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HABITAT SELECTION BY MOUNTAIN SHEEP IN THE SONORAN DESERT: IMPLICATIONS FOR CONSERVATION IN THE UNITED STATES AND MEXICO

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'er photo: Mountain sheep gathered at an artificial water source in the Lower Colorado sub- sion of the Sonoran Desert, California-- Nancy G. Andrew and Leon M. Lesicka.

e mission of the Department of Fish and Game is to manage California's diverse h, wildlife, and plant resources, and the habitats upon which they depend, for ›ir ecological values and for their use and enjoyment by the public.

HABITAT SELECTION BY MOUNTAIN SHEEP IN THE SONORAN DESERT: IMPLICATIONS FOR CONSERVATION IN THE UNITED STATES AND MEXICO

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ABSTRACT: We used aerial telemetry to determine diurnal habitat use by mountain sheep (*Ovis canadensis*) in the East Chocolate Mountains, Imperial County, California during June 1992 through December 1993. We empirically derived a 95% circular error polygon (3.14 km^2 around each telemetry point), and this was the fundamental unit for habitat analyses for which we used vector- and raster-based Geographical Information System data processing. Eight habitat variables (elevation, slope, aspect, terrain roughness, vegetation, and distances to water, escape terrain, and human disturbance) were evaluated by gender for hot and cool seasons of the year. Females used all elevation classes in proportion to their availability, selected upland vegetation in all seasons, used rough terrain in proportion to its availability, and avoided flat landscapes. Males avoided the 225-299 m elevation class but used all other elevations in proportion to availability. Males also avoided flat terrain, selected the moderately rough terrain classes, and used all other terrain conditions in proportion to availability. Males selected upland vegetation in all seasons. Neither gender selected nor avoided specific slope or aspect classes. All sheep occurred closer to water and to escape terrain than would be expected by chance. Females occurred farther from areas of human disturbance than did males. Cunningham's (1989) habitat evaluation model assigned ratings of only poor or fair quality to areas we found to be important to mountain sheep. We developed a linear discriminant function model to identify locations used extensively; the model correctly classified approximately 75% of the analytical cells with respect to sheep abundance. Our findings indicate that conservationists working to restore mountain sheep to historical ranges along the international border between the United States and Mexico should select a habitat assessment model developed specifically for that region.

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INTRODUCTION

The conservation of biodiversity in North America is a monumental task, particularly in the vicinity of the international border between the United States and Mexico (Ganster 1998, Osborn 1998); the success of this effort is contingent upon cooperation between these nations (Ceballos 1997, Medellin 1998). Indeed, it was recognized more than two decades ago that an international effort involving scientists from both countries would be necessary to acquire data essential for the conservation or restoration of mountain sheep (*Ovis canadensis*) in northern Mexico (Desert and Mexican Bighorn Sheep Working Group 1975). Nevertheless, it has been only recently that such cooperative efforts have occurred with any frequency.

Mountain sheep in northern Mexico and the southwestern United States occupy a diversity of terrain in the desert ecosystems represented in that geographic area, and there is substantial variation in habitat requirements within and among populations of wild sheep (Hansen 1980, McCarty and Bailey 1994). Forage quality and availability, water availability, and ruggedness of terrain have been repeatedly emphasized as important variables affecting habitat use by these specialized ungulates. Climatic conditions, competition with other ungulates, and human impacts also affect the distribution of mountain sheep (Hansen 1980, Berger 1990, Bleich et al. 1990a, 1996, McCarty and Bailey 1994).

The total numbers of mountain sheep occupying desert regions have declined since the 1800's (see, for example, Wehausen et al. 1987), and American efforts to restore this species to previously occupied mountain ranges have been extensive (Ramey 1993). In the United States, conservation efforts have focused primarily on: 1) determining population size, demographic characteristics, and distributional status of extant populations of mountain sheep; 2) assessing and protecting habitat of sheep in the different desert and mountain ecosystems where they occur; 3) improving habitat; and 4) re-establishing populations in mountain ranges that previously were occupied (Bleich and Torres 1994).

Few detailed investigations have been conducted on desert sheep in northern Mexico (Tarango and Krausman, 1997 for review) with the exception of the recent demographic work by Lopez et al. (1995), conservation or research efforts largely have been limited to regulating the harvest of mature males and protecting populations from poaching (Oliver and Sanchez 1970, Cossio 1975, Araujo 1976), descriptions of basic biology (Dominguez 1976, Fonseca and Gonzalez 1976, M. Gonzalez 1976, P. D. Gonzalez 1976, Fonseca 1979), and reports on the status and distribution of this species (Alvarez 1976, Valverde 1976, DeForge et al. 1984, 1993, Lee and Lopez-Saavedra 1993, 1994, Lee and Mellink 1996, Lee 1997). In an early international effort, mountain sheep were captured in Sonora, Mexico and translocated to New Mexico in an attempt to reestablish these ungulates in that state (Gates 1972). During 1975, mountain sheep were moved from Sonora to formerly unoccupied habitat on Isla Tiburon (Montoya and Gates 1975), and DeForge et al.(1997) and Jimenez et al.(1997) described the translocation and demography of animals moved to Carmen Island to provide a source of sheep for restoration efforts.

Habitat and demographic data obtained from Sonoran Desert ranges occupied by mountain sheep in the United States will be of value in protecting habitat and, potentially, for the restoration of this species in northern Mexico. Given the metapopulation structure of mountain sheep (Schwartz et al. 1986, Bleich et al. 1990a, Bleich et al. 1996), habitat conservation and restoration efforts in each of these nations have implications for the long-term maintenance of viable populations of these specialized ungulates in suitable habitat adjacent to the international border (Ceballos 1997). We studied a population of mountain sheep occupying the East Chocolate Mountains in the Sonoran Desert, immediately north of border between the United States and Mexico. The primary goal of our project was to quantify and describe the habitat used by sheep in the region, to quantify use and selection of habitats by this species with an emphasis on habitat conservation and population restoration, and to develop a quantified, predictive model of habitat use that could be used in the conservation of mountain sheep habitat in both the United States and Mexico.

We used radio-telemetry and a detailed database of terrain, vegetation, and land use for the region to quantify use and selection of habitat by mountain sheep. Furthermore, we tested for seasonal and gender differences in habitat use and developed and evaluated multivariate models of sheep abundance that will be applicable to the conservation of these ungulates in the Sonoran Desert of western North America.

ACKNOWLEDGMENTS

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METHODS

Study Area

The East Chocolate Mountains (maximum elevation 647 m) are centered (33°7' N, 114°53' W) approximately 75 km east of the town of Brawley, Imperial County, California, USA, and 50 km north of Algodones, Baja California Norte, Mexico

(Figure 1). Our study area encompassed approximately 1,400 km^2, and the climate was characterized by extreme aridity and high summer temperatures (Loeltz et al. 1975).

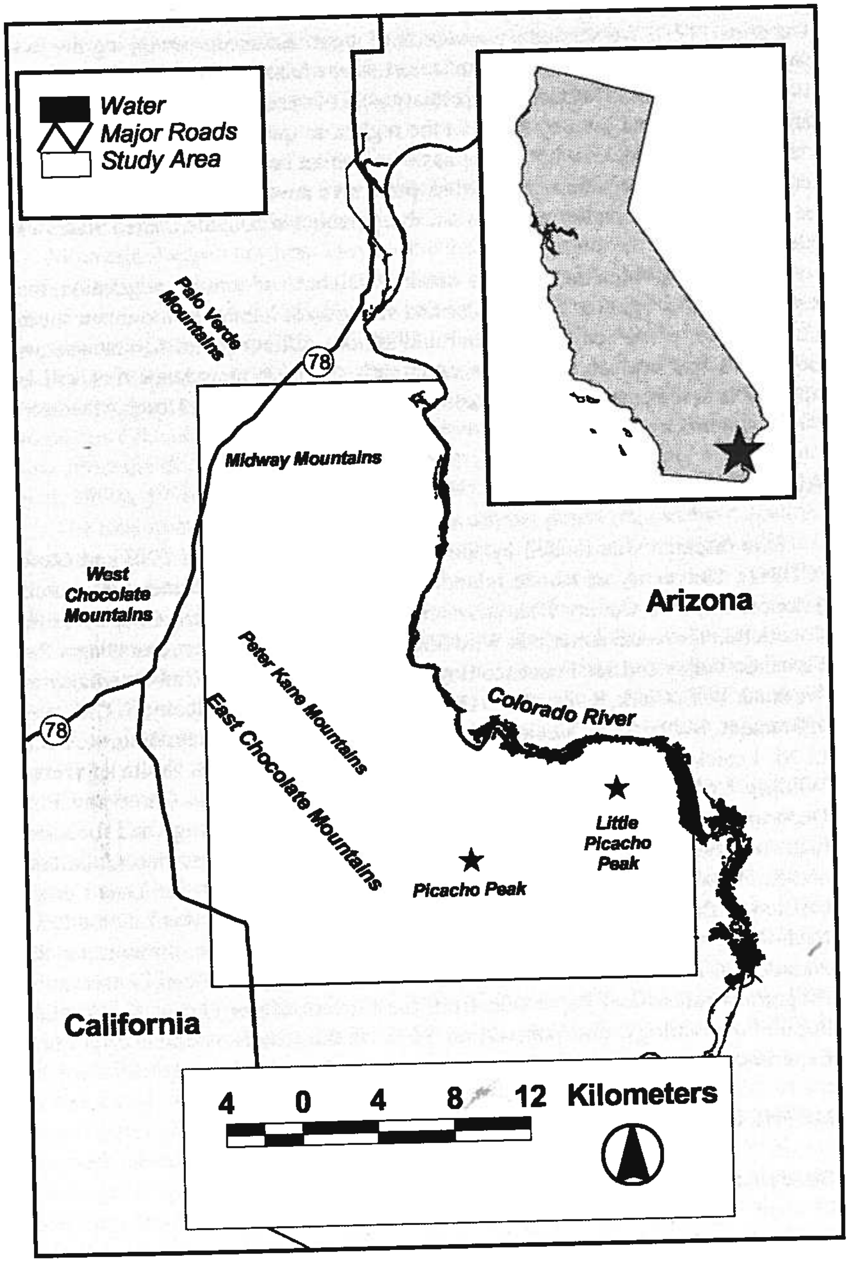

Figure 1. Location of the East Chocolate Mountains study area in Imperial County, California, USA.

Vegetation in the study area (Figure 2) is typical of the Lower Colorado River Valley Desert, the driest sub-division of the Sonoran Desert (Paysen et al. 1980, Turner and Brown 1982). Upland areas are dominated by creosote bush (*Larrea tridentata*), burro bush (*Ambrosia dumosa*), and ocotillo (*Fouquieria splendens*) except at sites adjacent to the Colorado River where salt cedar (*Tamarix* spp.), cattails (*Typha domingensis*), and arrowweed (*Pluchea sericea*) are abundant. Vegetation in the numerous desert washes consisted mainly of palo verde (*Cercidium floridum*), ironwood (*Olneya tesota*), catclaw (*Acacia greggii*), mesquite (*Prosopis glandulosa*), and cheese bush (*Hymenoclea salsola*). Andrew (1994) provided a detailed description of the vegetation communities of the East Chocolate Mountains.

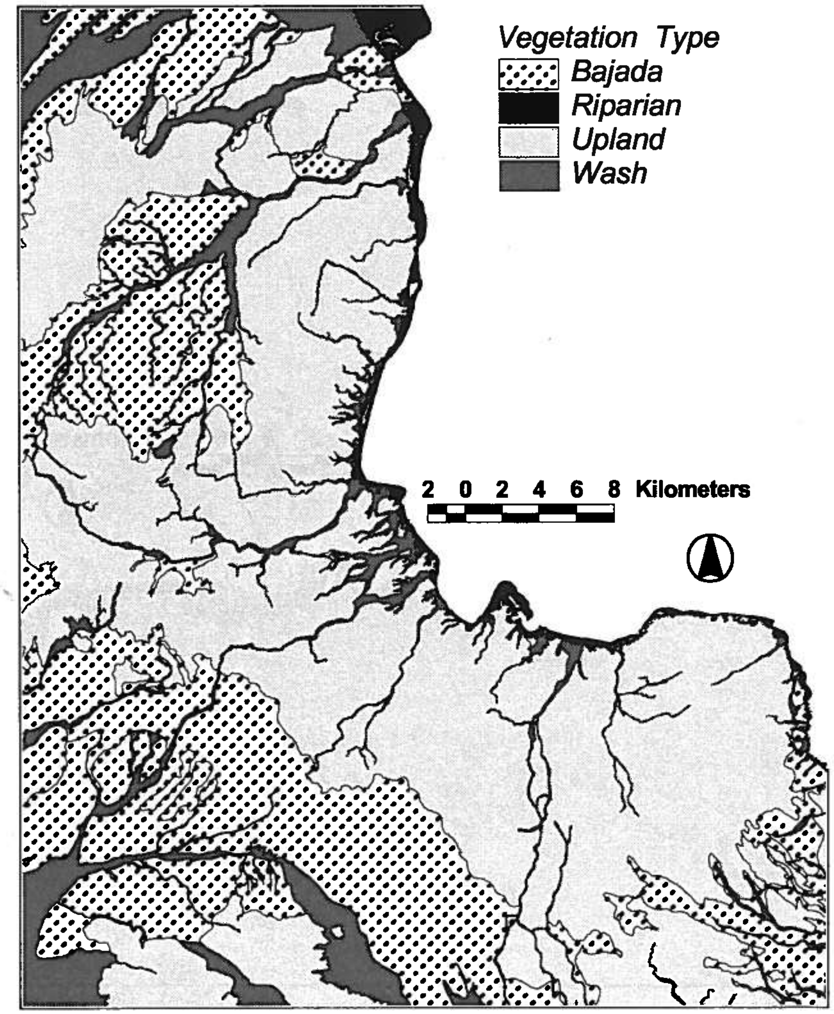

Figure 2. Four major vegetation types in the East Chocolate Mountains study area, Imperial County, California.

Twenty-nine, mostly ephemeral, water sources were present in the study area and may have been used by mountain sheep during some portion of the year; ungulates also obtained water at three locations along the Colorado River (Figure 3). Two large, active gold mines and numerous heavily traveled roads were major sources of human disturbance in the region (Figure 4). Mule deer (*Odocoileus hemionus eremicus*) also are native to the study area (Bowyer and Bleich 1984) but they occurred at extremely low densities (Thompson and Bleich 1993). No livestock were grazed in the Chocolate Mountains during our research, but numerous feral asses (*Equus assinus*) inhabited the study area (Andrew 1994).

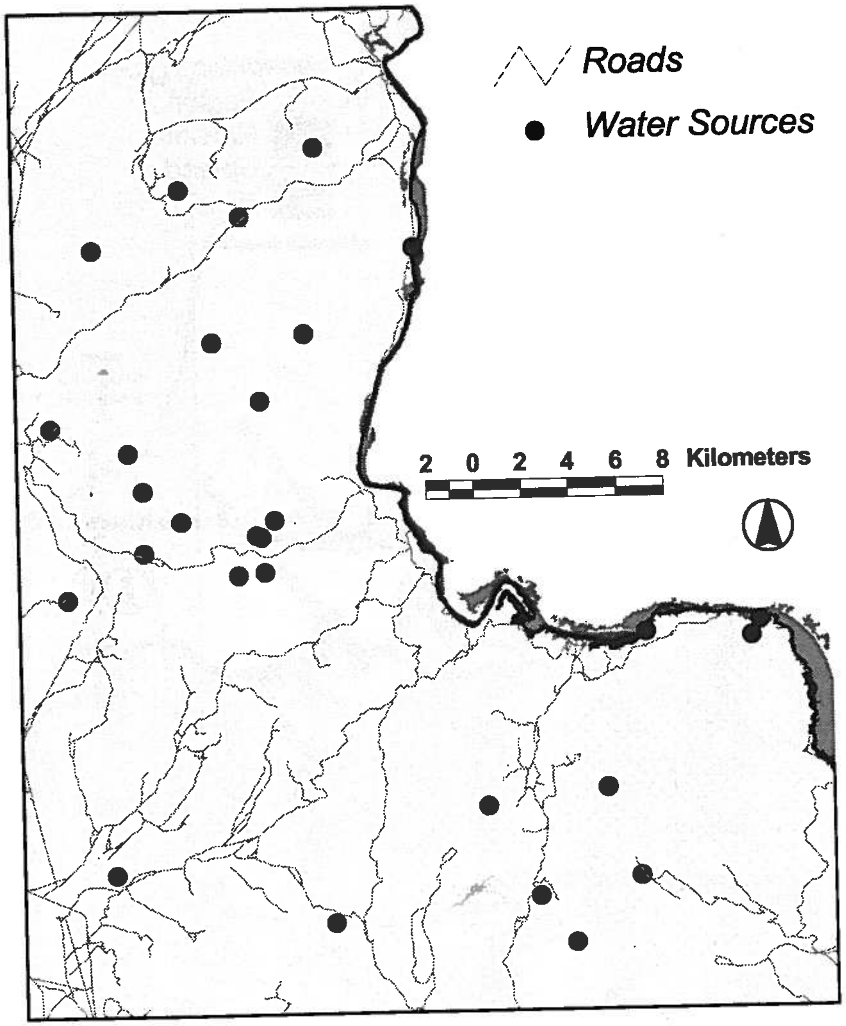

Figure 3. Distribution of known water sources potentially used by mountain sheep during some portion of the year, the East Chocolate Mountains, Imperial County, California.

Marking and Monitoring Sheep

We captured 25 adult mountain sheep (17 females, 8 males) in June 1992 using a hand-held net gun fired from a helicopter (Krausman et al. 1985). We estimated the age of each captured sheep using tooth replacement patterns (Deming 1952) and annular horn rings (Geist 1966). We fitted each animal with a radio-collar (Bleich et al. 1990b) equipped with a mortality sensor (6 hr. delay, Model 500, Telonics Inc., Mesa, Arizona, USA) and two plastic ear-tags having a unique number and color pattern. All aspects of animal handling complied with protocols set forth in the California Department of Fish and Game (CDFG) animal restraint handbook (Jessup et al. 1986).

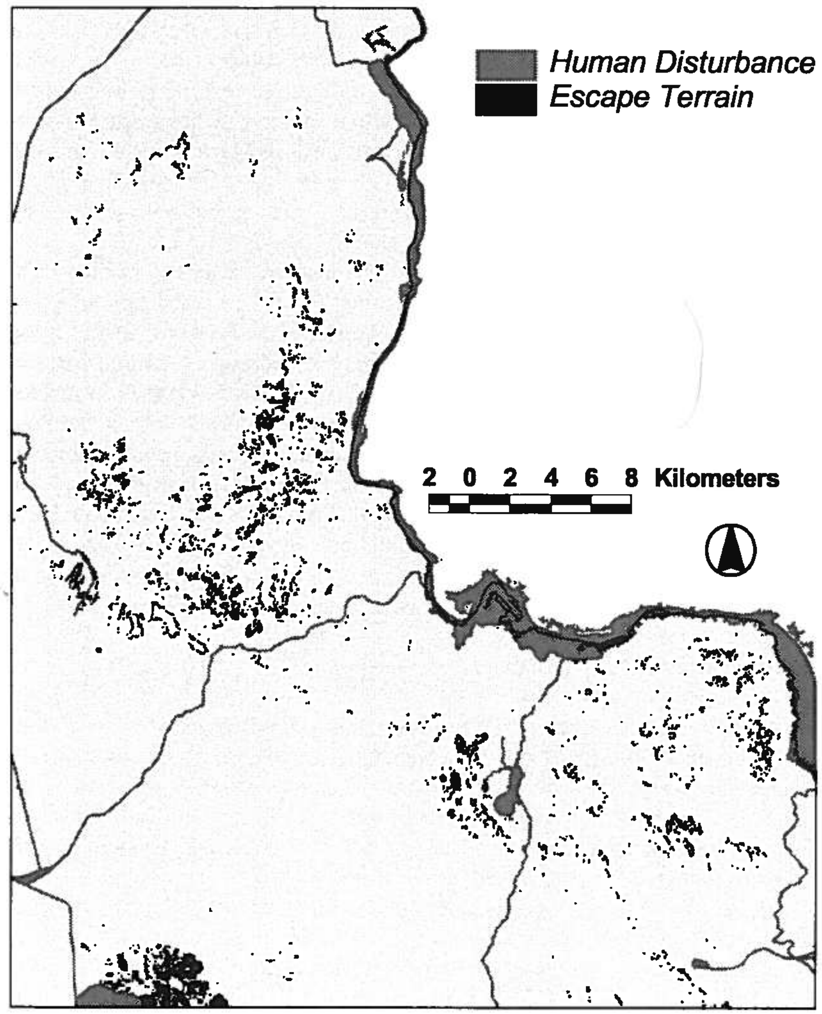

Figure 4. Escape terrain and areas of human disturbance in the East Chocolate Mountains, Imperial County, California.

We used a fixed-wing aircraft (Krausman et al. 1984) operated by a pilot experienced in radio telemetry to locate collared sheep every other week. We estimated geographic coordinates of each animal's position with a LORAN-C navigation unit (Model 612B, II Morrow Inc., Salem, Oregon, USA) installed in the aircraft. We assumed these locations were statistically independent (*sensu* Swihart and Slade 1985) because no two flights occurred within 10 days of each other. Moreover, we conducted telemetry flights at various times throughout the day (0700-1500). Ebert and Douglas (1993) used the method of Swihart and Slade (1985) to determine that estimated locations obtained during flights separated by >1 day met the criterion of independence.

Positions determined by LORAN-C in interior regions of California frequently show a systematic directional bias (Jaeger et al. 1993, Andrew 1994, Bleich et al. 1994, 1997, Jaeger 1994, Oehler et al. 1996, Nicholson et al. 1997). Thus, we estimated this source of error using the method of Bleich et al. (1997). We used the mean east-west shift (=554 m) and mean north-south shift (=-1,447 m) measured from 5 reference locations as estimates of the LORAN-C directional bias for the study area (Patric et al. 1988). All coordinates of telemetry locations obtained from the aircraft were shifted by these distances prior to analysis (Andrew 1994). Because our sample of reference locations was relatively small, we were unable to reliably detect geographic shifts in the bias across the study area, as has been reported by others (Nicholson et al. 1997).

We measured the pilot's ability to locate telemetered animals by placing eight radio-collars in locations known to be inhabited by sheep in the study area. We determined the true location (error < 6 m; August et al. 1994) of each of these transmitters using a global positioning system (GPS) receiver (Pathfinder Basic, Trimble Navigation, Sunnyvale, California, USA). We corrected the coordinates using data from a base station 170 km away in Encino, California, USA, and shifted them to account for LORAN-C bias. We also calculated the distance and direction of each GPS-derived position of a radio collar from the pilot's estimate of its position. There was no consistent shift in either the X- or Y-axis when data were pooled, and the radius of the 95% circular error probability polygon (CEP; August et al. 1994) was 1 km. Hence, we considered the error polygon for each telemetry location to be a circle centered on that location and with a radius of 1 km (Andrew 1994).

Habitat Data

We analyzed sheep habitat using raster and vector GIS analytical processes (August et al. 1996, Berry 1993). The eight habitat variables entered into the GIS database for the study area were elevation, slope, aspect, overall terrain roughness, vegetation, drinking water, escape terrain, and areas of human disturbance. We derived elevation, aspect, and slope data from 1:24,000 Digital Elevation Models (DEMs) purchased from the United States Geological Survey (USGS 1990, August 1993); the 30-m cell (= pixel) size of the USGS DEM was retained for all analyses. We assembled the data sets to create a single DEM for the entire study area (Figure 5), and created raster representations for elevation class, slope, and aspect using the GRID module of ARC/INFO (Environmental Systems Research Institute, Redlands, Calif., USA). Elevation was divided into 7 classes of 75 m intervals. Percent slope (Figure 6) was divided into 5 discrete classes using the intervals

adopted by Cunningham (1989) and Ebert and Douglas (1993). Eight aspect classes (plus level ground) were used and these were N, NE, E, SE, S, SW, W, and NW.

We developed an index of terrain roughness that reflects variation in slope and aspect at any given location. This index is calculated as:

$$R_{ij} = ((V_s/V_m)*100) + ((A_n/9)*100) \qquad \text{eq. 1}$$

where R_{ij} = roughness at pixel row i, column j; V_s is the standard deviation of slope in a 90-m radius around pixel_{ij}; V_m is the maximum standard deviation in slope in the study area, and A_n is the number of different aspect classes within 90 m of pixel_{ij}. Any pixel with high variation in slope and many different aspect classes in

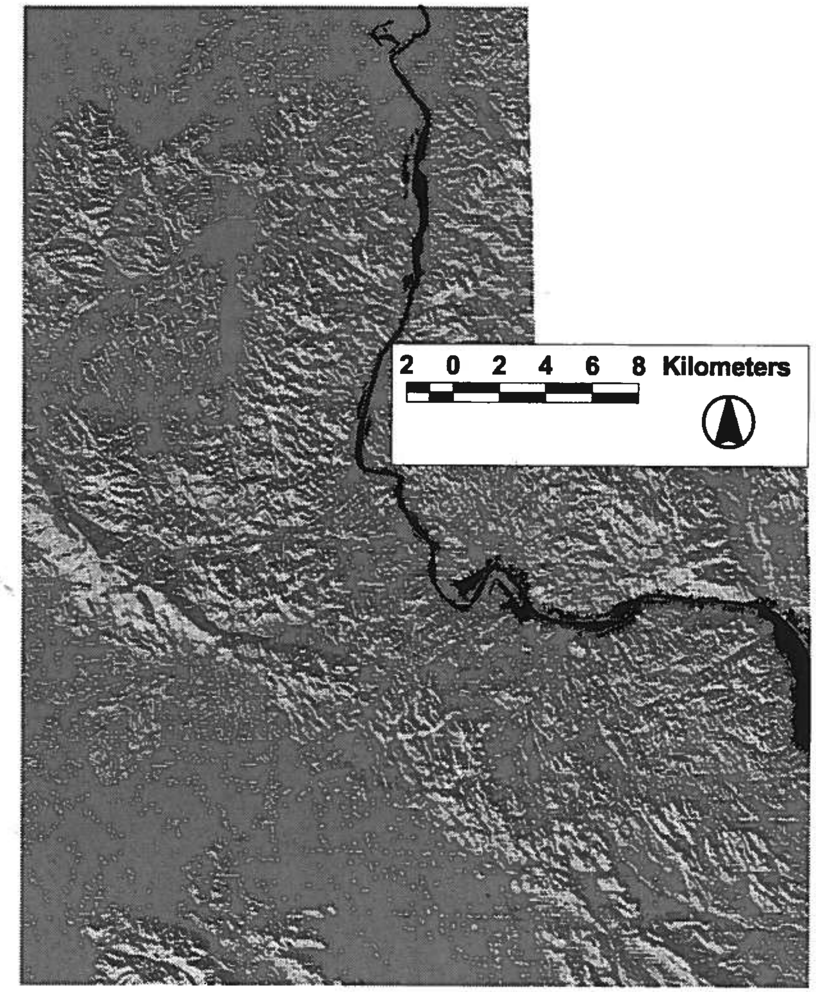

Figure 5. Shaded relief map of the East Chocolate Mountains, Imperial County, California.

the 90-m analytical radius would have a high R value. Commensurate with a decrease in the variation of slope or aspect would be a decrease in R. Although the R value is a continuous variable, five terrain roughness classes were created to facilitate analysis and these were described as flat (R=0), low (R=1), moderate (R=2-4), medium high (R=5-9), and high (R>10).

Escape terrain was defined as all areas where slope exceeded 60% (Bleich and Holl 1982, Cunningham 1989, Ebert and Douglas 1993). We defined areas of human disturbance as being within 50 m of mines, heavily used roads, or the Colorado River (Figure 4). This extremely conservative distance was based upon field

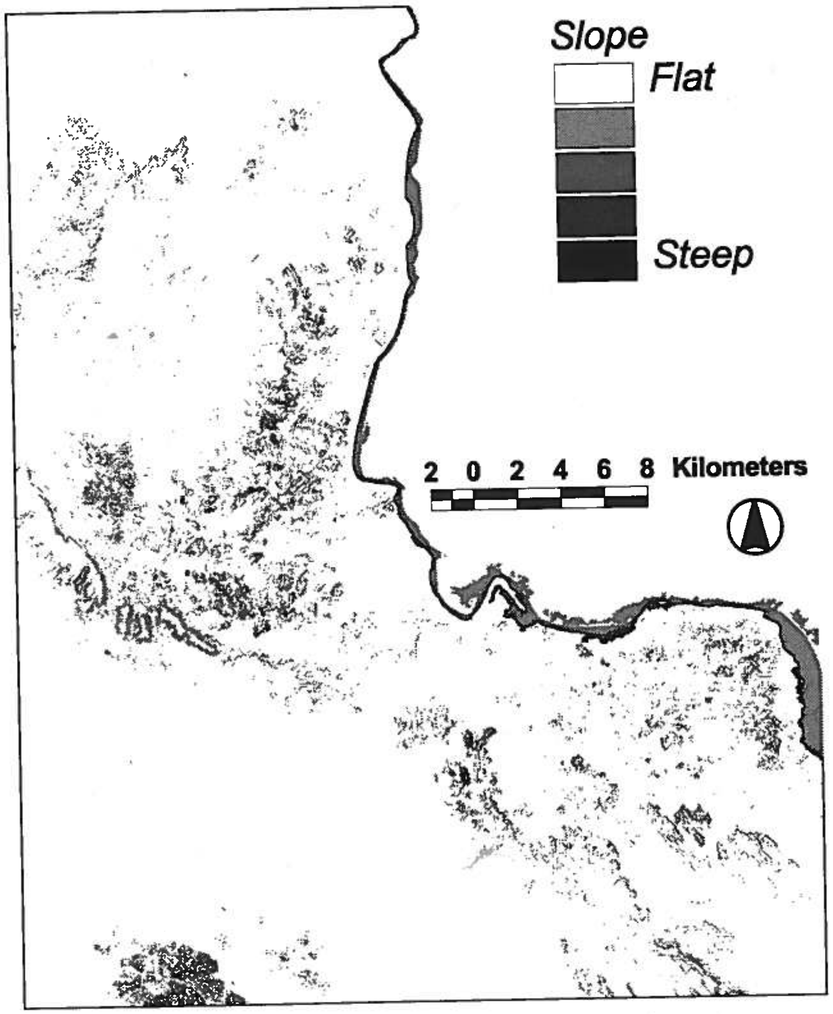

Figure 6. Distribution of slope classes in the East Chocolate Mountains, Imperial County, California.

observations of the distance that sheep typically engaged in a flight response (N. G. Andrew, pers. obs.). We judged heavy use to be any road or river segment on which motorized vehicles passed at least three times per week during summer. The drinking water data set consisted of the 26 point sources potentially used by sheep and three sites along the Colorado River where sheep were known to drink.

We mapped the distribution of four vegetation types (Figure 2): wash, bajada (associated with flat or rolling topography), riparian (abutting the Colorado River), and upland (associated with montane topography) in the study area using 1:36,000 black and white aerial photographs (USGS National High Altitude Photography; Rasher and Weaver 1990, Andrew 1994) taken in 1985 and enlarged to 1:24,000. We recompiled the delineations of vegetation types to 1:24,000 topographic quadrangles and digitized them into the GIS. These were converted to a raster data structure (30-m cell size) prior to analysis.

Analytical Procedures

The area within the 1-km radius CEP around each telemetry fix was the fundamental spatial unit for the analyses of habitat data (elevation, slope, aspect, terrain roughness and vegetation). For each circle, we measured the proportion of its total area (3.14 km^2) in each habitat category. We tested if sheep were selecting or avoiding habitats using the methods of Neu et al. (1974) and Byers et al. (1984). Bonferroni confidence intervals were computed to compensate for experiment-wise error. "Used" habitat was the sum of the proportions of habitats within CEPs. The amount of "available" habitat was the total area of each habitat type within the study area as a whole, which included 1 km beyond the extreme southwest and northeast locations where sheep were observed. Thus, the limits of the study area (sensu Alldredge and Ratti 1986, Porter and Church 1987, Thomas and Taylor 1990) were determined by the distribution of sheep and, therefore, it is conceivable that all areas within this region were used by sheep. We excluded that area east of the Colorado River because telemetered sheep did not traverse the river during the study.

We defined two seasons based on the monthly temperature and rainfall summaries provided by the Imperial Irrigation District (City of Imperial, Imperial County, Calif.). "Hot" months were April-October and the "cool" months were November-March. For vegetation analyses, we subdivided the hot months into hot/dry and hot/wet based on rainfall patterns during the study period (see Andrew, 1994 for details).

For analyses of the proximity to drinking water, escape terrain, and areas of human disturbance we created a data set of 1,000 points randomly located in the study area. For each of the random points and for each location of a sheep sighting we measured the distance to the closest water, escape terrain, or human disturbance. When a random point or a sheep sighting fell inside a landscape feature being measured, it was deleted from the analyses. There was no bias in excluding random points or sheep sightings that fell inside landscape features; the same proportion of points were excluded in both datasets (Escape terrain $\chi^2 = 0.17$, $p > 0.1$; Human disturbance $\chi^2 = 0.01$, $p > 0.1$). We used the Wilcoxon 2-Sample Test to evaluate the null hypothesis that mean distance to a resource (or source of disturbance) was the same for random points and sheep sightings, to compare mean distances to resources (or source of disturbance) between genders, and for seasonal comparisons.

The fundamental unit of our statistical analyses was the location of each individual animal in each telemetry sample. We tested for differences in habitat association by the individual sheep, but the results were inconsistent and confusing. Some sheep showed some differences with respect to other sheep for some variables some of the time. Because of this ambiguity, we ignored the individual identity of sheep and only considered gender and season as class variables.

Because our habitat use data were not normally distributed (and an arcsine transformation for proportional data [Zar 1996] did not normalize them) we used non-parametric tests for all statistical comparisons. The Wilcoxon 2-Sample Test was used for two-way comparisons and the Kruskal-Wallis Test was used for multi-class comparisons; the chi-square approximations of the Wilcoxon "*t*" and Kruskal-Wallis "*H*" statistics are reported (SAS Institute 1990). Categorical data were analyzed with a G-Test (Sokal and Rohlf 1981), and we used the Spearman Rank for correlation analyses. All statistical tests were computed using PC-SAS software (SAS Institute, 1990).

We evaluated Cunningham's (1989) habitat model by creating a grid network over the study area; each cell was 2 km on a side with an area of 4 km^2. For each cell, we calculated the Cunningham score (0-85 points) that indexed the suitability of the habitat for sheep. This index is the sum of five different habitat measures: natural topography, vegetation type, precipitation, availability of drinking water, and human use. Each grid-cell was classified according to this standard and assigned a sheep habitat rating of poor (0-50), fair (51-69), good (70-79), or excellent quality (80-85). We calculated the total number of sheep sightings that fell within the boundaries of each 4 km^2 cell and the total number of 1-km CEPs that fell within each cell. We evaluated the Cunningham model by comparing the frequency of occurrences of sheep in cells having high Cunningham scores with that in cells having low scores.

We developed a linear discriminant function to predict locations in the East Chocolate Mountains that were most suitable for sheep. For these analyses, we retained the 4 km^2 grid system used to test the Cunningham model. For each grid cell, we calculated the total area of vegetation type and highly "rough" terrain. To distinguish cells characterized by steep slopes from those that were less steep, we calculated the slope of each pixel in the digital terrain model (DTM) and summed these for each 4 km^2 analysis cell; the larger the resulting sum, the steeper and more extensive the slope was over the 4 km^2 cell. We followed the same procedure for elevation by summing for each 4 km^2 analysis cell the elevation value for every pixel in the DTM. To assess the availability of water for sheep, we counted the number of drinking water sources that occurred in each cell. To evaluate the level of human disturbance, we measured the total area of each cell that contained "disturbed" regions.

RESULTS

Habitat Profile

We used aerial telemetry to obtain 640 locations of mountain sheep (456 female, 184 male) during June 1992-December 1993 (Figure 7). Females used elevation classes in proportion to availability and showed little seasonal variation; however, females occurred at elevations from 225-299 m significantly more during the hot season than the cool season (Table 1). Males avoided elevations from 225-229 m during both seasons, but used all others in proportion to availability (Table 1). There was no seasonal difference other than greater use of elevations > 300 m during cool months than during hot months.

Males and females used eight aspect categories in proportion to availability during all seasons (Table 2). Females differed in their use of aspect among seasons. They used south-facing slopes more in the cool season than the hot season and, similarly, they used north-facing slopes less in the cool season than in the hot season. Males showed much less seasonal variation in the use of aspect, but used southwest aspects in the cool months and north-facing slopes more in the warm season. Females avoided level terrain during both seasons, whereas males showed no selection for or against this aspect category.

Females and males used slope categories similarly (Table 3). Both genders used flat (0-20% slope) areas less frequently and preferred slopes from 21-40% during the hot season. Females showed a significant preference for 21-40% slopes in all seasons, and slopes of 41-60% during the hot months. Males showed no seasonal variation in use within slope classes, whereas females used slopes ranging from 21-40% more often during the cool season.

All sheep selected upland vegetation and avoided bajada and wash vegetation during all seasons (Table 4). Females avoided riparian habitat in the hot season, and used it in proportion to availability the remainder of the year. This modest use of riparian habitat likely was an artifact of our sampling techniques, combined with the size of the circular error of probability, since three heavily used water sources are near the Colorado River. Males used riparian habitat in proportion to availability throughout the year. There was no significant difference in the use of vegetation classes between genders or seasons.

Both genders avoided flat terrain and preferred moderately rough terrain during all seasons (Table 5). In general, there was little seasonal variation in the use of terrain classes by either gender, although females selected landscapes with low terrain roughness during the hot season but not the cool season.

To test the hypotheses that sheep distribute themselves on the landscape in a random fashion, we compared the distances that sheep sightings occurred from the nearest water sources, escape terrain, and human disturbance to distances from randomly generated points. Throughout the year, male and female telemetry locations were closer to water than random points (Table 6), and the distance to water did not differ between genders during either season (Table 7). Throughout all seasons, females occurred farther from human disturbance than did random points, whereas males occurred closer (Table 6), and the difference between genders was significant in both seasons (Table 7). Females increased their distance from human disturbance during the hot season ($\chi^2 = 14.7$, 1 df, $p < 0.001$), but males showed no seasonal shift ($\chi^2 = 1.2$, 1 df, $p = 0.27$). Both males and females were significantly closer to escape terrain than random points (Table 6), and neither females ($\chi^2 = 1.8$, 1 df, $p = 0.176$) nor males ($\chi^2 = 2.7$, 1 df, $p = 0.099$) showed significant seasonal variation in proximity to escape terrain (Table 7).

Habitat Suitability Models

We used the Cunningham model to rate each of the 4 km² cells for their suitability as wild sheep habitat. In our study area, the cells with the highest scores were judged to be only "fair" quality habitat using Cunningham's (1989) classification.

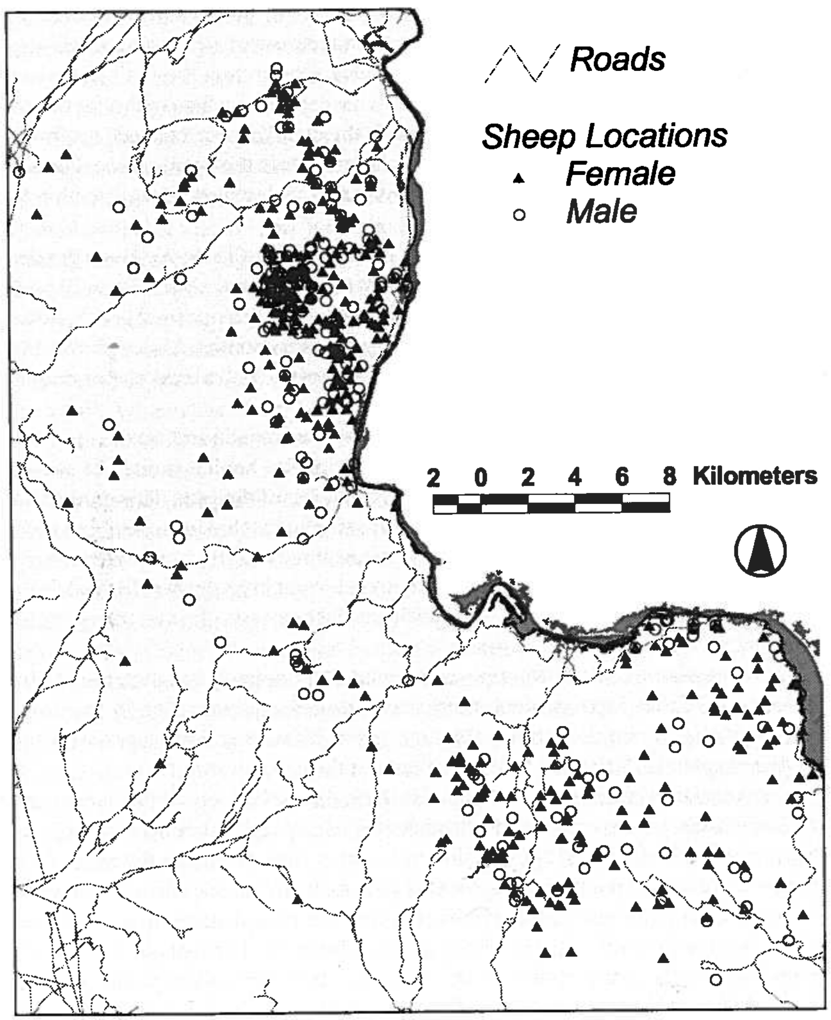

Figure 7. Telemetry locations obtained for male and female sheep in the East Chocolate Mountains, Imperial County, California, 1992-1993.

Table 1. Proportional use of elevation classes by female and male mountain sheep, by seasons. Mean (and standard deviation in parentheses) values are the average proportion of 1-km error polygons that consist of that elevation class. The number of times (n) that a particular elevation class appeared within the circular error of probability associated with telemetry locations of males or females is presented, along with means and standard deviations for the proportion of each elevation class in which a telemetry signal was detected. For each sex and season, a "+" symbol indicates habitat selection ($p < 0.05$) and a "-" symbol indicates habitat avoidance ($p < 0.05$). For males and females, differences within elevation classes between seasons are indicated as follows: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Elevation Class	Available		Males			Females		
Season	ha	Prop.	n	$\bar{x}$	(SD)	n	$\bar{x}$	(SD)
0-149m	18,324	0.19						
Hot			97	0.34	(0.27)	166	0.37	(0.35)
Cool			36	0.29	(0.26)	92	0.36	(0.24)
p				ns			ns	
150-224m	30,438	0.31						
Hot			112	0.42	(0.33)	315	0.39	(0.33)
Cool			36	0.52	(0.34)	116	0.42	(0.23)
p				ns			ns	
225-299m	31,503	0.32						
Hot			104	0.25	(0.25)(-)	277	0.34	(0.24)
Cool			40	0.22	(0.28)(-)	118	0.25	(0.26)
p				ns			***	
300-647m	18,025	0.18						
Hot			56	0.094	(0.15)	66	0.023	(0.026)
Cool			32	0.24	(0.24)	41	0.024	(0.041)
p					***		ns	

The mean number of sheep sightings in our "fair" quality cells (mean = 5.8 ± 10.1 [SD] sightings/cell; $n = 51$) was larger than the mean number of sightings in "poor" quality cells (mean = 1.5 ± 3.9 sightings/cell; $n = 224$) and this difference was highly significant ($\chi^2 = 28.6$, 1 df, $p < 0.001$). The total number of telemetry points per cell was highly correlated ($r_s = 0.79$, $p < 0.001$) with the total number of CEPs occurring within a cell; thus, it is not surprising that there were significantly greater number of CEPs occurring within "fair" quality than "poor" quality cells ($\chi^2 = 31.1$, $p < 0.001$). Cunningham scores were significantly correlated with number of sightings per cell ($r_s = 0.49$, $p < 0.001$) and total number of CEPs falling within each cell ($r_s = 0.53$, $p < 0.001$).

We used the same 4 km² grid network to evaluate habitat and sheep sighting data. The distribution of habitat resources within cells where sheep were frequently seen (> 3 sightings/cell), infrequently seen (1-3 sightings/cell), and never seen are presented in Table 8. Sheep were more common in cells characterized by steep slope, abundant upland habitat, sparse bajada habitat, plentiful escape terrain, more water sources, and low human disturbance.

Table 2. Proportional use of aspect category by female and male mountain sheep, by seasons. Mean (and standard deviation in parentheses) values are the average proportion of 1-km error polygons that consist of that aspect class. The number of times (*n*) that a particular aspect category appeared within the circular error probability polygons associated with telemetry locations of males or females is presented, along with means and standard deviations. For each sex and season, a "+" symbol indicates habitat selection ($p < 0.05$) and a "-" symbol indicates habitat avoidance ($p < 0.05$). For males and females, differences within aspect classes between seasons are indicated as follows: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Aspect category	Available		Males			Females		
Season	ha	Prop.	n	$\bar{x}$	(SD)	n	$\bar{x}$	(SD)
North	11,543	0.12						
Hot			130	0.13	(0.04)	331	0.12	(0.03)
Cool			54	0.12	(0.05)	125	0.10	(0.03)
p				*			***	
Northeast	13,600	0.14						
Hot			130	0.14	(0.03)	331	0.15	(0.03)
Cool			54	0.14	(0.04)	25	0.15	(0.03)
p				ns			ns	
East	14,217	0.15						
Hot			130	0.15	(0.04)	331	0.18	(0.04)
Cool			54	0.15	(0.04)	125	0.19	(0.03)
p				ns			***	
Southeast	12,479	0.13						
Hot			130	0.12	(0.04)	331	0.12	(0.04)
Cool			54	0.12	(0.04)	125	0.13	(0.03)
p				ns			***	
South	10,888	0.11						
Hot			130	0.10	(0.04)	331	0.09	(0.04)
Cool			54	0.12	(0.04)	125	0.10	(0.03)
p				ns			**	
Southwest	11,510	0.12						
Hot			130	0.10	(0.04)	331	0.10	(0.04)
Cool			54	0.11	(0.04)	125	0.11	(0.04)
p				*			**	
West	12,222	0.12						
Hot			130	0.12	(0.05)	331	0.13	(0.05)
Cool			54	0.12	(0.04)	125	0.11	(0.04)
p				ns			**	
Northwest	11,228	0.11						
Hot			130	0.13	(0.04)	331	0.12	(0.04)
Cool			54	0.12	(0.04)	125	0.10	(0.03)
p				ns			***	
Level	602	0.01						
Hot			33	0.01	0.04	172	0.002	0.009(-)
Cool			23	0.01	0.03	77	0.004	0.01(-)
p				ns			*	

Table 3. Proportional use of slope categories by female and male mountain sheep, by seasons. Mean (and standard deviation in parentheses) values are the average proportion of 1-km error polygons that consisted of that slope category. The number of times (n) that a particular slope category appeared within the circular error probability polygon associated with telemetry locations of males or females is presented, along with means and standard deviations. For each sex and season, a "+" symbol indicates habitat selection ($p < 0.05$) and a "-" symbol indicates habitat avoidance ($p < 0.05$). For males and females, differences within slope categories between seasons are indicated as follows: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Slope class	Available		Males			Females		
Season	ha	Prop.	n	$\bar{x}$	(SD)	n	$\bar{x}$	(SD)
0-20%	74,529	0.76						
Hot			130	0.55	(0.20)(-)	331	0.59	(0.22)(-)
Cool			54	0.53	(0.21)(-)	125	0.56	(0.16)(-)
p				ns			ns	
21-40%	16,907	0.17						
Hot			129	0.31	(0.11)(+)	330	0.28	(0.12)(+)
Cool			53	0.32	(0.12)	125	0.31	(0.09)(+)
p				ns			*	
41-60%	5,424	0.06						
Hot			126	0.11	(0.08)	303	0.11	(0.08)(+)
Cool			51	0.13	(0.08)	123	0.11	(0.07)
p				ns			ns	
> 61%	1,429	0.012						
Hot			226	0.02	(0.02)	469	0.02	(0.02)
Cool			89	0.02	(0.02)	201	0.02	(0.02)
p				ns			ns	

We developed a linear discriminant function to determine how well we could predict cells with and without sheep. The classification variable was category of sheep sightings per cell (none, infrequent, frequent; as above) and the independent variables were the habitat variables shown in Table 8. There was a highly significant difference in habitat characteristics among abundance classes (Wilks' Lambda; $F = 9.3$; 16, 530 df; $p < 0.001$). The amount of upland vegetation, terrain roughness, and slope were the variables most effective in discriminating among categories of sheep abundance (Table 8). Using a jackknife procedure (Quenouille 1956), the model correctly classified cells where sheep were absent 71% of the time and cells where sheep were present 75% of the time. Cells where more than three sheep were sighted were correctly identified in 61% of the cases and cells where sheep were seen three or fewer times were correctly identified only 31% of the time. Thus, the model did quite well at identifying locations where sheep were absent or frequent, but did less well at identifying locations where sheep occurred only infrequently.

Table 4. Proportional use of vegetation types by female and male mountain sheep, by seasons; sample sizes are the number of circular error probability polygons for males and females, by season; data are presented as mean proportions and standard deviation. For each sex and season, a "+" symbol indicates habitat selection ($p < 0.05$) and a "-" symbol indicates habitat avoidance ($p < 0.05$). For males and females, annual differences and differences within vegetation types among seasons are indicated as follows: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

		Vegetation Type: Upland		Bajada		Wash		Riparian	
Total Avail. (ha)		54,540		31,499		10,418		1,649	
Proportion Avail.		0.56		0.32		0.11		0.02	
		Use							
	n	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Annual									
Fem.	455	0.92	0.10 +	0.20	0.23-	0.05	0.07 -	0.09	0.05
Males	183	0.89	0.18 +	0.25	0.27-	0.05	0.08 -	0.07	0.05
p		ns		ns		ns		ns	
Females by Season									
Hot/Dry	155	0.91	0.18 +	0.22	0.27-	0.05	0.07 -	0.09	0.06 -
Hot/Wet	175	0.91	0.16 +	0.19	0.21-	0.06	0.09 -	0.09	0.07 -
Cool	125	0.92	0.14 +	0.19	0.21-	0.03	0.03 -	0.09	0.05
p		ns		ns		ns		ns	
Males by Season									
Hot/Dry	59	0.92	0.11 +	0.17	0.07-	0.07	0.05 -	0.08	0.07
Hot/Wet	71	0.87	0.21 +	0.19	0.21-	0.05	0.09 -	0.06	0.04
Cool	53	0.90	0.19 +	0.26	0.34-	0.04	0.08 -	0.10	0.05
p		ns		ns		ns		ns	

DISCUSSION

Habitat use implies that a particular environmental element is utilized for some purpose (Gysel and Lyon 1980). Associating specific ecological characteristics with the reasons that animals select or avoid certain habitats is often a difficult process. Indeed, it is impossible to know for certain whether animals are responding to a specific habitat element or to one or more other factors that covary with the habitat element under study. For example, our data show that mountain sheep have a marked tendency to associate with upland habitats. It is not clear from our univariate analyses if they are selecting upland habitats by keying on one or more other factors, such as a terrain ruggedness, vegetation association, micro-climate, visibility within the landscape, or proximity to water. The complex interactions among variables can be of significant importance in defining the way that sheep use geographic areas; therefore, we presented the results of multivariate analyses to elucidate the relative importance of the habitat variables.

Table 5. Proportional use of terrain roughness categories by female and male mountain sheep, by seasons. Mean (and standard deviation in parentheses) values are the average proportion of 1-km error polygons that consisted of that terrain roughness category. The number of times (n) that a particular terrain roughness category appeared within the circular error probability polygon associated with telemetry locations of males or females is presented, along with means and standard deviations. For each sex and season, a "+" symbol indicates habitat selection ($p < 0.05$) and a "-" symbol indicates habitat avoidance ($p < 0.05$). For males and females, differences within terrain roughness categories between seasons are indicated as follows: ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Terrain Category & Season	ha	Prop.	Available: Males n	$\bar{x}$	(SD)	Females n	$\bar{x}$	(SD)
Flat	79,986	0.82						
Hot			130	0.67	(0.18)(-)	331	0.69	(0.21)(-)
Cool			54	0.64	(0.18)(-)	125	0.66	(0.16)(-)
p				ns			ns	
Low	8,612	0.09						
Hot			129	0.17	(0.07)	326	0.15	(0.08)(+)
Cool			51	0.19	(0.05)	124	0.16	(0.06)
p				*			ns	
Moderate	6,406	0.07						
Hot			127	0.14	(0.09)(+)	310	0.14	(0.10)(+)
Cool			51	0.16	(0.09)(+)	124	0.14	(0.08)(+)
p				ns			ns	
Med. High	2,389	0.02						
Hot			113	0.03	(0.03)	255	0.04	(0.03)
Cool			48	0.03	(0.03)	119	0.03	(0.03)
p				ns			ns	
High	236	0.001						
Hot			63	0.01	(0.02)	151	0.008	(0.02)
Cool			29	0.005	(0.007)	60	0.004	(0.006)
p				ns			ns	

In this paper, we described for the first time diurnal habitat use by mountain sheep in the Lower Colorado River Subdivision of the Sonoran Desert. A common application of radio-telemetry is to assess habitat use (White and Garrott 1990), but researchers frequently fail to consider error associated with this procedure (Saltz 1994). We were extremely conservative in the analysis of our telemetry data; we considered any habitat occurring within 1 km of a telemetry point to possibly be of significance to an animal. There are potential problems of statistical sensitivity when error polygons are large and the patch size of habitat features (e.g., vegetation

Table 6. Mean distances in meters and standard deviation from sheep locations (n) and random points to water sources, escape terrain, and areas of human disturbance. The results of a Wilcoxon 2-Sample Test that mean random distances are equal to the mean distance of males or females for each resource or disturbance variable are indicated by asterisks (* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$).

Distance (m) to:	n	$\bar{x}$	SD
Water sources			
Random Points	1,000	3,142	1,730
Females	456	2,029***	1,164
Males	184	2,079***	1,299
Escape terrain			
Random Points	990	1,305	1,268
Females	441	464***	666
Males	174	509***	612
Human disturbance			
Random Points	970	2,860	2,009
Females	452	2,964**	1,425
Males	174	2,369**	1,545

Table 7. Mean distances in meters (standard deviation in parentheses), by season and gender, of sheep locations to water sources, escape terrain, and points of human disturbance by season. The results of a Wilcoxon 2-Sample Test of distance to each resource or disturbance variable are presented by gender. Differences between males and females within seasons are indicated as follows: ns = $p > 0.05$, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

	Season					
	Hot			Cool		
Distance (m) to	n	$\bar{x}$	(SD)	n	$\bar{x}$	(SD)
Water sources						
Females	331	2,044	(1,188)	125	1,994	(1,102)
Males	130	1,948	(1,203)	54	2,395	(1,473)
p		ns			ns	
Human disturbance						
Females	328	3,121	(1,458)	124	550	(1,249)
Males	128	2,444	(1,550)	54	2,194	(1,535)
p		***			*	
Escape terrain						
Females	321	633	(741)	120	382	(344)
Males	123	532	(588)	51	455	(670)
p		ns			ns	

Table 8. Habitat characteristics for 4 km^2 cells with none, 1-3, and >3 sheep sightings per cell. Sample sizes are the number of cells in which observations of no sheep, 1-3 sheep, and >3 sheep occurred; mean values (standard deviation in parentheses) are presented. Results of the Kruskal-Wallis Tests used to test the null hypothesis that the mean value for the habitat variable was equal among categories of sheep abundance are shown. χ^2 values and probabilities of differences among cell categories are presented (ns = $p > 0.05$, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$). Standard canonical coefficients for the independent variables were used to predict sheep abundance. The larger the standardized coefficient, the more important the variable was in distinguishing sheep classes for that canonical variate. We also present eigenvalues and the amount of total variation explained for each canonical variate.

Variable	No Sheep (n = 165)	1-3 Sheep/cell (n = 64)	>3 Sheep/cell (n = 46)	χ^2	CV1	CV2
Elevation (# of pixels)	881,021 (340,761)	1,008,290 (442,925)	886,699 (340,761)	1.1 ns	0.55	0.97
Slope (# of pixels)	43,664 (39,609)	74,069 (40,090)	89,461 (36,087)	59.5**	-0.53	-1.25
Upland Habitat (ha)	130 (149)	265 (132)	344 (9)	82.2***	1.14	-0.12
Bajada Habitat (ha)	151 (152)	82 (116)	19 (57)	38.2***	0.31	-0.18
Escape Terrain (# of pixels)	3 (14)	7 (10)	10 (14)	48.8***	-0.31	-0.42
Ruggedness (# of pixels)	1,515 (1,952)	2,536 (2,814)	4,468 (3,069)	64.7***	1.13	1.04
Human Activity (m)	21 (48)	10 (25)	7 (23)	13.0**	-0.24	-0.17
Water Sources (#)	0.05 (0.24)	0.25 (0.62)	0.25 (0.36)	19.6***	0.15	0.69
Eigenvalue					0.58	0.04
Percent variation explained					94	6

type, slope, etc.) are very small (White and Garrott 1986, Nicholson, August, Andrew, and Bleich, unpublished data). In theory, it should be easier to detect differences in the use of habitat that occurs in large patches (relative to the size of the error polygon) as compared to habitat features that are very small. We observed this in our results; we clearly detected differences in the use of vegetation types (large patches, average size is 500 hectares), but differences in habitat features that were fine grain and occurred in small patches (e.g., aspect, 0.09 hectare cell size) were more difficult to detect. Nevertheless, we were able to clearly detect use and avoidance among some of the habitat features that were developed from fine grain data (e.g., terrain roughness). Despite this conservative approach, our habitat use results generally are consistent with those obtained from populations of mountain sheep in other regions of the southwestern United States (Krausman et al. 1989, Ebert and Douglas 1993, Bleich et al. 1997, Elenowitz 1984). Moreover, our analyses of habitat features appear to be very sensitive to small, but perhaps biologically meaningful, differences in habitat use between genders or seasons.

Use of elevation classes by females in our study area is consistent with the findings of Cunningham and Ohmart (1986), Zine et al.(1992), Berner and Krausman (1992), and Ebert and Douglas (1993); males generally used all elevation classes. Elevation by itself is not a key topographic feature for mountain sheep (Bleich et al. 1997), and it was not an important variable in our multivariate analyses. Other measures of terrain, such as slope, aspect, or ruggedness are more meaningful to mountain sheep (McCarty and Bailey 1994).

Eight aspect classes were distributed uniformly across the study area and both genders used them in proportion to their availability. Nevertheless, several authors have recorded selection of certain aspect classes by wild sheep. Wakeling and Miller (1989) noted a pronounced selection of north and northwest slopes, and Gionfriddo and Krausman (1986) reported selection of north, northwest, and west aspects. Merritt (1974) reported that sheep bedded primarily in certain aspect classes to avoid areas of intense solar radiation. Our results are consistent with this tenet; male and female sheep used southern aspects less in the hot season and more during the cool season. Similarly, we found north-facing slopes to be used more frequently than southern slopes in the hot months. Contrary to our results, Holl and Bleich (1983) observed sheep to select southern aspects in the summer. Their results suggested that factors other than those based on behavioral manifestations of thermoregulation contribute to aspect selection, and confound a single explanation of the importance of aspect to mountain sheep. For example, sheep may differentially use north and south facing slopes because of the distribution of forage plants (Risenhoover and Bailey 1985) rather than to maximize or minimize exposure to solar radiation.

Slope use by sheep in this study area is broadly consistent with the findings of other researchers (Robinson and Cronemiller 1954, Merritt 1974, Krausman et al. 1989, Wakeling and Miller 1990, Berner et al. 1992, Berner and Krausman 1992, Cunningham and Hanna 1992, Zine et al. 1992, Ebert and Douglas 1993, Bleich et al. 1997). We found that males and females avoided slopes less than 20% and selected steeper slopes. Sheep in our study area may have used less steep slopes in the hot season because the majority of water sources are located at low elevations.

Male and female sheep both selected upland vegetation in all seasons, and they avoided all other vegetation types. The slight use of riparian vegetation noted in our results is likely an over representation of its actual use and a result of our sampling techniques. Since three heavily used water sources are near the Colorado River, it is probable that riparian vegetation was included in the 1-km CEPs when sheep were near the river to drink. Indeed, sheep avoided similar vegetation along other stretches of the river (Figure 2).

Rough or broken terrain is an important component of sheep habitat (Ferrier and Bradley 1970, McQuivey 1978, Leslie and Douglas 1979, Hansen 1980). Previous investigators have described terrain roughness more in qualitative than in a quantitative terms (Hansen 1980, Brown 1983, Cunningham 1989). Beasom et al. (1983), Ebert and Douglas (1993), and Bleich et al. (1997) quantified roughness by measuring the length or number of contour lines falling within a study grid, cell, or pixel. Their indices, however, simultaneously measured variation in aspect and steepness of slope, but not variation in slope. Although these methods provided site-specific indices of terrain roughness they are not readily comparable among locations.

Our measure of terrain roughness reflects variation in slope (not just steepness) and aspect: highly broken, or rough, areas would have many different slopes and many different aspects. We found that sheep avoided flat areas and selected moderate terrain roughness categories. Females selected low roughness areas during the hot months and used all other categories in proportion to availability. Only males exhibited variation in seasonal use of the roughness categories, and they used habitats exhibiting low roughness in the cool months. Differences in the use of roughness categories may be a function of the differing life history strategies of males and females (Bleich et al. 1997). Moreover, nearly all heavily used water sources were located in either flat, low, or moderate roughness classes, and the availability of this resource likely affected terrain use.

The importance of standing water to desert sheep, particularly during the summer, has been questioned by Broyles (1996). Although some small, isolated populations appear to persist without perennial standing water (Krausman et al. 1985), most authors concur that water is important and may be a limiting factor for sheep in the warmer months of the year (Hansen 1965, Blong and Pollard 1968, Turner and Weaver 1980). Indeed, we found males and females closer to water than would be expected by chance alone, and there was no gender or seasonal affect. These findings contrast, however, with those of Dunn (1984) who found males closer to water than females, and Leslie and Douglas (1979), Ebert and Douglas (1993), and Bleich et al. (1997) reported that females occurred closer to water than males. Although we found females close to water throughout the year, careful interpretation of proximity data is mandated when one does not consider the juxtaposition of other potentially important landscape features relative to the water sources (Bleich et al. 1997).

This population of sheep experienced the effects of a severe drought, across their range from 1995-1998. During the 32 months of drought only 7.6 mm of rain was recorded on average across their range (Lesicka and Andrew, unpublished data). All interior water sources were dry and access to the three water sources along the Colorado River was severely restricted. By the end of this drought, we estimated fewer than 50 adult sheep in the region. Prior to the drought, the population was estimated to be 160 individuals (Andrews et al. 1997). Clearly, available water is a significant habitat resource for this population of sheep.

North American mountain sheep typically are associated with precipitous terrain (Geist 1971), and females are more likely to occupy terrain that is more rugged than that occupied by males (Bleich et al. 1997). Contrary to the findings of other researchers, our results indicate no difference between gender in the distance that they occur from escape terrain. We submit, however, our ability to detect differences using these fine grain data may have been compromised.

The nature of interactions between humans and sheep vary, as do the consequences of those interactions (Monson and Sumner 1980). Moreover, individual sheep vary in their reaction to human disturbance and reactions may vary among populations as well (Cunningham and Hanna, 1992). We found that males occurred closer to areas of human disturbance than did females during both seasons, suggesting that males are more tolerant of disturbance than are females in our study area. This finding is consistent with the notion that males use habitats that present more risks than those used by females (Bleich et al. 1997), but we did not quantify the motivation for doing so in our study area. Wild sheep occurred near the Colorado River during the hot season and showed some aversion to boat traffic (Andrew, pers. observ.). This source of disturbance was, however, not always sufficient to keep animals from drinking water.

There has been a proliferation of mountain sheep habitat use and evaluation models as researchers and managers seek to conserve or enhance remaining populations. Cunningham (1989) derived his model from Hansen's (1980) Mojave Desert model, but modified it for use in Sonoran Desert habitats of Arizona. Ebert and Douglas (1993) recently applied a modified version of Cunningham's (1989) model in a Mojave Desert ecosystem and found it to be an excellent predictor of sheep habitat in the Eldorado Range of Nevada. Our results suggest that Cunningham's (1989) original model is not as useful in the Lower Colorado River Subdivision of the Sonoran Desert in California. This finding has implications for the evaluation of potential conservation efforts including identifying reintroduction sites in southeastern California, southwestern Arizona, and northern Mexico.

Using Cunningham's (1989) model, the low rating assigned to the vegetation of our study area, locally heavy human disturbance, and the abundance of feral asses made it impossible to derive a score greater than 58 (fair quality) yet, prior to the aforementioned drought our study area supported an estimated 160 adult mountain sheep, the largest population in southeastern California (Andrew et al. 1997). Although sheep selected the "best" habitat available to them (i.e., fair over poor), absolute scores obtained using Cunningham's (1989) model would have led investigators to classify habitat as less valuable to mountain sheep than it was. Such conclusions could have important implications for the conservation of mountain sheep habitat and, almost certainly, for assessing the suitability of potential reintroduction sites. Thus, investigators working to reestablish mountain sheep within the Lower Colorado River Valley Subdivision of the Sonoran Desert should be aware of the differences in relative habitat values derived using Cunningham's (1989) model and ours. Application of Cunningham's (1989) model in this desert region could lead to the conclusion that habitat is of lower value than would be indicated by actual sheep use. We conclude that mountain sheep selected the most appropriate habitat available, even though a widely used habitat model assigned low value to it. Hence, investigators must view scores derived from the application of habitat models in a relative, rather than an absolute, context.

Our univariate analyses were insightful for describing how sheep used their environment, but our GIS-based multivariate analyses provided a different perspective on how sheep used the landscape as we attempted to develop a predictive habitat model. The model correctly classified cells where sheep were absent 71% of the time, and cells where sheep were present 75% of the time. Cells where more than three sheep were sighted were correctly identified in 61% of the cases and cells where sheep were seen three or fewer times were correctly identified only 31% of the time. Thus, the model did quite well at identifying locations where sheep were absent or abundant, but did less well at identifying locations where sheep occurred only infrequently. Nevertheless, application of this model has the potential to enhance the probability of selecting suitable locations for restoration of these ungulates to unoccupied habitat as well as providing direction for land protection strategies and other active management needs. Currently we are studying sheep movements and resource availability in an adjacent mountain range in order to test our model on an independent dataset.

There is a sizeable literature on the ecology of mountain sheep, but there is a lack of quantitative information on how they use the environment on a site-specific basis. As McCarty and Bailey (1994) pointed out, the absence of manipulative experiments and a lack of adherence to the scientific method have limited what we know and, therefore, what we can model about mountain sheep habitat.

Undertaking mountain sheep research armed with robust experimental designs and falsifiable hypotheses (e.g., Romesburg 1981, Murphy and Noon 1991, Sinclair 1991) will enhance our ability to model habitat requirements and, ultimately, will be of great importance in the conservation and restoration of this unique ungulate. The advent of GIS and GPS technologies make it easier and more cost-effective to obtain and rigorously analyze information at the level of the landscape. Access to "over the counter" geographical data, such as digital elevation models, aerial photography, and satellite imagery (August et al. 1996, Congalton et al. 1998) make it possible to quantitatively assess many elements of sheep habitat without the associated high costs of conducting extensive field work in remote and rugged areas. Proper application of those data, using models appropriate to the geographic area in question, have important implications for the conservation of mountain sheep in northern Mexico, southeastern California, and southwestern Arizona.

As articulated by Medellin (1998), significant achievements can be made when biologists from the United States and Mexico share their scientific expertise, quality data, predictive models, and creative solutions to the wildlife conservation challenges facing both countries. The data and model we present here will, no doubt, make a significant contribution to the cooperative efforts required to conserve viable populations of desert sheep in the Sonoran Desert.

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