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HABITAT FEATURES AND PREDICTIVE HABITAT MODELING FOR THE COLORADO CHIPMUNK IN SOUTHERN NEW MEXICO

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ABSTRACT.—Two subspecies of Colorado chipmunk (state threatened and federal species of concern) occur in southern New Mexico: *Tamias quadrivittatus australis* in the Organ Mountains and *T. q. oscuraensis* in the Oscura Mountains. We developed a GIS model of potentially suitable habitat based on vegetation and elevation features, evaluated site classifications of the GIS model, and determined vegetation and terrain features associated with chipmunk occurrence. We compared GIS model classifications with actual vegetation and elevation features measured at 37 sites. At 60 sites we measured 18 habitat variables regarding slope, aspect, tree species, shrub species, and ground cover. We used logistic regression to analyze habitat variables associated with chipmunk presence/absence. All (100%) 37 sample sites (28 predicted suitable, 9 predicted unsuitable) were classified correctly by the GIS model regarding elevation and vegetation. For 28 sites predicted suitable by the GIS model, 18 sites (64%) appeared visually suitable based on habitat variables selected from logistic regression analyses, of which 10 sites (36%) were specifically predicted as suitable habitat via logistic regression. We detected chipmunks at 70% of sites deemed suitable via the logistic regression models. Shrub cover, tree density, plant proximity, presence of logs, and presence of rock outcrop were retained in the logistic model for the Oscura Mountains; litter, shrub cover, and grass cover were retained in the logistic model for the Organ Mountains. Evaluation of predictive models illustrates the need for multi-stage analyses to best judge performance. Microhabitat analyses indicate prospective needs for different management strategies between the subspecies. Sensitivities of each population of the Colorado chipmunk to natural and prescribed fire suggest that partial burnings of areas inhabited by Colorado chipmunks in southern New Mexico may be beneficial. These partial burnings may later help avoid a fire that could substantially reduce habitat of chipmunks over a mountain range.

Key words: Colorado chipmunk, GIS, habitat modeling, New Mexico, Tamias quadrivittatus.

The Colorado chipmunk, *Tamias quadrivittatus,* occurs in Arizona, Colorado, New Mexico, and Oklahoma (Best et al. 1994). There are 3 subspecies, all of which occur in New Mexico (Findley et al. 1975, Sullivan 1996). The 2 subspecies that occur in central and southern New Mexico are the Organ Mountains chipmunk (*T. q. australis*) and the Oscura Mountains chipmunk (*T. q. oscuraensis;* Patterson 1980a, 1980b, Sullivan 1996). They are restricted to their corresponding mountain range and are listed as threatened by New Mexico and as a species of concern by the U.S. Fish and Wildlife Service (Patterson 1980a, Sullivan 1996, New Mexico Department of Game and Fish [NMDGF] 1988, New Mexico Administrative Code 19.33.1).

Little is known about the 2 southern subspecies. The Organ Mountains chipmunk was found in various habitats such as mixed conifer, mesic woodland, and montane scrub in 1998 (New Mexico Natural Heritage Program, Post-fire ecological studies reported to U.S. Army Corps of Engineers, 1998), which contradicted previous indications that they occur only in spatially restricted and fragmented coniferous-forest habitats (U.S. Department of Defense [DoD] 1998, NMDGF Biota Information System of New Mexico, online database). Previous surveys found Oscura Mountains chipmunks primarily along west-facing slopes (R.M. Sullivan and R. Smartt unpublished report, Sullivan 1996) in pinyon pine–juniper (*Pinus edulis–Juniperus*) habitat, although Sullivan (personal communication 1998) identified north, northwest, and northeast slopes as critical habitat to be protected for this population.

Both southern subspecies occur primarily on military installations and were selected for

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species-at-risk evaluation on White Sands Missile Range (WSMR) and Fort Bliss (Boykin et al. 2001). Both subspecies are considered vulnerable due to geographic isolation and confinement to mesic, higher-elevation habitats that can support only a limited number of chipmunks (NMDGF 1988, Mehlhop et al. 1994). Because federally listed species can affect military operations in a variety of ways (DoD Directive 4715.3, Schreiber and Reed 1998), development of information that improves conservation practices and stabilizes these populations may preclude future special classification, thus being beneficial to the military installation and to the species at risk.

For the Organ Mountains chipmunk, Mehlhop et al. (1994:13) recommended "verification of suspected habitat affinities and subsequent protection of these habitats in the mountain range." Previous habitat modeling of the Colorado chipmunk in New Mexico did not predict chipmunk occurrence in the Oscura Mountains (Thompson et al. 1996), because modeling was completed before information was available from Sullivan (1996). We used a GIS-based model of potentially suitable habitat to classify and sample prospective Colorado chipmunk habitat in the Organ and Oscura Mountains. We tested the hypothesis that occurrence of the Organ Mountains chipmunk and the Oscura Mountains chipmunk corresponds to predictions of suitable habitat based on existing literature and GIS modeling from available spatially referenced information. Our research objectives were to (1) develop and evaluate a GIS-based habitat model of potential suitable habitat for each subspecies based on existing information and GIS-compatible information, (2) detect, through field observations, presence or absence of chipmunks and their habitats in areas predicted as suitable and unsuitable, and (3) measure and describe vegetation and terrain features (microhabitat) relating to use of habitat.

STUDY AREA

White Sands Missile Range and Fort Bliss are located in south central New Mexico (Fig. 1). These areas comprise 774,000 ha on WSMR and 446,000 ha on Fort Bliss within the Great Basin Conifer Woodland and the Chihuahuan biogeographic provinces (Brown 1982). Approximate elevations of the 2 mountain ranges (Fig. 1) are 1500–2700 m in the Oscura Mountains on WSMR (Lincoln and Socorro Counties, NM) and 1300–2700 m in the Organ Mountains on Fort Bliss (Doña Ana County, NM). Vegetation communities in which Colorado chipmunks have been found in New Mexico include ponderosa pine (*Pinus ponderosa*) forest, pinyon-juniper woodland, montane scrub, and coniferous and mixed woodland (Patterson 1980a, Dick-Peddie 1993, Mehlhop et al. 1994, Sullivan 1996, Thompson et al. 1996).

METHODS

GIS-based Habitat Model

We used elevation and vegetation associations to develop the GIS-based habitat model with information obtained from technical literature. Vegetation associations used in the model for the Organ Mountains chipmunk were montane shrubland, pinyon-juniper woodland, and ponderosa pine forest (Patterson 1980b, NMDGF Biota Information System of New Mexico). Vegetation associations used for the Oscura Mountains chipmunk were ponderosa pine forest, juniper woodland, pinyon pine–Gambel's oak (*Quercus gambelii*), and montane scrub (Sullivan 1996). Dominant plant species associated with these vegetation communities included pinyon pine, juniper, ponderosa pine, oak (*Quercus*), and mountain mahogany (*Cercocarpus breviflorus*). For both models, elevations used were >1380 m (Best et al. 1994).

Aspect and slope were not used as model variables for 2 reasons. In the Organ Mountains, chipmunks occurred on a variety of aspects and slopes (New Mexico Natural Heritage Program unpublished data). In the Oscura Mountains no information was available regarding slope and data pertaining to aspect were contradictory.

We used 4 measures to evaluate predictive ability of GIS-based habitat models. The 1st measure of performance was the degree to which elevation and vegetation variables used in the GIS model characterized sites. A 2nd measure was the degree to which model-predicted sites corresponded to visual assessments of habitat suitability. For 3rd and 4th measures of performance, we examined the degree to which model-predicted suitable sites were determined to be suitable either by detection or prediction of chipmunks via a logistic

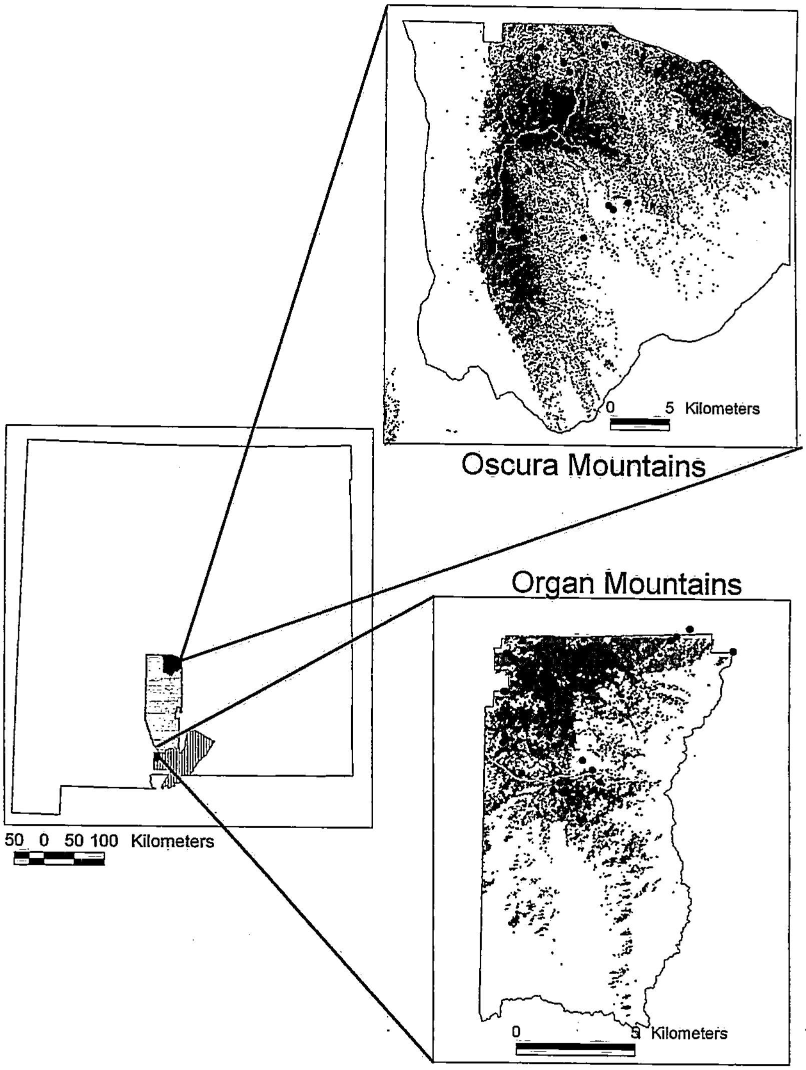

Fig. 1. Map of Colorado chipmunk study area in the Oscura and Organ Mountains of New Mexico within White Sands Missile Range (horizontal lines) and Fort Bliss (vertical lines); gray shading illustrates habitat predicted from the GIS model; dots indicate sites examined for chipmunks and measured for habitat variables. One dot in the Oscura Mountains represents 2 sites; 2 dots in the Organ Mountains (1 inside modeled habitat, 1 outside modeled habitat) represent 2 sites each.

regression model based primarily on detections of chipmunks independent of model-predicted sites.

Surveys

Survey sites were a random subset of sites where the GIS model predicted Colorado chipmunk habitat should (model-predicted suitable) or should not (model-predicted unsuitable) occur. These 37 sites were randomly selected using a random number generator in ArcView (Environmental Systems Research Institute, Inc. [ESRI], Redlands, CA) applied to center coordinates of numbered analytical cells (30 × 30-m pixels) in the spatial data.

We conducted field surveys at 28 model-predicted suitable and 9 unsuitable sites during July–October 1999 and March–August 2000. Each site surveyed was 2.7 ha, the home range of the Colorado chipmunk (Bergstrom

1988). Two observers spent about 20 minutes surveying at each site for chipmunks. This time was judged sufficient for detection, based on activity patterns of chipmunks discussed with M. Bogan (U.S. Geological Survey, personal communication, 1999) and previous research (Sullivan unpublished field data).

Habitat Variables

We considered habitat characteristics of chipmunks at landscape and micro-scales. We surveyed for presence of chipmunks and measured microhabitat features (Fig. 1) at 37 model-predicted sites, 14 previously known locations with chipmunks (New Mexico Natural Heritage Program unpublished data, Sullivan unpublished field data), and 9 opportunistic sightings (32 sites in the Oscura Mountains and 28 sites in the Organ Mountains). We obtained habitat data directly related to verified occurrence of chipmunks at 30 sites. Opportunistic sites were those at which a chipmunk was detected by an observer while traveling to and among field sites. Detection or nondetection of chipmunks was used to construct a logistic regression model for each mountain range surveyed. The majority (>75%) of 30 sites with chipmunks used in developing the logistic model were independent from the GIS model-predicted sites. Therefore, our use of microhabitat features to interpret predictions derived from the GIS-based habitat model is efficacious and relatively unique among other studies of habitats of small mammals.

We sampled 3 vegetation plots at each site surveyed. The center of the 1st plot was the randomly selected UTM coordinate for the survey site. The remaining 2 nonoverlapping plots were randomly placed within the site (Skalski 1987). Each plot consisted of 2 independent sampling units modified from Dueser and Shugart (1978): 2 perpendicular 20-m line transects and a circular plot with a 5-m radius (Buell and Cantlor 1950, Dueser and Shugart 1978, Bonham 1989). We recorded slope and aspect (Higgins et al. 1996) at the center of the 1st plot and presence or absence of a rock outcrop within each site. We used point-intercepts (every 1 m) along line transects to measure features of ground and shrub cover (Table 1). The circular plot was used to enumerate features of shrubs and trees (Table 1). Counts of shrubs and trees were converted to density values for subsequent analysis.

Analysis

We used confusion matrices and a Kappa statistic (K) to evaluate the degree to which the GIS-based habitat model predicted habitat in context with visual assessments of site suitability, logistic regression analyses, and detection of chipmunks (Fielding and Bell 1997). Sites initially were categorized as suitable or unsuitable based on congruence with GIS variables. Sites were also visually inspected and judged to be suitable or unsuitable based on our biological knowledge of the species. Subsequently, sites were classified as suitable or unsuitable habitat based on logistic regression models of presence for each mountain range. Those sites with estimated probability of detection ≥0.5 were considered to be suitable habitat. Akaike's Information Criterion (AIC, Akaike 1973) and our biological knowledge were used to select a parsimonious and estimated "best approximating model" (Burnham and Anderson 1998). Logistic regression is the preferred statistical technique when continuous and discrete variables are contained in a data set (Block et al. 1998) and when describing locations of presence or absence (Manly et al. 1993, Alldredge et al. 1998). We used a chi-square test to assess overall significance of the logistic regression model for each subspecies. We used quantitative variables except for presence or absence of rock outcrop and logs, which were dichotomous variables. In constructing the logistic regression model, we considered previously known locations as positive for chipmunks, even if a chipmunk was not detected during our specific survey. We were assessing habitat predictions, and it is known that detecting animals in occupied habitat can have probability substantially less than 1.0 (Karl et al. 2002, Kéry 2002). We examined performance of the logistic model using a jackknife approach because it is less biased than the resubstitution method in which the same data used to construct a model are used to test it (Olden et al. 2002).

RESULTS

Performance of Habitat Model

The GIS-based habitat model predicted a total of 79,900 ha as potentially suitable habitat for both subspecies (Fig. 1). Of the 37 model-predicted sites we examined, all (Kappa = 1.0) were correctly classified as predicted suitable

TABLE 1. Description of variables and methods used to measure habitat of the Colorado chipmunk in southern New Mexico.

Variable	Description
Measured along line transects[a]	
Canopy cover	Vegetation ≥2 m tall (Dueser and Shugart 1978)
Ground cover	Point having litter, bare soil, or plant cover (Dueser and Shugart 1978)
Shrub cover	Vegetation <2 m tall (Dueser and Shugart 1978). Shrub cover was further broken down into 2 categories: tall (>1 m) and short (≤1 m)
Closest herbaceous plant	Species of closest herbaceous ramet (grass or forb) from each point. Individuals were not counted twice (absence of any ramet within 5 m was noted as "no plant")
Measured within 5 m circular plot	
Tree species	Single stemmed and >1.75 m tall
Tree size	Diameter of trees (in centimeters)
Tree count	Number of trees by species
Shrub species	Multi-stemmed or single stemmed and ≤1.75 m tall
Shrub count	Number of shrubs by species: tall (>1 m) and short (≤1 m) in height
Vegetation species	Identification of species occurring within the plot
Logs	Number of logs (converted to present or absent for analysis)
Measured at site	
Aspect	Direction of slope measured at center of 1st plot
Slope	Measured using a clinometer at center of 1st plot
Elevation	Measured from topographic maps and ArcView
Rock outcrop	Presence of a rock outcrop within the site

[a]These variables were measured as percentage of points with the variable from 3 plots consisting of 41 point samples along 2 perpendicular line transects (Dueser and Shugart 1978).

or unsuitable according to vegetation and elevation variables in our GIS model (Table 2). The degree of agreement (Kappa = 0.47) between classifications of sites based on GIS modeling versus our visual assessment indicated a moderately successful characterization of sites using the landscape-level variables (Table 2).

Logistic modeling identified 10 sites as suitable habitat of the 28 predicted-suitable sites from the GIS habitat model. All 9 predicted-unsuitable sites were identified as unsuitable. Superficially, the corresponding Kappa statistic of 0.21 indicated poor overall performance of the GIS model. However, there were 16 of 20 previously known and opportunistic detection sites that occurred in predicted suitable habitat. These 16 sites were not included in calculating the Kappa statistic; if they had been included as model predicted and occupied, the Kappa would have been higher. Three other historic and opportunistic sites occurred outside the GIS coverage area, although microhabitat data were obtained at these sites.

Detection of Chipmunks Relative to Predicted Habitat

Suitable habitat features derived from logistic regression analysis were present at 10 of the predicted-suitable sites. We visually/audibly detected chipmunks during our 20-minute surveys at 7 of these sites in the Oscura (4/5) and Organ (3/5) Mountains. No chipmunks were detected at any of the 9 model-predicted unsuitable sites surveyed, and none of those sites appeared to be suitable chipmunk habitat.

OSCURA MOUNTAINS CHIPMUNK.—Chipmunks were detected at 2001–2565 m elevation on all aspects and slopes ranging up to 30°. A combination of the variables vegetation cover and terrain features was significant for predicting chipmunk presence or absence in the logistic regression model (Table 3). The model with the 2nd lowest AIC value was selected over the lowest (33.815 versus 33.400) because the latter model excluded the closest herbaceous plant and tree density variables, both of which represent important cover and food. The overall test of the model ($\chi^2 = 22.422$, 5 df, $P < 0.001$) indicated the model was significant in explaining chipmunk presence or absence.

As shrub cover, tree density, and herbaceous cover increased (the condition of "no plant" decreased), likelihood for presence of chipmunks increased. Shrub cover averaged 14.5% at nondetection sites and 24.7% at detection sites. Tree densities were <17.8 trees · 100 m^{-2} at all sites in the Oscura Mountains, with

TABLE 2. Performance of GIS and logistic regression predictive models of habitat of Colorado chipmunks for 37 sample sites in the Organ and Oscura Mountains, New Mexico, July 1999–August 2000. For all comparisons, n = 37.

Comparison derivation Model predicted	Kappa	Actual observed Suitable	 Unsuitable
All sites; GIS model variables only	1.00		
Suitable		28	0
Unsuitable		0	9[b]
All sites; GIS model variables and visual classification with variables based on expert opinion	0.47		
Suitable		18	10
Unsuitable		0	9[b]
All sites; GIS model variables and classification with logistic regression model of measured variables	0.21		
Suitable		10[a]	18
Unsuitable		0	9[b]

[a]Chipmunks were visually/audibly detected at 7 of these sites.
[b]Chipmunks wre not detected at any of these sites.

densities ≤7.6 trees · 100 m^{-2} at nondetection sites. Presence of logs and rocks also was associated with increased likelihood of chipmunks being present. Maximum likelihood estimates of coefficients corresponding to vegetation measures and associated logistic regression odds ratios are provided in Table 3. The odds ratio is the ratio of probability for occurrence of a chipmunk at a site to probability for absence of a chipmunk from that site, given the values for variables used in the model. An odds ratio of 1.0 indicates no change relative to unit change in explanatory variables (e.g., odds of a chipmunk being present at an Oscura Mountains site increases 11.6% when shrub cover increases by 1%; Table 3).

The logistic model correctly predicted presence or absence of habitat associations for 25 of 32 sites (78%) using a jackknife approach to assessment of the model. The logistic model predicted presence in 4 sites where none were detected. Chipmunks were detected at 3 sites in which the logistic model predicted absence of habitat. However, 2 of these sites were historic sites in which presence was assumed for construction of the model, but at which no chipmunk was detected on our surveys.

ORGAN MOUNTAINS CHIPMUNK.—Chipmunks were detected at elevations ranging from 1542 m to 2374 m, on all aspects, and on slopes of 10°–30°. The logistic regression model with the lowest AIC value included litter, grass, and shrub cover (Table 3). The overall test of the model (χ^2 = 24.058, 3 df, P < 0.001) indicated the model was significant in explaining presence or absence. As litter increased, likelihood of chipmunk presence increased, but as shrub cover and grass increased, likelihood of chipmunk presence decreased (Table 3). Shrub cover was similar on average at detection and nondetection sites ($\bar{x}$ = 17.8% and 17.3%, respectively), but variation among sites produced differences in likelihood of presence. Litter was more abundant at detection sites than nondetection sites ($\bar{x}$ = 32.1% vs. 8.3%), whereas grass cover was less at detection sites ($\bar{x}$ = 65.9%) than nondetection sites ($\bar{x}$ = 91.2%). Rocks did not enter into the model because all but 1 site had rock outcrops present. Logs were present at about half (14) of the sites, and chipmunks were present at 7 of these sites. The model correctly predicted 23 of 28 sites (82%) using a jackknife approach to assessing the model. The logistic model predicted presence in 2 sites where chipmunks were not detected. Chipmunks were detected at 3 sites in which the logistic model predicted absence of chipmunk habitat. However, these 3 sites were historic sites in which presence of chipmunks was assumed for construction of the model, but at which no chipmunk was detected on our surveys.

DISCUSSION

Our comparative assessment of generalized and quantitative habitat models illustrates the importance of considering several scales when qualifying predicted habitat as suitable or unsuitable. The GIS-based habitat model is a helpful tool for predicting suitable habitat for

TABLE 3. Variables included in logistic-regression models to predict habitat features of 2 subspecies of Colorado chipmunk in the Oscura and Organ Mountains, New Mexico.

Variable	Parameter estimate ($s_{\bar{x}}$)	Odds ratio	90% CI of odds ratio
Oscura Mountains			
Shrub cover	+0.1099 (0.0547)	1.116	1.02–1.22
Rock	+2.2458 (1.4179)	9.448	0.91–97.3
Log	+4.9908 (2.3200)	147.058	3.32–6682.2
Tree density (per 100 m^2)	+0.5876 (0.4368)	1.80	0.88–3.69
No plant[a]	–6.2605 (4.3727)	0.002	0.0–2.54
Organ Mountains			
Grass cover	–0.0838 (0.0420)	0.920	0.85–0.95
Shrub cover	–0.1796 (0.1355)	0.836	0.67–1.04
Litter cover	+0.0967 (0.0470)	1.102	1.02–1.19

[a]Refers to absence of any herbaceous plant ≤5 m from a sampling point.

several reasons. The habitat model helped narrow our search area, given size of the general landscape of interest. The GIS-based habitat model was proficient in describing landscape features of elevation and vegetation based on our Kappa value of 1.0 for landscape features at model-predicted sites, where K < 0.4 indicates a poor model and K > 0.75 indicates an excellent model (Landis and Koch 1977, Fielding and Bell 1997).

None of the model-predicted unsuitable sites contained habitat features considered suitable for Colorado chipmunks, and we detected no chipmunks at any of these sites. Thus, the model performed well at predicting apparently unsuitable habitat for chipmunks. However, the GIS-based model was a limited predictor of occurrence detectable by visual and auditory evidence of chipmunks. The GIS-based habitat model predicted suitable habitat based on information obtained from technical literature. Chipmunks use habitat features at several scales, and the GIS model did not incorporate all of these features or scales. Microhabitat features that are important for chipmunks, based on the logistic regression model, were not represented in spatial data included in the GIS-based habitat model. However, it is crucial to consider that such models predict habitat features first and foremost; actual occurrence of an animal at a specific place and time is conditioned by factors (e.g., behavior and demography) independent of physical habitat features. Additionally, not detecting a chipmunk at a predicted suitable site does not mean the site is unoccupied. Documenting occurrence of a species in predicted suitable habitat without long-term survey is an acknowledged difficulty (Edwards et al. 1996, Karl et al. 2002). As a result, it is important to assess habitat at several scales when attempting to describe suitable habitat as discussed in detail in Scott et al. (2002).

Our work differs from other studies because we relied on visual detections as opposed to sampling with traps (Dueser and Shugart 1978, Kitchings and Levy 1981, Bowers 1995, Sullivan 1996). We made that decision based on personal experience with trapping (M. Bogan, U.S. Geological Survey, personal communication, 2000; B. Thompson personal observation) and prior indication that the Organ Mountains chipmunk occurs where it is difficult to trap chipmunks safely (New Mexico Natural Heritage Program unpublished data). We acknowledge that some of our study sites could have contained undetected chipmunks. However, we preliminarily evaluated trapping for detection of Colorado chipmunks during 2 days of trapping (afternoon of day 1 through afternoon of day 3) with 30 traps set in an area with known chipmunk presence. That trapping effort captured only 1 of 4 chipmunks that we visually detected in the area. Further, we visually/audibly detected chipmunks on every occasion during multiple visits to 10 sites that contained chipmunks. All but 2 of the chipmunks we recorded on our randomly selected study sites were detected within 20 minutes. The other 2 chipmunks were detected within 25 minutes while we conducted vegetation measurements. Thus, we believe our detection process was sufficient for purposes of this research.

We detected more chipmunks at previously known locations surveyed in the Oscura Mountains than in the Organ Mountains. This difference may relate to detection of chipmunks along roads in the Oscura Mountains, whereas the Organ Mountains had no road accessible to us. Considerably more hiking was needed to reach sites in the Organ Mountains than in the Oscura Mountains, thus altering conditions for making detections and reducing overall opportunity for detection in different areas.

Chipmunks were detected at a wider range of elevations than previously reported in the Organ Mountains (1845–2225 m; Patterson 1980a). In the Oscura Mountains, chipmunks were not restricted to northwest-facing slopes as reported by Sullivan and Smartt (unpublished field data 1990) or associated only with north, northwest, or northeast slopes as indicated by previous surveys (Sullivan unpublished field data).

Our logistic regression models can be used to explain microhabitat differences between sites where chipmunks were or were not detected but were predicted as suitable habitat. In the Organ Mountains, model-predicted suitable sites where chipmunks were not detected had greater grass cover, less litter, and an absence of logs compared with sites where chipmunks were detected. These differences indicate that perhaps there was too much cover at these sites. In the Organ Mountains, 68% of the plots had high grass cover (>80%), whereas in the Oscura Mountains only 34% of the plots had high grass cover. It has been shown for chipmunks that "dense undergrowth inhibits the flow of visual signals across the communication channel" (Svendsen and Yahner 1979).

In the Oscura Mountains, at all model-predicted suitable sites where a chipmunk was detected, rocks and logs were present, and the sites had greater density of trees. At the 16 predicted-suitable sites in which a chipmunk was not detected (based on GIS model), 44% had a rock outcrop, 25% had logs present, and 13% had both features. This illustrates the importance of rocks and logs as cover in the Oscura Mountains. Rocks, logs, shrubs, and trees provide cover for chipmunks and play different roles in predictive models depending on their dispersion at sampled sites. Chipmunks dig burrows under rocks and logs (Svendsen and Yahner 1979). Because rocks were present at most sites in the Organ Mountains, shrub cover and presence of logs may not be as important there as in the Oscura Mountains, where chipmunks appear to use a combination of these 3 microsite features.

The scale at which we measured vegetation variables is the scale at which vegetation management usually is applied, and habitat models developed at this scale can be incorporated into habitat management plans (Block et al. 1998). The GIS layers that we used are at a scale different from the vegetation variables, although both are important in developing management plans. This allowed us to examine factors related to why chipmunks may not be present at some of the predicted-suitable sites. It also allowed us to obtain a more accurate description of chipmunk habitat. As more spatially and thematically resolved GIS information becomes available, the predictive model can be updated to enhance future prediction of habitat of chipmunks.

IMPLICATIONS

Our research revealed different environmental variables likely to influence distribution of Colorado chipmunks in 2 mountain ranges in southern New Mexico. These areas involve 2 distinct subspecies (Patterson 1980a, Sullivan 1996) that use different microhabitat configurations. This difference in variables signals future researchers to be cautious in extending habitat features to taxa that occur in different vegetation types, mountain ranges, or geographic regions. Although some researchers (e.g., Kitchings and Levy 1981) repeated a study elsewhere and found similar results, extrapolation of habitat features among areas must be done cautiously.

Variation in importance of variables in the different mountain ranges indicates that different management strategies may be needed. Sensitivities of each population of Colorado chipmunks to natural and prescribed fire need to be considered. The Organ Mountains chipmunk may have an affinity for habitats that have been burned (New Mexico Natural Heritage Program, unpublished data, 1998). After a burn, shrub, herbaceous, and grass cover are reduced. Fires in the Organ Mountains may be important and necessary to survival of chipmunks by producing desirable grass and shrub cover. In the Oscura Mountains, fire may have a different effect on the population because occurrence of chipmunks increases with increasing herbaceous and shrub cover. Partial burnings of areas inhabited by Colorado chipmunks in southern New Mexico may be a beneficial management experiment to help avoid destructive fires that might sweep extensive parts of a mountain range.

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