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Demography and Habitat Use of Desert-Dwelling Mountain Sheep in the East Chocolate Mountains, Imperial County, California

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DEMOGRAPHY AND HABITAT USE OF DESERT-DWELLING
MOUNTAIN SHEEP IN THE EAST CHOCOLATE MOUNTAINS,
IMPERIAL COUNTY, CALIFORNIA

BY

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ABSTRACT

I undertook a two year study in June 1992 to describe the demography and habitat use of desert-dwelling mountain sheep (Ovis canadensis nelsoni) inhabiting the East Chocolate Mountains, Imperial County, California. For demographic parameter description I collected data using ground observations, remote cameras, and helicopter surveys on 25 adult mountain sheep (17 females, 8 males) that had been captured and fitted with radio-collars in 1992. I used Bailey's (1952) method to estimate the population of males and females, in 1992 and 1993. Telemetry data indicated the presence of two female sub-populations. Based upon ground observations and on helicopter surveys conducted in 1993, I estimated this population to be 206 animals with a 95% confidence interval of 149-327 animals. Adult sex ratios (68-80 males:100 females) derived from the 1993 data were similar to those recorded for other unhunted populations of desert-dwelling mountain sheep. The 1993 lamb (14-44:100 females) and yearling (0-16:100 females) ratios suggest modest lamb production and low recruitment. Adult survivorship for this population is high.

For diurnal habitat use studies I collected aerial radio-telemetry location data, from June 1992 to December 1993, on 25 (17 females, 8 males) mountain sheep. in the East Chocolate Mountains, Imperial County, California. I empirically derived a 95% circular probability error polygon (CEP) of 1 km for telemetry data collected in the study area. The CEP (3.14 km^2) around each telemetry point was the fundamental unit for habitat analyses, which used vector- and raster-based Geographical Information System (GIS) data processing. The selected eight habitat variables were evaluated by gender for three seasons of the year: hot/dry, hot/wet, and cool. Females avoided the lowest and highest elevation and slope classes, selected upland vegetation in all seasons, used rough terrain, and avoided flat landscapes. Males used all elevation classes in proportion to their availability except mid-elevation habitats which they avoided. Males avoided extremely flat and extremely rough terrain classes and used all other in proportion to availability. Males selected upland habitats in all seasons. Neither gender showed selection or avoidance of any aspect class. All sheep were found closer to water sources, and escape terrain, and farther from areas of human disturbance than would be expected by random movement on the landscape. Females were located farther from areas of human disturbance than males but did not differ from males in their distance from drinking water or escape terrain. I used Cunningham's (1989) habitat evaluation model to rate habitat quality of areas with the highest observed sheep densities. The model rated these habitats to be only "fair" quality.

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myself and that I could, "at my age," have a career for which I felt passion.

PREFACE

Mountain sheep (Ovis canadensis) once were widespread in California; however, by 1940, 45 of 108 known populations had been extirpated (Wehausen et al. 1987, Bleich et al. 1990). As early as 1873, the State of California began to protect wild sheep, but with limited success. Current efforts to conserve this species include: determining the distribution, demographics, and the status of remaining populations; improving habitat in mountain ranges inhabited by wild sheep; and, re-establishing sheep populations in areas they previously occupied.

The East Chocolate Mountains, in eastern Imperial County, California, support a population of mountain sheep (Ovis canadensis nelsoni) that has not been adequately investigated (Weaver and Mensch 1969). In 1992, I initiated a 2-year investigation to estimate demographic characteristics, quantify the habitat use by this population, and make general management recommendations.

This thesis was written in manuscript form in accordance with the requirements of the Graduate School of the University of Rhode Island. Chapter 1 was written in the style of *California Fish and Game*, whereas Chapter 2 was written in the style of the *Journal of Wildlife Management*.

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CHAPTER 1

DEMOGRAPHY OF DESERT-DWELLING MOUNTAIN SHEEP IN THE EAST CHOCOLATE MOUNTAINS, IMPERIAL COUNTY, CALIFORNIA

ABSTRACT

I collected data using ground observations, remote cameras, and helicopter surveys for 25 adult mountain sheep (17 females, 8 males) that had been captured and fitted with radio-collars in 1992, to determine the demographic profile of that species (*Ovis canadensis nelsoni*) in the East Chocolate Mountains, Imperial County, California. I used Bailey's (1952) method to estimate the population of males and females in 1992 and 1993. Telemetry data indicated the presence of two female sub-populations. Based upon ground observations and on helicopter surveys conducted in 1993, I estimated this population to be 206 animals with a 95% confidence interval of 149-327 animals. Adult sex ratios (68-80 males:100 females) derived from the 1993 data were similar to those recorded for other unhunted populations of desert-dwelling mountain sheep. The 1993 lamb (14-44:100 females) and yearling (0-16:100 females) ratios suggest modest lamb production and low recruitment. Adult survivorship for this population is high.

INTRODUCTION

Mountain sheep (*Ovis canadensis*) once were widespread in California; however, by 1940, 45 of 108 known populations had been extirpated (Wehausen et al. 1987, Bleich et al. 1990*b*). As early as 1873, the State of California began to protect wild sheep populations, but with limited success (Wehausen et al. 1987). Current efforts to conserve this species include: determining the distribution, demography, and status of remaining populations; undertaking habitat improvements in mountain ranges known to be inhabited by wild sheep; and, re-establishing sheep populations in areas that they previously occupied.

The East Chocolate Mountains, in eastern Imperial County, California, support a population of mountain sheep (O. c. nelsoni) that previously had not been intensively investigated (Weaver and Mensch 1969). In 1992, I initiated a 2-year project to estimate demographic characteristics of the population, explore the feasibility of using this population as a source of translocation stock for reintroduction efforts, and provide information so that the California Department of Fish and Game could ascertain whether the population could support a limited sport harvest of mature males.

THE STUDY AREA

The Chocolate Mountains, oriented on a northwest/southeast axis, are located in southeastern California (Figure 1.1). California State Highway 78 bisects the range; the mountains west of the highway are managed by the U. S. Department of Defense and are used as an aerial gunnery range (Thompson 1989). Only that part of the Chocolate Mountains east of the highway is included in this study. The majority of this area is managed by the Bureau of Land Management. The center of the study site (33° 07' N, 114° 53' W) is approximately 75 km east of the town of Brawley, Imperial County. Smaller mountain ranges included in the study area are the Peter Kane, Midway, and Cargo Muchacho mountains (Figure 1.1). Nearby ranges, within 20 km of the study area, and possibly important to this population of sheep, include the West Chocolate Mountains and the Palo Verde Mountains, located northwest of the study area.

The highest elevation in the study area is 647 m. The Colorado River forms the 50 km eastern boundary of the study area and is an important landscape feature that affects mountain sheep distribution and movement. The level of the river fluctuates with releases of water from multiple upstream dams.

The climate is characterized by extreme aridity and high summer temperatures (Figure 1.2; Loeltz et al. 1975, Turner and Brown 1982). Average annual rainfall is 6.35 cm (Weaver and Mensch 1969), with the majority of precipitation from late summer thunderstorms. A second "wet" season is evident during winter and early spring (Figure 1.2). Late summer thunderstorms often are localized and areas adjacent to the Colorado River receive more moisture than those areas removed from the river (Weaver and Mensch 1969). Summer maximum temperatures routinely exceed 44^{o} C and winter minimums seldom are below 0^{o} C (Turner and Brown 1982).

Predators of mountain sheep (Kelly 1980) occurring in the study area include mountain lion (Felis concolor), bobcat (Lynx rufus), coyote (Canis latrans), and Golden Eagle (Aquila chysaetos). Neither the population densities nor the effect of these predators on mountain sheep in the Chocolate Mountains are known.

Mule deer (Odocoileus hemionus) and feral asses (Equus asinus) are sympatric ungulates that occur throughout the Chocolate Mountains; however, population estimates for these species do not exist. Currently, no livestock allotments occur within the study area, but cattle previously were grazed in northern portions of the study area (BLM Range Specialist, El Centro Resource Unit, El Centro, California, pers. comm.).

METHODS

California Department of Fish and Game (CDFG) personnel captured 25 adult mountain sheep (17 females, 8 males) in June, 1992 (APPENDIX 1). All sheep were captured using a hand-held net-gun fired from a Bell 206B-III helicopter (Krausman et al. 1985). The age (Deming 1952, Geist 1966) and gender of each sheep were determined, and each animal received a brief physical examination. If the age of an individual could not be determined it was recorded, simply, as "adult." Whole blood, nasal swabs, and deep ear swabs were collected prior to the sheep being properly fitted with a radio-collar (Bleich et al. 1990a) equipped with a mortality sensor (6-hr delay; Model 500, Telonics Inc., Mesa, AZ). Biological samples were used to generate a health profile for this population and were examined for the following: Brucella ovis, bluetongue, bovine viral diarrhea, epizootic hemorragic, parainfluenza virus 3, bovine respiratory syncytial virus, anaplasmosis, chlamydia, contagious ecthyma, and the Leptospira series (3) (APPENDIX 2). The sheep also were fitted with two ear-tags having unique number and color combinations. These telemerted animals served as "marked" individuals throughout the study period. All aspects of animal handling complied with protocols established by the California Department of Fish and Game (Jessup et al. 1986).

I conducted intensive demographic sampling over two summers (1992 and 1993) and used three methods: direct observations, remote cameras, and helicopter surveys. I classified mountain sheep as Class I (yearling), II, III, and IV males (Geist 1968); yearling and adult females; and lambs (individuals of either gender less than 1 year old). During ground observations, any aggregation of two or more sheep was considered a group when the individuals were less than 50 m from each other (Siegfried 1979). During helicopter surveys, aggregations of two or more sheep were considered a group when they were less than 100 m from each other (Bleich 1993).

I recorded direct observations on both a scheduled and opportunistic basis, either from a vehicle or on foot. I divided the study area into six survey blocks (Norton-Griffiths 1978), and sampled each in rotation; some blocks were sampled less frequently because of limited access. Approximately 300 and 400 hours were spent in sheep habitat conducting ground surveys during the summers of 1992 and 1993, respectively.

A waterhole count and a vehicle survey were conducted during July, 1992. Six water sources were observed during one weekend and the vehicle survey involved five vehicles over eight hours during a single day. In both cases volunteers were given training in identifying sheep and at least one person experienced in proper mountain sheep identification was paired with novices. The water hole count focused on water holes in the northern study area; however, the vehicle survey included all drivable areas within the entire study area. I did not estimate population abundance using these data because of the small number of observations (n=35 and n=13 for each method, respectively).

However, both surveys were useful in refining my understanding of sheep distribution and influenced survey design for the 1993 field season.

Time-lapse Super 8mm movie cameras and 8mm video cameras were used to record sheep at water sources. I placed cameras near water sources in a manner described by Constantino (1974). The time-lapse movie cameras (various manufacturers and quality) exposed one frame of film (Kodak Ektachrome 160) every 60 seconds. The time-lapse video camera system (Compu-Tech Model RM-680-31 Surveillance Video Camera System) was composed of a Sony Handycam CCD-TR31 equipped with a passive infrared transmitter/receiver switch, and a 10X zoom lens. The camera was set to run for three minutes when the infrared signal was interrupted. The camera was reactivated when the signal was again broken. I installed the cameras at waterholes used by mountain sheep and accessible to me. Sampling effort at the waterholes was not equal between the northern and southern regions, nor between the six sampling zones. Twenty of the 31 known water locations were located in the northern portion of the study area. Ten rolls of movie film were exposed in 1992 at six water sources. Six rolls of movie film and 10 video tapes were exposed during 1993 at five different water sources. I analyzed movie film and video tapes using the group sampling method of Jaeger et al. (1991).

In 1993, CDFG personnel conducted helicopter surveys during June (8.4 hrs) and September (10.4 hrs). Sampling blocks were delineated prior to these counts based upon the known distribution of female sheep determined from the previous 11 months of telemetry data. Sampling blocks were identical during the June and September surveys, and sampling blocks were flown systematically. Prior to each survey, I collected aerial telemetry data to determine the presence of marked animals within the sampling blocks and, thus, available to be counted. During both helicopter surveys a simultaneous double-count method (Graham and Bell 1989) was used. Observers recorded the location, group composition, age, and gender of each sheep observed; marked animals also were noted. Helicopter surveys of a closed population generally are considered sampling without replacement (Krebs 1989); however, at least one marked animal was seen on multiple occasions during the September survey. Therefore, I used Bailey's (1952) method which accounts for sampling with replacement.

I used computer programs provided by Krebs (1989) to estimate male, female, and total population size using Bailey's (1952) modification of Lincoln's (1930) method. A brief discussion of the assumptions of this model is included in APPENDIX 3. When possible, each assumption of the model was empirically tested. Equal catchability between marked animals was tested using the Zero-Truncated Poisson Test of Equal Catchability (Caughley 1977) and Cormack's Test of Equal Catchability (Cormack 1966). I calculated 95% confidence intervals based on either a Poisson or binomial distribution according to the criteria suggested by Seber (1982). I also calculated sex and age class ratios and 95% confidence intervals for each data set (Zar 1984). Because telemetry data, collected bimonthly, suggested the presence of two, and possibly three, female sub-populations Figure 1.3), I generated separate estimates of female sheep for each deme using the 1992 and 1993 ground observation data.

I estimated survivorship and 95% confidence intervals of adult radio-collared sheep using the method of Heisey and Fuller (1985).

sampling intervals (telemetry months) were rounded to the nearest 0.5 month since all mortalities were known within a two week period.

RESULTS

Population estimates for both 1992 data sets were similar to each other but appeared different from the results obtained in 1993 (Table 1.1). Bailey's (1952) method removes nearly all of the upward bias associated with the Lincoln (1930) method when there is sampling with replacement. Combining data sets would increase the total sample size and thus decrease the width of the confidence intervals. After testing for equal catchability between various combinations of all six data sets, only the 1993 ground observations, and the June and September helicopter survey data could be combined (Zero-Truncated Poisson Test of Equal Catchability; $\underline{X}^2 = 0.495$, 2 df, $\underline{P} < 0.05$).

Estimates of adult sex ratio and associated 95% confidence intervals are presented in Table 1.2. The 1993 camera data do not include sampling of the southern portion of the study area and these data are excluded from statistical comparisons. Similar ratios were found among the different data sets collected in 1993 and ranged from 68-86:males per 100 females. However, the 1992 data produced a higher ratio of males to females for both the ground and time-lapse camera data, 171 and 122 males per 100 females respectively. I found no difference in male:female ratio data among the 1993 data sets; G-Test; $\underline{G} = 8.39$, 2 df, $\underline{P} = 0.869$), although I did find that when I included the 1992 data there was a significant difference in male:female ratios (G-Test; $\underline{G} = 8.39$, 4 df, $\underline{P} = 0.009$). I calculated lamb ratio estimates and 95% confidence intervals for every method during both field seasons (Table 1.3). The various methods produced estimates ranging from 0-44 lambs per 100 females. When comparing the 1992 and 1993 ground data with the June and September helicopter data, I found there was a difference (G-Test; G = 8.39, 3 df, P = 0.039). I determined that only the June helicopter differed from the other three. It also was the highest lamb ratio recorded during the study. Yearling ratio estimates are low and range from 6-16 yearlings per 100 females (Table 1.4). I detected no differences among yearling ratios when I compared the different data sets (G-Test; G = 1.28, 3 df, P = 0.734). The low yearling numbers indicate that there is low recruitment of lambs into this population.

Survivorship of adult radio-collared animals was high on both a monthly and annual basis; however, the sample size of marked animals, especially males, from which survivorship was calculated is small. Nevertheless, males appear to have had a lower annual survivorship (0.95) than females (0.98) when the study area is considered as a whole (APPENDIX 4).

DISCUSSION

Several censuses of mountain sheep have been conducted for the East Chocolate Mountains (Weaver and Mensch 1969; Botti 1978; Thompson 1987, 1990) and have included helicopter surveys and waterhole counts. These censuses recorded 25-53 animals. For the period 1985-1989, CDFG officially estimated this population to be 25-40 animals (CDFG 1985, 1986, 1987, 1989). These estimates probably were inaccurate due to the sporadic and subjective nature of the surveys, and the lack of marked individuals from which population estimates could be derived.

My population estimates for 1992 and 1993 indicate far more than 40 sheep in the East Chocolate Mountains. Although population estimates based on ground sampling did not differ greatly between years, the estimates for females and males differ markedly between 1992 and 1993 (Table 1.1). Estimates derived from 1992 data are less reliable than those made in 1993 because I did not sample randomly or consistently across the entire study area in 1992. For example, I intensively sampled known water sources to the exclusion of other areas. All 1993 data, however, are based on uniform sampling effort across the entire study area, except for the camera sampling that focused on the northern study area. Additionally, I sampled at water sources unknown to me during 1992 and, in 1993, I was much more familiar with wild sheep and the study area.

The distribution of radio-collared females (Figure 1.3) suggests the presence of at least two separate female sub-populations. Telemetry data and ground observations consistently showed that all females initially collared in the northern and southern zones of the study area were always observed in those areas (Andrew 1994, Torres 1993). These observations are consistent with what has been observed in numerous other populations of mountain sheep. Indeed, female sheep exhibit a high degree of philopatry and more than one female deme frequently occurs within a given mountain range (Wehausen et al. 1987, Wehausen 1992, Festa-Bianchet 1986a, Stevens and Goodson 1993). Females remain on the home range of their maternal female group (Geist 1971, Festa-Bianchet 1986a), recognize herdmates, and learn most of the traditional migration routes and seasonal range locations from older females (Festa-Bianchet 1986a). Moreover, differing reproductive strategies of male and female sheep suggest that females should take fewer risks than males (Bleich 1993). Females moving across flat open areas between the northern and southern parts of the study area would potentially expose themselves to greater risks than those remaining in mountainous regions because they might encounter higher predator densities than occur in steep, rugged, and broken terrain and have less opportunity to evade predation (Bleich 1993). Only the 1992 and 1993 ground observations lent themselves to calculating separate population estimates for each deme (Table 1.1). Differences in my sampling methods between years, and not actual changes in the population, probably account for the variation between 1992 and 1993.

The northern female deme, (Figure 1.3) contained more sheep than the southern group (Table 1.1) during both years. Although the habitat (e.g., vegetation, terrain) in both areas was similar (Chapter 2), there was 23% less suitable habitat in the southern portion of the study area when compared to the north. In addition, the southern portion of the study area had fewer known water sources and greater human disturbance, including one large active gold mine and the Picacho State Recreation Area.

All 1992 and 1993 estimates of the female population, regardless of method used, probably are inflated because of the low number of marked females (Robson and Reiger 1964, Roff 1973). This situation is exacerbated by the few subsequent sightings of marked animals during ground and time-lapse camera sampling (<10% re-sighting), although the June and September helicopter surveys produced slightly greater resighting percentages (13% and 18%, respectively). Population estimates based on low numbers of initially marked animals, coupled with low "recapture" probabilities, result in an inflated, imprecise population estimate. Robson and Reiger (1964) and Roff (1973) recommend that at least 50% of the population be marked and that there should be high recapture rates in order to attain even modest levels of precision in estimating population size. Clearly, I have fewer marked animals and lower re-sighting rates than desirable. Nevertheless, the results reported here are the only empirical estimates of this population using an appropriate mark and resample methodology.

According to telemetry, ground observation, and helicopter data (Torres 1993, Andrew 1994), six of eight collared males stayed either in the northern or southern areas, depending on where they initially were collared. Site fidelity was noted even during the rut (Festa-Bianchet 1986b, Figure 1.4), but male mountain sheep are more likely to move between mountainous areas than are females (Bleich et al. 1990a, Schwartz et al. 1986). Because of small sample sizes and the observation that two males moved between the northern and southern areas, I felt it prudent to make a single estimate of male abundance for the entire study area. All estimates of male abundance suffer more acutely from the problems discussed for female estimates; ie., the low number of marked animals and very few re-sightings of those animals probably resulted in an upward bias in the population estimate.

Habitat used by adult male sheep in California's Mojave Desert includes the same habitat used by females, but also less steep, less rugged, and less open terrain (Bleich 1993). Because I concentrated my efforts in areas used primarily by females, those habitat types were not systematically sampled in this study and may have resulted in the under-sampling of males; hence, may be an additional source of bias in the population estimate. During periods of sexual segregation, younger males tend to be found with female groups (Bleich 1993, Geist 1971), possibly biasing my sampling of young males. The period of sexual aggregation for California's Mojave desert mountain sheep is August-November (Bleich 1993). However, over-sampling of young males may not be a significant problem in my study because of the small number of Class I and Class II males reported for both field seasons and during both helicopter surveys. The September helicopter survey was conducted during the middle of the rut, a period when Bleich (1993) recorded the highest percentage of mixed groups and when most adult sheep should be together.

The theoretical sex ratio for adult mountain sheep is 1:1 (Geist 1971, McQuivey 1978, Turner and Hansen 1980). This ratio, however, is rarely seen in field situations (Welles and Welles 1961, Monson 1963, Wehausen 1992, Jaeger and Wehausen 1993). The unbalanced sex ratio I observed (Table 1.2) is typical in many sexually dimorphic, polygynous ungulates, and is related to differing life history strategies of males and females (Main and Coblentz 1990, Miquelle et al. 1992, Bleich 1993). Males assume greater predation risks by foraging and traveling farther from escape terrain to exploit resources, which enable them to increase their body size and thus, compete more effectively for breeding rights. In mountain sheep, the majority of breeding is done by dominant males. Dominance is based on body size and overall physical condition (Geist 1971). Females increase their fitness by avoiding predation by remaining closer to escape terrain and successfully rearing their young to reproductive maturity.

Ground and camera observation data from 1992 produced a highly inflated adult sex ratio of 171 males:100 females and 122 males:100 females; clearly, males were over represented in that sample. The 1993 data produced sex ratios of 68-86 males per 100 females, more typical of those reported for other California desert populations (Wehausen 1992, Jaeger and Wehausen 1993). The male:female ratios from helicopter surveys were 81:100 and 68:100, respectively, and further support rejection of the 1992 estimates as unreliable.

The summer lamb ratio estimates (Table 1.3) indicate a good lambing season (19-44 lambs:100 females) and suggest the potential for an increasing population. The fact that no lambs were recorded with the camera method in 1992 is likely an artifact of my sampling strategy. Wild sheep in general suffer high mortality rates during the first year of life (Murie 1944, Geist 1971, McQuivey 1978). High lamb mortality is expected during the stressful summer months, (Turner and Hansen 1980) when there is declining forage quality (APPENDIX 2.) and fewer sources of water. An autumn lamb ratio offers a clearer picture of how many lambs survived their first four to eight months of life. An autumn lamb ratio of 26 lambs per 100 females is sufficient to maintain a stable population of some desert mountain sheep populations (McQuivey 1978), although Wehausen (1992) determined that as few as 18 lambs per 100 females was sufficient as a maintenance level for a population in one California desert herd. The autumn ratio, coupled with the following year's yearling ratios, reflects young animal survival and subsequent recruitment into the population. The fall (late September, 1993) helicopter survey produced a lamb to female ratio of 38:100 and indicates high lamb survival during the summer 1993.

The yearling ratios I measured by all sampling methods are low (Table 1.4), and may reflect high mortality due to a number of factors. Moreover, it is often difficult to discern yearlings and sample error may result in false ratios. Based on these low recruitment rates, it is possible this population is not expanding.

Survivorship of radio-collared adult animals is high. This is consistent with the lack of evidence for excessive predation rates or high mortality from disease. Life table data from the Desert National Wildlife Range indicate that if male and female lambs survive past the age of two years, their chances of surviving another seven years is high (Hansen 1980). After the age of nine, mortality rates increase. All animals in my study were adults when captured. Two radio-collared sheep died during the study; one female, and one Class IV male. The exact causes of death were not determined, but neither appeared to have been killed by predators. Additionally, three uncollared males (one Class II and two Class III), one uncollared adult female, and five lambs were found dead. The Class II ram was found in a wash below a water source. One Class III male was found in a waterhole that it could have easily climbed out of. The other Class III male was found on a sandbar in the Colorado River, but it is unknown if this individual was from Arizona or California. Among these three males, the cause of death was not predation. An uncollared adult female was found dead where she had bedded in a wash above a water hole. Of the five dead lambs found, one drowned in a steep-sided tinaja, and the cause of death was not determined for the other four. None of the animals had broken limbs or other evidence of trauma caused by an accidental fall.

CONCLUSIONS

I estimated the size of this population to be 206 adult sheep, based on the combined 1993 data (Table 1.1). Long term monitoring and demographic sampling will be required to further refine our understanding of this population.

The probable presence of two, and possibly three, female demes should be further substantiated by periodic sampling. Quantifying the dynamics of multiple female sub-populations would greatly enhance our understanding of the performance of this population (Festa-Bianchet 1986a). Continuous, long-term, sampling of the population as a whole should be maintained in order to better determine and understand the effects environmental and demographic stochasticity that invariably drives the dynamics of this population.

My overall population estimate and the estimate of the proportion of males (88 males:100 females) meet the criteria of CDFG's (1994) Draft environmental document for bighorn sheep hunting guidelines that allows for limited sport hunting of mountain sheep. The East Chocolate Mountain area is currently being proposed as a new hunt zone for the 1994-1995 hunting season.

This population should be further evaluated to determine if it can support sheep removal for translocation efforts. A more thorough understanding of the distribution and population dynamics of the female demes is critical before removals take place (Stevens and Goodson 1993). Historically, CDFG has used two different desert mountain sheep populations, Old Dad/Kelso Peak and Marble Mountains, as sources for translocation stock. The East Chocolate Mountains represent a third possible source of mountain sheep for repopulating historic ranges within California's southeast desert.

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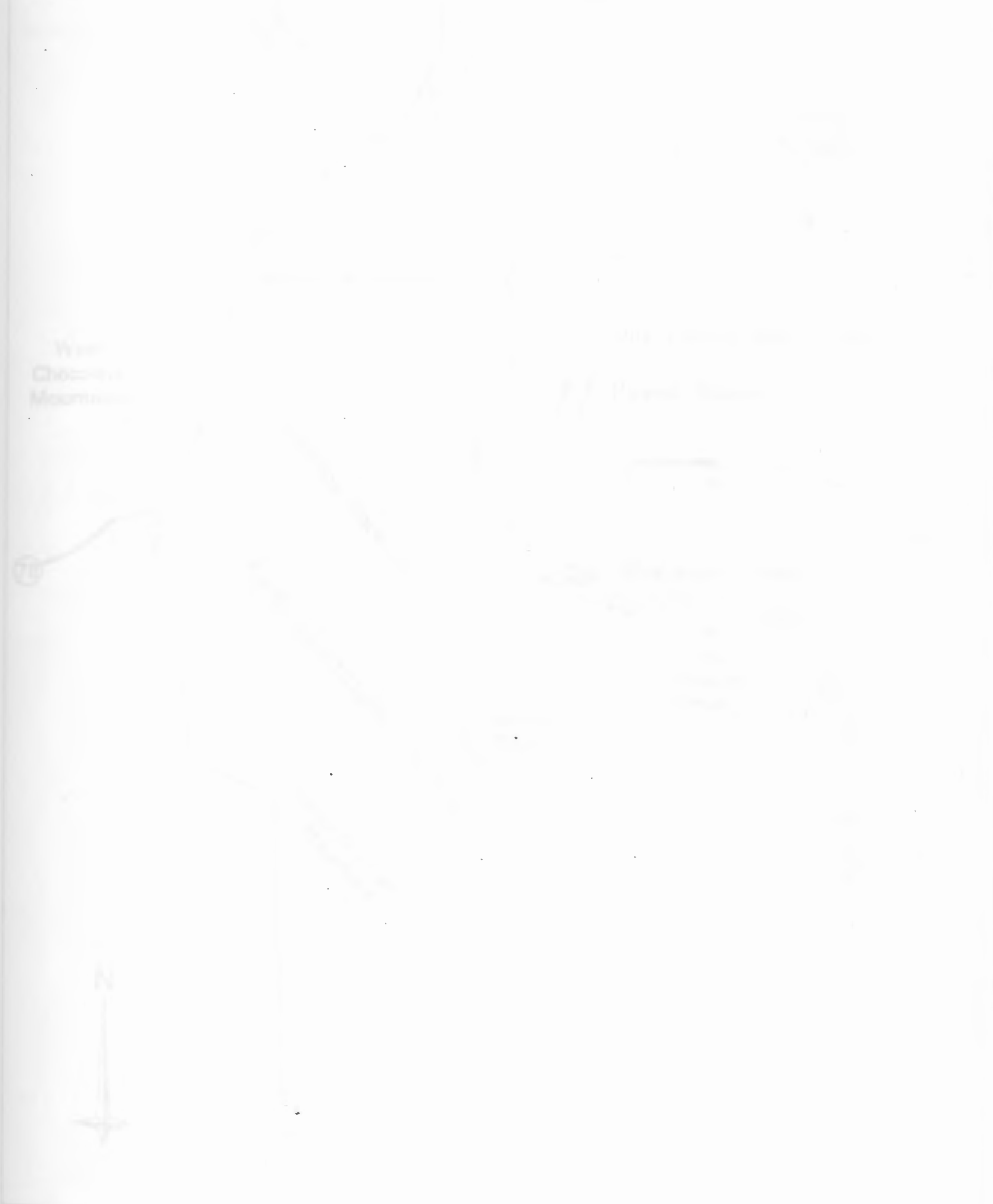
Figure 1.1. Map of the East Chocolate Mountains study area in Imperial County, California.



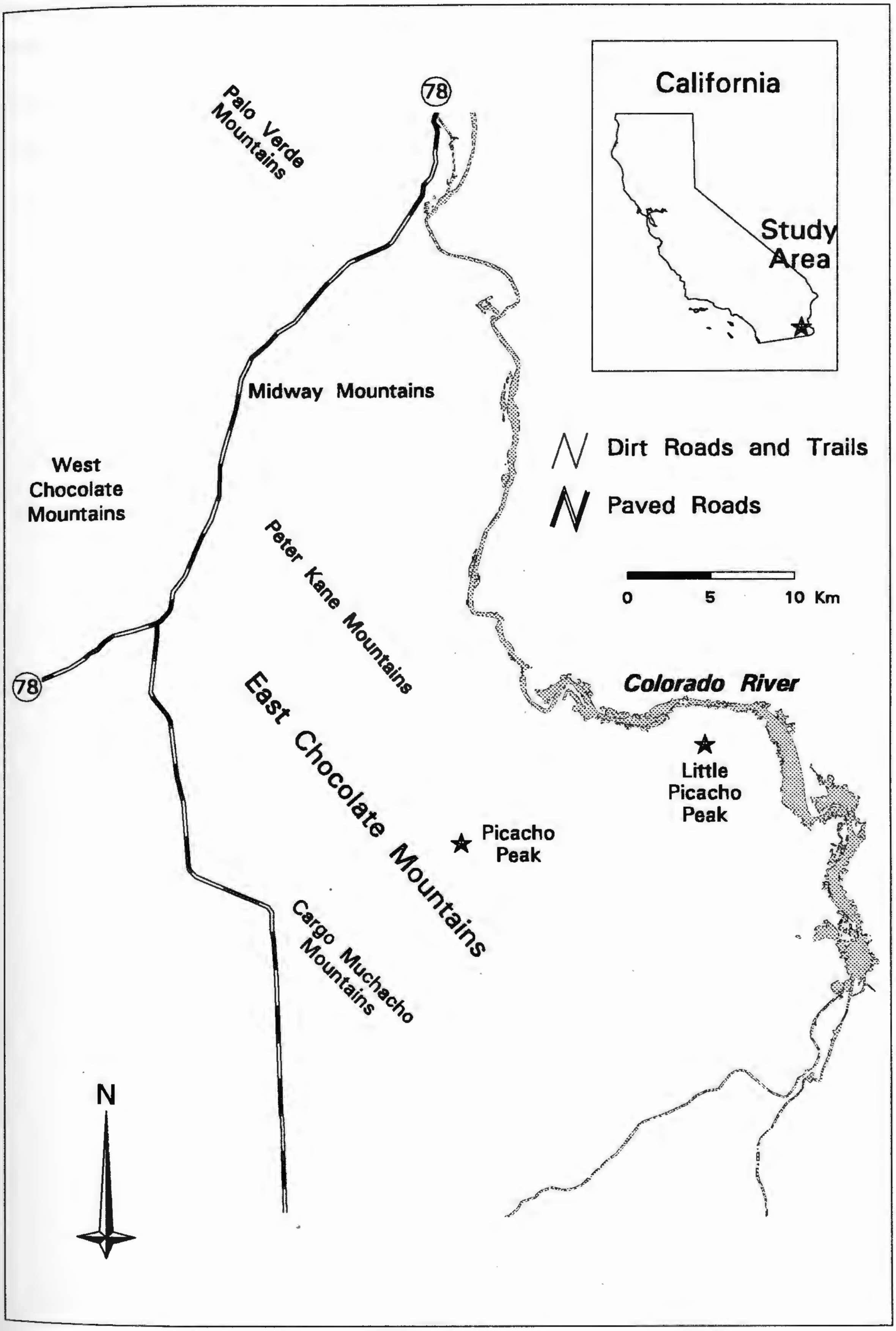
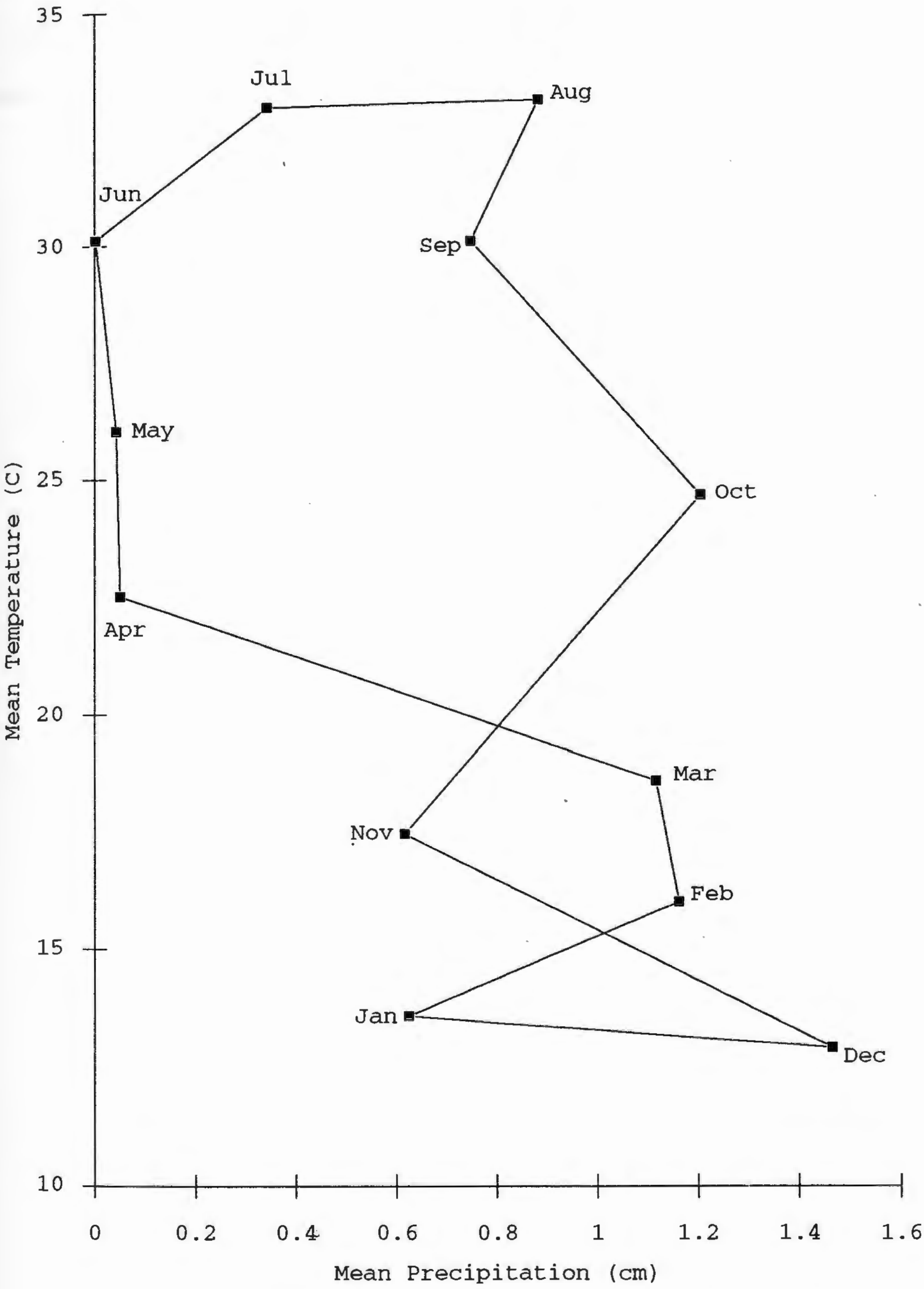

California
Study Area
Palo Verde Mountains
78
Midway Mountains
West Chocolate Mountains
Dirt Roads and Trails
Paved Roads
0
5
10 Km
Peter Kane Mountains
78
Colorado River
East Chocolate Mountains
Little Picacho Peak
Picacho Peak
Cargo Muchacho Mountains
N

Figure 1.2. Climograph of mean monthly temperature (^{o}C) and mean monthly precipitation (cm) from 1983-1992, for Imperial, California (data collected by Imperial Irrigation District, Imperial, California).



35
30
25
20
15
10
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Mean Temperature (C)
Mean Precipitation (cm)
Jul
Aug
Jun
Sep
May
Oct
Apr
Mar
Nov
Feb
Jan
Dec

Figure 1.3. Distribution of 17 radio-collared females in the East Chocolate Mountains, Imperial County, California, June 1992 to December 1993. All females captured in the northern and southern areas remained in those areas throughout the study, and suggest the presence of two female sub-populations.

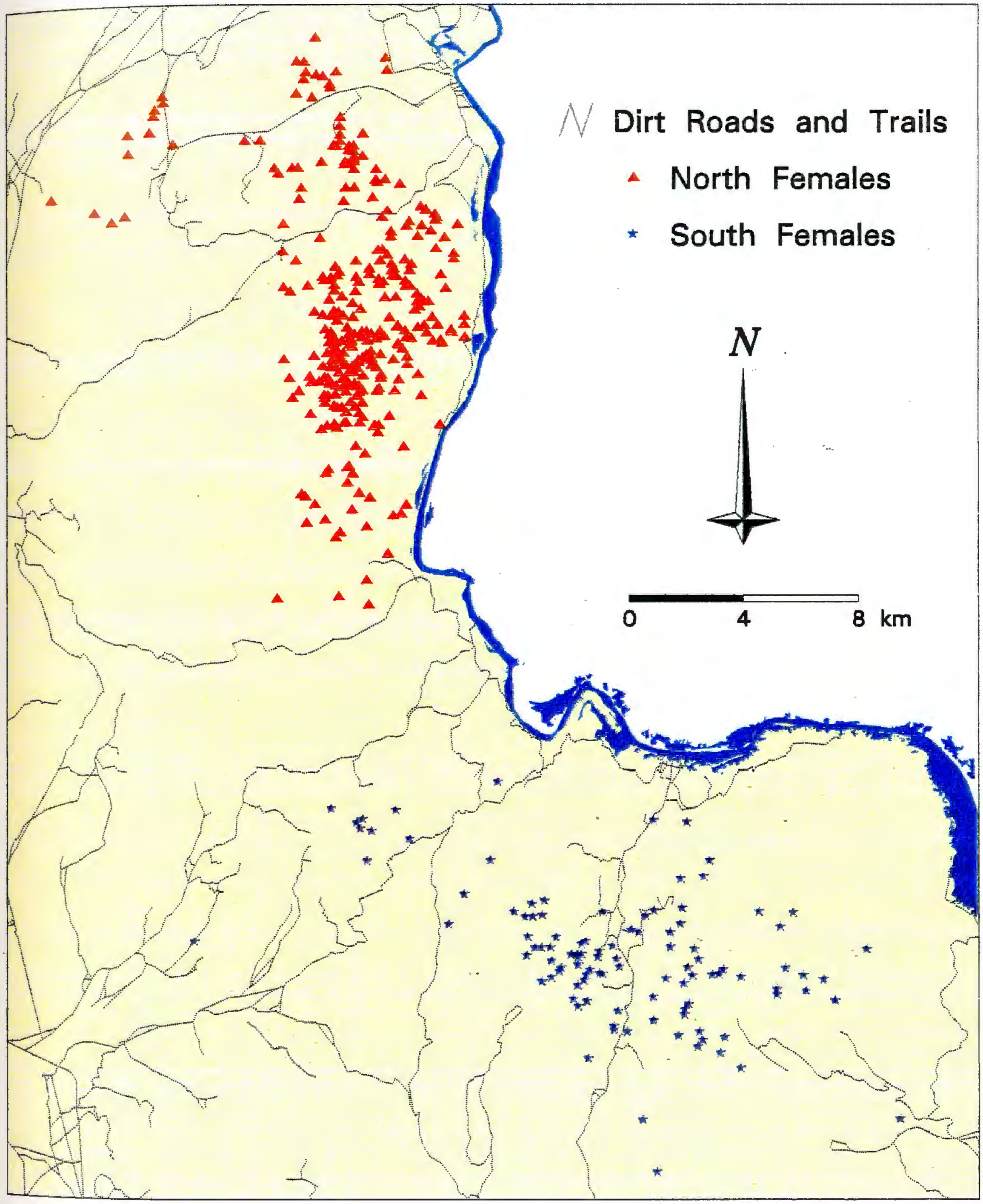

Dirt Roads and Trails
North Females
South Females
N
0
4
8 km

Figure 1.4. Distribution of eight radio-collared males in the East Chocolate Mountains, Imperial County, California, June 1992 to December 1993.

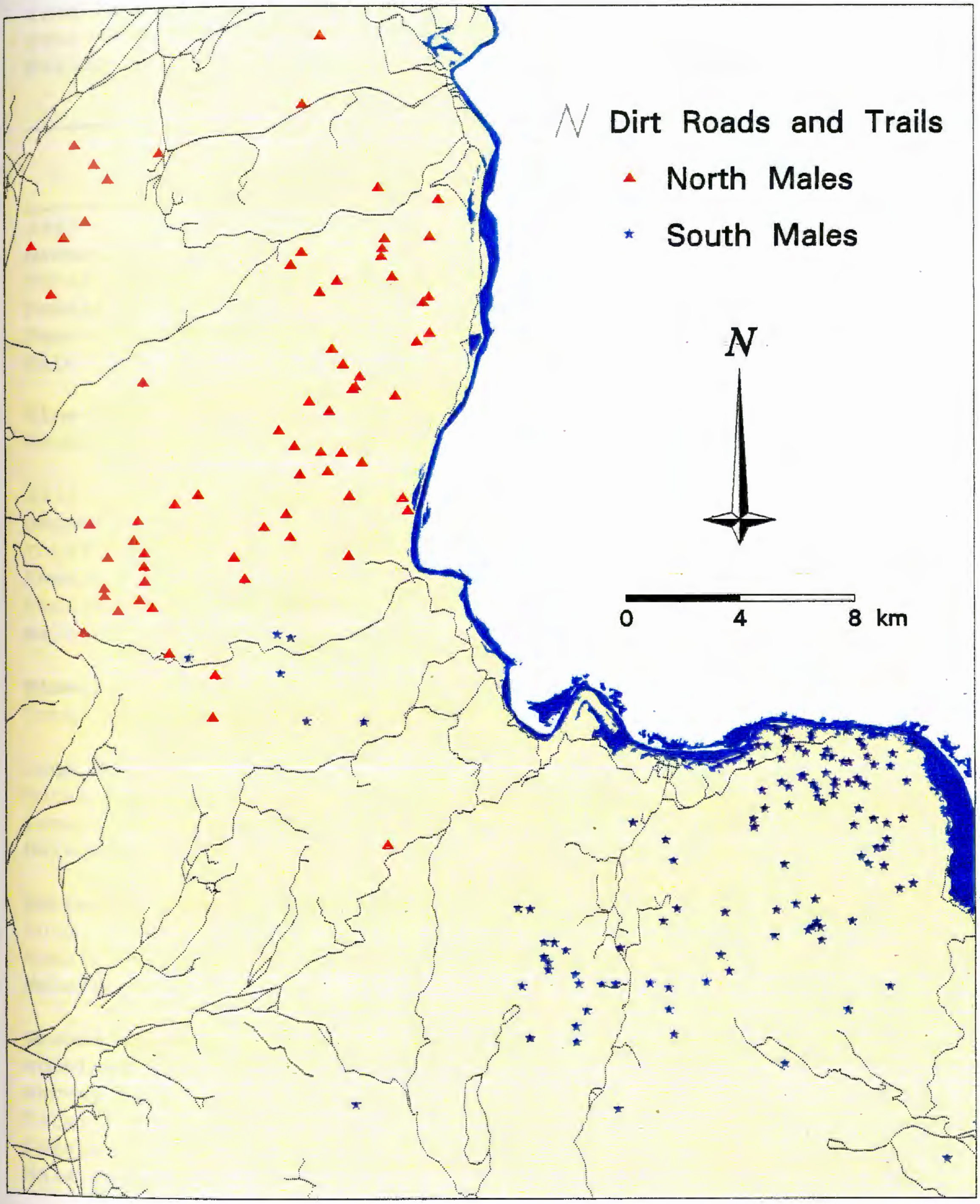

Dirt Roads and Trails
North Males
South Males
N
0
4
8 km

Table 1.1. Estimates of males, females, and the total population (and 95% confidence intervals) of mountain sheep in the East Chocolate Mountains using Bailey's (1952) method. Population estimates include both yearling and adult animals. Ground observation data were collected from June to August 1992 and April to August 1993. Time-lapse camera data were obtained from July to August 1992 and June to August 1993. Helicopter data were recorded during June and September, 1993.

	Estimated Population	Lower 95%	Upper 95%
1992			
Ground Observation Data			
Total Population	250	161	427
Female Population (North)	42	32	68
Female Population (South)	11	7	36
Male Population (Entire Area)	180	88	445
Time-lapse Data			
Total Population	263	85	519
1993			
Ground Observation Data			
Total Population	265	198	427
Female Population (North)	185	122	324
Female Population (South)	43	27	135
Male Population (Entire Area)	115	75	281
Time-lapse Data			
Total Population	396	233	760
June Helicopter Survey			
Total Population	149	103	273
Female Population	77	50	171
Male Population	48	24	124
September Helicopter Survey			
Total Population	189	121	360
Female Population	105	67	235
Male Population	55	25	145
Ground observation data combined with helicopter survey data			
Total Population	206	149	327
Female Population	121	76	189
Male Population	71	45	159

Table 1.2. Sex ratio estimates of mountain sheep from ground observation, time-lapse camera, and helicopter survey data for the East Chocolate Mountains, Imperial County, California, in 1992 and 1993. Estimates include both yearling and adult animals. Confidence intervals (95%) are for male estimates after they were standardized to 100 females.

Survey Period	Sample Method	Males Observed	Females Observed	Males: Females	95% C.I.
June-August, 1992	Ground	60	35	171:100	155-189
July-August, 1992	Camera	11	9	122:100	98-136
June-August, 1993	Ground	57	73	80:100	71-87
June-August, 1993	Camera	87	101	86:100	78-92
June, 1993	Helicopter	27	33	82:100	73-88
September, 1993	Helicopter	31	45	68:100	58-77
1993 Ground and helicopter surveys	Combined	113	151	75:100	68-83

Table 1.3. Lamb ratio estimates of mountain sheep from ground observation, time-lapse camera, and helicopter survey data for the East Chocolate Mountains, Imperial County, California, in 1992 and 1993. Confidence intervals (95%) are for lamb ratios after they were standardized to 100 females.

Survey Period	Sample Method	Lambs Observed	Females Observed	Lambs: Female	95% C.I.
June-August, 1992	Ground	14	35	40:100	30-50
July-August, 1992	Camera	0	9	0:100	NA
June-August, 1993	Ground	33	174	19:100	11-28
June-August, 1993	Camera	15	101	14:100	7-22
June, 1993	Helicopter	14	33	44:100	34-54
September, 1993	Helicopter	17	45	38:100	28-48
1993 Ground and helicopter surveys	Combined	49	151	33:100	23-43

Table 1.4. Yearling ratio estimates and 95% confidence intervals of mountain sheep from ground sampling, time-lapse camera, and helicopter survey data for the East Chocolate Mountains, Imperial County, California, in 1992 and 1993. Yearling ratios include both sexes and were standardized to 100 females.

Survey Period	Sample Method	Yearlings Sampled	Females Sampled	Yearling: Females	95% C.I.
June-August, 1992	Ground	5	31	16:100	9-24
July-August, 1992	Camera	0	9	0:100	NA
June-August, 1993	Ground	16	160	10:100	4-17
June-August, 1993	Camera	7	101	6:100	2-13
June, 1993	Helicopter	3	32	9:100	4-16
September, 1993	Helicopter	6	39	15:100	8-23
1993 Ground and helicopter surveys	Combined	18	144	12:100	6-20

CHAPTER 2

HABITAT USE BY DESERT-DWELLING MOUNTAIN SHEEP IN THE EAST CHOCOLATE MOUNTAINS, IMPERIAL COUNTY, CALIFORNIA

ABSTRACT

I collected aerial telemetry data, from June 1992 to December 1993, on 25 (17 females, 8 males) mountain sheep to determine diurnal habitat use in the East Chocolate Mountains, Imperial County, California. I empirically derived a 95% circular error polygon (CEP) (3.14 km^2) around each telemetry point and this was the fundamental unit for habitat analyses, which used vector- and raster-based Geographical Information System (GIS) data processing. The 8 habitat variables were evaluated by gender for 3 seasons of the year: hot/dry, hot/wet, and cool. Females avoided the lowest and highest elevation and slope classes, selected upland vegetation in all seasons, used rough terrain, and avoided flat landscapes. Males used all elevation classes in proportion to their availability, except mid-elevation habitats which they avoided. Males avoided extremely flat and extremely rough terrain classes and used all others in proportion to availability. Males selected upland vegetation in all seasons. Neither gender showed selection or avoidance of any aspect class. All sheep were found closer to water sources, and escape terrain, and farther from areas of human disturbance than would be expected by random movement on the landscape. Females were located farther from areas of human disturbance than males but did not differ from males in their distance from drinking water or escape terrain. I used Cunningham's (1989) habitat evaluation model to

rate habitat quality of areas with the highest observed sheep densities. The model rated these habitats to be only "fair" quality.

INTRODUCTION

Some mountain sheep (Ovis canadensis) sub-species are considered threatened by the state of California (Leach et al. 1974). Conservation efforts by the California Department of Fish and Game (CDFG) focus on 4 aspects of sheep biology and management: 1) determining population size, demographic characteristics, and distributional status of extant populations of mountain sheep; 2) assessing and protecting habitat requirements of sheep in the different desert and mountain ecosystems where they occur; 3) improving habitat in mountains occupied by sheep; and 4) re-establishing sheep populations in mountain ranges that they previously occupied (Bleich and Torres 1994). Each of these measures requires a solid understanding of the biology and natural history of the population(s) of sheep under study.

The East Chocolate Mountains in eastern Imperial County, California, support a population of mountain sheep (Ovis canadensis nelsoni) that has not been extensively studied (Weaver and Mensch 1969). While this sub-species is not listed as threatened, its numbers have been reduced from historical levels (Wehausen et al. 1987, Bleich and Torres 1994). In 1992, I initiated a 2-year investigation of this population. The primary goals of the project were to: estimate the population size and demographic profile of sheep occupying the East Chocolate Mountains (Chapter 1); and quantify the habitat used by sheep in the region. Although others have assessed mountain sheep habitat in other parts of its range (Arizona: Krausman et al. 1989; Nevada: Ebert and Douglas 1993; California: Bleich 1993; New Mexico: Elenowitz 1984), there have been no studies of sheep habitat use in the Sonoran Desert of southeastern California.

A clear understanding of habitat requirements of a species is fundamental to any conservation program. This is especially true for mountain sheep because the CDFG supports a vigorous program of reintroducing mountain sheep to mountain ranges which were known to historically support viable populations of animals (CDFG 1994). Potential translocation sites are evaluated, in part, on the abundance and quality of sheep habitat. Such assessments require knowledge of what constitutes favorable ecological conditions for sheep. I used radio-telemetry and a detailed database of terrain, vegetation, and land use for the region to determine habitat use by mountain sheep in the Chocolate Mountains. Furthermore, I tested for seasonal and gender variation in habitat use by sheep.

MATERIALS AND METHODS

STUDY AREA

The Chocolate Mountains are oriented on a northwest/southeast axis (Figure 1.1) approximately 75 km east of the town of Brawley, Imperial County, California. The highest elevation in the mountain range is 647 m. The study area encompassed approximately 1,410 km^2 and was bounded by the Colorado River to the east, California State Highway 78 and Milpitas Wash to the north, Ogilby Road to the west, and Interstate Highway 8 on the south. The climate was characterized by extreme aridity and high summer temperatures (Loeltz et al. 1975, Figure 1.2). A detailed description of the study area is given in Chapter 1.

Vegetation in the East Chocolate Mountains was typical of the Lower Colorado River Valley Desert, the driest sub-division of the Sonoran Desert (Paysen et al. 1980, Turner and Brown 1982). It is dominated by creosote-scrub (Larrea tridentata) and (Ambrosia dumosa) except at sites adjacent to the Colorado River where salt cedar (Tamarix spp.), cattails (Typha domingensis) and arrowweed (Pluchea sericea) predominated. Wash vegetation consisted mainly of palo verde (Cercidium floridum), ironwood (Olneya tesota), catclaw (Acacia greggii), mesquite (Prosopis glandulosa), and cheese bush (Hymenoclea salsola). Common plants in the study area were listed by Weaver and Mensch (1969).

Twenty-nine water sources (Figure 2.1) existed in the study area and may have been used by mountain sheep during some portion of the year. Twenty-one of these were natural water tanks, also known as tinajas, which are depressions in the bedrock that collect rainwater during the wet seasons. Some tinajas exceeded 3 m in depth and 6 m in diameter. The geology of the area has allowed for the formation of numerous tinajas (Weaver and Mensch 1969); however, nearly all dry up in the early spring. Only 2 of the tinajas within the study area predictably contained water during drought conditions and are permanent (CDFG waterhole data book for Imperial County). The 5 artificial water sources constructed by a local conservation group, Desert Wildlife Unlimited, were permanent sources of drinking water for deer and other wildlife. The Colorado River and associated inland lakes were used by sheep as a water source at 1 known location in the northern portion, and 2 locations in the southern portion of the study area. The availability of water at these sites varies depending on fluctuations in the level of the Colorado River.

The Chocolate Mountains have a rich mining history. Two large gold mines, Picacho Mine and American Girl Mine, were active in the southern part of the study area, and Gold Fields mining operation is located just outside the study area. At least 3 other large mines formerly were worked in the region. As a result, much of the study area was dissected with old mining roads. There was active mineral exploration within the area and numerous small mining claims were worked by recreational miners. Active mines and heavily traveled roads were a major source of human disturbance in the region.

Marking and Monitoring Sheep

California Department of Fish and Game personnel captured 25 adult mountain sheep (17 females, 8 males) in June, 1992 (APPENDIX 1), using a hand-held net gun fired from a Bell 206B-III helicopter (Krausman et al. 1985). Age (Deming 1952, Geist 1966) and gender of each captured sheep were determined, and each animal received a brief physical examination. If the age could not be clearly ascertained, it was recorded simply as "adult." Each animal was properly fitted (Bleich et al. 1990b) with a radio-collar equipped with a mortality sensor (6 hr. delay, Model 500, Telonics Inc., Mesa, Arizona) and 2 plastic ear-tags having a unique number and color pattern. All aspects of animal handling complied with protocols set forth in the CDFG animal restraint handbook (Jessup et al. 1986).

I attempted to locate collared sheep on a bimonthly schedule using a Cessna 185 fixed-wing aircraft operated by an experienced CDFG pilot, but some flights were canceled because of inclement weather or mechanical problems with the aircraft. In total, 30 missions were flown from June 1992 to December 1993. The aircraft was equipped with 2 directional "H" antennae (Telonics, Mesa, Arizona) 1 mounted on each wing strut. The pilot used a Telonics scanner and the protocol described by Krausman et al. (1984) to locate each radio-collared animal. Geographic coordinates of an animal's position were estimated by the aircraft's Apollo II LORAN-C navigation unit (Model 612B, II Morrow Inc., Salem, Oregon) and were recorded on data sheets along with a written description of the location, by a spotter accompanying the pilot.

Positions determined by LORAN-C in interior regions of California frequently show a systematic directional bias (Bleich 1993, Jaeger et al. 1993). I measured this bias in this study area by comparing the geographic coordinates taken from U. S. Geological Survey 1:24,000 scale maps of 5 conspicuous landmarks (i.e., mountain peaks, buildings, and windmills) with coordinates recorded by the CDFG pilot using the aircraft's LORAN system. The USGS map coordinates were measured in Universal Transverse Mercator (UTM) units and consisted of the mean of 20 replicate points digitized for each site. Digitizing was done with a Calcomp 9100 series tablet (Calcomp Inc, Anaheim, California) using ARC/INFO (version 6.1) Geographic Information System (GIS) software (Environmental Systems Research Institute, Redlands, California) running on a Data General 5220 workstation computer (Data General Corporation, Westboro, Massachusetts).

To determine the geographic coordinates of each of the 5 landmarks, the pilot made 8 replicate passes of each on 2 different occasions and provided a latitude/longitude coordinate for each pass. I converted the latitude/longitude coordinates to UTM's using the ARC/INFO

PROJECT utility. For each LORAN-C fix, I calculated the mean deviation (in m) in the east/west (X) and north/south (Y) axes from the USGS coordinate for the landmark. None of the deviations differed from the others on the X-axis (ANOVA; $F = 0.52$, $P = 0.72$); however, there were deviations on the Y-axis (ANOVA; $F = 3.53$, $P = 0.02$). All landmarks had deviations in both directions that significantly differed from 0 (Table 2.1). I used the mean X (554 m) and mean Y (-1,447 m) deviations of the 5 landmarks to estimate the LORAN-C directional biases for the study area (Patric et al. 1988, Jaeger et al. 1993). All coordinates obtained from the aircraft's LORAN-C system were shifted by these values.

To determine the location of a radio transmitter, the pilot must maneuver the aircraft until he is positioned over the strongest radio signal (Krausman et al. 1984). When the pilot judges that the aircraft is above the radio transmitter, the latitude/longitude of the plane is read from the LORAN-C receiver in the cockpit.

I measured the pilot's ability to locate telemetry collars by placing 8 "placebo sheep" radio-collars in locations known to be inhabited by sheep in the study area. I determined the true location of each transmitter using a global positioning system (GPS) receiver (Pathfinder Basic, Trimble Navigation, Sunnyvale, California). At least 300 GPS fixes were obtained at each site of these "placebo sheep" collars, and these were differentially corrected (August et al. 1994) using data obtained from a base station 170 km away in San Diego, California. Using this protocol, fixes at each "placebo" site should be within 4 to 7 m of true (August et al. 1994). The pilot located each "placebo" collar on 3 different occasions using the same protocol used for sheep. In total, 24 fixes were collected but 5 were discarded due to technical problems. These geographic coordinates were converted to UTM coordinates and shifted to account for LORAN directional bias (Patric et al. 1988, Jaeger et al. 1993). For each fix, I calculated the distance from the GPS-derived position of the "placebo sheep" from the pilot's estimate of the collar position, as well as the X(east/west) and Y (north/south) deviations. There was no consistent shift in either X- or Y-axes when data were pooled. The radius of the 95% circular error probability polygon (CEP, August et al. 1994) was 1 km. This implies that there is a 95% probability that the true location of a radio-collar is within 1 km of the location estimated by the pilot. A 1 km radius circle around each radio-collar location was considered to be the error polygon for an observation and I used this as the fundamental unit of analysis for this study.

Habitat Data

I analyzed sheep habitat using raster and vector GIS analytical processes (Berry 1993). The 8 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.

Elevation, aspect, and slope data were derived from 1:24,000 Digital Elevation Models (DEM) purchased from the U. S. Geological Survey (USGS 1990, August 1993). The 30 m cell (= pixel) size of the USGS DEM was retained for all analyses. I assembled the quadrangle-based data sets to create a single DEM for the entire study area (Figure 2.2). From this composite DEM I created raster representations for elevation class, slope, and aspect using the GRID module of ARC/INFO.

Elevation was divided into 7 classes of 75 m intervals: 0-75 m, 76-150 m, 151-225 m, 226-300 m, 301-375 m, 376-450 m, and 451-647 m). Percent slope (Figure 2.3) was divided into 6 discrete classes using the intervals adopted by Cunningham (1989) and Ebert and Douglas (1993): 0-20%, 21-40%, 41-60%, 61-80%, 81-100%, 101-240%. Nine aspect classes were created: N (337.5^{o}-22.5^{o}), NE (22.6^{o}-67.5^{o}), E (67.6^{o}-112.5^{o}), SE (112.6^{o}-157.5^{o}), S (157.6^{o}-202.5^{o}), SW (202.6^{o}-247.5^{o}), W (247.6^{o}-292.5^{o}), NW (292.6^{o}-337.6^{o}), and level.

Terrain roughness is a single index that reflects slope and aspect variation at any given location. I calculated terrain roughness using the following equation:

$$R_{ij} = ((V_s/V_m)*100) + ((A_n/9)*100)$$

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, 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 the 90 m analytical radius would have a high R value. A decrease in the variation of slope or aspect would result in a decrease in R. Roughness was divided into 5 classes: Flat (R=0), Low (R=1), Medium Low (R=2-4), Medium High (R=5-9), and High ($R \geq 10$).

Escape terrain was defined as all areas where slope exceeded 60% (Cunningham 1989, Ebert and Douglas 1993, Figure 2.4). I defined human disturbance areas as any location within 50 m of mines, heavily used roads, or the Colorado River (Figure 2.4). I judged heavy use to be any road or river segment in which motorized vehicles passed at least 3 times per week in the summer months. The drinking water source data set consisted of a coverage of the 26 waterholes possibly used by sheep (Figure 2.1) and 3 sites along the Colorado River where sheep were known to drink.

I mapped the distribution of 4 vegetation classes in the study area using 1:36,000 black and white aerial photographs (USGS National High Altitude Photography, Rasher and Weaver 1990) taken in 1985 and enlarged to 1:24,000 scale. I distinguished 4 vegetation classes: wash, bajada (flat or rolling topography), riparian (abutting the Colorado River), and upland (montane) (Figure 2.5). In APPENDIX 5, I provide a detailed description of the plant composition of these 4 classes. I recompiled the delineations of vegetation classes to 1:24,000 topographic quadrangles and digitized them into the GIS. These were converted to a raster data structure (30 m cell size) for analysis.

Habitat Analyses

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, I measured the proportion of the total area (3.14 km^2) in each habitat class. I tested if sheep were selecting or avoiding habitats using the statistical procedures described by Neu et al. (1974) and Byers et al. (1984). Bonferroni confidence intervals were computed to account for experiment-wise error. "Used" habitat was the sum of the proportions of habitats within CEP's. The amount of "available" habitat was the total area of each habitat type within a region 1 km beyond the extreme southwest and northeast locations where sheep were observed (Figure 2.2). 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. I excluded land east of the Colorado River from the study area because I assumed that sheep did not traverse the river during the study period.

Because my habitat use data were not normally distributed, and an arcsine transformation for proportional data (Zar 1984) did not normalize them, I used non-parametric tests for all statistical comparisons. The Wilcoxon 2-Sample Test was used for 2 class comparisons and the Kruskal-Wallis Test was used for multi-class comparisons. The chi-square approximation of the Wilcoxon t and Kruskal-Wallis H statistics are reported (SAS 1990). Categorical data were analyzed with a G-Test (Sokal and Rohlf 1981). All statistical tests were computed using PC-SAS software (SAS Institute, Cary, North Carolina) on a 486-66 MHz microcomputer.

I recognized 3 distinct seasons in my study area (Chapter 1) based upon the past 10 years of weather data (Figure 1.2) obtained from the Imperial Irrigation District (Imperial, Imperial County, California). These seasons were the hot/dry months of April-July, hot/wet months of August-October, and the cool (wet and dry) months of November-March.

For analyses of the proximity to drinking water, escape terrain, and areas of human disturbance, I used a different analytical approach. I created a data set of 1,000 randomly located points in the study area. For each random point and for each location of a sheep sighting, I measured the distance to the closest source of drinking water, escape terrain, or area of human disturbance. When a random point fell inside a landscape feature being measured it was deleted from analytical comparisons. I 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. I used the Wilcoxon 2-Sample Test to compare mean distances to resources (or source of disturbance) between genders and the Kruskal-Wallis Test for seasonal comparisons.

I conducted a preliminary test of Cunningham's (1989) habitat evaluation model in the areas with the greatest sheep concentrations in my study area. Three cells, each 4 km^2, were overlaid in areas with the highest sheep densities (Figure 2.6). For each cell I derived Cunningham scores for natural topography, vegetation type, precipitation, water source (4 sub-categories), and human use. Scores for each variable were summed to generate a final score with a possible range of 0 to 85. Each 4 km^2 cell was classified according to this standard and assigned a rating (based on Cunningham's classes) of poor (0-50), fair (51-69), good (70-79), and excellent quality (80-85) for sheep.

RESULTS

I recorded 693 mountain sheep locations between June 1992-December 1993. I eliminated 53 sightings because of conflicts between the LORAN location and written descriptions of where the sighting occurred. I assumed that telemetry locations were statistically independent (sensu Swihart and Slade 1985) because no 2 flights occurred within 10 days of each other and all were conducted at various times in the day (0700-1500). The final data set included 640 telemetry points; 456 for females and 184 for males (Figure 2.7). The proportion of telemetry observations for each gender did not differ among seasons (G-Test; $\underline{G}$ = 0.32, 2 df, $\underline{P}$ = 0.85). Figures 2.8 and 2.9 show a schematic representation of areas used by radio-collared females and males by seasons.

Females used elevation classes in proportion to availability, except for the lowest and highest classes, which were avoided (Table 2.2). Males used all elevation classes in proportion to availability except for the 225-300m class, which was significantly avoided in the cool and wet seasons (Table 2.2). Use by males of the 6 elevation classes did not differ among seasons, with the exception of the 375-450m class. Females, however, showed seasonal shifts in the use of mid-elevation classes (Table 2.2).

Males and females used all 9 aspect classes in proportion to availability during all seasons (Table 2.3). Females differed in their use of aspect among seasons for all but northeast and west-facing aspects. Males showed seasonal variation only in the use of southwest-facing slopes.

Females and males used available slope categories in similar ways (Table 2.4). Both sexes avoided flat areas (0-20% slope) and used the remaining slope classes in proportion to availability. Females, however, showed a significant preference for the 21-40% slope classes during the hot/dry and the cool seasons. Males showed very little variation in the use of slope classes by season, whereas females showed significant seasonal variation in their distribution among the 3 lowest slope classes.

All sheep, regardless of gender, selected upland vegetation habitats and avoided bajada and wash vegetation during all seasons

(Table 2.5). Females avoided riparian habitats in the warm seasons. There is no significant difference in the use of vegetation classes between genders or among seasons. Upland and bajada habitats did not differ in vegetation composition (G-Test; $\underline{G}$ = 2.67, 3 df, $\underline{P}$ = 0.43), but both differed significantly from wash (G-Test; $\underline{G}$ = 15.6, 6 df, $\underline{P}$ 0.016) and riparian (G-Test; $\underline{G}$ = 87.4, 9 df, $\underline{P}$ < 0.001), (APPENDIX 5, Table 6).

Both genders avoided flat terrain during all seasons (Table 2.6). Males and females used all remaining classes in proportion to the availability, with the exception of females, which selected both Low and Medium-Low classes during the hot/dry season (Table 2.6). There was no seasonal variation in the use of all 5 terrain classes by females during 3 seasons.

I compared the distances that sheep telemetry points occurred from water sources, escape terrain, and human disturbance to a similar measure for random points to test the hypotheses that sheep distribute themselves around water sources, areas of human disturbance, and escape terrain in random fashion. Both male and female sheep were located closer to water than random points (Table 2.7), but the distance to water did not differ between males and females or among seasons (Table 2.8).

Sheep were found farther from areas of human disturbance than random points (Table 2.7). In all seasons, females occurred farther from disturbed areas than did males (Table 2.8). There was significant seasonal variation in the distance to human disturbance for females (Kruskal-Wallis Test; $\underline{X}^2$ = 14.7, 2 df, $\underline{P}$ < 0.001) but not for males (Kruskal-Wallis Test; $\underline{X}^2$ = 1.8, 2 df, $\underline{P}$ = 0.41). Both males and females were found significantly closer to escape terrain than random points

(Table 2.7), but only females showed significant seasonal variation in proximity to escape terrain (Table 2.8).

The Cunningham (1989) scores of habitat suitability for sheep (Table 2.9) indicate that the Chocolate Mountains are only "fair" habitat quality. The highest score, 58, was derived from the northern cell, and scores of 47 and 45 were calculated for the southern sites.

DISCUSSION

The general habitat requirements of desert-dwelling mountain sheep have been described for a number of populations throughout the western United States (Monson and Sumner 1980 for an overview). There is substantial variation in habitat requirements within and between sheep populations occupying desert ecosystems (Hansen 1980). Forage quality and availability, water availability, and terrain have been repeatedly singled out as important variables; however, climatic conditions, competition with other ungulates, and human impacts are potentially important factors affecting the distribution of mountain sheep (Hansen 1980).

Habitat use implies that a particular environmental element is utilized for some purpose (Gysel and Lyon 1980). Associating specific ecological characteristics with the reasons why animals use or avoid certain habitats is often a difficult process. It is impossible to know for certain whether animals are responding to a specific habitat element or to 1 or more other factors that covary with the habitat element under study. For example, my data show that mountain sheep have a marked tendency to associate with upland habitats. It is not at all clear from my univariate analyses if they are selecting upland habitats by keying in on 1 or a combination of factors, such as a terrain ruggedness, vegetation associations, 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.

In this paper, I describe for the first time diurnal habitat use by mountain sheep in the Lower Colorado Sonoran Desert of California. A common application of radio-telemetry data is to assess habitat use (White and Garrot 1990). Researchers, however, frequently fail to account for error associated with this procedure (Saltz 1994). For example, Bleich et al. (1992) did not report telemetry error when testing the usefulness of Hansen's (1980) habitat model. Jaeger et al. (1993) systematically measured LORAN-C derived telemetry error in their studies of mountain sheep in the Mojave Desert, and they found that error polygons ranged from 0.5 km^2 to 1.5 km^2. Jaeger et al. (1993) concluded that telemetry data were most suitable for delineating population boundaries or long distance movements and urged that researchers consider the limitations of LORAN-C precision and accuracy on a study area by study area basis.

I have been extremely conservative in the analysis of my telemetry data. I considered any habitat occurring within 1 km of a telemetry point to possibly be of significance to an animal. Despite the conservative approach I have taken, my results generally are consistent with those obtained from populations of mountain sheep in other habitats, and in other regions of the southwest. Moreover, my analyses appear to be very sensitive to small, but perhaps biologically meaningful differences between genders or among seasons.

Avoidance of the lowest and highest elevation classes by females, and their selection of mid-elevation classes is consistent with the findings of Cunningham and Ohmart (1986), Zine et al. (1992), Berner and Krausman (1992), and Ebert and Douglas (1993). This may be due, in part, to the distribution of water sources. The most heavily used water sources occur between 151-375 m and these are the same elevation classes being used by sheep during the hot/dry season. The highest elevations in my study area have the greatest human disturbance and this may, in part, account for avoidance of those elevation classes.

Aspect classes were distributed uniformly across the study area and all sheep used them in proportion to their availability. 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) recorded selection of north, northwest, and western aspects. Merritt (1974) found that sheep bedded primarily in certain aspect classes and attributed this to sheep selecting or avoiding areas of intense solar radiation. She found that sheep selected north slopes during the summer and hypothesized that this enabled them to reduce their exposure to solar radiation. My results are consistent with this tenet; female sheep used southern aspects less in the hot seasons and more during the cool seasons. Similarly, north-facing slopes were used in greater frequency than southern slopes in the hot months; however, I did not find this to be so for males. In fact, I was unable to detect any differences in male use of aspect classes among seasons in nearly all other habitat variables tested. This finding may be a reflection of the limited power of my test because of the smaller number of telemetry points per seasons for males, rather than the lack of selection.

Contrary to my results, Holl and Bleich (1983) observed sheep to preferentially use southern aspects in the summer. Their results suggest that factors other than those based on behavioral manifestations of thermal regulation contribute to aspect selection, and confound a single explanation of the importance of slope aspect to mountain sheep. Aspect significantly affects plant species distribution, abundance, phenological patterns, and productivity. Sheep may differentially use north and south facing slopes because of the distribution of forage plants (Risenhoover and Bailey 1985) rather than seeking or avoiding 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 1993). I found that males and females avoided slopes less than 20% and used moderate slopes more frequently. Female sheep in my study area may use lower slopes in the hot/wet season, but not in the hot/dry season when they are lambing. Females with lambs born in late winter and early spring characteristically remain close to rugged terrain (Turner and Hansen 1980, Bleich 1993). By the hot/wet season (August-October), lambs are more mature and females may be more inclined to occupy less protected, flatter terrain.

Sheep preferred upland vegetation in all seasons and avoided all other habitats. The modest use of riparian habitat by sheep may be an artifact of my sampling combined with the size of my circular error probability polygon. Since 3 heavily used water sources are within 1.5 km of the Colorado River, I suspect that riparian habitat was included in the 1 km CEP areas when sheep were near the river to drink. Sheep avoided riverine habitats along most other stretches of the river (Figure 2.6 and Figure 2.7).

Bleich (1993) noted that males obtained higher quality diets and used less steep areas than females during periods of sexual segregation. I did not note male use of bajada habitats, but this may be due to the level of spatial resolution of my data and the small number of male observations. I recorded numerous ground sightings of males foraging and bedding under vegetation in wash habitats, especially during the hot/dry seasons. The quality of browse forage in washes may remain higher longer into the summer (see APPENDIX 6 for a review of methods and results of diet quality). In addition, vegetation in wash habitats is taller than bajada and upland areas (APPENDIX 5) and, therefore, affords greater opportunity for thermal cover. The importance of wash habitats to sheep may be obscured in my study due to the under-representation of wash in the vegetation map. I was unable to photo-interpret and digitize all washes during the creation of the vegetation data set.

"Rough" or "broken" terrain is recognized as critical to sheep (Ferrier and Bradley 1970, McQuivey 1978, Leslie and Douglas 1979, Hansen 1980). Historically, it has been described more in qualitative than in a quantitative terms (Hansen 1980, Brown 1983, Cunningham 1989). Beasom et al. (1983), Bleich (1993) and Ebert and Douglas (1993) quantified roughness by measuring the length or number of contour lines falling within a study grid, cell, or pixel. This method relies on the fact that steep slope areas have a greater density of contour lines than flatter areas. High variation in aspect would lead to increased curvilinearity of contours as opposed to rectilinear contour lines in areas where aspect does not change. Their indices, therefore, simultaneously measure variation in aspect and steepness of slope, but not variation in slope. These methods should provide reliable estimates of terrain roughness for a particular area; however, the indices are not readily comparable across studies because they require that topography be mapped to the same cartographic specifications (scale, contour interval) between study areas.

My measure of terrain roughness reflects variation in slope (not just steepness) and aspect. A highly broken area would have many different slope conditions and many different aspects. I found sheep avoided flat areas but used all other classes in proportion to availability. Only females exhibited seasonal use variation in the roughness classes. This may be related to parturition requirements of females. Females retreat to very rough areas 2 weeks prior to giving birth and remain there with newborns for several more weeks, after which they may venture into less rough areas (Turner and Hansen 1980). Furthermore, nearly all heavily used water sources were located in either Flat, Low and Medium-Low terrain classes. Sheep movement to these water sources during the hot/dry season and away from them after late summer rain may account for the seasonal variation I detected. This also may be the same for other habitat variables tested.

The importance of standing water to desert sheep, particularly during the summer, remains open to debate, particularly with small populations. Although some small, isolated populations persist without free water (Krausman et al. 1985), most researchers agree that water is important for larger populations 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). Many researchers have measured sheep distributions with respect to proximity to water and have postulated that female sheep, and other ungulates may be found closer to water than males because of the metabolic and water balance demands of lactation. Bowyer (1984) speculated that this was the case for mule deer in arid habitats. My results showed that males and females were found closer to sources of water than expected by random (Table 2.7) and there was no difference among seasons in proximity to water. This is in contrast to Dunn (1984) who found males closer to water than females. Leslie and Douglas (1979), Ebert and Douglas (1993), and Bleich (1993) all reported that females occurred closer to water than males. During this study, sheep were, on average, found within 2 km of water; this is farther than distances reported by Merritt (1974) and Wakeling and Miller (1989), but similar to those reported by Blong and Pollard (1968), Cunningham and Ohmart (1986), and Ebert and Douglas (1993). This variation in reported distances may be accounted for by the location of water sources within each study area. The mountain sheep in the Chocolate Mountains had to use water sources that typically were located in the low slope, low elevation, and low rough terrain classes. Sheep may have come to drink and then retreated to more secure terrain, especially females with lambs. Bleich (1993), however, found that females with lambs were as close to water as females without lambs. Careful interpretation of proximity data is suggested when one does not know the juxtaposition of landscape features relative to the water sources or any other landscape feature being measured.

North American mountain sheep are typically associated with precipitous terrain (Geist 1971), and it has been determined that females are more likely to occupy escape terrain than males (Bleich 1993). Escape terrain has been defined "qualitatively" as steep, rugged and broken terrain (Hansen 1980, Cunningham 1989). In quantitative terms it is usually described as areas where slope exceeds 60-80%. My results indicate no difference between genders in their distance to escape terrain. This may merely be the result of the size of my CEP, which may in turn limit the resolution needed to detect such differences.

Many human interactions with wild sheep have been disastrous for that species. The nature of interactions between human and sheep vary, and so do the consequences of those interactions (see Monson and Sumner 1980 for an overview). Additionally, individual sheep, as well as populations, vary in their reaction to human disturbance (Cunningham and Hanna 1992). In California, nearly half of the mountain sheep populations have been lost due to the introduction of domestic livestock and their diseases, habitat loss, and poaching (Wehausen et al. 1987). I found that males were closer to areas of human disturbance than females during all seasons, suggesting that males are more tolerant of disturbances. As a result, they can exploit resources found near areas of human disturbance, but they also may be at greater risk and suffer negative impacts associated with such interactions with humans. Such dangers might include poaching and exposure to domestic livestock and their diseases. Wild sheep are found near the Colorado River during the hot/dry season and show some aversion to boat traffic along the river (Andrew, pers. observ.). This source of disturbance, however, is not always sufficient to keep animals from drinking water.

There has been a proliferation of habitat use and evaluation models for mountain sheep as researchers and managers seek to conserve and enhance remaining populations (e.g., Ferrier and Bradley 1970, Hansen 1980, Brown 1983, Armentrout and Brigham 1988, Cunningham 1989, Wakeling and Miller 1990, Bleich et al. 1992). Cunningham (1989) derived his model from Hansen's (1980) but it was modified for use in Sonoran Desert habitat. Ebert and Douglas (1993) recently used a modified version of Cunningham's (1989) model in a Mojave Desert ecosystem and found it to be an excellent predictor of sheep habitat use in the Eldorado Range of Nevada. My results suggest that the original model is not as useful in the Lower Colorado River Desert in the East Chocolate Mountains. The low rating given to the vegetation of the area, locally heavy areas of human disturbance, and the preponderance of feral asses make it impossible for a score greater than 58 (fair quality) to be extracted using this protocol. The Cunningham (1989) model may require some degree of modification to account for habitat use by this population of wild sheep. Specifically, a higher rating for the vegetation of this, the driest sub-habitat type of the Sonoran Desert, is needed.

MANAGEMENT IMPLICATIONS

Food, water and cover, in the form of escape terrain are essential components of mountain sheep habitat. To achieve management objectives it may require the manipulation of 1 or more of these parameters.

Habitat improvement for mountain sheep generally has been restricted to water source enhancement. Many such projects have been undertaken in states with populations of desert-dwelling sheep (Tsukamoto and Stiver 1988). Persistent water sources, not used by feral asses, are conspicuously lacking in the East Chocolate Mountains. Five artificial sources have been built by Desert Wildlife Unlimited but were installed to benefit mule deer and are located such that they are not readily accessible to sheep. The installation of artificial water sources has been shown to be beneficial to populations of desert ungulates (Remmington et al. 1984), and may help to increase population size where water is limiting. Also, the removal of feral asses has resulted in the use of water sources that sheep had previously avoided (Dunn 1993). The installation of permanent water sources, across the entire study area may benefit this population. Existing natural water sources should also be enhanced (e.g., Cripple Hawk, Midway, and Noel Tanks, as well as Draper Point and Old Salt Spring). Enhancement activities could include fencing to keep feral asses out, or the removal of heavy vegetation to afford sheep easier access. These recommendations are consistent with those of the sheep management plan for the East Chocolate Mountains (Bleich and Torres 1993). If artificial water sources are installed, they must be regularly evaluated and maintained; however, all existing water sources (natural and artificial) should be systematically monitored for water availability.

Competition between mountain sheep and feral asses for water and forage around water sources, particularly during the dry seasons, occurs in other areas (see Jones 1980 for an overview). Although such competition has not been quantified in the East Chocolate Mountains, it is a point of concern in the Department of Interior (DOI), Bureau of Land Management (BLM) (1984) herd management plan for this area. Current burro numbers (Bleich and Torres 1993, Torres 1993, Andrew 1994) exceed the population levels advocated in the BLM's (1984) plan. Moreover, vegetation is heavily denuded around some water sources that experience high burro use (Andrew, pers. observ.). The installation of burro fences around all water holes in sheep habitat may force burros towards the Colorado River and reduce competition with sheep. The management goal to remove all feral asses within this area (Bleich and Torres 1993) should be vigorously pursued. At the very minimum, burro numbers should be reduced to those specified as minimum numbers by the BLM (1984).

Areas that receive only marginal sheep use (Figure 2.6 and 2.7) must be included in any management plan. Research has clearly shown that once sheep have abandoned habitat, they are reticent to recolonize it even if it is suitable (Bleich et al. 1990a). The management goal must be to protect and enhance all currently used habitat and provide the opportunity for sheep to move throughout the East Chocolate Mountains and adjacent ranges. The installation of permanent water sources in unoccupied mountain ranges might increase the probability that colonizing sheep permanently establish themselves these areas.

The potential negative impacts of some types of human-sheep interactions cannot be understated. Areas receiving the highest human use in this region are the Colorado River, Picacho State Recreation Area, and large mining operations. If water sources can be installed that attract sheep away from the river, that source of sheep-human interaction would be potentially reduced. Little can be done to reduce the level of traffic on existing roads leading to mining claims and Picacho State Recreation Area. Future plans for new road development in the area that would further fragment and reduce wild sheep habitat should be carefully scrutinized.

This sheep population is larger than previously thought (Chapter 1) and represents an important mountain sheep resource in the state. Additional monitoring should continue to determine how use varies temporally and with differing population levels (Fretwell 1972). The vigorous implementation of the CDFG's management plan (Bleich and Torres 1993) should be undertaken to ensure the continued conservation and enhancement of this remnant native population, which may well be the largest population of wild mountain sheep in the Sonoran desert of California.

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Figure 2.1. Distribution of known water sources potentially used by mountain sheep during some portion of the year in the East Chocolate Mountains study area, Imperial County, California, 1992-1993.

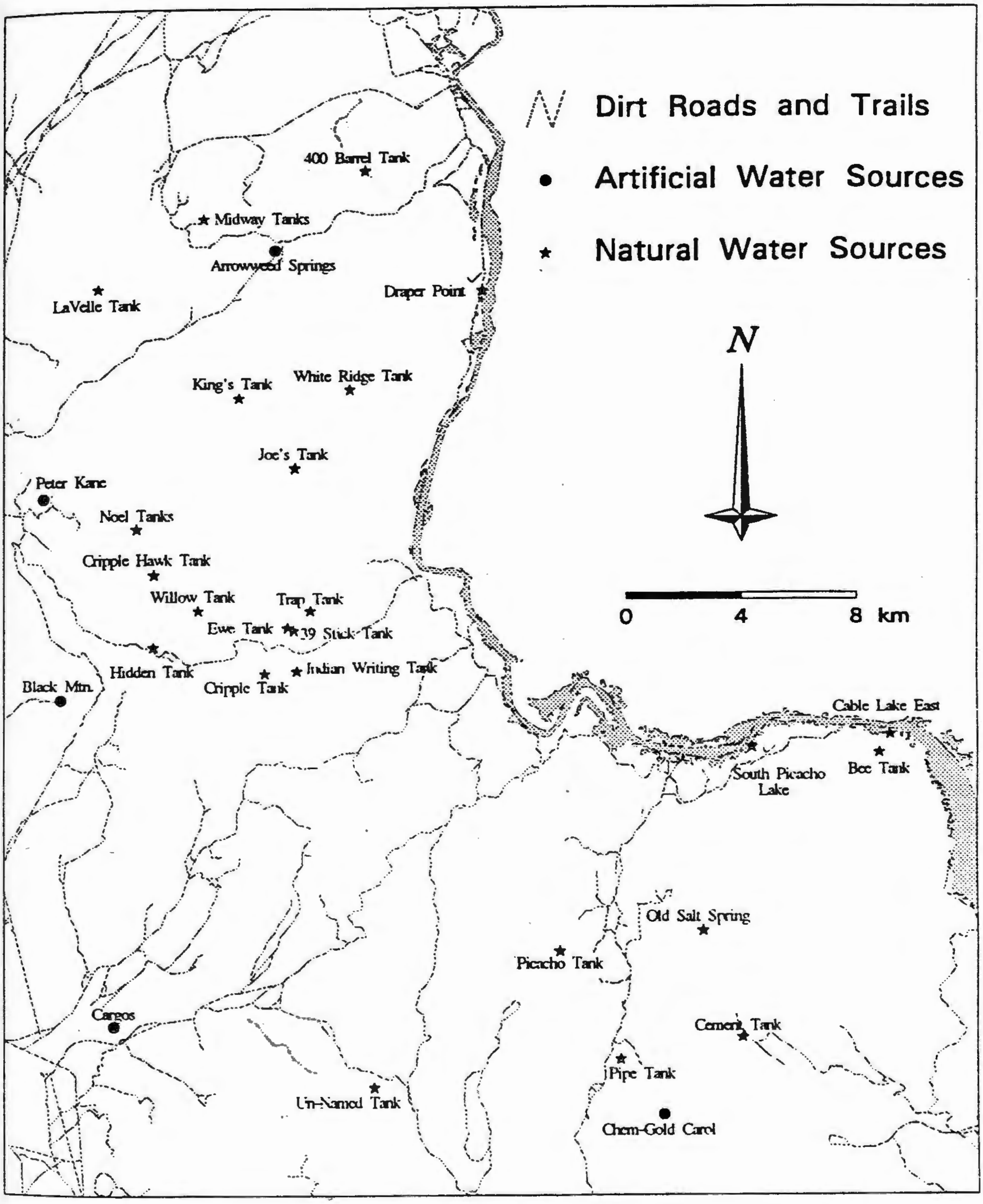
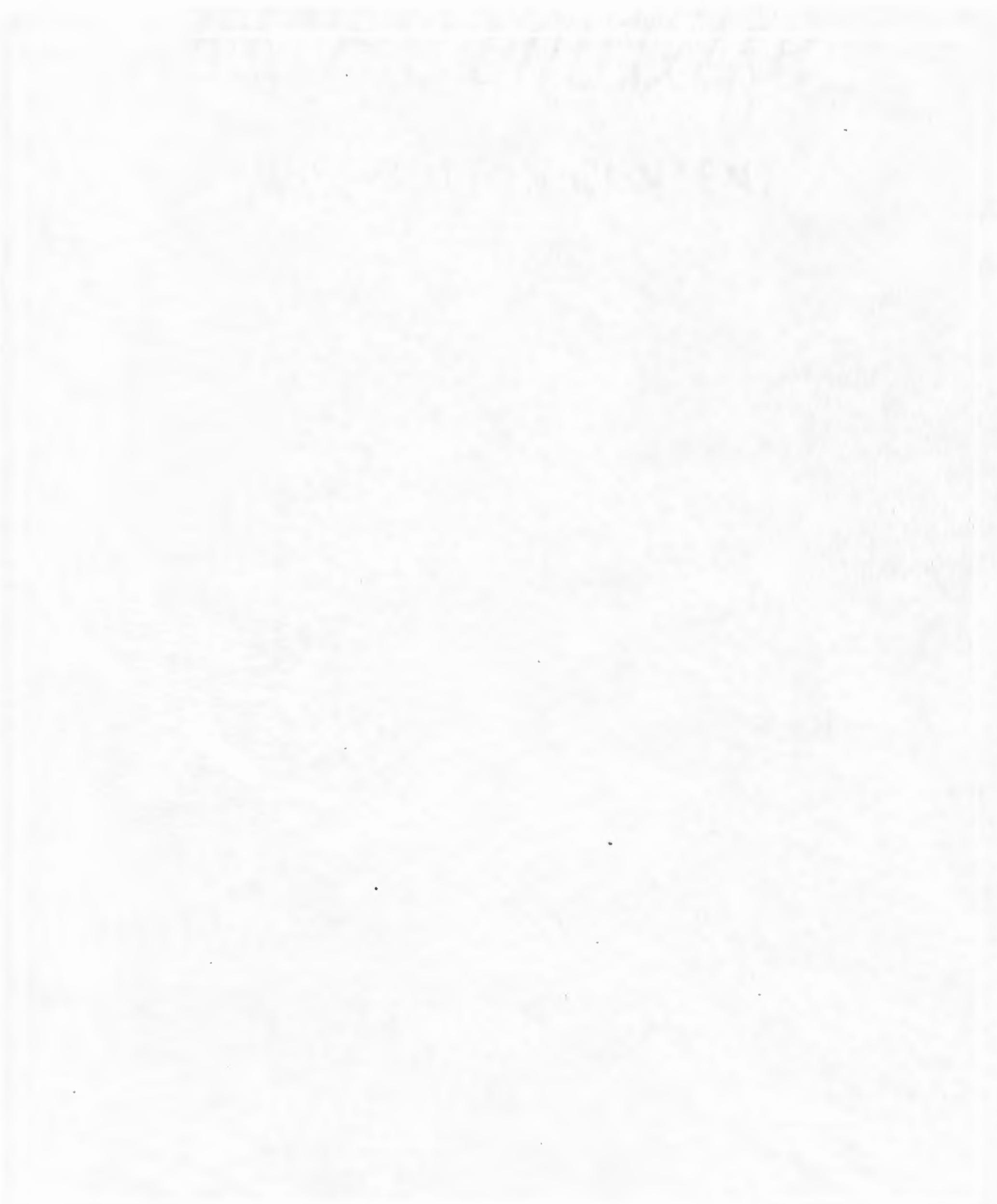

Dirt Roads and Trails
Artificial Water Sources
Natural Water Sources
N
0
4
8 km
400 Barrel Tank
Midway Tanks
Arrowweed Springs
LaVelle Tank
Draper Point
King's Tank
White Ridge Tank
Joe's Tank
Peter Kane
Noel Tanks
Cripple Hawk Tank
Willow Tank
Trap Tank
Ewe Tank
39 Stick Tank
Hidden Tank
Cripple Tank
Indian Writing Tank
Black Mtn.
Cable Lake East
South Picacho Lake
Bee Tank
Old Salt Spring
Picacho Tank
Cargos
Cement Tank
Pipe Tank
Un-Named Tank
Chem-Gold Carol

Figure 2.2. Hillshade representation of the East Chocolate Mountains study area, derived from USGS 1:24,000 digital elevation models Imperial County, California.



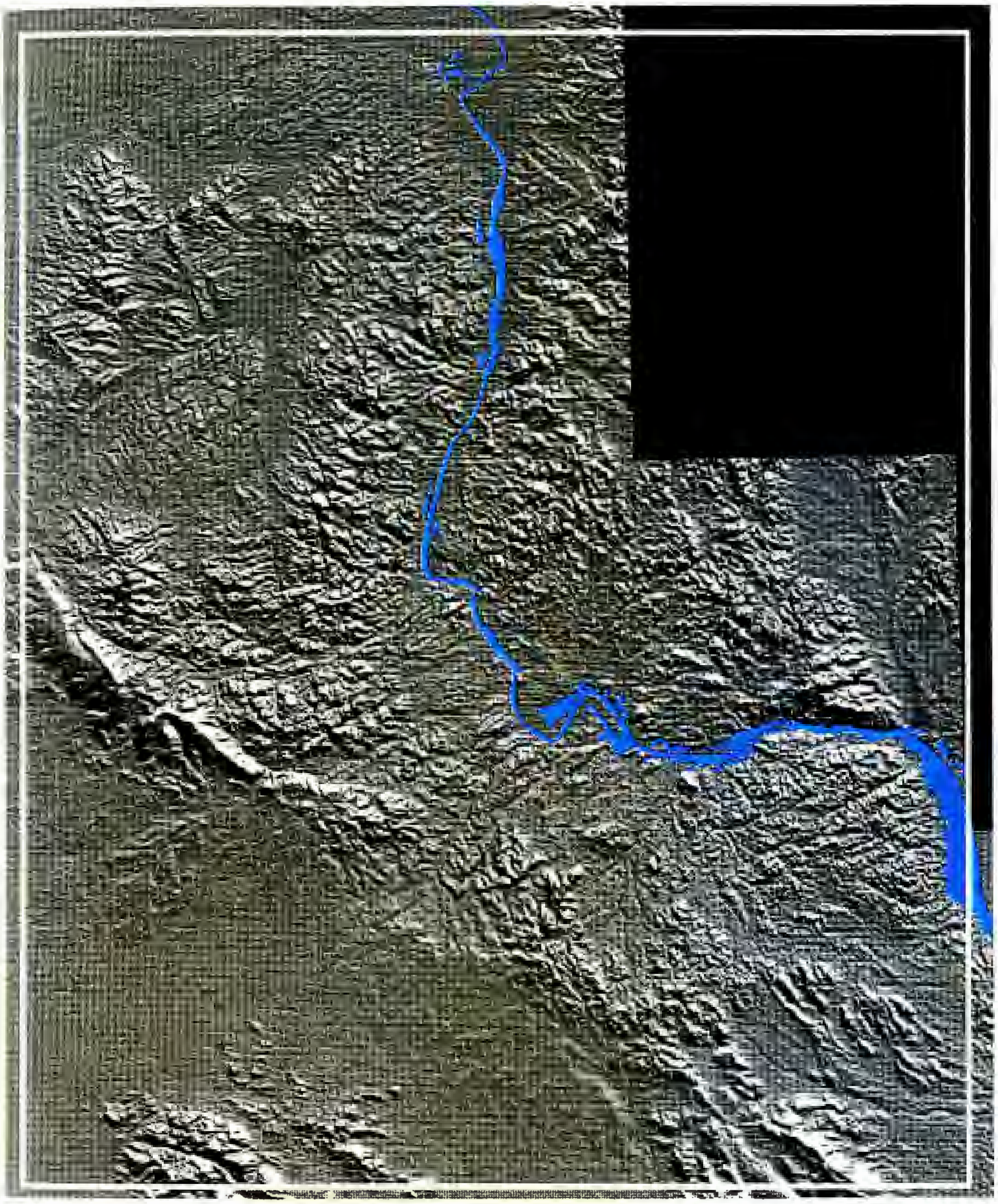
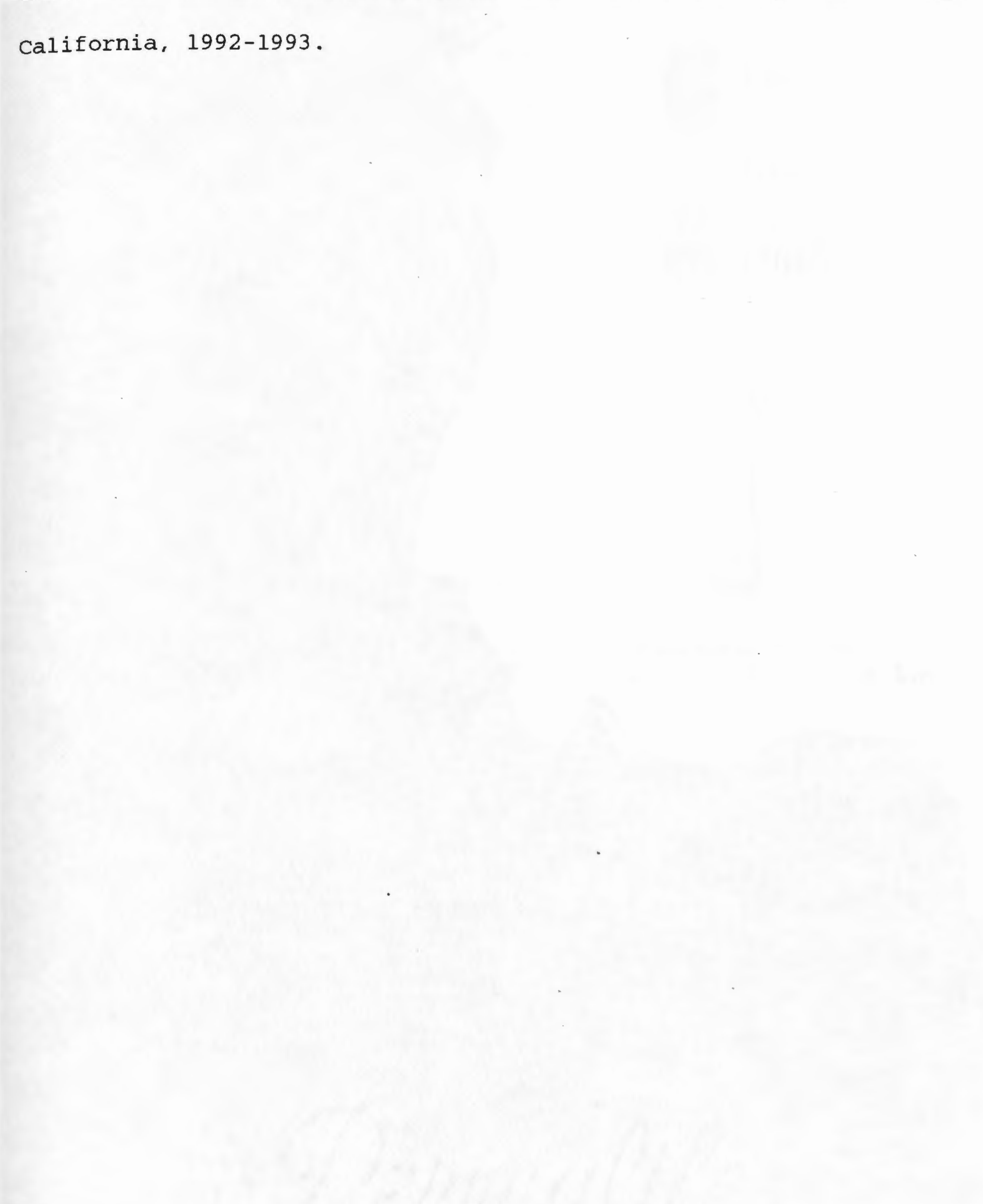


Figure 2.3. Slope map derived from USGS 1:24,000 digital elevation models for the East Chocolate Mountains study area, Imperial County, California, 1992-1993.



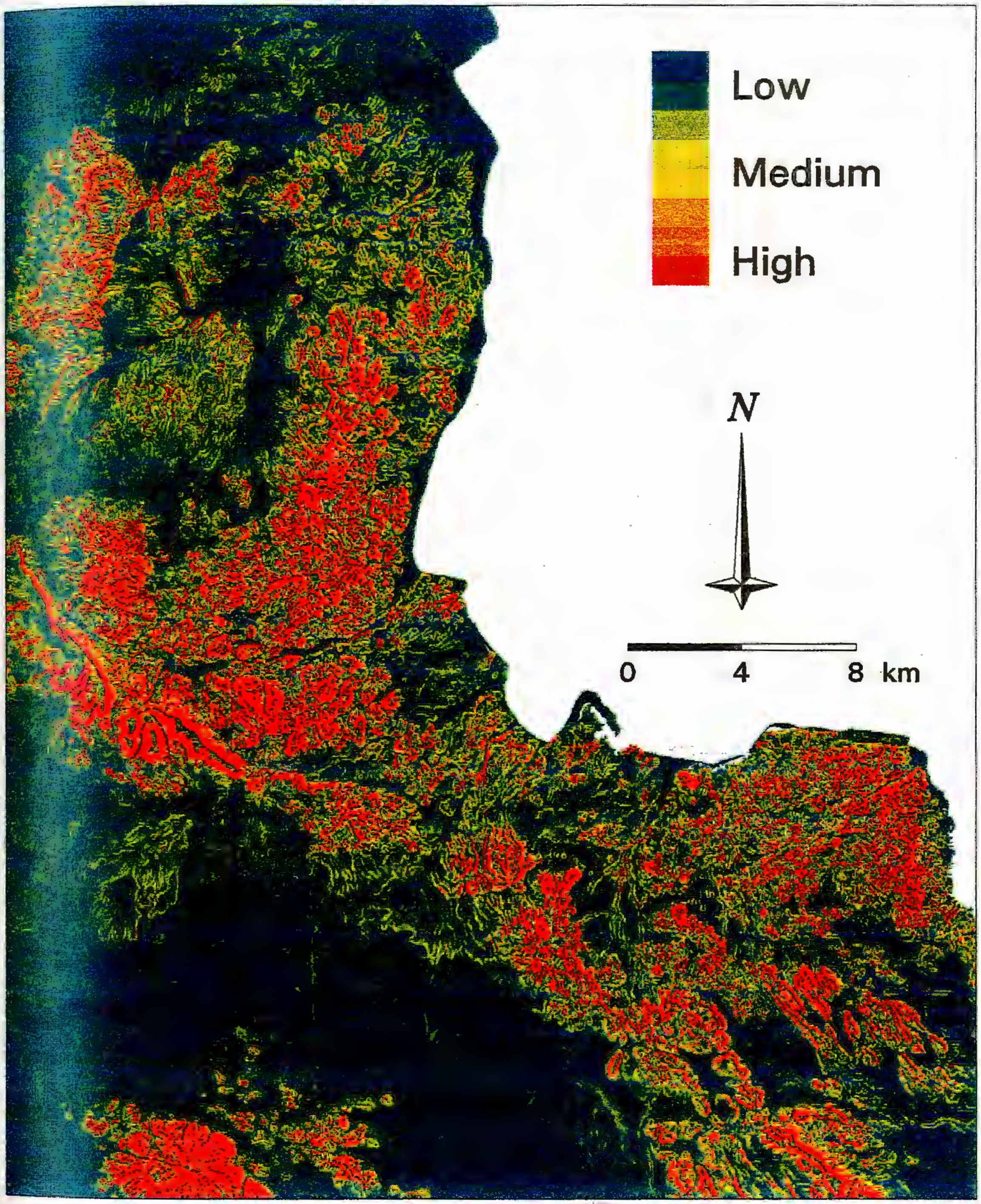
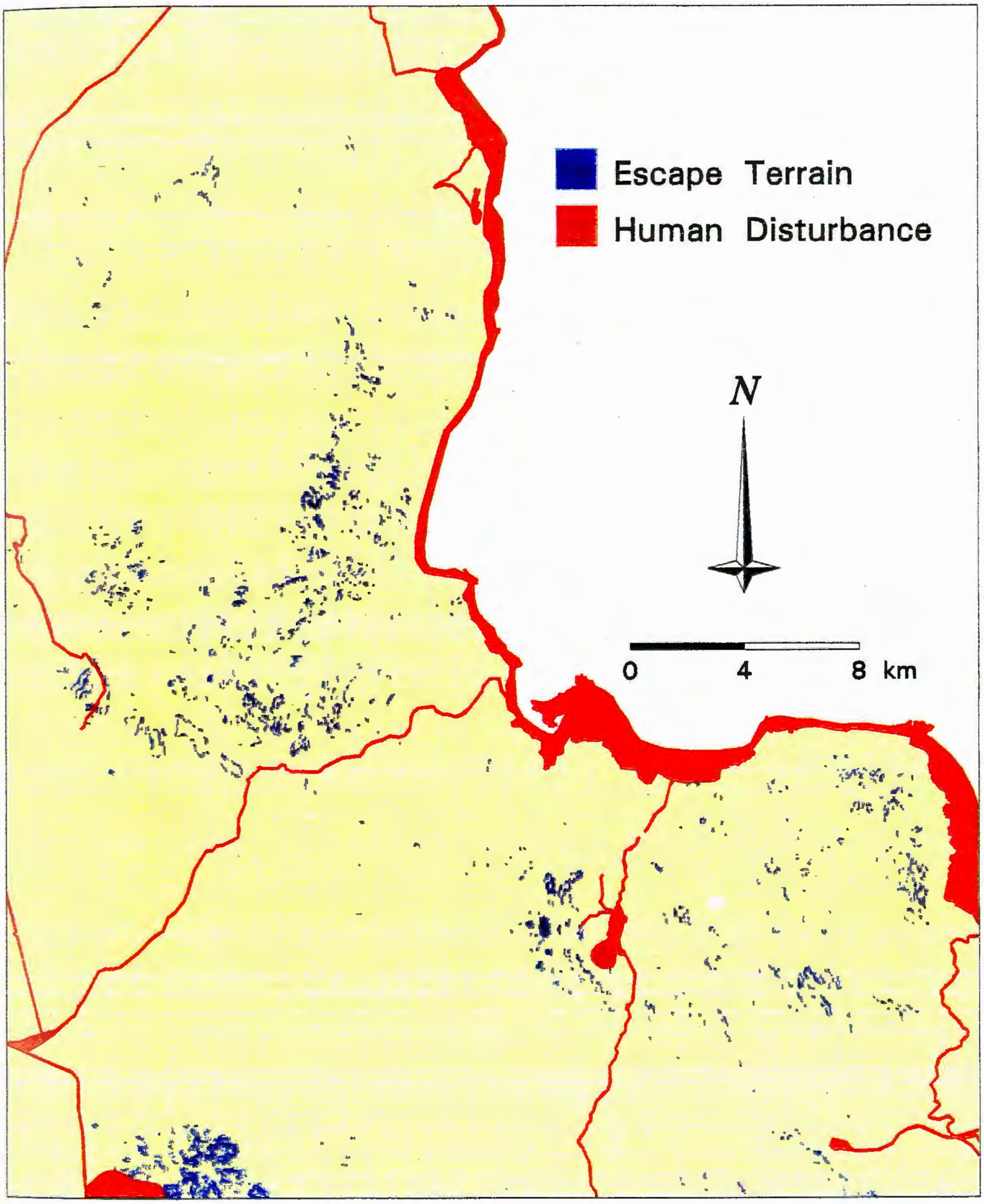

Low
Medium
High
N
0
4
8 km

Figure 2.4 Escape terrain and areas of human disturbance in the East Chocolate Mountains study area, Imperial County, California.



Escape Terrain
Human Disturbance
N
0
4
8 km

Figure 2.5. Four major vegetation classes delineated within the East Chocolate Mountains study area, Imperial County, California. These were mapped from 1985 1:36,000 black and white National High Altitude Photography, enlarged to 1:24,000.

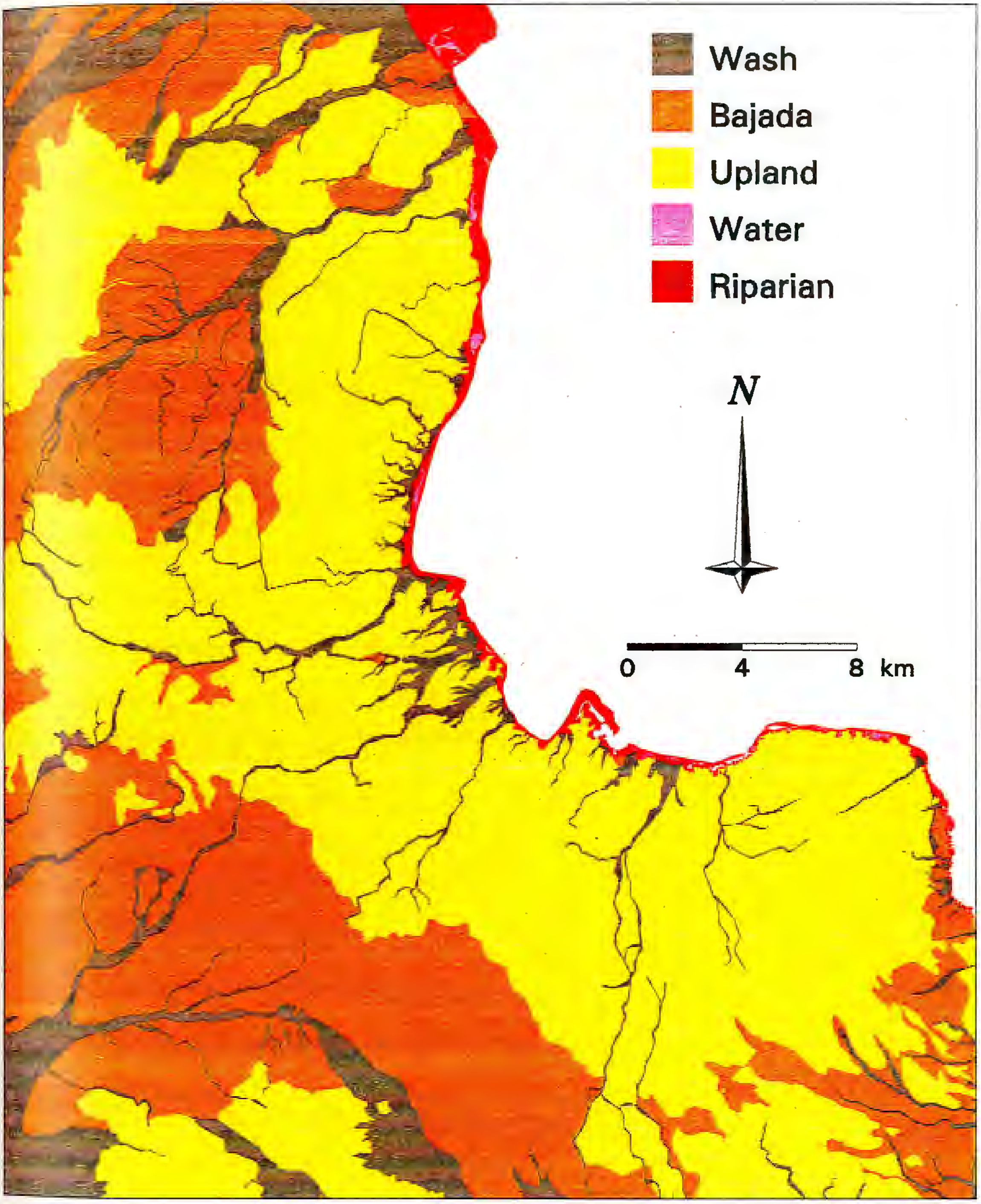

Wash
Bajada
Upland
Water
Riparian
N
0
4
8 km

Figure 2.6. Map showing the location of mountain sheep and 3 cells used to evaluate the usefulness of Cunningham's (1989) habitat evaluation model in the East Chocolate Mountains, Imperial County, California, 1992-1993.

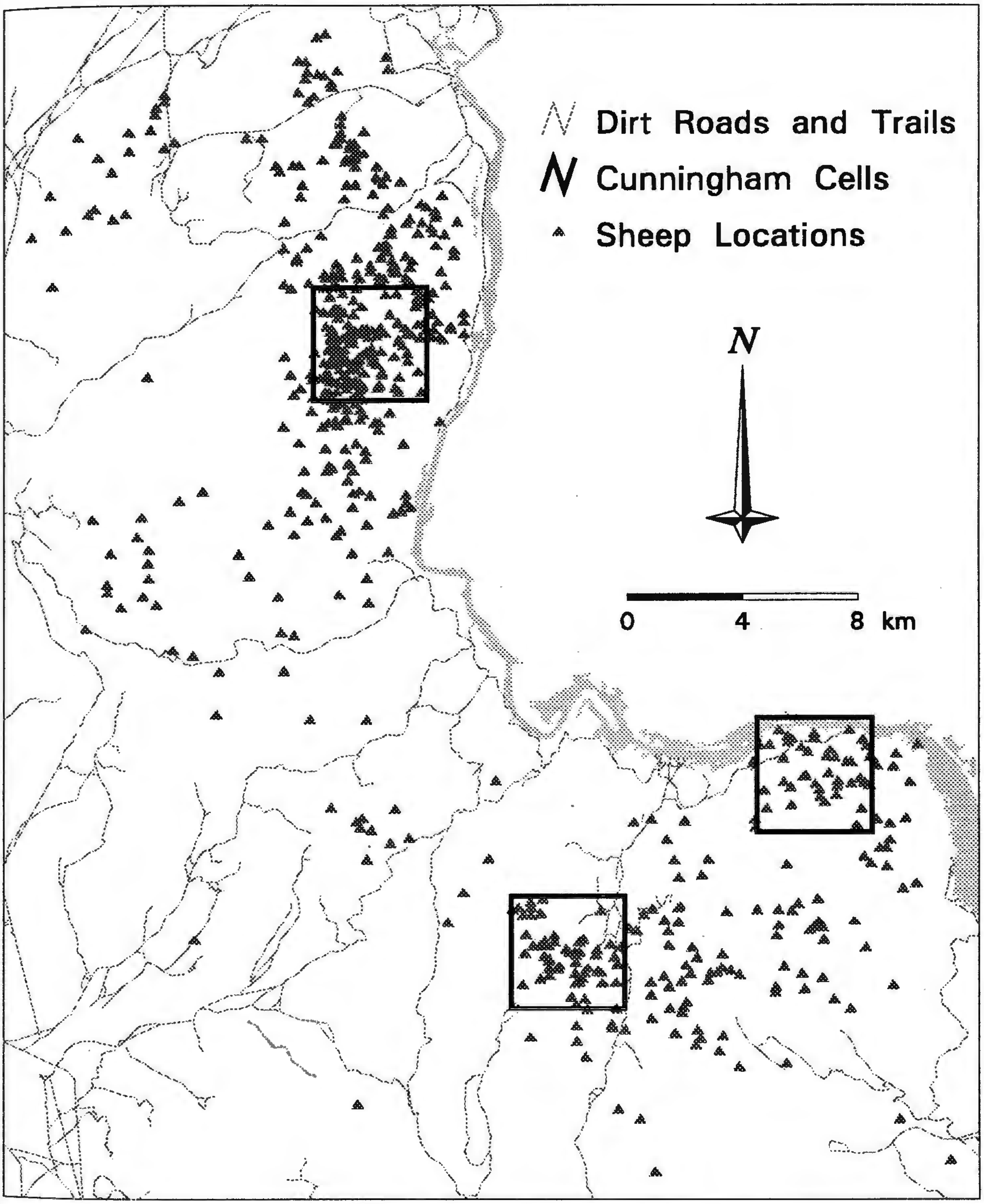
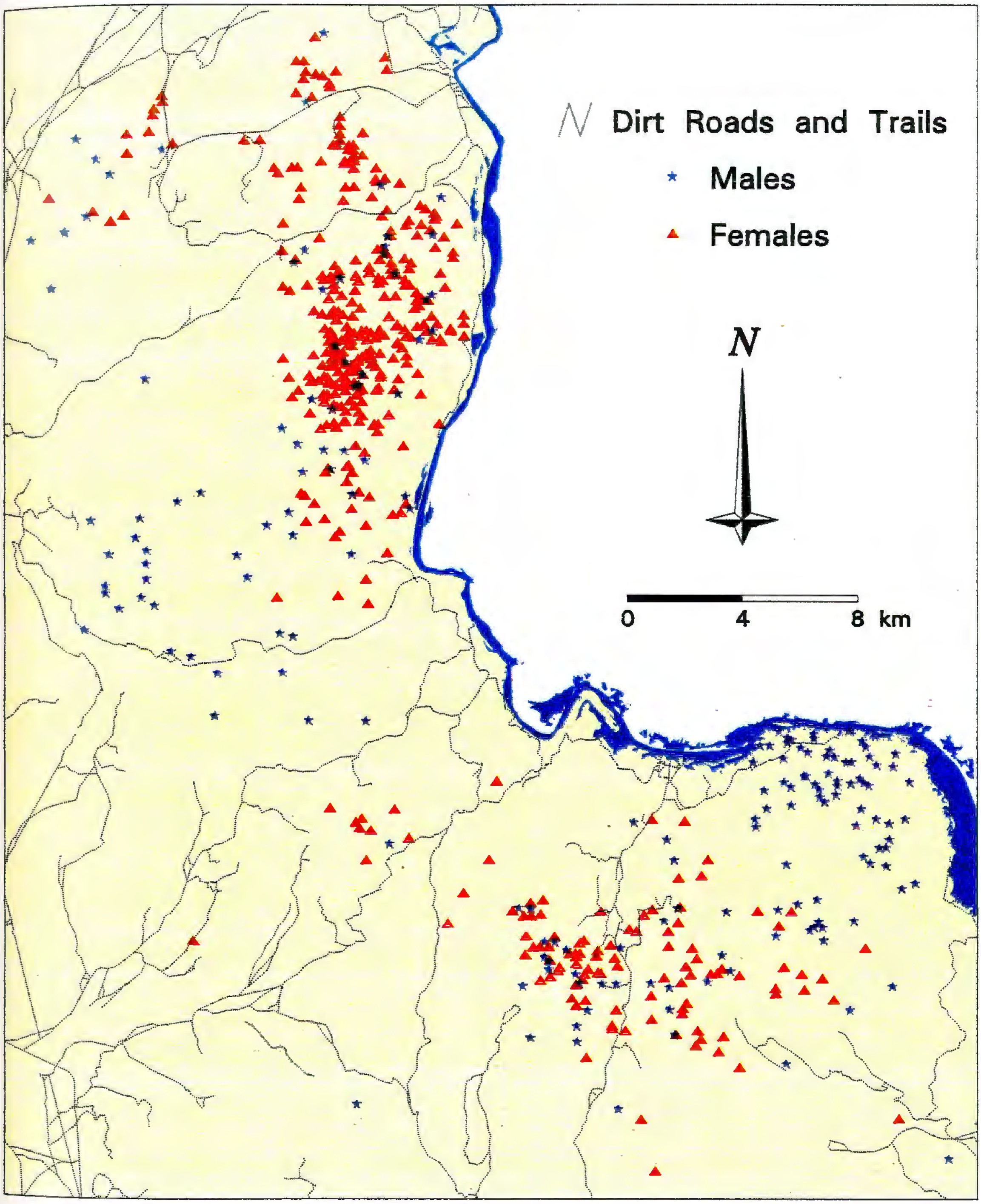
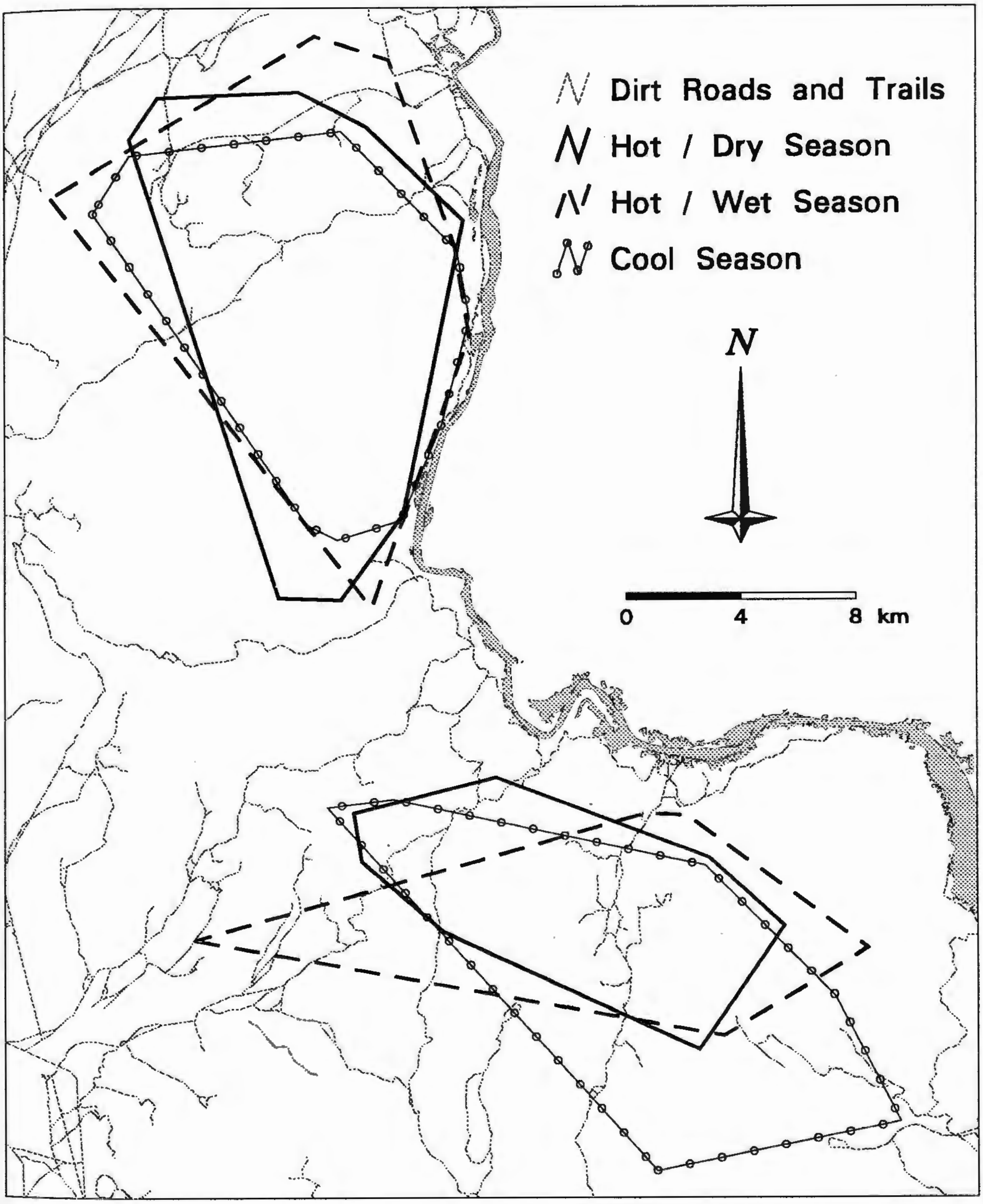

Dirt Roads and Trails
Cunningham Cells
Sheep Locations
N
0
4
8 km

Figure 2.7. Telemetry locations obtained for male and female sheep in the East Chocolate Mountains, Imperial County, California, 1992-1993.



Dirt Roads and Trails
Males
Females
N
0
4
8 km

Figure 2.8. Map showing the distribution of radio-collared females for the northern and southern female demes, by seasons, in the East Chocolate Mountains, Imperial County, California, 1992-1993. Distributions were outlined by connecting the outer points for all females in each of the 3 seasons.



Dirt Roads and Trails
Hot / Dry Season
Hot / Wet Season
Cool Season
N
0
4
8 km

Figure 2.9. Map showing the distribution of radio-collared males for the northern and southern areas, by seasons, in the East Chocolate Mountains, Imperial County, California, 1992-1993. Distributions were outlined by connecting the outer points for all males in each of the 3 seasons.

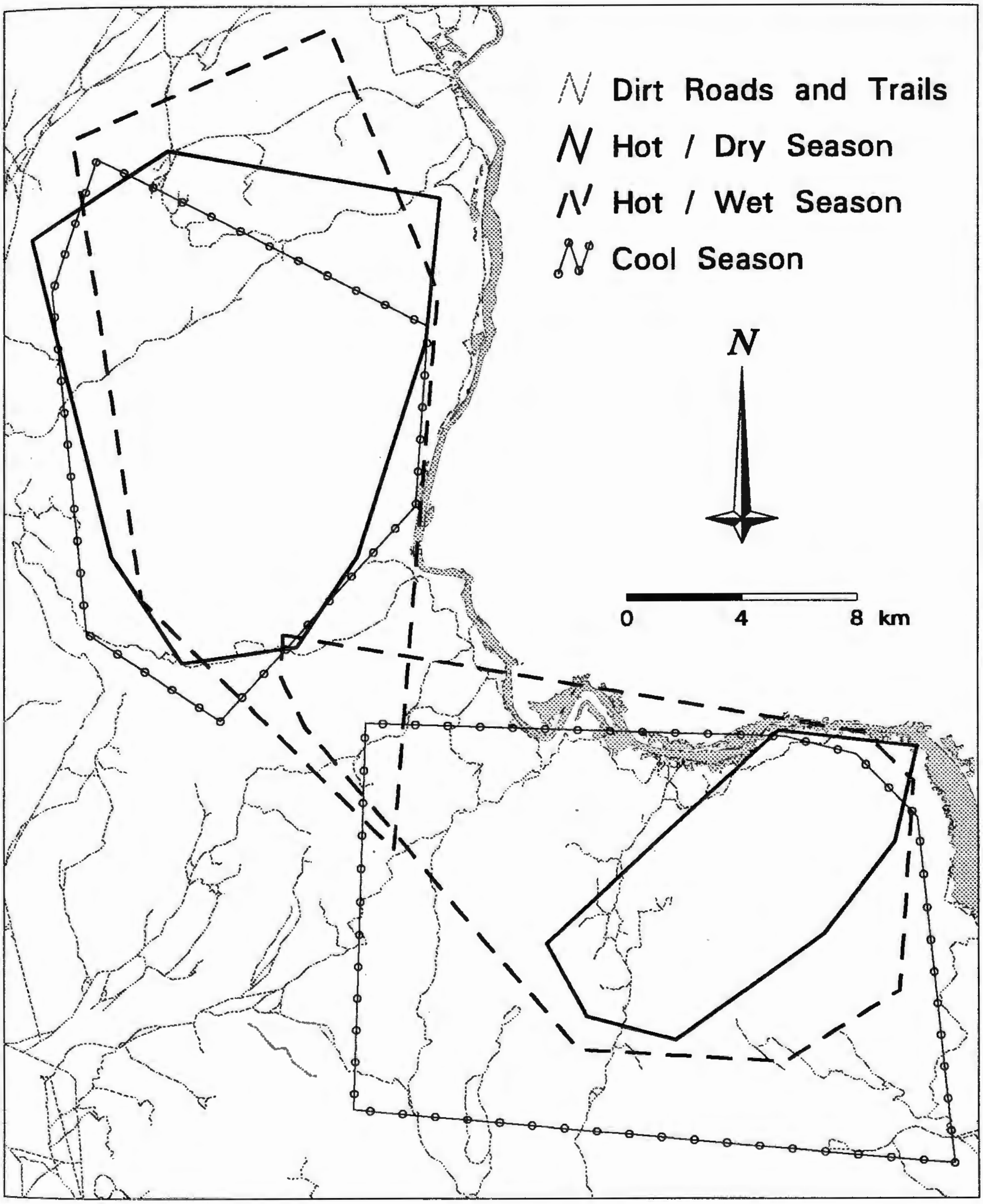

Dirt Roads and Trails
Hot / Dry Season
Hot / Wet Season
Cool Season
N
0
4
8 km

Table 2.1. LORAN-C directional bias for the East Chocolate Mountains study area based on replicate fixes (n=8) for each landmark. A t-test was used to determine if the mean deviation at each landmark was equal to zero.

	Deviation From USGS Map (m)							
Landmarks	X	SD	t Value	_P_=0	Y	SD	t Value	_P_=0
Arrowweed Spring	-594	503	3.35	<0.05	1724	428	11.39	<0.001
Draper Cabin	-687	216	7.78	<0.001	1576	355	10.85	<0.001
Picacho Boat Ramp	-520	316	3.68	<0.05	1426	349	9.14	<0.001
Little Picacho Peak	-509	235	6.12	<0.001	1398	239	1.55	<0.001
Little Picacho	-462	173	7.56	<0.01	1106	323	9.66	<0.001
Grand Mean	-554				1447			

Table 2.2. Proportional use of elevation classes by female and male mountain sheep, by seasons, for the East Chocolate Mountains, Imperial County, California, 1992-1993.

Elevation/ Season	Available ha	Total Proportion	Males n	Males $\bar{x}$	Males SD	Females n	Females $\bar{x}$	Females SD
0-75m	3,070	0.03						
Hot/Dry			12	0.26	0.23	9	0.11	0.15(-)
Hot/Wet			14	0.21	0.16	11	0.09	0.15(-)
Cool			11	0.18	0.21	15	0.17	0.18
P				*ns*			*ns*	
75-150m	15,254	0.16						
Hot/Dry			29	0.42	0.29	57	0.35	0.34
Hot/Wet			42	0.36	0.27	89	0.44	0.36
Cool			25	0.35	0.27	77	0.38	0.24
P				*ns*			*ns*	
150-225m	30,438	0.31						
Hot/Dry			49	0.38	0.31	149	0.35	0.31
Hot/Wet			63	0.45	0.34	166	0.42	0.34
Cool			36	0.52	0.34	116	0.42	0.23
P				ns			*	
225-300m	31,503	0.32						
Hot/Dry			46	0.28	0.26	138	0.38	0.24
Hot/Wet			58	0.22	0.25(-)	139	0.31	0.24
Cool			40	0.22	0.28(-)	118	0.26	0.26
P				ns			***	
300-375m	12,771	0.13						
Hot/Dry			29	0.30	0.24	109	0.25	0.19
Hot/Wet			28	0.35	0.28	91	0.24	0.20
Cool			22	0.37	0.28	67	0.20	0.20(-)
P				*ns*			*ns*	
375-450m	3,156	0.03						
Hot/Dry			19	0.10	0.11	81	0.03	0.03
Hot/Wet			19	0.08	0.11	62	0.02	0.03(-)
Cool			19	0.21	0.18	37	0.03	0.04(-)
P				*			ns	
450-647m	2,098	0.02						
Hot/Dry			9	0.15	0.27	9	0.01	0.01(-)
Hot/Wet			9	0.04	0.09	14	0.01	0.01(-)
Cool			13	0.28	0.30	4	0.00	0.00(-)
P				*ns*			*ns*	

ns-$P>0.05$; *$P<0.05$; **$P<0.01$; ***$P<0.001$ using Kruskal-Wallis Test of habitat use among seasons within gender/elevation classes.

Symbols indicate significant ($P<0.05$) habitat selection (+), and avoidance (-) in proportion to their availability (Neu et al. 1974, Byers et al. 1984).

Table 2.3. Proportional use of aspect classes by female and male mountain sheep, by seasons, for the East Chocolate Mountains, Imperial County, California, 1992-1993.

Aspect/ Season	Available ha	Available Total Proportion	Males n	Males $\bar{x}$	Males SD	Females n	Females $\bar{x}$	Females SD
North	11,543	0.12						
Hot/Dry			59	0.13	0.04	155	0.11	0.03
Hot/Wet			71	0.13	0.04	176	0.12	0.29
Cool			54	0.12	0.05	125	0.10	0.03
P				ns			***	
Northeast	13,600	0.14						
Hot/Dry			59	0.15	0.03	155	0.15	0.03
Hot/Wet			71	0.14	0.03	176	0.15	0.03
Cool			54	0.14	0.04	125	0.15	0.03
P				*ns*			*ns*	
East	14,217	0.15						
Hot/Dry			59	0.16	0.05	155	0.18	0.04
Hot/Wet			71	0.15	0.04	176	0.17	0.04
Cool			54	0.15	0.04	125	0.19	0.03
P				ns			***	
Southeast	12,479	0.13						
Hot/Dry			59	0.11	0.04	155	0.12	0.04
Hot/Wet			71	0.12	0.04	176	0.15	0.04
Cool			54	0.12	0.04	125	0.13	0.03
P				ns			***	
South	10,888	0.11						
Hot/Dry			59	0.10	0.03	155	0.09	0.04
Hot/Wet			71	0.11	0.04	176	0.09	0.03
Cool			54	0.12	0.04	125	0.10	0.03
P				ns			*	
Southwest	11,510	0.12						
Hot/Dry			59	0.10	0.04	155	0.10	0.04
Hot/Wet			71	0.09	0.04	176	0.10	0.04
Cool			54	0.11	0.04	125	0.11	0.04
P				*			**	
West	12,222	0.12						
Hot/Dry			59	0.12	0.05	155	0.13	0.05
Hot/Wet			71	0.11	0.05	176	0.12	0.05
Cool			54	0.12	0.04	125	0.11	0.04
P				*ns*			*ns*	

Table 2.3 continued.

Northwest	11,228	0.11						
Hot/Dry			59	0.13	0.04	155	0.12	0.04
Hot/Wet			71	0.13	0.04	176	0.12	0.03
Cool			54	0.12	0.04	125	0.10	0.03
P				ns			***	
Level	602	0.01						
Hot/Dry			33	0.02	0.04	64	0.00	0.01
Hot/Wet			38	0.01	0.03	108	0.00	0.01
Cool			23	0.01	0.03	77	0.00	0.01
P				ns			*	

ns-$P>0.05$; *$P<0.05$; **$P<0.01$; ***$P<0.001$ using Kruskal-Wallis Test of habitat use among seasons within gender/aspect classes.

Symbols indicate significant ($P<0.05$) habitat selection (+), and avoidance (-) in proportion to their availability (Neu et al. 1974, Byers et al. 1984).

Table 2.4. Proportional use of slope classes by female and male mountain sheep, by seasons, for the East Chocolate Mountains, Imperial County, California, 1992-1993.

Slope/	Available		Males			Females		
Season	ha	Total Proportion	n	$\bar{x}$	SD	n	$\bar{x}$	SD
0-20%	74,529	0.76						
Hot/Dry			59	0.54	0.18(-)	155	0.54	0.21(-)
Hot/Wet			71	0.56	0.22(-)	176	0.63	0.22(-)
Cool			54	0.53	0.21(-)	125	0.57	0.16(-)
P				ns			***	
21-40%	16,907	0.17						
Hot/Dry			59	0.32	0.09	155	0.31	0.12(+)
Hot/Wet			70	0.31	0.12	175	0.26	0.12
Cool			53	0.32	0.12	125	0.31	0.09(+)
P				ns			***	
41-60%	5,424	0.06						
Hot/Dry			58	0.12	0.08	145	0.13	0.08
Hot/Wet			68	0.11	0.08	158	0.10	0.08
Cool			51	0.13	0.08	123	0.11	0.07
P	*			ns			***	
61-80%	1,212	0.01						
Hot/Dry			52	0.03	0.02	127	0.03	0.02
Hot/Wet			57	0.03	0.03	123	0.03	0.03
Cool			47	0.03	0.03	116	0.03	0.03
p				ns			ns	
81-100%	174	0.002						
Hot/Dry			42	0.00	0.01	84	0.00	0.01
Hot/Wet			45	0.01	0.01	84	0.01	0.01
Cool			33	0.00	0.00	65	0.00	0.01
P				ns			ns	
101-240%	43	0.000						
Hot/Dry			12	0.01	0.01	22	0.01	0.01
Hot/Wet			18	0.01	0.02	29	0.01	0.02
Cool			9	0.00	0.01	20	0.00	0.00
P				*			ns	

ns-$P>0.05$; *$P<0.05$; **$P<0.01$; ***$P<0.001$ using Kruskal-Wallis Test of habitat use among seasons within gender/slope classes.

Symbols indicate significant ($P<0.05$) habitat selection (+), and avoidance (-) in proportion to their availability (Neu et al. 1974, Byers et al. 1984).

Table 2.5. Proportional use of vegetation classes by female and male mountain sheep in the East Chocolate Mountains, Imperial County, California, 1992-1993.

		Vegetation Classes			
		Upland	Bajada	Wash	Riparian
Dataset	N	$\bar{X}$ + SD	$\bar{X}$ + SD	$\bar{X}$ + SD	$\bar{X}$ + SD
Total hectares available		54,540	31,499	10,418	1,649
Proportion available		0.56	0.32	0.11	0.02
Females vs. Males					
Females	455	0.92 + 0.1 (+)	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 Seasons					
Hotdry	155	0.91 + 0.18(+)	0.22 + 0.27(-)	0.05 + 0.07(-)	0.09 + 0.06(-)
Hotwet	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 Seasons					
Hotdry	59	0.92 + 0.11(+)	0.17 + 0.07(-)	0.07 + 0.05(-)	0.08 + 0.07
Hotwet	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

Symbols indicate significant (P<0.05) habitat selection (+), and avoidance (-), in proportion to their availability (Neu et al. 1974, Byers et al. 1984).

ns-P>0.05; *P<0.05; **P<0.01; ***P<0.001 using Kruskal-Wallis Test.

Table 2.6 Proportional use of terrain roughness classes by female and male mountain sheep, by seasons, for the East Chocolate Mountains, Imperial County, California, 1992-1993.

Roughness/ Season	Available ha	Available Total Proportion	Males n	Males $\bar{x}$	Males SD	Females n	Females $\bar{x}$	Females SD
Flat	79,986	0.82						
Hot/Dry			59	0.65	0.16(-)	155	0.65	0.20(-)
Hot/Wet			71	0.68	0.20(-)	176	0.72	0.20(-)
Cool			54	0.64	0.18(-)	125	0.66	0.16(-)
P				ns			***	
Low	8,612	0.09						
Hot/Dry			59	0.17	0.06	155	0.16	0.08(+)
Hot/Wet			70	0.16	0.08	171	0.14	0.08
Cool			51	0.19	0.05	124	0.16	0.06
P				ns			***	
Medium Low	6,406	0.07						
Hot/Dry			59	0.14	0.08	144	0.16	0.10(+)
Hot/Wet			68	0.16	0.09	148	0.12	0.10
Cool			51	0.19	0.09	124	0.14	0.08
P				ns			**	
Medium High	2389	0.02						
Hot/Dry			54	0.03	0.03	127	0.04	0.03
Hot/Wet			59	0.04	0.03	128	0.03	0.03
Cool			48	0.03	0.03	119	0.03	0.03
P				ns			*	
High	236	0.00						
Hot/Dry			31	0.01	0.01	81	0.01	0.01
Hot/Wet			34	0.01	0.02	70	0.01	0.02
Cool			29	0.01	0.01	60	0.00	0.01
P				ns			*	

ns-$P>0.05$; *$P<0.05$; **$P<0.01$; ***$P<0.001$ using Kruskal-Wallis Test of habitat use among seasons within gender/slope classes.

Symbols indicate significant ($P<0.05$) habitat selection (+), and avoidance (-) in proportion to their availability (Neu et al. 1974, Byers et al. 1984).

Table 2.7. Distances (in meters) between sheep locations and random points to water sources, escape terrain, and areas of human disturbance in the East Chocolate Mountains, Imperial County, California, 1992-1993. 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. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Data Set	N	Mean	SD
Proximity to Water Sources			
Random	1000	3,142	1,730
Females	456	2,029***	1,164
Males	184	2,079***	1,299
Proximity to Escape Terrain			
Random	970	1,305	1,267
Females	452	564***	666
Males	182	509***	612
Proximity to Human Disturbance			
Random	990	2,860	2,009
Females	441	2,964**	1,425
Males	174	2,369**	1,545

Table 2.8. Distances (in meters) from sheep locations and random points to water sources, escape terrain, and areas of human disturbance in the East Chocolate Mountains, Imperial County, California, 1992-1993. Data are presented by gender and season. The results of a Wilcoxon 2-Sample Test that mean distances are equal between genders within seasons are indicated by asterisks. *ns* $P > 0.05$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

Dataset	Total N	Seasons: Hot/dry $\bar{X} \pm SD$	Hot/wet $\bar{X} \pm SD$	Cool $\bar{X} \pm SD$
Proximity to Water Sources				
Females	456	2008 ± 1288	2075 ± 1097	1994 ± 1102
Males	184	1770 ± 1015	2096 ± 1328	2395 ± 1473
P		*ns*	*ns*	*ns*
Proximity to Human Disturbance				
Females	452	3180 ± 1400	3067 ± 1509	2550 ± 1249
Males	182	2292 ± 1409	2565 ± 1654	2194 ± 1535
P		***	*	**
Proximity to Escape Terrain				
Females	441	529 ± 644	721 ± 807	382 ± 344
Males	174	461 ± 501	589 ± 648	455 ± 670
P		*ns*	*ns*	*ns*

Table 2.9. Cunningham's (1989) habitat model scores for 3, 4 km^2 cells in the East Chocolate Mountains, Imperial County, California, 1992-1993.

Habitat Variable (total possible points)	North Cell	Southwest Cell	Southeast Cell
Natural topography (20)	20	16	20
Vegetation type (20)	8	8	8
Precipitation (5)	1	1	1
Water source, type (5)	2	2	3
Water source, use (5)	2	2	3
Water source, competition (5)	5	3	3
Water source, location (5)	5	5	5
Human use (20)	15	10	7
Total Possible Score (85)	58	47	50

APPENDIX 1. Capture history of marked mountain sheep in the East Chocolate Mountains, Imperial County, California, from June 1992 to February 1994. Captured sheep were fitted with a radio-collar and two unique ear-tags.

Capture Location	Gender	Approx. Age (Years)	Approx. Date of Death
1.6 km E of Vinagre Wash	Female	4	
Little Picacho Peak	Male	6	
Between Julian & Vinagre Wash	Female	Adult	06/93
4.8 km N of Julian Wash	Female	4	
3.2 km N of Julian Wash	Female	5 Lamb Received 1 ear-tag	
Midway Mountains	Female	Adult	
1.6 km SW of Picacho Mine	Female	3	
N of Julian Wash	Male	11	11/93
N of Julian Wash	Female	Adult	
1 km SE of Picacho Mine	Male	9+	
Midway Mountains	Female	Adult	
4 km N of Quartz Peak	Male	8	
1 km SW of Picacho Mine	Female	6	
3.2 km N of Picacho Peak	Male	7	

APPENDIX 1. continued.

Capture Location	Gender	Approx. Age (Years)	Approx. Date of Death
1 km SW of Picacho Mine	Female	6	
8 km SE of Picacho Mine	Male	4	06/93*
N of mouth to Draper Wash	Female	5	
Midway Mountains	Male	Adult	04/93**
1.6 km N of Julian Wash	Female	Adult	
Midway Mountains	Female	Adult	
Not Recorded	Female	5	01/94
N of Julian Wash	Female	4	
Between Little Picacho Peak and Gavlin Wash	Male	6	
N of Arrowweed Springs	Female	Adult	
3.2 km N of Julian Wash	Female	Adult	

* Radio-collar of animal found but no body remains in association with it.

** Animal was last located during the April 1993 telemetry flight.

APPENDIX 2. Serology results for adult radio-collared mountain sheep in the East Chocolate Mountains, Imperial County, California. Samples were collected during June 1992 capture operations.

Animal Number	Gender	Age	Brucella ovis	Bluetongue Virus	Bovine Viral Diarreha	Caprine Arthritis-Encephalitis	Epizootic Hemorrhagic Disease	Parainfluenza Virus 3
450	F	Ad	Neg	Neg	Neg @1:4	Neg	Neg	Neg @1:8
680	M	6	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
550	M	7+	Neg	Pos	Neg @1:4	Neg	Neg	Neg @1:8
270	F	4+	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
480	F	3	Neg	Neg	Neg @1:4	Neg	Neg	Neg @1:8
610	F	Ad	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
620	F	Ad	Neg	Neg	Neg @1:4	Neg	Neg	Neg @1:8
540	F	6	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
589	M	Ad	Pos	Pos	Neg @1:4	Neg	Pos	Neg @1:8
500	F	Ad	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
650	F	5	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
400	F	Ad	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
670	F	4	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
580	F	5	Neg	Neg	Neg @1:4	Neg	Pos	Neg @1:8
569	M	4	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
440	F	5	Neg	Neg	Neg @1:4	Neg	Neg	1:16
710	F	5+	Neg	Neg	Neg @1:4	Neg	Pos	Neg @1:8
431	F	4	Retest	Pos	Neg @1:4	Neg	Pos	Neg @1:8
370	M	6	Neg	Neg	Neg @1:4	Neg	Neg	Neg @1:8
490	M	11+	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
700	F	Ad	Neg	Pos	Neg @1:4	Neg	Neg	Neg @1:8
560	F	6	Neg	Pos	Neg @1:4	Neg	Neg	Neg @1:8
530	M	8+	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8
520	F	Ad	Neg	Neg	Neg @1:4	Neg	Neg	Neg @1:8
510	M	9	Neg	Pos	Neg @1:4	Neg	Pos	Neg @1:8

APPENDIX 2. continued.

Animal Number	Gender	Age	Bovine Respiratory Syncytial Virus	Anaplasmosis	Chlamydia	Contagious Ecthyma	Leptospira Series L. Pomona	L. Canico.	L. Ictero.
450	F	Ad	Neg @1:4	Qty Not Suff.	1:10	1:10	Neg @ 100	Neg @ 100	Neg @ 100
680	M	6	1:4	2+ @1:5	Neg	1:20	Neg @ 100	Neg @ 100	Neg @ 100
550	M	7+	1:4	Not Tested	Neg	1:05	Neg @ 100	Neg @ 100	Neg @ 100
270	F	4+	>1:16	Qty Not Suff.	Neg	1:10	Neg @ 100	Neg @ 100	Neg @ 100
480	F	3	1:4	2+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
610	F	Ad	>1:16	2+ @1:5	1:20	1:10	Neg @ 100	Neg @ 100	Neg @ 100
620	F	Ad	>1:16	4+ @1:5	Neg	1:05	Neg @ 100	Neg @ 100	Neg @ 100
540	F	6	>1:16	4+ @1:5	1:10	1:10	Neg @ 100	Neg @ 100	Neg @ 100
589	M	Ad	1:4	4+ @1:5	1:10	1:10	Neg @ 100	Neg @ 100	Neg @ 100
500	F	Ad	>1:16	4+ @1:5	Neg	Anti-compl.	Neg @ 100	Neg @ 100	Neg @ 100
650	F	5	>1:16	1+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
400	F	Ad	>1:16	1+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
670	F	4	>1:16	3+ @1:5	Neg	1:20	Neg @ 100	Neg @ 100	Neg @ 100
580	F	5	1:8	3+ @1:5	Neg	1:10	Neg @ 100	Neg @ 100	Neg @ 100
569	M	4	Neg @1:4	3+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
440	F	5	Neg @1:4	1+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
710	F	5+	>1:16	1+ @1:5	Neg	1:10	Neg @ 100	Neg @ 100	Neg @ 100
431	F	4	>1:16	4+ @1:5	Neg	1:20	Neg @ 100	Neg @ 100	Neg @ 100
370	M	6	Neg @1:4	4+ @1:5	Neg	1:10	Neg @ 100	Neg @ 100	Neg @ 100
490	M	11+	>1:16	2+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
700	F	Ad	Neg @1:4	Qty Not Suff.	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
560	F	6	>1:16	4+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100
530	M	8+	>1:16	4+ @1:5	Neg	1:10	Neg @ 100	Neg @ 100	Neg @ 100
520	F	Ad	>1:16	Qty Not Suff.	1:10	Anti-compl.	Neg @ 100	1:400	Neg @ 100
510	M	9	>1:16	2+ @1:5	Neg	Neg	Neg @ 100	Neg @ 100	Neg @ 100

APPENDIX 3. Discussion of Bailey's (1952) population model assumptions following an outline by Begon (1979).

1. *The population is closed (no birth, death, immigration, or emigration) such that N (population size) is constant during the survey.* The telemetry data show that the collared ewes and rams were located in the study area throughout the 3-month sampling periods (Figure 1.3), thus, there appears no emigration of collared animals. Births and deaths did occur during the sampling periods, however, adult mortality rates are probably very low. I assume that birth and death worked in balance such that there was no net change in the population. I have no evidence that unmarked sheep had different birth or death rates as compared to collared sheep.

2. *All animals caught, handled, and marked had the same chance of being captured in the first sample and that this had no effect on the animal's subsequent chances of observation.* In 1992, the entire study area was uniformly flown in search of sheep to collar. Because ewes form the reproductive base of the population and were of greater interest to this research effort, they were preferentially collared over rams at a 2:1 ratio. In reality, there is a bias in "catchability" among individuals based on age, sex, and physiological conditions (Begon 1979) which could not be mitigated by this research design or during actual sampling and analysis.

3. *All animals have an equal chance of being observed in subsequent samples regardless of whether they are marked or not. This assumes that the population is sampled at random.* My data show that marked animals have an equal catchability regardless of survey technique (ground, time-lapse camera, helicopter). I can not test whether marked

animals and unmarked animals have different observabilities, but I have no reason to believe that they do.

4. *Animals do not lose their marks between sampling periods and all marks are reported upon discovery in subsequent samples.* All radio-collars were equipped with mortality sensors; thus, I knew within a two week period (time between telemetry flights) when an animal died. Four animals lost one of their ear-tags; however, no animal lost both ear tags and their radio collar.

APPENDIX 4. Adult radio-collared mountain sheep survival in the East Chocolate Mountains, Imperial County, California. Survival rates were calculated by the method of Heisey and Fuller (1985) on data from June 1992 to February 1994. Sampling intervals (telemetry months) were rounded to the nearest 0.5 month since all mortalities were known within a two week period.

Gender	Location	Sheep Collared	Number of Mortalities	Telemetry Months	Monthly Survival Rate	Monthly 95% C. I.	Annual Survival Rate
Females	Northern Area	13	1	530	0.99	0.97-0.99	0.97
Females	Southern Area	3	1	123	0.99	0.97-0.99	0.91
Females	Entire Area	16	2	653	0.99	0.97-0.99	0.98
Males	Entire Area	6	1	244	0.99	0.95-0.99	0.95

APPENDIX 5. Vegetation Sampling

Methods

During August 1993, I sampled 4 vegetation classes: riparian, wash, bajada, and upland, within the study area, using 145 randomly located 100-m step-point transects (Evens and Love 1957). I recorded a cover "hit" if the point contacted the stem of any plant where it entered the ground or any point which fell beneath the canopy of a plant. I also recorded the number of plants greater than 1 m in height. Points not recorded as cover were tallied as bare ground. The transects were stratified across each vegetation type, with the most transects in upland vegetation (n=56) and the fewest (n=20) in riparian vegetation. Because of the dense nature of riparian vegetation, I sampled that vegetation by overlaying random sampling transects on high resolution, large scale aerial photographs. Mean percent cover, standard deviation, and coefficient of variation are reported for each plant species observed in each vegetation class. Scientific names of plants followed Munz (1974).

At the middle (50 m) and end of each 100 m step-point transect, horizontal cover was estimated using the cover-pole technique described by Griffith and Youtie (1988). The cover-pole was 2 m in height and was divided into 8, 25 cm color-coded bands (Bleich 1993). I recorded the percent of each band that was not visible from the 4 cardinal directions at a distance of 15 m while crouched such that my eye level was similar to that of a mountain sheep.

Results

I identified 33 plant species during my sampling effort. Table 1 contains a floristic list of plants categorized as annuals, succulents, shrubs, and trees. Because of the time of year that vegetation sampling was conducted, I was not able to classify annuals in greater detail. I also calculated the % mean cover, standard deviation, and coefficient of variation of plants across the entire study area (Tables 2 through 5).

I compared the abundance of vegetation types (annuals, succulents, shrubs and trees) among the vegetation classes (Table 5.) Because the riparian data were collected by a different sampling method, I excluded it from statistical analyses; I did the same for "unknown" plants. There was a significant difference in the relative frequency of vegetation types among the wash, bajada, and upland vegetation classes (G-Test; $\underline{G} = 15.60$, 6 df, $\underline{P} = 0.016$).

I compared the mean number of occurrences of annuals, succulents, shrubs, and trees per transect which contained those vegetation classes (Table 7.A). There was a significant difference in the number of annuals, shrubs, succulents, and trees across vegetation classes but I was unable to detect differences in the number of succulents in the 4 habitats.

There was a significant difference among the 4 vegetation classes in the mean number of plants per transect greater than 1 m in height (Kruskal Wallis Test; $X^2 = 56.62$, 3 df, $\underline{P} < 0.0001$). Riparian vegetation had the greatest mean number of plants greater than 1 m per transect at 37.52 plants per transect; followed by wash with 1.82, bajada with 0.7, and upland 0.35 plants. When I compared wash, upland, and bajada habitats there was still a significant differance in the mean number of plants greater than 1 m per transect (Kruskal Wallis Test; $X^2 = 15.65$, 2 df, $\underline{P} < 0.0004$)

I used the cover-pole data to provide an index of visibility among the vegetation classes. Horizontal cover was found to be different among the 4 vegetation types (Table 2.8). Bajada and upland habitats were similar with the smallest amounts of the lower and upper cover-pole obscured, and hence greater visibility, while wash and riparian habitats obscured much of the pole.

APPENDIX 5, Table 1. Number of plant occurrences by species within the 4 major habitats during August 1993.

Cover Type	Upland	Bajada	Wash	Riparian
n	5600	3500	3400	2000
Bare Ground	4656	2876	2712	407
Annuals	631	423	214	0
Succulents				
Ferocactus acanthodes	1			
Opuntia acanthocarpa	3	12	2	
Opuntia basilaris	9	2		
Opuntia bigelovii	6	3		
Opuntia ramosissima		2		
Shrubs				
Acacia greggii	1	2	71	
Acamptopappus sphaerocephalus		1	43	
Ambrosia dumosa	108	18	1	
Atriplex hymenelytra			1	
Asclepias subulata	2			
Bebbia juncea	8			
Calliandra eriophylla		8		
Encelia farinosa	43	18	4	
Ephedra californica	2			
Eriogonum deflexum	5			
Eriogonum inflatum	10	9		
Eucnide urens	2			
Fouquieria splendens	27	8		
Gutierrezia microcephala		16		
Hymenoclea salsola			51	
Hyptis emoryi			17	
Krameria parviflora	11	4		
Larrea tridentata	64	75	34	22
Lycium brevipes	1	5	20	
Sphaeralcea ambigua	5			
Typha domingesis				588
Pluchea sericea				202
Trees				
Cercidium floridum		14	47	
Dalea spinosa			37	
Olneya tesota		4	122	
Prosopis glandulosa			12	
Tamarix spp.				803
Unknown	5	1	13	

APPENDIX 5, Table 2. Cover of plants in upland habitat in the East Chocolate Mountains, Imperial County, California, August 1993.

SPECIES	% MEAN COVER	SD	CV
Annual growth	11.26	6.61	0.58
Acacia greggii	0.01	0.13	7.41
Ambrosia dumosa	1.92	2.25	1.18
Asclepias subulata	0.03	0.18	5.19
Bebbia juncea	0.14	0.58	4.06
Encelia farinosa	0.76	1.06	1.39
Ephedra californica	0.03	0.26	7.41
Eriogonum deflexum	0.08	0.34	3.83
Eriogonum inflatum	0.17	0.65	3.68
Eucnide urens	0.03	0.26	7.41
Ferocactus acanthodes	0.01	0.13	7.41
Fouquieria splendens	0.48	1.25	2.59
Krameria parvifolia	0.19	0.71	3.65
Larrea tridentata	1.14	1.48	1.29
Lycium brevipes	0.01	0.13	7.41
Opuntia acanthocarpa	0.05	0.2	5.48
Opuntia basilaris	0.16	0.45	2.82
Opuntia bigelovii	0.10	0.55	5.19
Sphaeralcea ambigua	0.08	0.39	4.37
Unknown	0.08	0.43	4.86

APPENDIX 5, Table 3. Cover of plants in bajada habitat in the East Chocolate Mountains, Imperial County, California, August 1993.

SPECIES	% MEAN COVER	SD	CV
Annual growth	12.08	42.44	0.35
Acacia greggii	0.05	0.33	5.83
Acamptopappus sphaerocephalus	0.02	0.16	5.83
Ambrosia dumosa	0.51	0.84	1.63
Calliandra eriophylla	0.22	0.83	3.63
Cercidium floridum	0.40	1.22	3.05
Encelia farinosa	0.51	0.96	1.88
Eriogonum inflatum	0.25	0.55	2.14
Fouquieria splendens	0.22	0.75	3.32
Gutierrezia microcephala	0.45	1.07	2.35
Krameria parvifolia	0.11	0.39	3.48
Larrea tridentata	2.14	2.30	1.07
Lycium brevipes	0.14	0.48	3.40
Olneya tesota	0.11	0.52	4.56
Opuntia acanthocarpa	0.34	0.79	2.30
Opuntia basilaris	0.02	0.16	5.83
Opuntia bigelovii	0.08	0.27	3.26
Opuntia ramosissima	0.05	0.33	5.83
Unknown	0.02	0.16	5.83

APPENDIX 5, Table 4. Cover of plants in wash habitat in the East Chocolate Mountains, Imperial County, California, August 1993.

SPECIES	% MEAN COVER	SD	CV
Annual growth	6.29	5.56	0.88
Acacia greggii	2.08	4.14	1.98
Acamptopappus sphaerocephalus	1.26	2.87	2.27
Ambrosia dumosa	0.02	0.16	5.74
Atriplex hymenelytra	0.02	0.16	5.74
Cercidium floridum	1.38	3.58	2.59
Dalea spinosa	1.08	2.29	2.10
Encelia farinosa	0.11	0.40	3.42
Hymenoclea salsola	1.50	2.39	1.59
Hyptis emoryi	0.50	1.35	2.71
Larrea tridentata	1.00	1.76	1.76
Lycium brevipes	0.58	1.43	2.44
Olneya tesota	3.58	4.99	1.31
Opuntia acanthocarpa	0.05	0.23	4.00
Prosopis glandulosa	0.35	1.55	4.39
Unknown	0.38	1.57	4.11

APPENDIX 5, Table 5. Cover of plants in riparian habitat in the East Chocolate Mountains, Imperial County, California, August 1993.

SPECIES	% MEAN COVER	SD	CV
Larrea tridentata	1.12	3.53	3.21
Tamarix spp.	40.15	27.62	0.68
Pluchea sericea	10.1	19.46	1.92
Typha domingensis	29.4	20.79	0.70

APPENDIX 5, Table 6. Abundance of vegetation types in 4 major vegetation classes. Abundance is expressed as the number of occurrences per 1000 step-point samples, however, the statistical test was conducted on absolute values. Since riparian data were collected by a different method than the other 3 types it was excluded from statistical analysis, as were unknowns. The 3 habitats varied significantly in the abundance of the 4 vegetation types (G-Test; $\underline{G}$ = 15.60, 6 df, $\underline{P}$ = 0.016).

Cover Type	Upland	Bajada	Wash	Riparian
N	5600	3500	3400	2000
Bare Ground	813	821	797	204
Annuals	113	121	63	0
Succulents	3	5	1	0
Shrubs	1	47	75	395
Trees	0	5	64	402
Unknown	1	0	4	0

APPENDIX 5, Table 7. Comparison of the mean cover of vegetation types among the 4 habitats. The values presented are the mean number of occurrences per transect for each habitat type. Transects for which the vegetation were not found were excluded.

Vegetation Type	Upland X ± SD	Bajada X ± SD	Wash X ± SD	Riparian X ± SD	*P* Value
Annuals	11.3 ± 6.7	12.4 ± 3.8	8.2 ± 6.1	NA	**
Shrubs	5.4 ± 3.9	6.9 ± 5.1	11.9 ± 9.1	59.6 ± 26.7	***
Succulents	1.7 ± 1.0	1.4 ± 0.9	0.0	NA	*ns*
Trees	NA	2.0 ± 1.1	9.1 ± 5.1	45.8 ± 27.9	***

ns-$P>0.05$; *$P<0.05$; **$P<0.01$; ***$P<0.001$ using a Kruskal-Wallis Test.

APPENDIX 5, Table 8. Mean percent of upper and lower 2 m cover-pole obscured in 4 habitat classes by the method of Griffith and Youtie (1988).

Habitat type	Number of transects	Lower Pole X % pole Obscured	Upper Pole X % Pole Obscured
Wash	34	25.15	11.06
Bajada	35	14.37	3.00
Upland	56	19.68	3.68
Riparian	20	> 90	NA

APPENDIX 6 Diet Quality

Methods

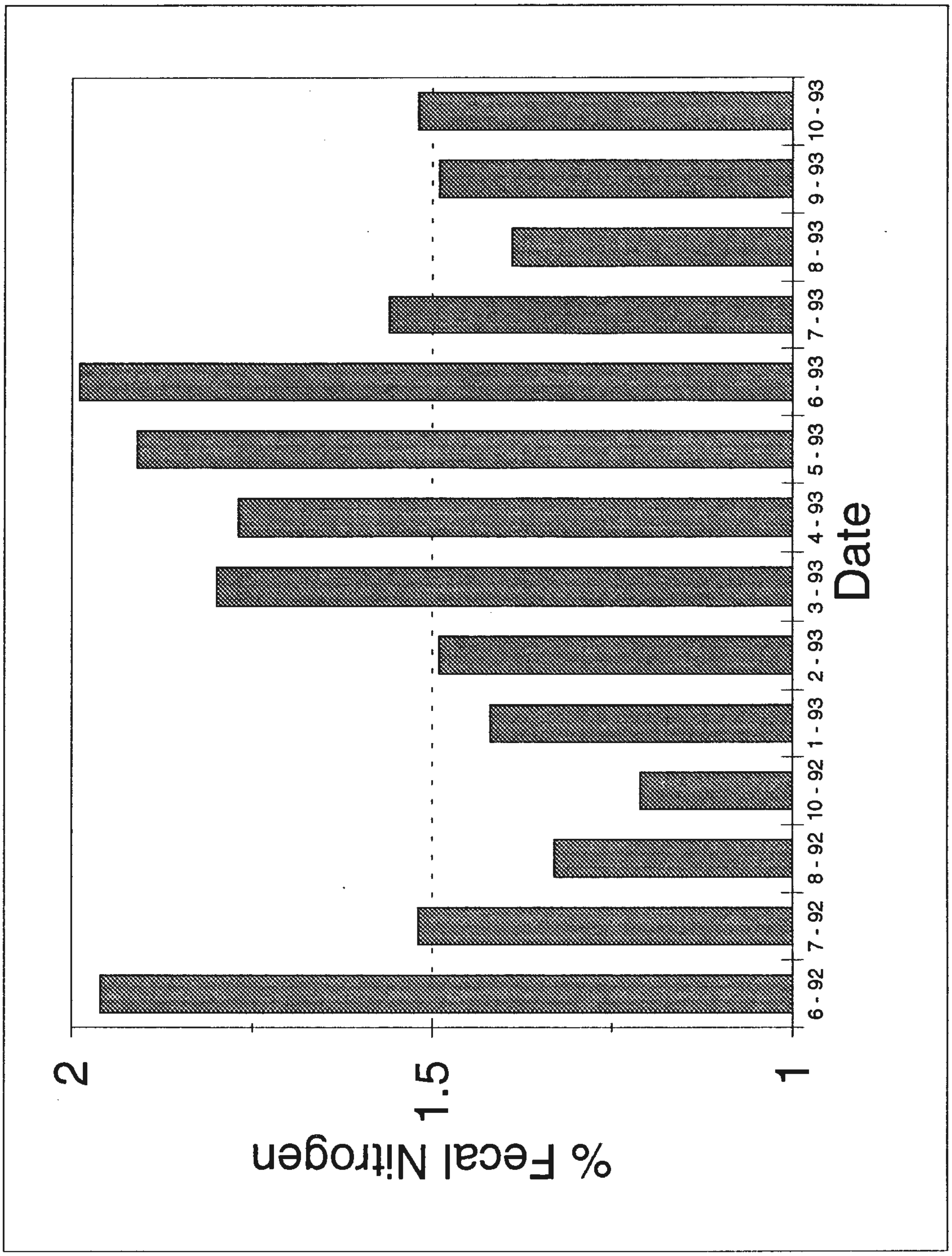
I attempted to collect fresh fecal samples from June 1992 to December 1993 in order to determine fecal crude protein (FCP = fecal nitrogen x 6.25). I used this value as an index of diet quality. I collected samples on an opportunistic basis during each month. Samples collected during a 1 month period were aggregated into 1 monthly sample. The monthly sample contained 25 pellets and all samples collected during each month, contributed an equal number of pellets to that sample.

Analyses, using micro-Kjeldahl digestion, were conducted at the Wildlife Habitat Laboratory, Washington State University. While shortcomings of this technique have been noted (Robbins et al. 1987), FCP remains useful as an index of diet quality for mountain sheep (Wehausen 1980, 1992; Bleich 1993).

Results

Table 1 contains the actual percent of fecal crude protein and fecal nitrogen detected for composited samples collected during 14 months from June 1992 to October 1993. The nutritional quality of forage available to sheep, as indicated by fecal nitrogen, varied markedly among months (Figure 1). Forage quality was best in June of both years and poorest during August of both years. These data suggest that the peak in forage quality for this range occurs 2 months later than reported values in California's Mojave desert (Wehausen 1992, Bleich 1993).

APPENDIX 6, Figure 1. Histogram of percent fecal nitrogen derived from monthly mountain sheep fecal samples in the East Chocolate Mountains, Imperial County, California, 1992-1993.


% Fecal Nitrogen
2
1.5
1
6 - 92
7 - 92
8 - 92
10 - 92
1 - 93
2 - 93
3 - 93
4 - 93
5 - 93
6 - 93
7 - 93
8 - 93
9 - 93
10 - 93
Date

APPENDIX 6, Table 1. Analysis of mountain sheep fecal samples for percent of crude protein and percent of fecal nitrogen from June 1992 to October 1993. These values were obtained from an aggregate sample of 25 fecal pellets analyzed per month.

Sample Date	% Crude Protein	% Fecal Nitrogen
June-92	12.28	1.96
July-92	9.50	1.52
August-92	8.30	1.33
October-92	7.56	1.21
January-93	8.87	1.42
February-93	9.30	1.49
March-93	11.25	1.80
April-93	11.05	1.77
May-93	11.95	1.91
June-93	12.42	1.99
July-93	9.73	1.56
August-93	8.69	1.39
September-93	9.30	1.49
October-93	9.50	1.52

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