Ecogeographical Variables Associated with the Presence of *Echinocereus reichenbachii* (Terscheck ex Walp.) ssp. (Cactaceae) in the Wichita Mountains Wildlife Refuge

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Recently, numerous papers have been published that use ecological niche models to model the distribution of plant species. However, due to logistical constraints, these models are often fairly coarse (e.g. they typically have a resolution of at least 1 ha) which may not detect the finer-scale ecogeographic variables (EGVs) that affect whether a particular plant species is present. We used the cactus *Echinocereus reichenbachii* as a model system in order to examine whether finer-scale EGVs may help explain variations in the distribution of the species at a local scale. We hypothesized that the distribution of *E. reichenbachii* ssp. was affected by topsoil depth, slope, aspect, elevation and habitat class. We traversed five 1-km transects in the Wichita Mountains Wildlife Refuge (Caddo County, Oklahoma). A t every 50 m, soil depth, habitat class, and number of cacti present data were recorded. We then downloaded a map of elevation from the National Elevation Dataset and used Spatial Analyst in ArcGIS to derive maps of slope and aspect. Logistic regression was not successful in separating areas with cacti from areas without cacti. However, we found that the cacti grew in more shallow soil depths in areas with exposed granite outcrops; elevation, slope, and aspect were not significant factors in the distribution of *E. reichenbachii* ssp. These results suggest that the accuracy of ecological niche models can be improved by including finer-scale data.

INTRODUCTION

The study of why individual species are present in some areas but absent in others has long interested ecologists. In 1898 Merriam created a map of life zones (areas with similar plant and animal communities) for the American Southwest (Odum 1945). Holdridge (1947) then created a scheme for classifying the biota of land masses by environmental variables such as humidity, annual precipitation and potential evapotranspiration ratio. The term "niche" was first used by Grinnell (1917) who noted that California Thrashers (*Toxostoma redivivum*) were typically found in a relatively narrow range of environmental conditions with the California chaparral. Hutchinson (1957) expanded upon this idea, suggesting that there were numerous factors (e.g. temperature, moisture, food, etc.) that might limit the distribution of a species and that these could be represented as an *n*-dimensional hypervolume. Ecological niche models use ecogeographical variables (Hirzel et al. 2006) to create a habitat suitability map (Hirzel et al. 2002) and identify the potential range of a species (Dullinger et al. 2009). These models generally rely on relatively coarse resolution data from downloaded layers (e.g. from a Digital Elevation Model or DEM where each pixel represents an area of 10 m x 10 m), and there is a need for a more accurate depiction of microhabitat data (e.g. calculating aspect, slope in microhabitats using a compass, and other tools). Better field techniques are needed to get a better idea on where species can occur (Guisan and Zimmermann, 2000).

Plant species distribution is hypothesized to be due to environmental factors (Kuhner and Kleyer, 2008). However, many species (such as palms and most cacti) show a clumped spatial distribution pattern, which may be the reflection of a patchy resource distribution within their heterogeneous environments (Godínez – Álvarez *et al.* 2003, Butler et al. *in press*.). *E. reichenbachii* ssp. is a small cactus and a good model organism to test whether finer-scale data (e.g. land use, land cover, elevation, slope, aspect, and soil type) can improve predictive models of where the species can occur.

Roots of *Echinocereus reichenbachii ssp.* (grown from corm type stem) grow in relatively shallow soil with mean depths of 7 to 10 cm (Nobel, 2009). Slope angle, aspect, and altitude are hypothesized to correlate with the success of growth of the *Echinocereus reichenbachii ssp.* (Yeaton & Cody 1979). In addition, the microhabitat class may be correlated with the presence of *E. reichenbachii* ssp. Areas with granite may be more suitable for *E. reichenbachii* ssp. (Buck 1964) than areas with less granite (Coppedge *et al.* 1998 and Crockett 1964).

We hypothesized the number of *E. reichenbachii* ssp. in the WMWR found in granite outcrops, grasslands, grasslands containing granite (cobblestones), and mountainous areas would differ. We hypothesized that there would be a significant difference in number of cacti growing in shallow soil depths than in deeper soil. Finally, we hypothesized that the presence of *E. reichenbachii* would depend on aspect, elevation, and slope.

METHODS

The Wichita Mountains Wildlife Refuge (Caddo County, Oklahoma) encompasses 59,020 acres located in southwestern Oklahoma was established in 1901. The Wichita Mountains provides a unique habitat with mixed grass prairie and geological outcrops of igneous rocks of elevated terrain formed during the Cambrian period (Johnson *et al.* 1972). We generated five random 1-km transects within the Wichita Mountains Wildlife Refuge (Figure 1). On the 13-14 of March 2009, we walked each transect, stopping every 50 m to note whether *E. reichenbachii*

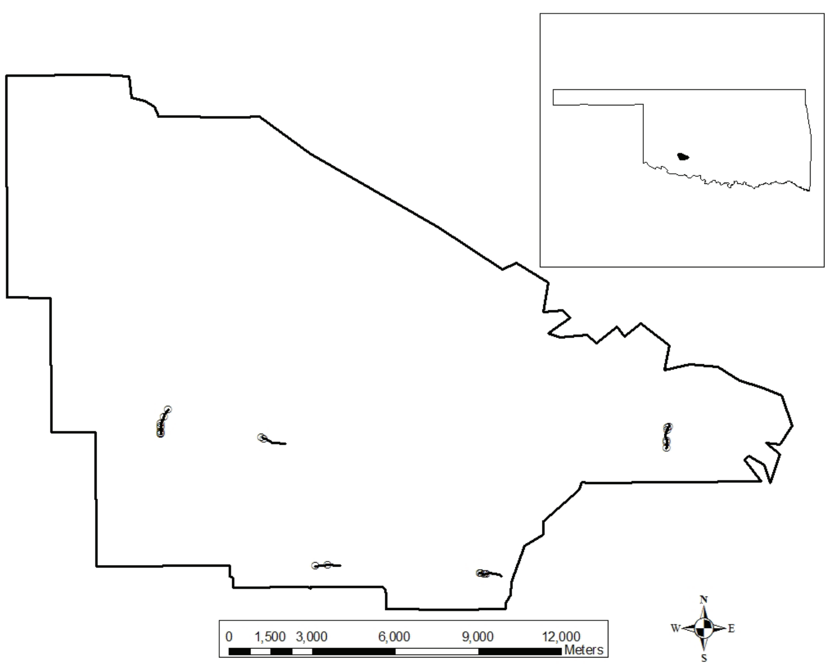


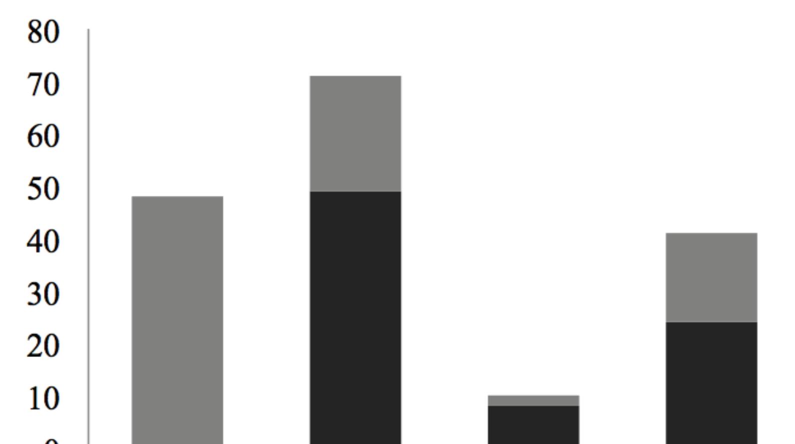
Figure 1. This map shows the five transects of 1000 meters in the refuge where we collected soil depth, land cover and number of cacti present at each 50 meter interval.

was present, as well as classifying the microhabitat (as grassland, grasslands containing granite (cobblestones), granite outcrops, or mountain granite). Soil depth at each location was measured by injecting a thin metal rod into the soil next to each hedgehog cacti we found at each stop, and also into the soil in areas where there were no cacti present. We also downloaded a map of elevation from the National Elevation Dataset (http://ned.usgs.gov/) and used Spatial Analyst in ArcGIS 9.3 to derive slope and aspect from the map of elevation

We used a binary logistic regression to examine whether soil depth, aspect, slope, elevation, and microhabitat could be used to predict whether *E. reichenbachii* ssp. was present or absent at each location. Soil depth, elevation, and slope were analyzed with a Mann-Whitney test and we used a Rayleigh test to test whether the aspect for areas with E. reichenbachii ssp. differed significantly from random. A Kruskal-Wallis test was used to compare the number of cacti in each microhabitat. A Spearman rank correlation was also used to compare soil depth and slope. Results are presented as mean ± standard error.

RESULTS

The five transects provided us with 48 grasslands locations, 22 granite outcrop locations, two grasslands with granite locations, and 17 mountain granite locations. We found no *E. reichenbachii* at grassland locations; however, we found eight cacti in two locations (mean 4 cacti/location) where granite cobblestones were present in grasslands. We found 49 cacti on granite outcrops (mean 2.2 cacti/location) and 24 cacti on mountain granite locations (mean 1.4 cacti/location). Mean soil depths in areas with *E. reichenbachii* ssp. were 4.12 cm while areas lacking *E. reichenbachii* ssp. averaged 7.55 cm, a significant difference (Mann-Whitney U = 35,343, $p<0.001$). The Kruskal-Wallis test for microhabitat with and without *Echinocereus reichenbachii* ssp. showed significant difference ($\chi^2=81.18$, df=4, $p<0.0001$). Granite outcrops had the largest number of cacti found per point location (Figure 2). *E. reichenbachii*



	grassland	granite outcrop	grassland with granite (cobblestone)	mountain granite
# of points marked	48	22	2	17
cacti found	0	49	8	24

Figure 2. More *E. reichenbachii* ssp. were found in areas where there was granite present than in areas without granite in the Wichita Mountains Wildlife Refuge.

ssp. were generally found in areas with a steeper slope (U = 4142.5, $p < 0.0001$). Soil depth was strongly negatively correlated with slope ($p < 0.0001$). A Rayleigh test of aspect showed no significant difference from random (p=0.32). Likewise, elevation did not differ between areas where *E. reichenbachii* was present and where it was absent (p = 0.47).

DISCUSSION

We hypothesized the number of *E. reichenbachii* ssp. in the WMWR found in granite outcrops, grasslands, grasslands containing granite (cobblestones), and mountainous areas would differ. We found that cacti were not encountered in grassland, but were encountered in other rocky areas. We believe that the absence of this cactus in the grassland was due to the deeper soils in this microhabitat.

Based on our observations, *E. reichenbachii* ssp. grew in more shallow sandy loams with a strong gravel-like texture; this was identified in the granite outcrop, grassland, grassland with granite (cobblestones), and mountainous granite microhabitats. Growth of cacti primarily occurred in soil accumulation inside cracks and crevices of the granite formations. The grassland typically had deeper soil with less gravel-like texture for significant drainage for cacti growth. Upper soil horizons of the grassland had less gravel and sand texture due to accumulation of dead grasses.

We also hypothesized that the presence of *E. reichenbachii ssp*. would depend on aspect, elevation, and slope. Aspect and elevation did not have an effect on the presence of this cactus. However, greater numbers of *E. reichenbachii ssp*. were found in areas with steeper slope. Soil depth and slope were negatively correlated, and we believe that the presence of this species on areas with steeper slopes was due to the relatively shallow soil depth.

The results of this study suggest that microhabitat preferences may be important in describing a species range. This may be particularly important for rare cacti such as *E. reichenbachii ssp*. which is classified as a S2 species in Oklahoma according to the Oklahoma Natural History Inventory. The "S2" indicates that it is considered to be imperiled in Oklahoma either because of extreme rarity or because it is otherwise vulnerable to extinction. While the Oklahoma Vascular Plants Database has records from 18 counties, the distribution of this species does not appear to have been mapped using ecological niche modeling techniques. Any future ecological niche modeling of this species (which might, for example, be used to determine whether an adequate proportion of the remaining population is in protected areas) or other cacti should make an effort to include microhabitats in the model in order to more accurately reflect the habitat preferences of these species.

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