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HABITAT UTILIZATION BY THE TEXAS HORNED LIZARD (*PHRYNOSOMA CORNUTUM*) FROM TWO SITES IN CENTRAL TEXAS

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ABSTRACT — The Texas Horned Lizard (*Phrynosoma cornutum*) is found in a variety of habitats. Although several studies have been conducted on habitat use by this species, none have been performed in central Texas, a more mesic habitat than most of those previously studied. This area is of special interest because horned lizard populations have been experiencing sharp declines in central Texas over the last approximately 50 years. We collected habitat data at two sites in central Texas, Camp Bowie and Blue Mountain Peak Ranch. Microhabitat data included canopy cover and ground cover from digitized photographs of Daubenmire quadrats; macrohabitat variables included vegetation height and length, cactus height, soil penetrability, woody plant species richness, tree density, tree diameter at breast height (DBH), and density of ant mounds collected along 100-m by 2-m transects. Similar patterns of habitat use were observed between the two sites. At Blue Mountain Peak Ranch, lizards appeared to be located in areas with a diversity of ground cover types, as observed in previous studies. At Camp Bowie, vegetation encroachment limited lizards in some areas to the use of roads and road margins. Implementation of prescribed burns or other vegetation management could create the preferred ground cover mosaic at such sites.

INTRODUCTION

The genus *Phrynosoma*, collectively known as horned lizards, contains some of the most distinct examples of North American saurian fauna – both in terms of general appearance and aspects of their biology. *Phrynosoma* species are characterized by a dorsoventrally flattened body, occipital horns, and a primarily myrmecophagous diet. Other notable characteristics include late maturation – many species do not breed until their second year – and unusually large relative clutch masses (Pianka and Parker 1975).

The Texas Horned Lizard (*Phrynosoma cornutum*) is found throughout much of the south-central and southwestern United States, as well as the northern states of Mexico. Throughout this range it occupies a variety of habitats including shortgrass prairie, mesquite-grassland, shrubland, oak savanna, and desert (Price 1990). It has also been transported throughout the country, largely through intentional collecting by would-be pet keepers, and breeding populations have become established outside of its native range including areas in coastal North Carolina, South Carolina, and Florida (Palmer and Braswell 1995).

Unfortunately, *P. cornutum* has declined over much of its geographic range. Over the last several decades populations have declined precipitously in central and east Texas and parts of Oklahoma (Carpenter et al. 1993, Donaldson et al. 1994; Henke 2003). In Texas the species has a state designation of threatened (Donaldson et al. 1994). It is also listed as a species of special concern in Colorado and Oklahoma. Hypotheses for the causal factors for these declines include effects of pesticides, impact of the red imported fire ant (*Solenopsis invicta*), habitat loss, and the legacy of collection for the pet or curio trade (Donaldson et al. 1994).

Understanding an organism's habitat requirements is essential in making informed management decisions. Studies of habitat preferences for *P. cornutum* have been conducted in several localities throughout its range including south Texas (Fair 1995; Burrow et al. 2001), northwest Texas (Henry 2009), and Colorado (Montgomery and Mackessy 2003). Studies focused primarily on habitat use in relation to habitat management, such as prescribed burns or grazing have also been conducted, mostly in Texas (Fair and Henke 1997; Hellgren et al. 2010; Inslee 2010) but also in Kansas (Wilgers and Horne 2006). However, no research on habitat use for this species has been conducted in central Texas, where it has experienced the most dramatic population declines. Our objective was to provide managers and restoration ecologists with quantitative habitat use data based on current lizard encounters. We documented habitat use at two spatial scales: the microhabitat (immediately near each animal) level and the macrohabitat (patch) level.

MATERIALS AND METHODS

Study Area — This study was conducted at two sites located 128 km apart in central Texas (Fig. 1). From April 2007 to October 2010 we collected data at Camp Bowie, a 3,542 ha Texas National Army Guard (TXANG) training facility located 7 km southeast of Brownwood, in Brown County, Texas, and from June 2008 to November 2010 at Blue Mountain Peak Ranch, a 335 ha private ranch located 29 km southwest of Mason, in Mason County, Texas. Camp Bowie is managed primarily for training military personnel, although limited hunting and fishing have at times been allowed by permit. Camp Bowie has a natural resources management plan, which includes the use of prescribed fire and brush removal to manage plant communities and preserve biodiversity, but these activities were mostly suspended during our data collection due to training activities. Blue Mountain Peak Ranch is managed primarily for habitat restoration in an effort to increase water to the aquifer and increase species diversity on the property. An aggressive management plan has been implemented – including regular prescribed fires and brush removal – primarily to reduce Ashe juniper (*Juniperus ashei*) density.

Methods — We located individual *P. cornutum* either by conducting surveys via road cruising at 20 km/h or less or through fortuitous encounters; lizards were captured by hand. Upon capture we recorded date, time of day, GPS coordinates (UTM, Garmin GPSmap 76CS), and sex. We determined the sex by examining the cloacal region to check for the presence of a hemipenal bulge and/or femoral pores. Individuals with either of these characteristics present were recorded as males. Hatchlings or juveniles that were too small to exhibit these characteristics or those individuals whose sex we could not confidently discern were assigned as "undetermined." Snout-vent length (SVL) and tail length were measured with a ruler to the nearest mm and mass was taken using an appropriately-sized spring scale (micro-line spring, PESOLA AG, Baar, Switzerland) to the nearest 0.1 g. We permanently marked individuals larger than 20 g and 65 mm SVL with a PIT tag (passive integrated

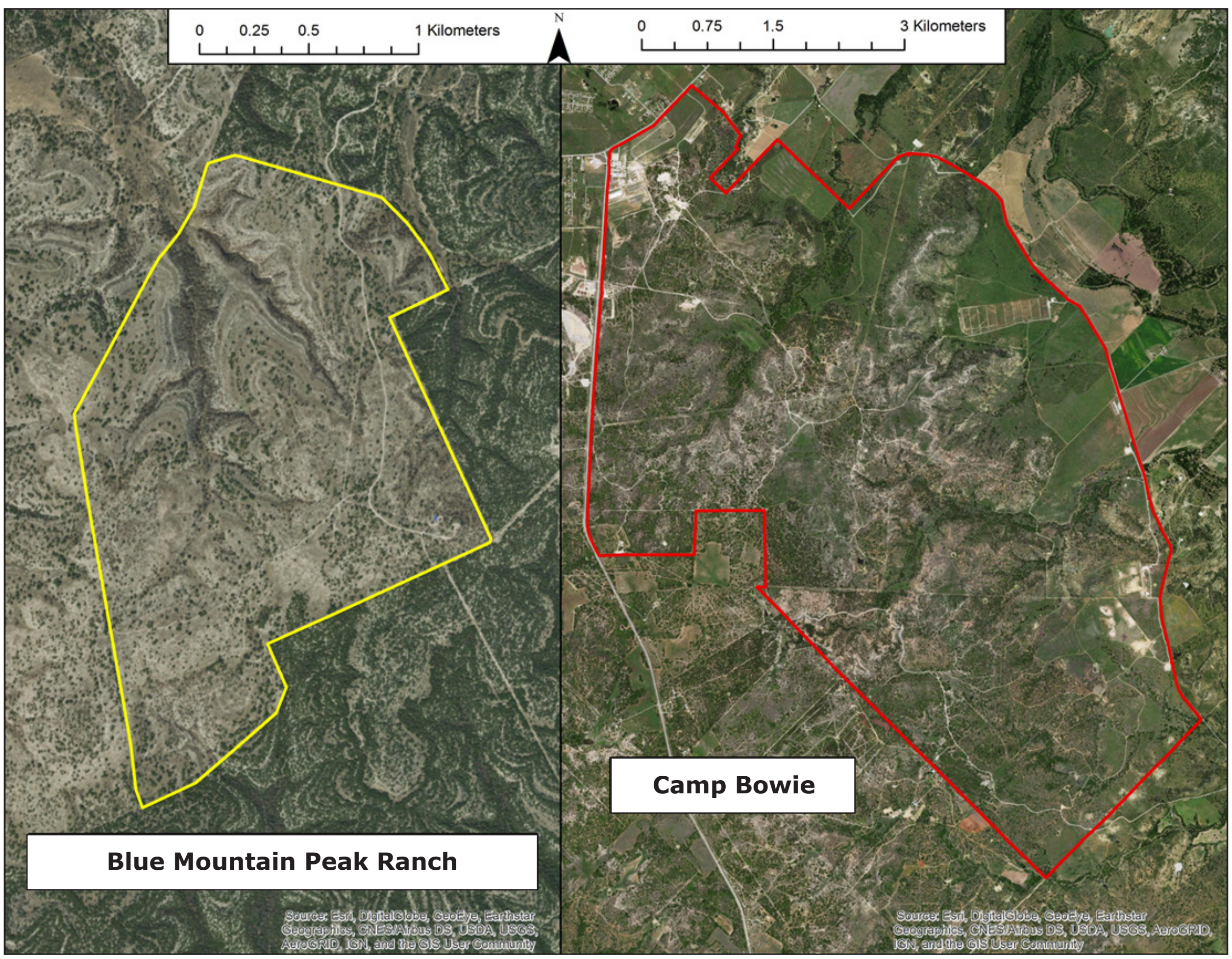

Figure 1. Aerial photographs of study sites and associated site boundaries in yellow and red for Blue Mountain Peak Ranch and Camp Bowie, respectively.

Table 1. Microhabitat ground cover by treatment and encounter type at Blue Mountain Peak Ranch. Each cover type was analyzed with a test of equality of binomial proportions with α = 0.05. Location: site where a lizard was initially seen. Because many lizards were first seen on a road, data for sightings that could be more representative are provided separately.

	Initial Encounter for All Lizards			Initial Off-Road Encounter		
Ground Cover Type	*Location (% ± SD)*	*Random (% ± SD)*	*p-value*	*Location (% ± SD)*	*Random (% ± SD)*	*p-value*
Bare Ground	43.06 ± 23.28	25.44 ± 17.05	< 0.0001	26.89 ± 16.29	30.63 ± 17.94	0.0109
Litter	4.94 ± 8.87	13.50 ± 19.20	< 0.0001	9.79 ± 10.93	11.84 ± 18.26	0.0415
Grass	17.76 ± 19.95	35.00 ± 21.57	< 0.0001	31.63 ± 25.15	24.89 ± 20.37	< 0.0001
Forb	5.00 ± 15.55	5.59 ± 6.29	0.2786	8.37 ± 20.40	5.32 ± 5.41	0.0002
Cactus	0.00 ± 0.00	0.76 ± 4.12	< 0.0001	1.63 ± 7.11	0.26 ± 1.15	< 0.0001
Wood	1.62 ± 5.57	1.97 ± 5.14	0.2726	6.26 ± 12.43	2.79 ± 5.26	< 0.0001
Rock	4.24 ± 7.23	1.97 ± 4.22	< 0.0001	1.05 ± 1.65	0.84 ± 1.57	0.5025
Cobble	1.32 ± 2.28	4.29 ± 7.26	< 0.0001	2.68 ± 4.01	5.58 ± 6.30	< 0.0001
Pebble	22.03 ± 19.68	11.47 ± 10.68	< 0.0001	11.68 ± 11.87	17.84 ± 14.77	< 0.0001
Manmade	0.03 ± 0.17	0.00 ± 0.00	0.2390	0.00 ± 0.00	0.00 ± 0.00	1.0000

transponder tag, ID 100A, Trovan, UK) by implanting it subcutaneously on the dorsum slightly anterior to the right hip with a syringe and 12-gauge stainless steel needle (Camper and Dixon 1988). Incisions were closed with superglue. Individuals too small to be PIT tagged were temporarily marked with a unique code using a permanent marker on the ventral side.

Between 2007 and 2010 lizards from both sites were fitted with radio transmitters (Wildlife Materials SOPB-2070: 2007-2009, Holohil BD-2: 2008-2009, and ATS R1645/R1655: 2010; Fig. 2). Seventeen lizards (seven males and ten females) and nineteen lizards (nine males and ten females) were telemetered from Camp Bowie and Blue Mountain Peak Ranch, respectively. Transmitters were attached between the shoulder blades using clear silicone. To avoid loss of the transmitter when the lizard molts, we secured a zip tie collar around the lizard's neck and attached the transmitter to this collar with fishing line. In order to better camouflage the telemetered lizard, additional silicone was spread around the remaining exposed area of the transmitter and covered with native soil. The average weight for the transmitter assembly from 2009 and 2010 was 6.6 ± 2.4% (range - 3.2-13.1%) of the lizard's body weight at time of capture (Knapp and Abarca 2009; Mougey 2009). We relocated lizards using a hand-held receiver (Telemetry Receiver R-1000, Communications Specialists, Inc.) in conjunction with a 3-element folded Yagi antenna.

Figure 2. Two Texas Horned Lizards (*Phrynosoma cornutum*) encountered during this study at Blue Mountain Peak Ranch. The individual on the right has been equipped with a radio transmitter.

During the 2009 and 2010 field seasons, we collected microhabitat data. Upon initial sighting for each lizard (n = 34), a 0.5 m x 0.5 m (0.25 m^2) quadrat constructed of rebar was centered at the point of observation with one side oriented north. A photograph of the quadrat was taken at a constant height of 1 m with a 9.0 megapixel digital camera (PowerShot SX110 IS, Canon). Using image analysis software (SamplePoint v. 1.51, USDA ARS), we calculated crown cover percentages of bare ground, litter (dead organic matter), grass, forb, cactus, embedded rock (> 4 cm at widest point), cobble (> 4 cm at widest point), pebble (< 4 cm at widest point), and manmade objects. To determine relative availability of these habitat characteristics, each lizard relocation point was paired with a point 10 m away in a random direction selected from a random number table. Data for this random location were collected in the same manner as described above.

All telemetered lizards that were initially captured on roads were relocated approximately one week after release (n = 19), at which point the same habitat measurements were taken. This was in an effort to see what impact collecting data on roads might have on microhabitat variables and allow us to draw better conclusions by understanding any potential biases. Because only three lizards were located at Camp Bowie in 2009 and 2010, and two of those were only found while surveying on a road, microhabitat use for Camp Bowie was not quantified.

A pocket penetrometer (pocket penetrometer E-280, Geotest Instrument Corp.) was used to measure soil penetrability (kg/cm^2) during both years. Measurements were taken in the northeast, southeast, southwest, and northwest corners of the plot. Penetrability measurements for each corner were averaged and a penetrability measurement for the quadrat was calculated. As the penetrometer could not measure any surface with a penetrability > 4.50 kg/cm^2, these measurements were recorded as "> 4.50" and excluded from the quadrat average. For each quadrat we then tabulated how many of the four penetrability measurements were greater than 4.50 kg/cm^2.

In order to examine habitat use at a larger (patch) spatial scale, we established 100 m x 2 m belt transects. At both Camp Bowie and Blue Mountain Peak Ranch, we measured habitat variables along 30 transects originating at locations where an individual lizard was first observed and 30 transects originating at random

Table 2. Transect habitat characteristics (mean ± 1 standard deviation) by treatment and site. Each habitat characteristic was analyzed with a Wilcoxon Signed Rank Test with α = 0.05.

	Camp Bowie			Blue Mountain Peak Ranch		
Ground Cover Type	*Location*	*Random*	*p-value*	*Location*	*Random*	*p-value*
Herbaceous vegetation length (mm)	622.84 ± 201.55	567.20 ± 155.36	0.0412	576.57 ± 122.91	526.20 ± 141.06	0.0992
Herbaceous vegetation height (mm)	526.19 ± 180.17	455.90 ± 134.89	0.0173	477.70 ± 115.50	416.87 ± 137.77	0.0565
Cactus height (mm)	4.612 ± 18.05	5.10 ± 14.44	0.4532	5.03 ± 15.77	0.00 ± 0.00	0.0815
Harvester ant nest density (nests/transect)	0.23 ± 0.62	0.03 ± 0.18	0.0964	0.67 ± 0.25	0.67 ± 0.25	1.0000
Red imported fire ant nest density (nests/transect)	0.81 ± 1.38	1.43 ± 1.70	0.0769	0.73 ± 1.01	1.20 ± 1.35	0.1292
Soil penetrability (kg/cm^2)	2.55 ± 0.57	2.57 ± 0.56	0.7345	1.43 ± 0.82	1.65 ± 0.44	0.0122
Woody plant richness (species/transect)	5.06 ± 3.88	9.33 ± 4.28	0.0003	8.60 ± 3.11	8.30 ± 2.58	0.6074
Tree density (trees/transect)	1.87 ± 3.32	4.70 ± 4.06	0.0004	2.03 ± 2.61	2.83 ± 4.88	0.6787
Tree diameter at breast height (DBH; cm)	7.71 ± 11.71	11.57 ± 7.53	0.0177	9.39 ± 9.22	11.66 ± 11.94	0.4403

points. Location transects were established based on the 30 most recently located individual lizards at a site in an effort to avoid changes in habitat characteristics as much as possible. All transects were oriented in a random direction from the initial point. If a transect intersected a property line before it reached 100 m, the property line became 0 m and the transect proceeded 180º from the original direction.

Habitat variables were recorded within a 0.5 m x 0.5 m frame as described above, but five photographs were taken (at 20 m intervals starting at 20 m) along the centerline of each transect. Within each quadrat we measured greatest herbaceous vegetation height and length (distance from the base of the stem to tip) to the nearest 1.0 mm, greatest cactus height to the nearest 1.0 mm, and soil penetrability. Additional measurements within each belt transect included number of woody plant species, number and diameter at breast height (DBH) of all trees along transect (species of woody vegetation > 3 m in height and typically possessing a single trunk), number of red imported fire ant mounds (at least 51% of mound within one meter of centerline of transect), and number of red harvester ant (*Pogonomyrmex barbatus*) mounds (at least 51% of mound within one meter of centerline of transect).

All SamplePoint data for both microhabitat and transect quadrats were analyzed using a test of equality of binomial proportions. This test considers the individual point in each quadrat as the sampling unit and is preferable to a chi-square test where many of the cover type categories would have been combined to meet assumptions inherent to that test. All tests of equality of binomial proportions were performed in Program R v. 2.10.1. All other data were analyzed in JMP v. 8.0. Log-transformations were ineffective at stabilizing residual variance or reducing skew; therefore, all analyses were conducted using a Wilcoxon Signed Rank Test. All tests were considered significant at the α = 0.05 level.

RESULTS

Microhabitat ground cover data for lizards at Blue Mountain Peak Ranch differed between initial encounter locations and data collected off-road (Table 1). For initial lizard location and off-road location cover data, the three most common cover categories were the same: bare ground, grass, and pebble. Habitat use versus availability between the two encounter types; however, was different. Whereas initial lizard encounters were in areas of significantly higher bare ground and pebble cover and significantly lower grass cover, initial off-road lizard encounters were at locations significantly higher in grass cover and lower in bare ground and pebble cover. Although bare ground and herbaceous vegetation accounted for over 60% of average ground cover for individuals at Blue Mountain Peak Ranch, woody vegetation was poorly represented. Although telemetered lizards were sometimes observed thermoregulating within the shade of woody vegetation during midday, they were much more frequently observed under the fringe of a grass clump or under cobble during this time. Lizards were observed partially concealed in this manner during 173 of 409 (42.3%) observations at Blue Mountain Peak Ranch. During the heat of the day, telemetered lizards frequently would be located underneath the same rock they were last observed underneath (pers. obs). Lizards were observed fully concealed or buried during 92 of 409 (22.5%) observations.

At Camp Bowie, habitat along transects where lizards had been observed was characterized by greater herbaceous vegetation length, greater herbaceous vegetation height, presence of fewer woody plant species and fewer trees compared to transects at random locations (Table 2). Soil at Blue Mountain Peak Ranch was more penetrable at locations utilized by lizards than at random locations ($Z_{59} = 2.506$, $p = 0.012$) and was the only habitat characteristic that differed between location and random transects. The mean number of *S. invicta* nests did not significantly differ between lizard and random sites at either Camp Bowie or Blue Mountain Peak Ranch (Table 2).

Grass, bare ground, litter, and pebble were the most common patch-level ground cover categories at both Camp Bowie and Blue Mountain Peak Ranch (Table 3). All ground cover categories at Camp Bowie differed between lizard locations and random locations. Results at Blue Mountain Peak Ranch were similar. Canopy cover in areas utilized by lizards was significantly lower than on random transects at both Camp Bowie ($p < 0.0001$) and Blue Mountain Peak Ranch ($p = 0.0038$; Table 3).

DISCUSSION

Our findings match those of studies in northwest Texas (Henry 2009) and south Texas (Burrow et al. 2001), which indicate that lizards select areas containing

Table 3. Transect ground cover type and canopy cover by treatment and site. Each cover type was analyzed with a test of equality of binomial proportions with α = 0.05.

	Camp Bowie			Blue Mountain Peak Ranch		
	(% ± SD)	*Location (% ± SD)*	*Random p-value*	*(% ± SD)*	*Location (% ± SD)*	*Random p-value*
Ground Cover Type						
Bare Ground	21.57 ± 13.63	17.57 ± 9.70	< 0.0001	16.16 ± 8.83	17.7 ± 5.85	0.0004
Litter	10.12 ± 8.69	14.63 ± 14.28	< 0.0001	11.91 ± 7.97	10.86 ± 6.34	0.0043
Grass	57.15 ± 19.94	54.06 ± 16.52	< 0.0001	51.18 ± 12.26	47.41 ± 13.14	< 0.0001
Forb	2.43 ± 2.39	4.00 ± 5.31	< 0.0001	2.05 ± 1.84	2.33 ± 1.83	0.1057
Cactus	0.07 ± 0.36	0.26 ± 0.82	< 0.0001	0.33 ± 1.47	0.00 ± 0.00	< 0.0001
Wood	3.06 ± 4.95	5.27 ± 5.59	< 0.0001	4.88 ± 6.21	6.53 ± 7.77	< 0.0001
Rock	0.22 ± 0.48	0.47 ± 1.17	0.0001	1.81 ± 2.13	3.01 ± 3.82	< 0.0001
Cobble	0.20 ± 0.55	1.25 ± 3.89	< 0.0001	4.14 ± 4.01	4.71 ± 4.89	0.0158
Pebble	5.17 ± 7.77	2.49 ± 3.68	< 0.0001	7.53 ± 6.07	7.45 ± 5.69	0.8093
Manmade	0.00 ± 0.00	0.00 ± 0.00	1.0000	0.01 ± 0.04	0.00 ± 0.00	0.2390
Canopy Cover						
Canopy	9.27 ± 13.00	20.38 ± 15.29	<0.0001	9.19 ± 9.59	10.17 ± 11.21	0.0038

a mosaic of cover types – particularly bare ground, herbaceous vegetation, and woody vegetation. Given the geology of central Texas, particularly the Edwards Plateau, the numerous cobbles and boulders at our sites may serve a thermoregulatory role usually provided by woody vegetation elsewhere within *P. cornutum*'s range because a lizard could bask on top of, hide in the shadow of, or hide completely underneath a suitably-sized rock. Contrary to our findings, Henry (2009) stated that, outside of areas around human habitation, lizards were very rarely seen using any sort of rock for thermoregulation or refugia.

At Camp Bowie, herbaceous vegetation tended to be taller and tree and shrub densities lower in areas where lizards had been observed as opposed to random locations. This suggests lizards may be avoiding areas of higher woody vegetation density. Indeed, lizards were found in areas that, on average, had half as much canopy cover compared to cover at random locations (9.3% vs 20.4%). Interestingly, canopy cover in areas inhabited by lizards at Camp Bowie and at Blue Mountain Peak Ranch were very similar at about 9%, cover which may be ideal for *P. cornutum* in this part of its range.

At Blue Mountain Peak Ranch, the only habitat feature that differed between areas used by lizards and random locations was soil penetrability. Soils in areas where lizards had been encountered tended to be significantly more penetrable than average. Fair (1995) similarly found that in south Texas lizards prefer sandy loam soils that are easily penetrable for activities such as burrowing for thermoregulation, crypsis, and nesting. At Blue Mountain Peak Ranch the predominant soil type was the Tarrant-Rock outcrop complex (National Cooperative Soil Survey 2013A), which is characterized by 10% surface cover of cobbles, stones, or boulders and very cobbly clay to 33 cm below ground surface (bgs). Whereas the two predominant soil types at Camp Bowie (Douldle-Real association and Real association) tended to have fewer rocks at the surface than the soils at Blue Mountain Peak Ranch (National Cooperative Soil Survey 2013B), our studies indicate that these cobbly, silty clay, and very gravelly loams tended to be on average more compacted.

Invasion by *S. invicta* has been indicated as a potential cause of horned lizard declines (Donaldson et al. 1994). We were unable to show a difference in ant mound densities between lizard sites and random locations. However, because of the relatively low numbers of nests counted through transect measurements, it may be that there was not adequate ant mound density to test for an effect. Large *S. invicta* colonies may contain 220,000 workers (Tschinkel 1988), thus even with a small increase in mound density, worker density could increase substantially. The relationship between lizard and fire ant density requires additional study. A more effective way to examine this relationship may be to quantify foraging worker ant density through the use of bait traps.

Whereas most of Blue Mountain Peak Ranch offered suitable habitat, relatively little of Camp Bowie did. The assertion that Blue Mountain Peak Ranch contained larger amounts of suitable habitat is supported by the apparent higher density of lizards (at least in 2009 and 2010) compared to Camp Bowie (Anderson 2012). The mosaic of bare ground and grass reported by Burrow et al. (2001) was not present at Camp Bowie as it was at Blue Mountain Peak Ranch. Although percent ground cover composition along transects in known lizard locations was similar between the two sites, the distribution was very different. Whereas there existed a ground cover mosaic at Blue Mountain Peak Ranch, at Camp Bowie most of the bare soil was confined to the roads and the grass grew densely next to the roads.

Encounter observations and relocation of telemetered individuals at Camp Bowie suggest the lizards were largely confined to the roads with only marginal use of the adjacent fields. Newbold (2005) found that invasive grass significantly lowered the mobility of Desert Horned Lizards (*P. platyrhinos*). Because of their wide, dorsoventrally flattened body, it is likely that horned lizards in general have a difficult time moving through any species of dense grass. This may be the reason *P. cornutum* at Camp Bowie, where habitat management was less intensive and vegetation was denser, appeared confined to roads. Road utilization by lizards puts them into direct danger from human-induced mortality since roads at Camp Bowie are frequently traversed by military vehicles. Similarly, the homogeneity of the road surface likely reduces their ability to effectively employ crypsis – this species' primary defense – to avoid detection by predators. Habitat for *P. cornutum* at Camp Bowie could be improved through the use of prescribed burning, mechanical or chemical woody vegetation control, carefully-managed grazing, or a combination of these strategies.

Overall, the outlook for *P. cornutum* throughout Texas and elsewhere remains uncertain. Although research from across its range continues to increase our knowledge of aspects of its biology and responses to habitat management, important research questions remain unexamined. Researchers should focus their efforts on testing the hypotheses related to this species' decline. Data concerning egg and juvenile survival rates and cause-specific mortality as well as the effects of fire ants on this species would be particularly valuable (Anderson 2012). Until these data and a better understanding of factors behind its decline are available, scientists and natural resource managers should continue managing habitat to meet this species' habitat preferences.

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