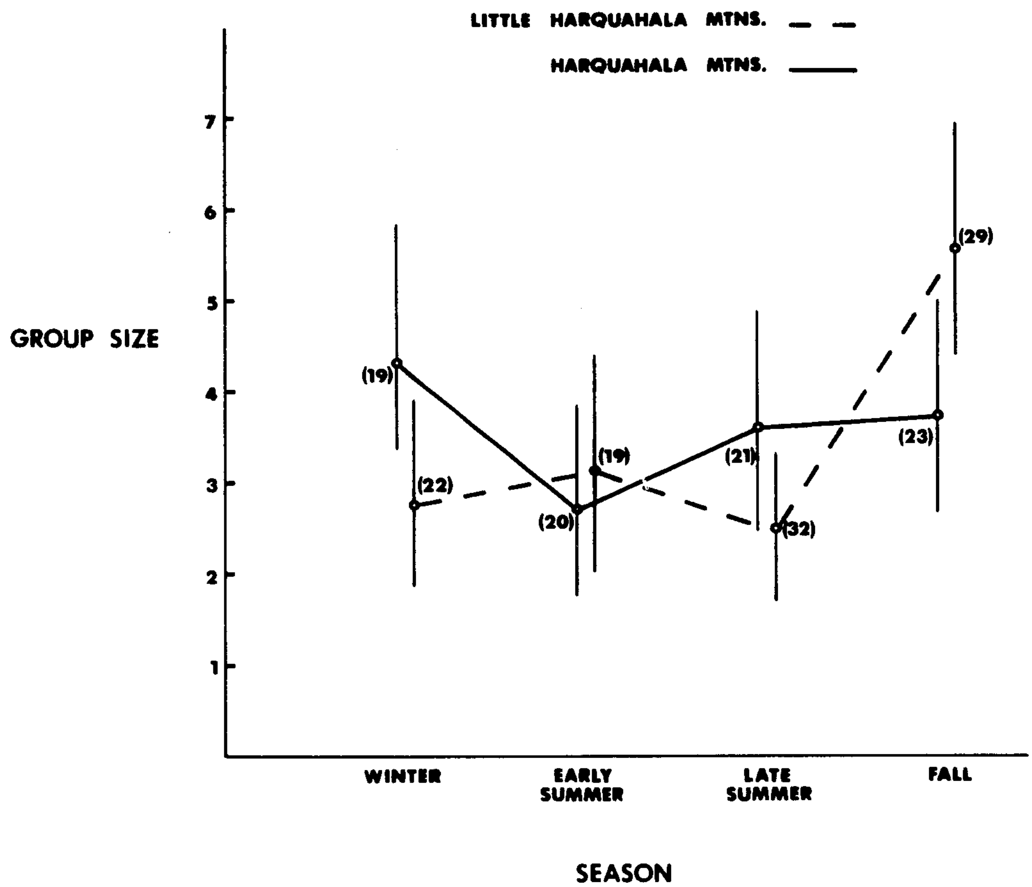

Figure 7. Seasonal group sizes formed by ewes in the Harquahala and Little Harquahala Mountains, Arizona, 1984. Number of groups sampled are in parentheses and 95% confidence intervals represented by vertical bars.

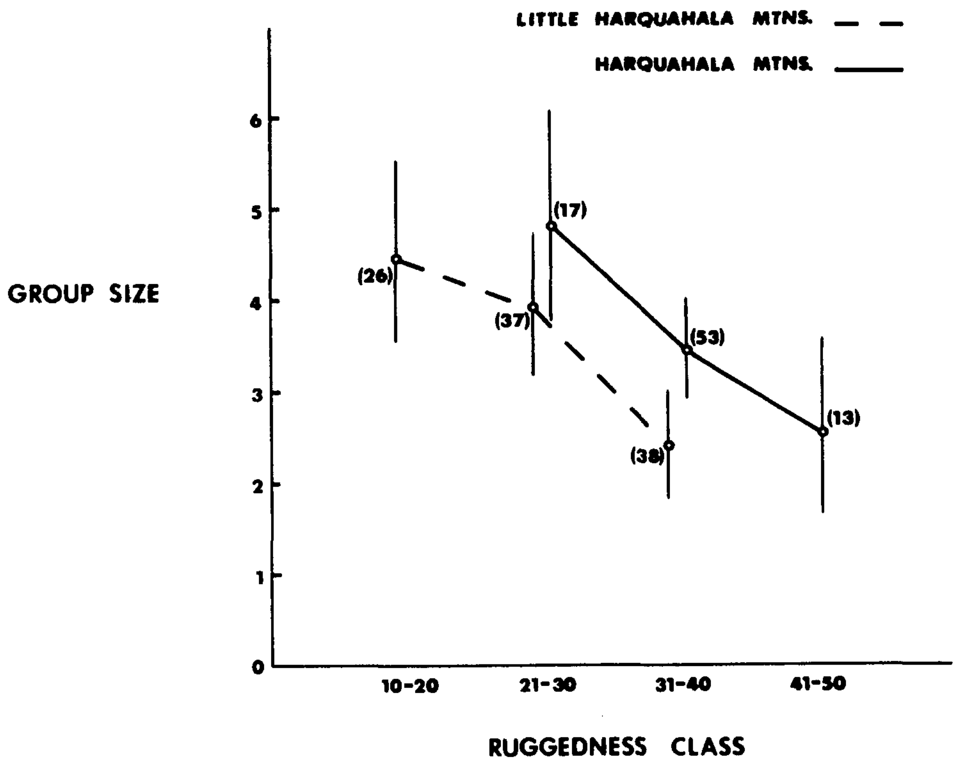

Figure 8. Average group sizes formed by foraging ewes in relation to ruggedness class in the Harquahala and Little Harquahala Mountains, Arizona, 1984. Vertical bars represent 95% confidence intervals and number of groups sampled are in parentheses.

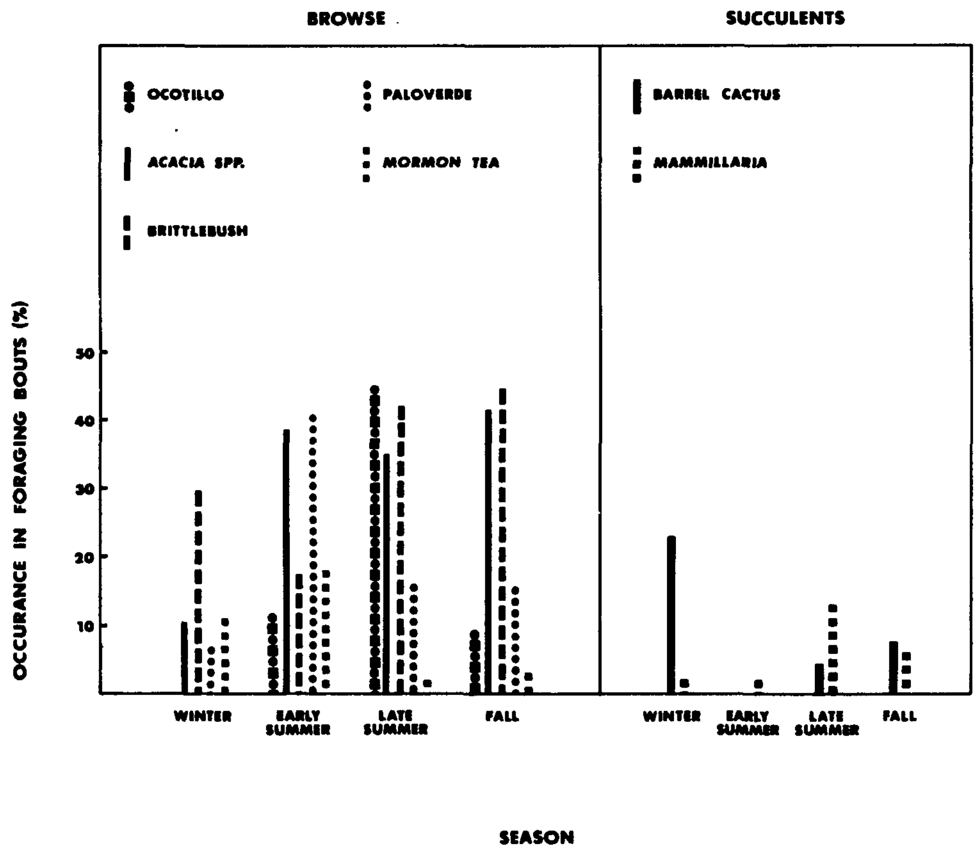

Figure 9. Forage plants used by ewes in the Harquahala Mountains, Arizona, 1984.

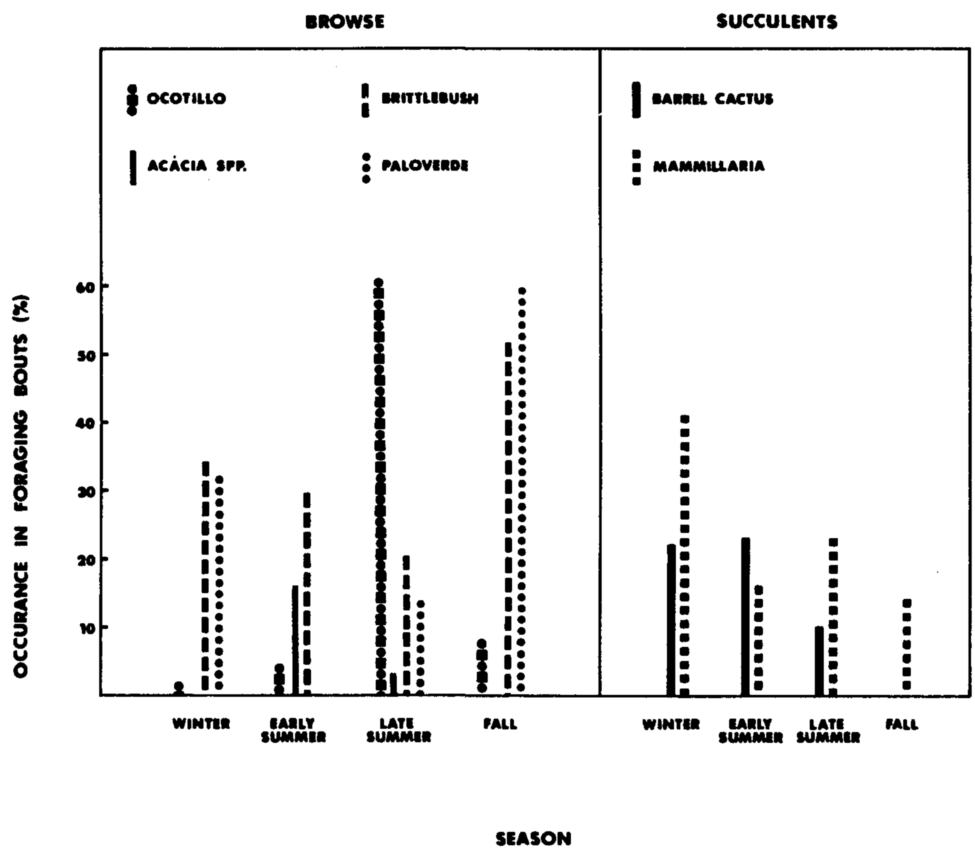

Figure 10. Forage plants used by ewes in the Little Harquahala Mountains, Arizona, 1984.

Table 1. Differences in use of topographic positions between ewes in the Harquahala and Little Harquahala Mountains, Arizona using the binomial test of two proportions (Sokal and Rohlf 1969). Significant differences at the .05 level denoted by *.

Topographic Position	Little Harquahala Mountains		Harquahala Mountains		
	No. groups	(%)	No. groups	(%)	
Top	3	.0294	3	.0361	
3/4	24	.2353	37	.4458	
1/2	27	.2647	32	.3855	
1/4	37	.3627	11	.1325	*
Base	11	.1078	0	.0000	*

LITERATURE CITED

Beasom, S. L., Wiggers, E. P., and J. R. Giardino. 1983. A technique for assessing land surface ruggedness. J. Wildl. Manage. 47:1163-1166.

Berger, J. 1978. Group size, foraging, and antipredator ploys: an analysis of bighorn sheep decisions. Beh. Ecol. Sociobiol., 4:91-100.

______. 1983. Pronghorn foraging economy and predator avoidance in a desert ecosystem: Implications for the conservation of large mammalian herbivores. Biol. Conserv. 25:193-208.

Charnov, E. L. 1976. Optimal foraging: the marginal value theorum. Theor. Pop. Biol. 9:129-136.

Chilelli, M. and P. R. Krausman. 1981. Group organization and activity patterns of desert bighorn sheep. Desert Bighorn Council Trans. 25:17-24.

Gibbons, J. D. 1976. Nonparametric methods for quantitative analysis. Holt, Rinehart, and Winston. N.Y. 463 pp.

Hansen, C. G. 1980. Habitat. Pp. 64-79. in The Desert Bighorn: its life history, ecology, and management. G. Monson and L. Sumner eds. University of Arizona Press, Tucson, Arizona. 207 pp.

Kenward, R. E. 1978. Hawks and doves: factors affecting success and selection in goshawk attacks on wood pigeons. J. Anim. Ecol. 47: 449-460.

Krausman, P. R. 1985. Impacts of the Central Arizona Project on desert mule deer and desert bighorn sheep. Contract No. 9-07-30-X069. U.S. Bur. of Reclamation. 246 pp.

Lowe, C. H., ed. 1964. The vertebrates of Arizona. The Univ. of Arizona Press, Tucson, Arizona. 207 pp.

Murie, A. 1944. The wolves of Mount Mckinley. U.S. Nat. Park Service, Fauna Series No. 5. 238 pp.

Novellie, P. 1978. Comparison of the foraging strategies of blesbok and springbok on the Transvaal highveld. S. Afr. J. Wildl. Res. 8:137-144.

Owen-Smith, N. 1979. Assessing the foraging effeciency of a large herbivore, the kudu. S. Afr. J. Wild. Res., 9:102-110.

Owen-Smith, N. and Novellie, P. 1982. What should a clever ungulate eat? Am. Nat., 119:151-178.

Powell, G. V. N. 1974. Experimental analysis of the social value of flocking by starlings in relation to predation and foraging. Animal. Behav. 22:501-505.

Risenhoover, K. L. and J. A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. J. Wildl. Manage. 49: 797-804.

Ruyle, G. B. and D. D. Dwyer. 1985. Feeding stations of sheep as an indicator of diminished forage supply. J. Anim. Sci. 61,2: 349-353.

Schaller, G. B. 1972. The Serengeti lion. Chicago, Chicago University Press. 480 pp.

Sellers, W. D., Hill, R. H., and M. Sanderson-Rae. 1985. Arizona climate: the first hundred years. The University of Arizona Press, Tucson, Arizona. 143 pp.

Siegfried, W. R. and Underhill, L. G. 1975. Flocking as an antipredator strategy in doves. Anim. Behav. 23:504-508.

Simmons, N. M. 1980. Behavior. Pp. 125-144. in The Desert Bighorn: its life history, ecology, and management. G. Monson and L. Sumner eds. University of Arizona Press, Tucson, Arizona. 207 pp.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry, the principles and practice of statistics in biological research. Freeman and Co., San Francisco, California. 859 pp.

Tilton, M. E., and E. E. Willard. 1982. Winter habitat selection by mountain sheep. J. Wildl. Manage. 46:359-366.

Trudell J. and R. G. White. 1981. The effect of forage structure and availability on food intake, biting rate, bite size and daily eating time of reindeer. J. Appl. Ecol. 18:63-82.

Underwood, R. 1982. Vigilance behaviour in grazing African antelopes. Behavior. 79:81-107.

U.S. Weather Bureau. 1984. Climatological data, annual summary, Arizona. U.S. Govt. Printing Office, Washington, D.C. 88(13) 27 pp.

Van Orsdol, K. G. 1984. Foraging behaviour and hunting success of lions in Queen Elizabeth National Park, Uganda. Afr. J. Ecol. 22:79-100.

Wishart, W. 1978. Bighorn sheep. Pp. 161-171. in J. L. Schmidt and D. L. Gilbert, eds. Big game of North America: ecology and management. Stackpole Books, Harrisburg, Pennsylvania. 494 pp.

Zar, J. H. 1984. Biostatistical analysis, Prentice-Hall Inc. Englewood Cliffs, N.J. 718 pp.