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MOUNTAIN SHEEP HABITAT CHARACTERISTICS IN THE PUSCH RIDGE WILDERNESS, ARIZONA

by

Richard Carl Etchberger

A Thesis Submitted to the Faculty of the

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For the Degree of

MASTER OF SCIENCE
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In the Graduate College

THE UNIVERSITY OF ARIZONA

1988

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ABSTRACT

Mountain sheep (*Ovis canadensis mexicana*) in the Pusch Ridge Wilderness (PRW), Santa Catalina Mountains, Arizona have abandoned historic habitat and now occupy 44 km^2. I used univariate analyses to quantify differences of physiographic and vegetational variables between abandoned habitat and habitat that is still used by mountain sheep. A discriminant function model characterized the magnitude of the differences between the 2 habitats. Habitat that supports mountain sheep has less human disturbance and is more open with more side oats grama (*Bouteloua curtipendula*), red brome (*Bromus rubens*), brittle bush (*Encelia farinosa*), and forb cover, but less ground cover, bush muhly (*Muhlenbergia porteri*), and turpentine bush (*Haplopappus laricifolius*) than habitat that was abandoned by mountain sheep. Fire is important in still used habitat because it reduces tall plants that obstruct mountain sheep vision. Human disturbances should be minimized in mountain sheep habitat.

INTRODUCTION

Mountain sheep numbers have declined in the PRW, Santa Catalina Mountains, Arizona and their distribution has been reduced since 1938 (Fig. 1). The population (N = 50-100)(R. J. Olding, Annu. Bighorn Survey, Ariz. Game and Fish Dep. [AGFD], Tucson, 1988) occupies 44 km^2 of the PRW in the southwest portion of the Santa Catalina Mountains (Krausman et al. 1979, Gionfriddo and Krausman 1986). Data from AGFD surveys and U. S. Forest Service (USFS) reports document mountain sheep use of about 250 km^2 of the Santa Catalina range. Mountain sheep have abandoned 206 km^2 of former habitat.

Most populations of mountain sheep in the Southwest are small (<100) and are threatened by human disturbance and continued alteration of their habitat (Krausman and Leopold 1986b). Krausman et al. (1979) emphasized the need to study the long term effects of human disturbance on the PRW mountain sheep population. Tucson lies at the base of the Santa Catalina Mountains and the PRW is subject to increasing pressure from human development and recreational use.

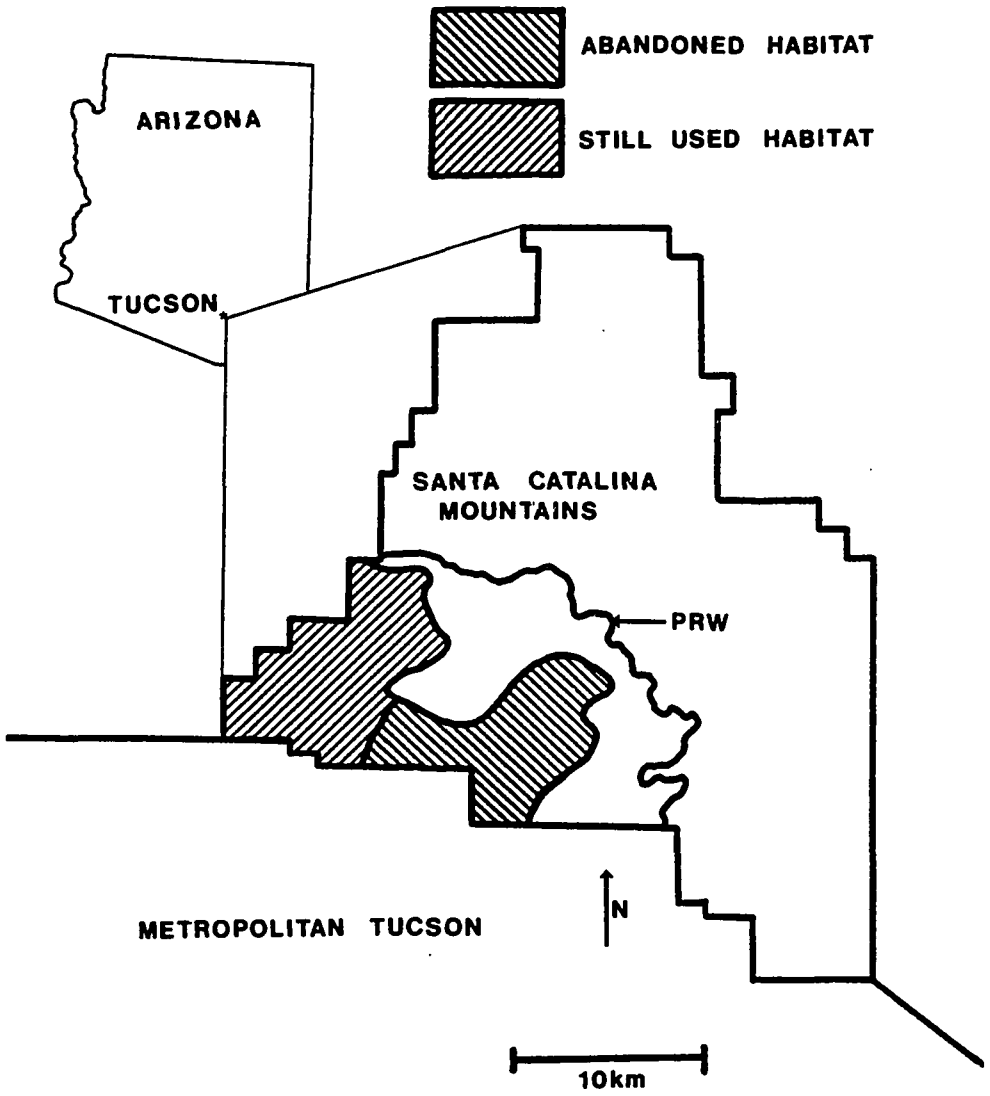

Figure 1. Abandoned and still used mountain sheep habitat in the Pusch Ridge Wilderness (PRW), Arizona, 1987-88.

Wildlife managers of the PRW have expressed concern that continued human population growth and development adjacent to the PRW boundary may effect mountain sheep negatively (Pusch Ridge Bighorn Sheep Manage. Plan, USFS, Coronado Nat. For., Tucson, 1985). Mountain sheep habitat use in the Santa Catalina Mountains was examined prior to extensive urban development on private land adjoining the PRW (Gionfriddo and Krausman 1986).

My objectives were to identify differences between still used and abandoned habitat of mountain sheep in the PRW and to develop a model that describes important mountain sheep habitat characteristics in the PRW.

STUDY AREA

The study area is 7,800 ha of the southwestern corner of the PRW, Santa Catalina Mountains in the Coronado National Forest bordering metropolitan Tucson, Arizona (Fig. 1). Elevation ranges from 905 to 1,710 m. The topography consists of eroded, granitic cliffs fronted by steep, broken slopes, interspersed with numerous large canyons. Sonoran desertscrub, semi-desert grassland, and Madrean evergreen woodland are the dominant vegetational communities found on the study area. Mean annual precipitation from 1949-70 in Tucson was 28.3 cm (Sellers and Hill 1974). Mean seasonal temperatures range from 16 C in winter to 30 C in summer.

The abandoned mountain sheep habitat in the PRW is 3,100 ha southwest and adjacent to habitat that is used by sheep (Fig. 1). Mountain sheep still use 4,700 ha in the southwestern portion of the PRW (DeVos 1983, Gionfriddo and Krausman 1986).

METHODS

Gionfriddo and Krausman (1986) identified habitat still used by mountain sheep by visually observing 5 radio-collared males and 6 radio-collared females. I identified abandoned habitat by examining a USFS reports and AGFD aerial surveys and ground counts from 1936 to 1978 (Krausman et al. 1979).

I randomly selected 6 2.6 km^2 blocks in habitat still used by mountain sheep and in abandoned habitat. Forty-nine plots (0.05 km^2) were sampled systematically in each block to assess mountain sheep habitat components. I excluded inaccessible plots. I collected data during 4 seasons (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec) from April 1987 to April 1988. I sampled 236 and 254 plots in abandoned habitat and in habitat still used by mountain sheep, respectively.

I randomly positioned 4 25-m line-intercept transects (Canfield 1941) from the center of each plot. Relative frequency of occurrence of plant species was recorded and the percent of each vegetational group (grasses, browse, forbs, and succulents) was calculated. Botanical nomenclature follows Lehr (1978).

I measured physiographic variables (Table 1) at the center of each plot and determined mean visibility as described by Risenhoover and Bailey (1985). Percent thermal cover (any vegetation >1 m high that could provide shade for a sheep) and percent ground cover were measured from the transects. Accessibility described the degree of difficulty for humans to access an area based on the Sierra Club numerical rating system (J. T. Light and R. Weaver, unpubl. rep., San Bernadino Natl. For., Calif., 1973). Horse, collared peccary (Tayassu tajuca), and deer (Odocoileus spp.) presence was determined from visual observations and fecal matter found in plots. I computed a ruggedness value for each plot (Beasom et al. 1983).

I compared abandoned and still used habitat with univariate and multivariate analyses. Data were examined for normality by plotting each variable against an expected value from a standard normal distribution (Norusis 1988). I transformed data if they were not normally distributed. The distributions of all variables expressed as percentages were normalized using the arcsine (arcsin square-root[relative frequency]) transformation. Discrete data were transformed with the square-root transformation (square-root[total count + 0.5]).

I used Mann-Whitney *U* and student's *t* tests to compare group means of variables describing abandoned habitat and habitat used by mountain sheep. Differences

Table 1. Descriptive statistics of physiographic variables of still used (n = 254) and abandoned (n = 236) mountain sheep habitat in the Pusch Ridge Wilderness, Arizona, 1987-88.

Variable	Still used habitat		Abandoned habitat	
	$\bar{x}$	SE	$\bar{x}$	SE
% Slope	0.555	0.010	0.532	0.009
Aspect	214.092	6.774	205.360	5.842
Elevation[a] (m)	1,199.713	8.198	1,132.525	8.064
% Ground cover[a]	44.500	0.903	49.050	0.911
% Thermal cover[a]	8.943	0.415	16.344	0.646
% Visibility[a]	8.660	0.403	4.035	0.414
Ruggedness index	5.575	0.090	5.661	0.093
Accessibility[b]	4.169	0.051	4.051	0.049
Terrain class[c]	4.717	0.053	4.631	0.058
Presence of:				
Horse[d]	0.016	0.008	0.047	0.020
Collared peccary[ad]	0.807	0.025	0.627	0.032
Ungulate[d]	0.998	0.007	0.979	0.009

Table 1 CONTINUED. Descriptive statistics of physiographic variables of still used (n = 254) and abandoned (n = 236) mountain sheep habitat in the Pusch Ridge Wilderness, Arizona, 1987-88.

Variable	Still used habitat		Abandoned habitat	
	$\bar{x}$	SE	$\bar{x}$	SE
Distance to:				
Water (m)	492.972	22.317	495.487	24.934
Disturbance (m)	962.500	38.679	451.267	24.934
Escape cover (m)	193.469	10.710	248.347	11.538

[a] $\bar{x}$ of still used and abandoned habitats different ($P \leq 0.05$).

[b] Accessibility recorded as 2 = easy walk (0-25% slope), 3 = moderate walk (26-45% slope), 4 = difficult walk (46-75% slope), 5 = very difficult walk (76-100% slope), and 6 = extremely difficult walk (>100% slope, vertical cliffs).

[c] Terrain class recorded as 0 = wash, 1 = flat (0-10%), 2 = bajada beyond foothills, 3 = gentle slope (11-25%), 4 = moderate slope (26-45%), 5 = steep slope (46-120%), 6 = cliff face (>120%), and 7 = table or mountain top.

[d] Recorded as 0 = absent, 1 = present.

were considered significant at $P \leq 0.05$. I examined seasonal variation of vegetational variables with analysis of variance.

I used discriminant function analysis with stepwise inclusion of variables (Williams 1983) to develop a model describing mountain sheep habitat in the Santa Catalina Mountains. I examined variable correlation to avoid interpretation problems. Pearson correlation coefficients indicated that no variables were correlated >0.6 (Noon 1981). I selected variables for inclusion in the discriminant function by maximizing Mahalanobis' distance between the 2 habitat centroids. Variables were entered when F-to-enter ≤ 0.05. A jackknife routine randomly divided the data into 2 equal groups. One group was used to develop the model and the other group was used to estimate the true misclassification rate of the derived model (Morrison 1969).

Multivariate statistical inference in wildlife habitat studies has been questioned (Rexstad et al. 1988). One criticism concerns the ability of discriminant function to produce significant results from functionally unrelated observations. This can occur when researchers conduct a posteriori searches for linear combinations of variables in the hope of learning about the structure or dynamics of a system (Rexstad et al. 1988). I selected ecologically meaningful variables, based on my objectives,

suggested as important habitat components for mountain sheep (Ferrier and Bradley 1970, Wilson et al. 1980, Krausman and Leopold 1986a). I controlled spurious relationships further by using univariate comparisons to eliminate all variables not significantly different. The data violated the assumption of equal dispersion matrices; however, I consider the discriminant function analysis to act as an exploratory, descriptive model (Johnson 1981).

Six discrete variables (accessibility, ruggedness index, terrain class, and horse, collared peccary, and ungulate presence) were not continuous data and were not included in the model.

Relative frequency of occurrence of plant species data were not included in the analysis if the species occurred on <5% of a transect line within a plot and were found in <10% of the overall plots (<49 plots)(Krausman and Leopold 1986a). The resulting nonsingular matrices yielded more interpretable results after this manipulation.

RESULTS

I combined all seasons for analysis because no seasonal differences ($P > 0.05$) of vegetational variables within the 2 habitats were detected. Nine of the 11 measures of plant species frequency of occurrence and the 4 vegetational groups were different ($P < 0.05$) between the 2 habitats (Table 2). Palo verde (*Cercidium* spp.), hop bush (*Dodonaea viscosa*), turpentine bush, bush muhly, and browse cover occurred in greater percentages in the abandoned habitat than in habitat still used by mountain sheep. Buckwheat (*Eriogonum fasciculatum*), fairy duster (*Calliandra eriophylla*), brittle bush, red brome, side oats grama, grass cover, forb cover, and succulent cover were found in greater percentages in habitat still used by sheep.

Seven of 15 physiographic variables were different ($P < 0.05$) between the 2 habitats (Table 1). Distance to escape cover, percent thermal cover, and percent ground cover were greater in abandoned habitat. Elevation, distance to disturbance, visibility, and collared peccary occurrence were greater in habitat still used by mountain sheep.

The stepwise entry method selected 9 of the initial 20 habitat variables to be used in the discriminant

Table 2. Descriptive statistics of relative frequency of occurrence (%) of vegetational variables of still used (n = 254) and abandoned (n = 236) mountain sheep habitat in the Pusch Ridge Wilderness, Arizona, 1987-88.

Variable	Still used habitat		Abandoned habitat	
	$\bar{x}$	SE	$\bar{x}$	SE
Mesquite (*Prosopis* spp.)	1.5	0.3	2.1	0.3
Palo verde[a]	1.3	0.2	3.3	0.4
Brittle bush[a]	2.4	0.3	1.1	0.2
Hop bush[a]	0.5	0.1	1.5	0.3
Buckwheat[a]	1.4	0.3	0.5	0.1
Side oats grama[a]	6.4	0.5	2.2	0.3
Bush muhly[a]	0.4	0.1	1.5	0.2
Red brome[a]	3.0	0.3	1.0	0.2
Turpentine bush[a]	0.6	0.1	1.0	0.2
Fairy duster[a]	2.5	0.2	0.8	0.2
Grass cover[a]	34.3	1.0	31.1	0.9
Forb cover[a]	7.4	0.5	4.8	0.4
Browse cover[a]	48.5	1.1	56.3	0.1
Succulent cover[a]	9.4	0.6	6.8	0.6

[a] $\bar{x}$ of still used and abandoned habitats different ($P \leq 0.05$).

analysis. The classification success of the derived model was 76.54%. Ninety-five of 122 plots (77.9%) in abandoned habitat were classified correctly. Ninety-one of 121 plots (75.2%) in habitat still used by mountain sheep were classified correctly. The 6 vegetational variables selected were side oats grama, bush muhly, red brome, brittle bush, turpentine bush, and percent forb cover. Distance to disturbance, visibility, and percent ground cover were the physiographic variables used to derive the model.

The relative contribution of each variable was determined from the standardized discriminant function coefficients (Table 3)(Klecka 1986). The standardized discriminant function coefficients were of the same sign and magnitude as the correlation coefficients between the canonical discriminant function and the discriminating variables.

Still used mountain sheep habitat in the Santa Catalina Mountains is further from human disturbance, has greater visibility, more side oats grama, red brome, brittle bush, and forbs, but less ground cover, bush muhly, and turpentine bush than abandoned habitat. The results of the discriminant model are interpretable and are supported by the univariate results.

This model is targeted for a specific set of objectives and discriminates well between abandoned habitat

Table 3. Standardized discriminant function coefficients of still used mountain sheep habitat variables in the Pusch Ridge Wilderness, Arizona, 1987-88.

Variable	Coefficient[a]	Rank	Significance
Disturbance distance	+0.575	1	Farther
% Visibility	+0.539	2	Greater
Side oats grama	+0.447	3	More
Bush muhly	-0.330	4	Less
% Ground cover	-0.314	5	Less
Red brome	+0.278	6	More
Brittle bush	+0.249	7	More
Turpentine bush	-0.197	8	Less
% Forb cover	+0.185	9	More

[a] Relative importance of variable based on absolute value of coefficients.

and habitat still used by mountain sheep in the Santa Catalina Mountains.

DISCUSSION

Mountain sheep habitat has been characterized as steep, rugged terrain (Risenhoover and Bailey 1985, Gionfriddo and Krausman 1986, Wakelyn 1987). Abandoned habitat and habitat still used by mountain sheep in the PRW do not differ in these characteristics; other characteristics appear to influence sheep distribution.

Two factors appear to combine and eliminate sheep from abandoned habitat. Human disturbances in and adjacent to the PRW may influence mountain sheep habitat use and fire suppression in abandoned habitat has allowed visibility obstructing vegetation to invade areas previously occupied by sheep.

The important habitat characteristics identified by the discriminant function analysis are dynamic factors. My results indicate that distance to human disturbance is 2 times greater in habitat still used by mountain sheep than in abandoned habitat. Distance to disturbance appears to be a critical factor in mountain sheep habitat use, however, I did not measure the direct effects of disturbance. Loss of habitat to urbanization has restricted sheep distribution in other areas of Arizona (Ferrier 1974). Tucson continues to grow and mountain sheep habitat is subject to increasing demands. Mountain

sheep will alter behavior patterns in response to construction activities (Leslie and Douglas 1980, Campbell and Remington 1981). A housing development is now under construction <0.6 km from still used mountain sheep habitat in the PRW.

Recreational uses within sheep habitat are also a human disturbance. The PRW is an important recreational resource for the people of Tucson (Purdy and Shaw 1981, Bugarsky 1986). Abandoned sheep habitat is bisected by 2 paved roads. A 10.6 km roadway in Sabino Canyon Recreation Area has trams which carry visitors up the canyon from 0900 to 1700 hours daily. Mountain sheep may tolerate controlled human visitation (Hicks and Elder 1979). However, King (1985) presents evidence that harassed mountain sheep fed less and were more wary than unharassed sheep. Purdy (1981) reported that back country users at upper elevations in sheep habitat are a greater threat to mountain sheep than visitors who use lower canyons. Numerous hiking trails traverse abandoned habitat at upper elevations.

I interpreted the vegetational and visibility differences identified by the discriminant function model by examining the fire history of the area. The vegetational characteristics on the 2 areas fit an ecological gradient representing the occurrence of fire.

Studies of vegetational response to fire in desert ecosystems have documented patterns between burned and control plots similar to my results (Humphrey 1949, White 1969, Bock and Bock 1978). Fire suppression reduces the high-visibility habitat needed by mountain sheep (Risenhoover 1981, Wakelyn 1987). Risenhoover and Bailey (1985) documented a strong preference by mountain sheep for grassy, open areas with high visibility. Fire was suppressed in the Santa Catalina Mountains until the early-1980's. Over 2,975 ha have burned in the Santa Catalina Mountains since 1958. Less than 2% of the fires burned >125 ha. Since 1973, 12 reported fires >4 ha burned 1,100 ha of still used sheep habitat, however, only 280 ha have burned in abandoned habitat (USFS fire reps., Catalina Dist., Coronado Nat. For., Tucson).

Mountain sheep habitat in the PRW has been abandoned, probably due to human disturbance and fire suppression. Development continues along the border of PRW adjacent to still used mountain sheep habitat. Current mountain sheep habitat in the PRW is being maintained by periodic fire. The policy of the USFS is to control fire in the PRW when it approaches <1.6 km from the National Forest boundary with human developments (T. S. Skinner, USFS, pers. commun.). Approximately 80% of still used sheep habitat is <1.6 km from a boundary. The USFS should

re-evaluate its policy and consider the effect of each fire on mountain sheep habitat.

Fire has been used to improve forage conditions in wildlife habitat. Forage in PRW is high in quality and quantity (R. Mazaika et al., unpubl. data). Controlled burning should be used to maintain high visibility habitat. When planning fires, managers should emphasize the reduction in visibility-obstructing vegetation. If fires do not remove visibility-obstructing vegetation, mechanical means should be used.

Mountain sheep have reduced their distribution in the PRW and the still used habitat is threatened. The effects of humans on remaining habitat must be monitored closely. Purdy and Shaw (1981) proposed that recreational use in PRW may contribute to the future decline of the mountain sheep population. Visitor surveys revealed that the public values mountain sheep in PRW (Bugarsky 1986) and the majority of visitors favored use restrictions to preserve the sheep population (Purdy and Shaw 1981). If the sheep distribution continues to decrease, such restrictions may be necessary.

Research should continue on these mountain sheep and their habitat. It is important to document causes and effects of different human disturbances. The increasing pressures from development and recreational use in PRW

warrant close monitoring and immediate action to maintain the mountain sheep population.

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