MICROHABITAT USE AND RANGE SIZE OF NATIVE AND REINTRODUCED POPULATIONS OF TEXAS HORNED LIZARDS (*PHRYNOSOMA CORNUTUM*)

by

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Introduction

One important strategy for the conservation of endangered and threatened species is the reintroduction of individuals from areas of abundance to areas of extirpation within their historic range. Since the passage of the Endangered Species Act of 1973, reintroductions and translocations became more common. Between 1973 and 1986, more than 700 annual translocations occurred (Griffith et al. 1989).

Reintroductions are not successful for all organisms. An analysis of the literature between 1979 and 1998 reported that only 26% of published translocations were classified as successful (Fischer and Lindenmayer 2000). For herpetofauna, the success rate of published reintroduction programs is 42% (Germano and Bishop 2009). Given that many failures are not published, this estimate is likely to be inflated. This is unfortunate, as many implementation pitfalls and mistakes will be repeated with future endeavors (Germano and Bishop 2009).

Reintroduction failures have been attributed to many causes including issues associated with funding, lack of continual community support, and the inability to carry out short- and long-term monitoring (Berger-Tal et al. 2020). A common complaint noted by land managers is the dispersal of individuals from the reintroduction site during the post-release period (Stamps and Swaisgood 2007). This dispersal has been shown in studies to be associated with higher stress, deterioration of body condition, and lower survival rates than individuals with more stable home ranges (DeGregorio et al. 2020).

The location of the reintroduction site has also been identified as an important contributor for reintroduction success, and poor habitat has been cited as a leading cause of poor reintroduction success (Griffith et al. 1989, Dodd and Seigel 1991, Kenward and Hodders 1998). Reintroduction sites that have similar habitat characteristics to the natal site shows a general decrease in dispersal distance, home range size, and daily distance traveled in several species (Stamps and Swaisgood 2007).

Texas horned lizards (*Phrynosoma cornutum*; Harlan, 1825) have experienced population declines across much of their range (Price 1990). Historically, they have been found throughout Texas, Oklahoma, Kansas, Missouri, New Mexico, Arizona, and Mexico (Price 1990). Since the 1970s, the range of Texas horned lizards has contracted and lizards have all but disappeared from much of east Texas (Price 1990, Donaldson et al. 1994). Declines have been attributed to several factors including habitat degradation and destruction following large scale farming, urbanization, and freeway expansion that has corresponded to a near tripling of the human population in Texas between 1970 and 2021 (Price 1990, US Census 1980, US Census 2020). Other reasons for decline include the spread of red imported fire ants (RIFA; *Solenopsis invicta*; Buren 1972), and the widespread poisoning of harvester ants (*Pogonomyrmex* spp.; Mayr 1868), the primary prey of Texas horned lizards (Buren et al. 1972, Summerlin and Green 1977, Price 1990).

Texas horned lizards occupy many different habitats from grasslands to shrublands to open deserts, ranging in elevation from sea level to 1830 m (Price 1990, Donaldson et al. 1994). Specific microhabitat use by Texas horned lizards has been the subject of much research (Table 1; Fair and Henke 1997, Fair and Henke 1998, Burrow et al. 2001, Burrow et al. 2002, Anderson et al. 2017). These studies have found that Texas horned lizards prefer a “mosaic” of microhabitats featuring bare soil, bunch grasses, and herbaceous and woody vegetation (Burrow et al. 2001). This type of habitat also often contains grasses that feed granivorous harvester ants (Holldobler and Wilson 1990). The soil also needs to be soft enough to facilitate burrowing by the Texas horned lizard and for the construction of their nests (Heath 1964, Pianka 1966, DeMers 1993).

Table 1: Microhabitat preferences of Texas horned lizards

Location	Favored overall habitat characteristics	Notes
Central TX	Tall woody vegetation, low shrub densities, and high densities of grass	Anderson 2017, (Brown Co. Pop.)
Central TX	Mosaic of bare soil and grass, rarely woody vegetation, Loose soil, and Rocks for thermal refuge	Anderson 2017, (Mason Co. Pop.)
South TX	Mosaic of bare soil, forbs, and woody vegetation. Bare soil and forb use higher in the morning and evening. Woody vegetation and litter use was higher in the afternoon	Burrow et al. 2001
Central TX	Overall random use of microhabitat by reintroduced lizards	Fink 2017
South TX	"Patchy" habitats with open areas interspersed with less than 60% vegetative canopy cover and less than 100 stems/yd^2	Henke and Fair 1998
Central TX	Disturbed patches with sparse invasive gasses and forbs	Whiting et al. 1993

Reintroduction programs for the Texas horned lizard have been implemented at Tinker Air Force Base in Oklahoma, McGillivray and Leona McKie Muse Wildlife Management Area in Brown County, TX, and Mason Mountain Wildlife Management Area (MMWMA) in Mason County, Texas (DeGregio et al. 2020, Miller et al. 2020, Fink 2017). Since 2015, Texas Parks and Wildlife Department (TPWD) has implemented a Texas horned lizard release program at three sites in MMWMA (Fink 2017). In 2015 and 2016, 38 wild-caught adults were translocated to this property, but few survived for more than a year after reintroduction (Williams, personal correspondence June 1st, 2021). Between 2017 and 2019, 210 captive-bred hatchlings were released, only four were known to have survived to maturity by the summer of 2021 (D. Barber, personal correspondence January 11th, 2022). In 2020, 257 captive bred hatchlings were released and 25 were noted to have survived as of the following winter (D. Barber, personal correspondence January 11th, 2022, Alenius, unpublished report).

Habitat and microhabitat suitability for Texas horned lizards at MMWMA has not been well studied and previous studies have mainly used the presence of harvester ant mounds as a proxy for the quality of the habitat (Fink 2017). The objective of this study was to compare microhabitat use and availability between reintroduced lizards at the MMWMA and a nearby natural population of Texas horned lizards on a privately-owned ranch. Using a combination of morphological measurements, radio-tracking, and microhabitat measurements, I asked whether the two sites differed with respect to home range size, daily distance traveled, and microhabitat features in ways that might be important for future management of the reintroduction site. For instance, if home ranges are larger, or daily distances traveled are longer at the reintroduction site compared to the private ranch, it may suggest that the habitat at the MMWMA is suboptimal. Comparing microhabitat use and availability between the two sites may then suggest management options to make the existing habitat more favorable for Texas horned lizards. The proposed study is part of a larger project seeking to identify factors that will increase reintroduction success of Texas horned lizards in central Texas.

Methods

Study Area

MMWMA, a former exotic hunting preserve, donated to the state of Texas in 1997 and has since been managed by TPWD (Singhurst et al. 2007). It is in the Edwards Plateau vegetative region in Mason County in central Texas (Fig. 1). Dominant vegetation types include shin oak (*Quercus sinuata* Walter), mesquite (*Prosopis glandulosa* Torr) and agarita (*Mahonia trifoliolata* (Moric.) Fedde). The property also has large areas dominated by prickly pear cacti (*Opuntia* sp. Miller) and elbow bush (*Forestiera pubescens* Nutt; M. Mitchell, personal correspondence February 22, 2022). It is dedicated to research and managed for native and exotic wildlife using prescribed burns. The reintroduction site has not been burned since 2003. The areas surrounding the release site are burned on a more frequent cycle, with the most recent burn in the winter of 2017 (Mitchell, personal correspondence).

The White Ranch (WR) is private property located 28 km away from MMWMA within Mason County. This property has a native population of Texas horned lizards and there is a paved highway that bisects the property. The woody vegetation and habitat types are similar to MMWMA, albeit with more areas of more encroaching mountain cedar (*Juniperus ashei* J. Buchholz). The area is a working cattle ranch and has multiple areas that have suffered from overgrazing in the past. The owners and managers have instituted a vigorous management plan that implements more moderate grazing, mechanical thinning of overgrown woody vegetation and prescribed burns to manage for native flora and fauna to promote native game hunting and ecotourism. Most areas with Texas horned lizards have been burned or are used for cattle grazing.

The climate for this county is described as humid and subtropical and characterized by hot summers, mild dry winters, low rainfall, high evaporation rates, high temperature, and high wind speeds. (Natural Resources Conservation Service 2010). Between 1921 and 2021, Mason County received an average of 68.0 cm of precipitation annually and recorded an annual average temperature of 18.5º C (NOAA 2022).

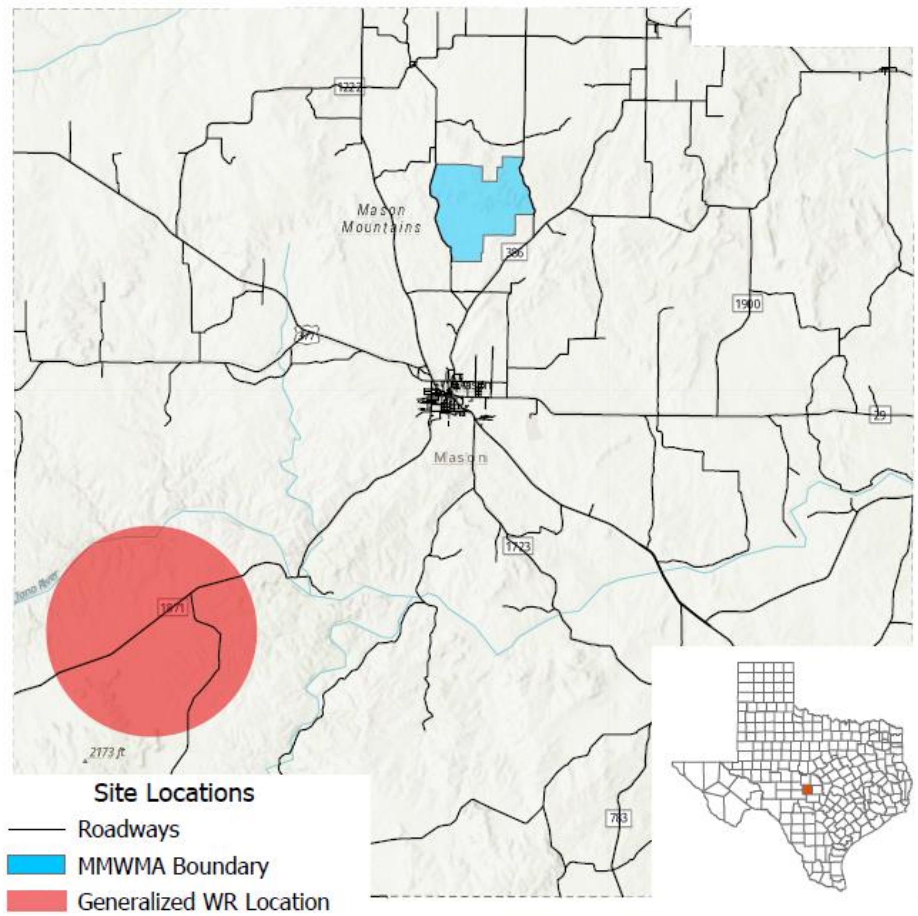


Fig. 1: Field sites in Mason County Texas. Mason County Wildlife Management Area (blue) is the site of the reintroduced population of Texas horned lizards. The White Ranch (red) is the site of the native population of Texas horned lizards. The White Ranch's location was obscured to protect the privacy of the owners.

Tracking

I tracked Texas horned lizards from June 2021 to August 2021. Lizards at both sites were captured using a combination of road cruising and fortuitous encounters. Upon capture, we gave each lizard an identification number, and we recorded basic morphological features including weight, snout to vent length (SVL), lizard condition (weight/SVL), sex, and age class according to size (Henke 2003). Lizards that weighed over 20 g were affixed a BD2 radio weighing 1.4-grams (Holohil Systems Ltd). Those that weighed between 10 and 20 g were affixed a 0.6-gram

BD2 radio (Holohil Systems Inc.). At the end of the field season, we removed the radios and again measured morphological features.

We attached the radios to the lizard via Mega Pro-Bonding Glue (JB Cosmetics Group) and were secondarily secured via a collar that was looped around the neck made of monofilament fishing line contained within intravenous tubing (Fig. 2). Following sheds or before the radios signal failed, radios were reglued to the lizard.

We tracked lizards every day using a R-1000 Telemetry Receiver and a R-150 Yagi Directional Antenna (Communication Specialists Inc.). To account for the different microhabitat requirements of the lizards at different times of the day throughout the summer, the times of day each lizard was tracked were rotated. Lizards were tracked an equal number of times between mornings (0700-1000), afternoon (1100-1500), and evenings (1700-2000; (Table 3).

Fig. 2: Adult Texas horned lizard equipped with a Holohil BD-2 VHF radio and collar used to relocate individual lizards throughout the study.

Microhabitat Sampling

Following the successful location of lizards, we placed the midpoint of 1.0 m^2 Daubenmire (1959) quadrat on the lizard's location (Fig. 2). Cover classes analyzed included bare soil, pebbles and cobbles, embedded rocks, litter, cow droppings, grasses (ex. *Eragrostis spp.*), herbaceous forbs (ex. *Ratibida columnifera* [Nutt.]), cacti (*Opuntia* spp.), and woody vegetation (*P. glandulosa*). This location was paired with a random location 10 meters away. We used a random number generator (Random Number Generator Plus; v2.4.8, RandomAppsInc) to determine compass direction of the random location. Each microhabitat plot was photographed with a 12-megapixel camera with ultrawide lens (Samsung) one meter above the ground.

To test soil compactness at each lizard and random location, we used a Pocket Penetrometer E-280 (Geotest Instrument Corp) at the midpoint of the quadrat and at each of the four corners of the plot and then averaged these points together. The scores ranged from 0 to 4.5 tons/ft^2. When points that were too compact to be read, we recorded these as 5 tons/ft^2 for data analysis. Post hos, we converted these measures to tons/m^2.

I obtained GPS locations with submeter accuracy via a Bad Elf GNSS Surveyor (Bad Elf). Information was recorded twice for redundancy via Collector (v.20.2.2, ESRI) and with Avenza (v.3.15.4, Avenza Systems Inc) before being uploaded to a central database. I recorded UTM coordinates using Zone 14 of the North American Datum 1983 (NAD83). In addition to mapping lizard and random microhabitat locations, we also recorded harvester ant mound locations.

Data Analysis

To ensure consistency among cover classification, I analyzed pictures through software SamplePoint (v.1.6, USDA). Some pictures were low quality, and so we were not able to use all pictures for analysis. Lizard and random microhabitat photos were cropped to inside of the frame of the quadrat using Adobe Photoshop Express (v.3.5.381, Adobe). One hundred points from each photo were manually recorded according to respective cover class.

We compared the cover classes to each other using Spearman's correlation to identify autocorrelated factors and multicollinearity. We considered factors to be autocorrelated based on a correlation coefficient value of 0.60 or higher.

I used binomial generalized linear mixed effects modeling (GLMM) to make comparisons of soil compactness and each cover class between (1) lizard location and random location, (2) lizard location between time of day (morning, afternoon, and evening), and (3) lizard location and random location for each of our study sites in Program R (v. 4.1.2, The R Foundation). Multiple packages were used including lme4, Matrix, and MuMIN. As I took repeated samples for each individual lizard, we included lizard ID as a random factor. I included soil compaction and vegetation categories as fixed effects. I used generalized linear mixed effects modeling on the random locations to make comparisons between soil compactness and each cover class between the two study sites using Minitab (v. 21.1, Minitab LLC.).

I delimited home ranges using 95% minimum convex Polygons (MCPs) via the AdehabitatHR package in Program R. We calculated daily distances traveled for lizards using Euclidean distance between successive locations. When relocations were separated by more than one day, I divided the Euclidean distances by the number of days. I compared home range size between the reintroduced lizards and the native lizards using two-sample t-tests in Minitab. I used generalized linear mixed effects modeling to compare the daily distance traveled between the reintroduced lizards and the native lizards.

Results

We tracked 18 lizards at MMWMA and WR, and 10 of these were relocated ≥10 times. We used data from all lizards for the microhabitat analyses and used data from lizards located at least 10 times for the home range analysis (Table 2). The sex ratio of all lizards was female biased (61%) and all but two were adults. We tracked four lizards at MMWMA (all adults, three females and one male) and 14 at the private ranch (eight adult females, two juvenile males, and four adult males). One radio on a female lizard and three on adult male lizards censored after two to three days and were not subsequently relocated. We tracked lizards for a total of 414 radio days. There were 647 photos taken of microhabitat plots. Of these, 218 were taken at MMWMA and 429 at WR (Table 3).

Table 2: Tracking summary for all Texas horned lizard adults (A) and juveniles (J) equipped with VHF radio transmitters at Mason Mountain Wildlife Management Area (MMWMA) and the White Ranch (WR) in Mason County. All locations occurred in the summer of 2021.

Lizard ID	Site	Sex	Age	Dates tracked	Successful locations	Fate
FMM1	MMWMA	Female	A	June 1 - August 11, 2021	60	Survived summer
FMM3	MMWMA	Female	A	June 7 - June 23, 2021	14	Mortality-Coachwhip
FMM8	MMWMA	Female	A	June 7 - August 11, 2021	58	Survived summer
MMM1*	MMWMA	Male	A	June 1 - June 18, 2021	15	Mortality-Vehicle
MWR1	WR	Male	A	June 2 - June 3, 2021	2	Mortality
MWR2	WR	Male	A	June 5 - June 7, 2021	3	Mortality - Vehicle
MWR3	WR	Male	J	June 6 - July 4, 2021	18	Radio Censored
MWR4	WR	Male	A	June 8 - June 10, 2021	2	Radio Censored
MWR5	WR	Male	J	June 8 - August 11, 2021	47	Survived summer
MWR6	WR	Male	A	June 17 - June 24, 2021	5	Mortality-unknown
FWR1	WR	Female	A	June 5 - June 6, 2021	2	Radio Censored
FWR2	WR	Female	A	June 7 - June 17, 2021	6	Mortality-Coachwhip
FWR3	WR	Female	A	June 8 - July 20, 2021	28	Shed radio
FWR4	WR	Female	A	June 8 - August 8, 2021	52	Survived summer
FWR5	WR	Female	A	June 10 - August 7, 2021	42	Mortality-Coachwhip
FWR6	WR	Female	A	June 16 - June 27, 2021	8	Mortality-Coachwhip
FWR7	WR	Female	A	June 22 - August 11, 2021	44	Survived summer
FWR8	WR	Female	A	June 28 - July 9, 2021	8	Mortality-Vehicle

*Included 21 points of supplemental data from April 6 - May 29, 2021 (used for home range analysis)

Table 3: Total number of lizard sightings, lizard microhabitat photos, and random microhabitat photos taken for tracked lizards at MMWMA and WR. Thirteen photos were omitted due to low quality.

Time Frame	Lizard sightings	Lizard Microhabitat Photos	Random Microhabitat Photos
Morning	145	114	119
Afternoon	146	111	113
Evening	125	92	98

Microhabitat Use

Pairwise correlations resulted in no combination of variables with a coefficient of 0.6 or greater for overall microhabitat characteristics. Due to few plots containing pebbles, cobbles, and/or rock, we merged these percentages with soil. Similarly, cactus was merged with forbs. Five GLMs for overall microhabitat characteristics were constructed using all measured microhabitat categories. The factor with the largest p-value was removed and then the model reran until all the factors had significant p-values. The model with the lowest AICc (Akaike information criterion) that was selected included four variables and had two factors that were significant: percent cover by grass, and percent cover by woody vegetation (Fig. 3). Percent cover by grass was negatively associated with horned lizard presence (Table 4, Fig. 3).

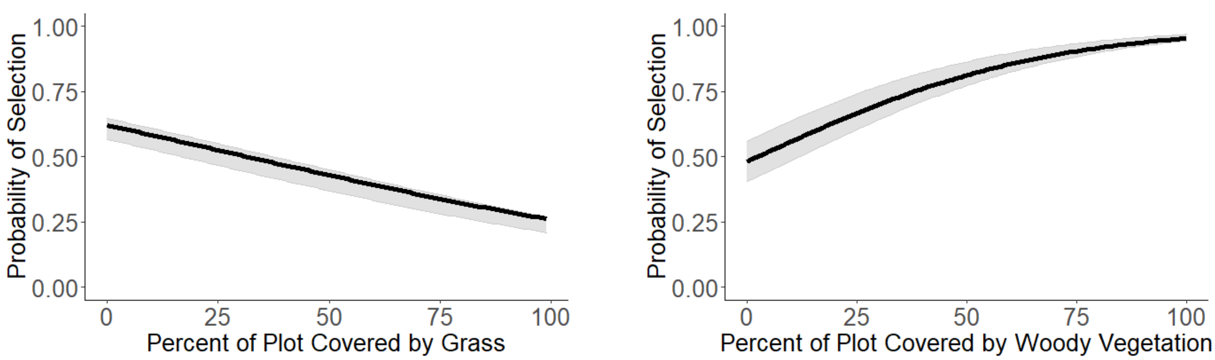


Fig. 3: Association between the probability of microhabitat selection by Texas horned lizards in Mason County, TX and the percentage of the sampling plot covered by grass and woody vegetation. The grey area represents the 95% confidence area.

Differences between sites

Pairwise correlations resulted in no combination of variables with a coefficient of 0.6 or greater for MMWMA. However, there was a pairwise correlation between grass and bare soil at WR ($r = -0.65$), so I ran models with just one or the other. Percent woody vegetation was positively associated with the presence of horned lizards at MMWMA (Table 4, Fig. 4). Percent litter and woody vegetation were positively associated with the presence of horned lizards and percent grass cover was negatively associated with the presence of horned lizards at WR (Table 4, Fig. 5). Using mixed effects models, we found that there were more open areas with bare soil at WR than at MMWMA ($F_{1,5.36} = 29.31$, $p = 0.002$), as well as more forbs at MMWMA (($F_{1,7.09} = 7.73$, $p = 0.027$; Fig. 6). There was no statistical difference between the sites in terms of grass ($F_{1,5.83} = 4.39$, $p = 0.082$), litter ($F_{1,5.88} = 4.22$, $p = 0.087$), woody vegetation ($F_{1,8.01} = 0.02$, $p = 0.082$), or cow droppings ($F_{1,12.37} = 1.43$, $p = 0.254$; Fig. 6).

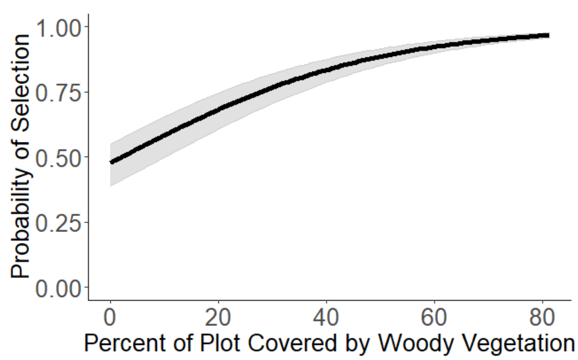


Fig. 4: Association between the probability of microhabitat selection of Texas horned lizards and the percentage of the sampling plot covered by woody vegetation by lizards at MMWMA. The grey area represents the 95% confidence area.

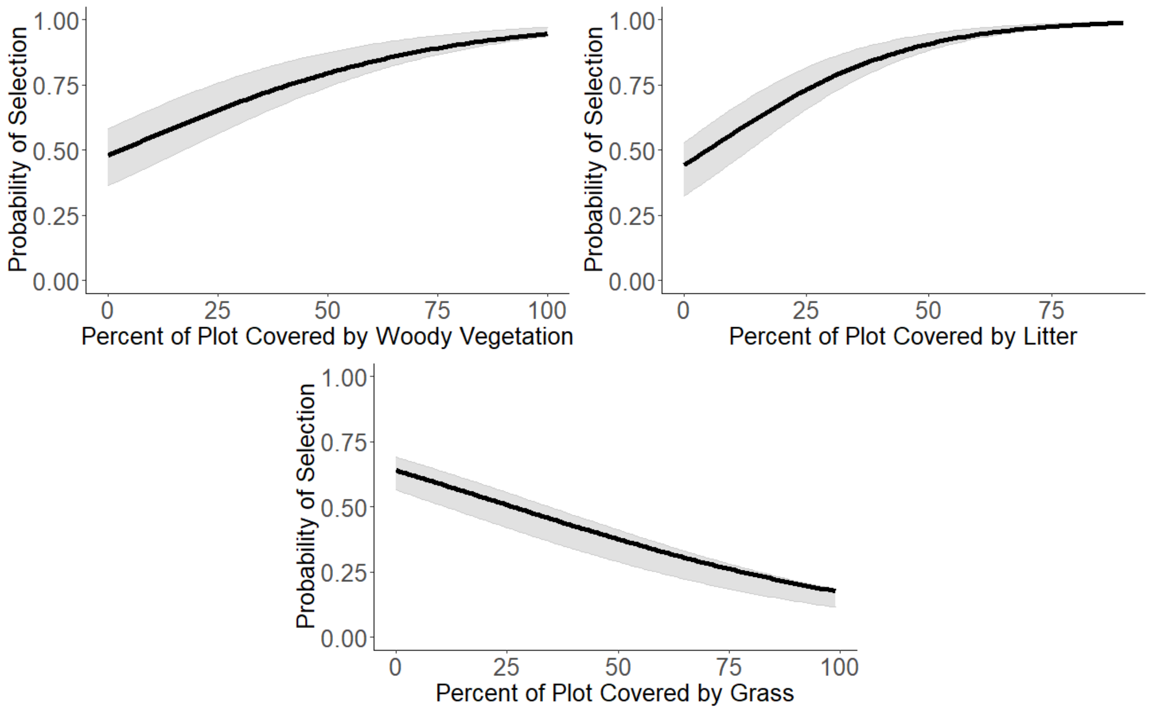


Fig. 5: Association between the probability of microhabitat selection by Texas horned lizards and the percentage of the sampling plot covered by woody vegetation, litter, and grass by lizards at WR. The grey area represents the 95% confidence area.

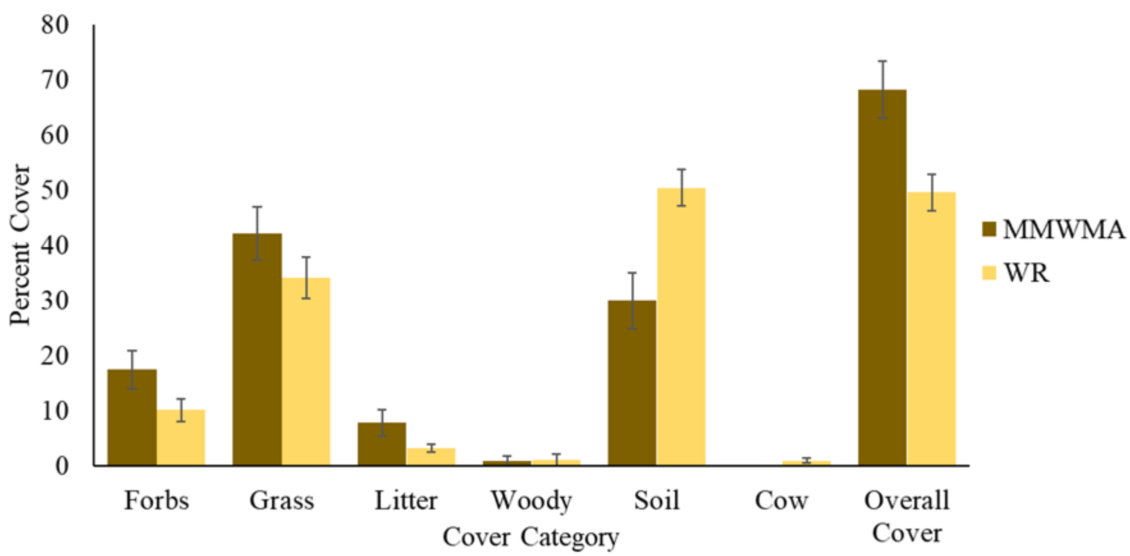


Fig 6: Average percentages of forbs, grass, litter, woody vegetation, soil, cow droppings, and overall cover available for use by Texas horned lizards at Mason Mountain WMA (MMWMA)

and the White Ranch (WR) during the summer of 2021. Error bars are two times standard error. N_{MMWMA} = 102 photos, N_{WR} = 201 photos.

Differences between times of day

During the mornings, there was a positive association between the percent of bare soil and the presence of a horned lizard (Table 4, Fig. 7). During the evenings, there was a positive association between percent cover by woody vegetation and presence of a horned lizard (Table 4, Fig. 8). No GLM was able to predict preference for microhabitat characteristics in the afternoon better than the null model.

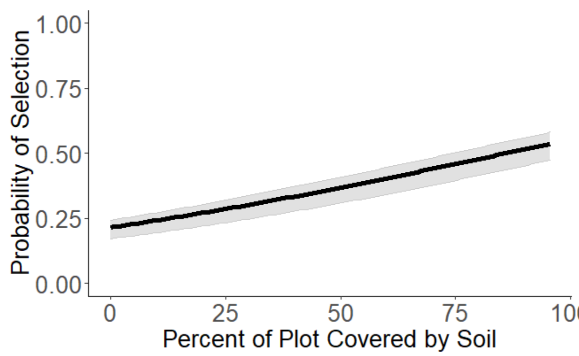


Fig. 7: Association between the probability of microhabitat selection by Texas horned lizards in Mason County TX during the morning and the percentage of the sampling plot covered by bare soil. The grey area represents the 95% confidence area.

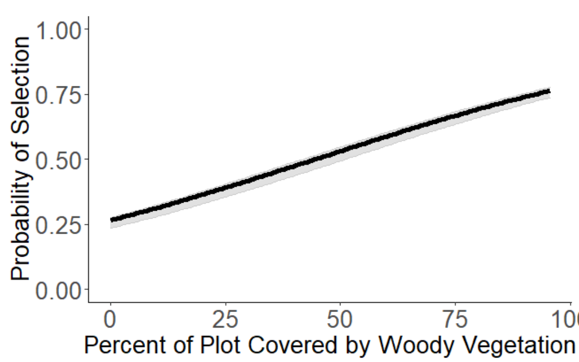


Fig. 8: Association between the probability of microhabitat selection by Texas horned lizards in Mason County TX during the evening and the percentage of the sampling plot covered by woody vegetation. The grey area represents the 95% confidence area.

Table 4: Model Coefficients of microhabitat characteristics selected by Texas horned lizard in Mason County, Texas from the summer of 2021. Estimates originated from model with the lowest AICc. Bolded p-values represent statistically significant values.

Selection Category	Habitat Characteristic	Estimate	Std. Error	Z value	P-value
Overall Selection	Intercept	0.069	0.211	0.326	0.744
	Compaction	0.010	0.005	1.863	0.063
	Grass	-0.016	0.004	-4.347	**<0.001**
	Litter	0.018	0.010	1.808	0.071
	Woody	0.032	0.011	2.937	**0.003**
Mason Mountain Selection	Intercept	-1.332	0.647	-2.059	0.040
	Compaction	0.015	0.009	1.698	0.089
	Grass	0.008	0.008	0.966	0.334
	Soil	0.015	0.008	1.808	0.071
	Woody	0.050	0.024	2.069	**0.039**
White Ranch Selection	Intercept	-0.043	0.277	-0.154	0.878
	Compaction	0.010	0.007	1.457	0.145
	Litter	0.055	0.019	2.833	**0.005**
	Grass	-0.023	0.005	-4.441	**<0.001**
	Woody	0.032	0.013	2.474	**0.013**
	Cow	0.042	0.023	1.829	0.067
Morning Selection	Intercept	-1.693	0.472	-3.584	0.000
	Grass	0.014	0.007	1.952	0.051
	Soil	0.015	0.006	2.39	**0.017**
Evening Selection	Intercept	-1.212	0.188	-6.463	0.000
	Forbs	0.017	0.010	1.676	0.094
	Woody	0.023	0.007	3.113	**0.002**

Home range and distance traveled

Average home range size for reintroduced lizards at MMWMA didn't differ from the home range size of native lizards at WR ($T_5 = 0.25$, $p = 0.81$; 1.34 ± 0.98 ha at MMWMA, and 1.20 ± 0.71 ha at WR; Table 5). The average daily distance traveled by MMWMA lizards did not differ from the distances traveled by WR lizards ($F_{1,7.32} = 1.94$, $p = 0.204$, 29.23 ± 36.27 m at MMWMA vs. 35.66 ± 38.47 m at WR). Values for home range and daily distance traveled for lizards reintroduced as hatchlings were similar to a study of translocated adults at MMWMA in 2014 (Table 6; Fink 2017; $T_6 = 0.59$, $p = 0.58$, daily distance $T_3 = 0.76$, $p = 0.504$). Mean ant mound/ha for each Texas horned lizard home range did not differ between sites ($W = 27$, $p = 0.34$; 9.04 ± 1.86 at MMWMA vs. 8.35 ± 7.50 at WR).

Table 5: Geospatial data for Texas horned lizards with 10 or more successful locations at MMWMA and WR during the summer of 2021.

Lizard ID	Site	Home range (95% MCP; ha)	Average Daily movement (m) + SD	No. of Ant mounds	Ant mounds/ha
FMM1	MMWMA	1.44	19.31 ± 2.47	17	11.81
FMM3	MMWMA	0.88	36.70 ± 11.4	7	7.95
FMM8	MMWMA	2.66	28.35 ± 4.43	22	8.28
MMM1*	MMWMA	0.37	44.40 ± 9.28	3	8.11
MWR3	WR	0.48	43.44 ± 6.86	11	22.89
MWR5	WR	0.63	30.00 ± 4.67	6	9.58
FWR3	WR	1.47	49.30 ± 12.6	4	2.72
FWR4	WR	2.42	34.11 ± 5.85	10	4.14
FWR5	WR	1.29	40.41 ± 5.59	8	6.18
FWR7	WR	0.88	27.84 ± 3.92	4	4.57

*Included 21 points of supplemental data from April 6 - May 29, 2021 (used for home range analysis)

Discussion

Microhabitat selection

Our results show that both native and reintroduced Texas horned lizards choose microhabitats that have less grass, more litter, and more woody vegetation. The selection of areas with less grass is similar to previously published data (Fair and Henke 1998, Burrow 2001, Anderson 2017). Texas horned lizards were more selective for sites with more litter and less grasses at WR compared to MMWMA. Previous research reports that Texas horned lizards preferred sites devoid of heavy litter (Fair and Henke 1998). However, lizards at WR favored sites that had more litter than what would be expected if they chose sites randomly. Unfortunately, no research has sought to define heavy litter. Across both sites, soil was selected in the morning and woody vegetation was selected in the evenings. This makes sense, given the lizards will need to warm themselves in the morning using the sun and to seek shade in the evening. Texas horned lizards did not select microhabitats based on soil compaction, unlike another nearby population in Mason County in an earlier study by Anderson et al. (2017). This may indicate that that soil conditions are different at our two sites. Horned lizards were recorded burrowing (n = 24) and creating nests (n = 8) on multiple occasions at both MMWMA and WR.

The presence and abundance of native horned lizard in cattle pastures is not surprising. Previous research indicates that Texas horned lizards are not negatively affected by low to moderate grazing by livestock (Fair and Henke 1997, Burrow et al. 2002). Burrow and colleagues (2010) reported that grazing has been shown to be beneficial to horned lizards because it stimulates the production of seed-bearing grasses and forbs and decrease ground litter resulting in the proliferation of harvester ants. It is interesting to note that MWR5, a juvenile male lizard, burrowed underneath cow droppings on five occasions. As this behavior was noted during the heat of the afternoon when ground temperatures measured between 29.7º C and 44º C, it suggests that this behavior may be an adaptation to shelter for thermoregulation purposes or to evade predators. To our knowledge, this is the first description of this behavior by Texas horned lizard. This may be rooted in historical adaptations of Texas horned lizards to historical large grazers in the region (Granberg et al. 2015). Paleontological evidence indicates that grasslands in south and central Texas have been grazed by the American bison (*Bison bison* Linnaeus, 1758) from the early Pleistocene until the decimation of the population in the 1880's (Huber 1991, Leuck 2002).

The home ranges and daily distances traveled by the horned lizards at MMWMA and WR are similar to those reported in other studies of Texas horned lizards that do not live in urban areas (Table 6). Although the sample size is small for MMWMA (n = 4 lizards), there is no indication that these lizards, originally released as hatchlings, are behaving differently from lizards in natural populations. Several other studies of translocated adult Texas horned lizards in the same region also found they had similar home range sizes to natural populations (Fink 2017, Miller et al. 2020, Table 6). Home range size was larger in reintroduced juveniles compared to reintroduced adults and native adults and juveniles at Tinker Airforce Base in Oklahoma (DeGregorio et al. 2020, Table 6). These juveniles also experienced higher survival, however, and so their larger home ranges and distance traveled may not have been a negative. The daily distance traveled at MMWMA and WR tended to be longer than the distances from the two earlier studies in the region (Fink 2017, Miller et al. 2020, Table 6) possibly because I included the longer daily distances traveled by females engaged in egg laying. As females laid eggs throughout the summer and many females constructed trial nests before laying eggs, it was not feasible to delimitate sampling points around egg laying as in other studies (i.e. Fair and Henke 1999, Fink 2017, Burrow et al. 2002).

Table 6: Average Home range sizes and diem distances traveled for Texas horned lizard. Home ranges represent the average 95% MCP ± standard deviation. All daily distances accompanied by standard deviation unless when noted.

Location	n (home range)	Home range size (ha)	Daily distance traveled (m)	Notes
Central TX	4	1.34 ± 0.49	29.23 ± 36.27	Present study (reintroduced pop.)
Central TX	6	1.05 ± 0.28	35.66 ± 38.47	Present study (native pop.)
Central TX	11 (no sex distinction reported)	2.22 ± 3.12	NA	Anderson 2012 (males, Blue Mountain Ranch)
Central TX		0.38 ± 0.46	NA	Anderson 2012 (females, Blue Mountain Ranch)
Central TX	12 (no sex distinction reported)	3.15 ± 2.92	NA	Anderson 2012 (males, Camp Bowie)
Central TX		1.01 ± 0.83	NA	Anderson 2012 (females, Camp Bowie)
Central TX	14	0.86 ± 1.12	15.4 ± 8.1	Fink 2017 (reintroduced pop.)
Central TX	56	1.20 ± 0.04	18.6 ± 36.9	Miller et al. 2020 (reintroduced pop)
Central TX	10	1.37 ± 1.73	NA	Granberg 2014
South TX	78	1.02 ± 4.34	NA	Burrow et al. 2002
South TX	30	0.73	36.5 ± 3.2 (SE)	Fair and Henke 1999 (100% MCP)
South TX	11	0.24 ± 0.1	NA	Wall 2014 (urban pop.)
Central OK	17	0.35 ± 0.37	3.5 ± 2.3	DeGregorio et al. 2020 (native adult pop)
Central OK	6	0.4 ± 0.4	1.4 ± 0.5	DeGregorio et al. 2020 (soft released adults)
Central OK	17	1.4 ± 2.2	4.5 ± 6.1	DeGregorio et al. 2020 (soft released juveniles)
Central OK	57	0.72 ± 1.14	NA	Vessey et al. 2021 (adults)
Central OK	13	0.43 ± 0.08	25.1 ± 4.7	Endriss 2006 (native pop.)

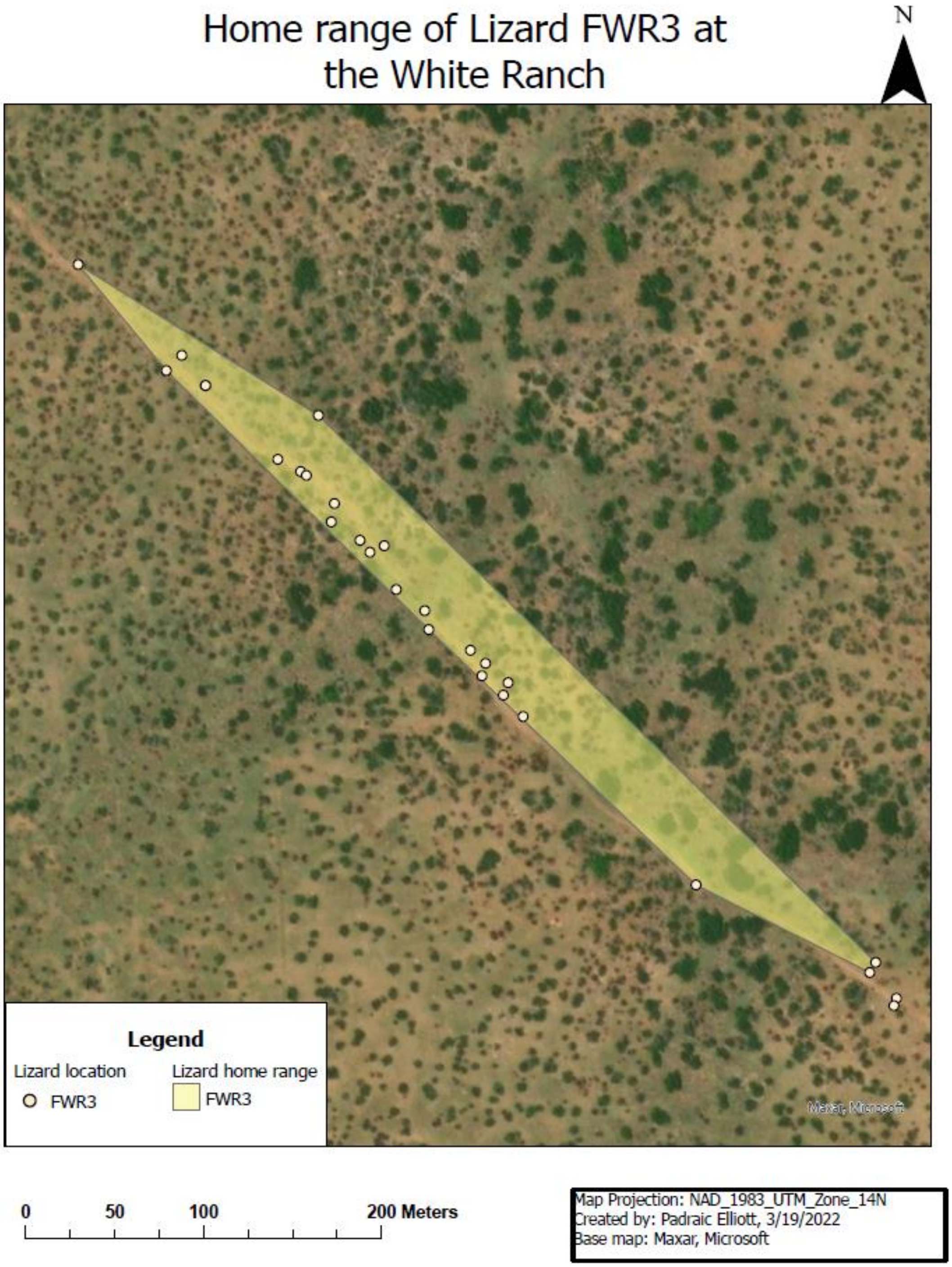
Conservation implementations

While not enough progress has been made to proclaim a reintroduction success at MMWMA, it was promising to see females build several nests and successful hatching from these nests (pers obs.). Wild-born offspring of captive-bred individuals have been shown to have increased survival compared to captive-bred individuals (Stamps and Swaisgood 2007, Beck et al. 1991).

It may be necessary to implement more prescribed burns at the release site in MMWMA and the areas surrounding this area on a more frequent basis. In the summer of 2021, lizards moved away from the release site into areas with more embedded rock and thicker rhizomatous grass cover that impedes horned lizard movement. Comparing random plots between the two sites revealed that WR had more open bare soil than MMWMA and that MMWMA had more cover than WR. Lizards at WR were also more likely to be in plots with less grass than random sites. Natural and anthropogenic fires reduce fuel loads, and clear underbrush that inhibits horned lizard movement as well as trigger reproductive processes in many plant species including grasses that attract harvester ants. It may also be useful to consider controlling fine fuel loads via reintroducing large native grazers to the areas around the reintroduction site to provide a moderate grazing pressure on local plants to encourage the proliferation of seeds to attract harvester ants.

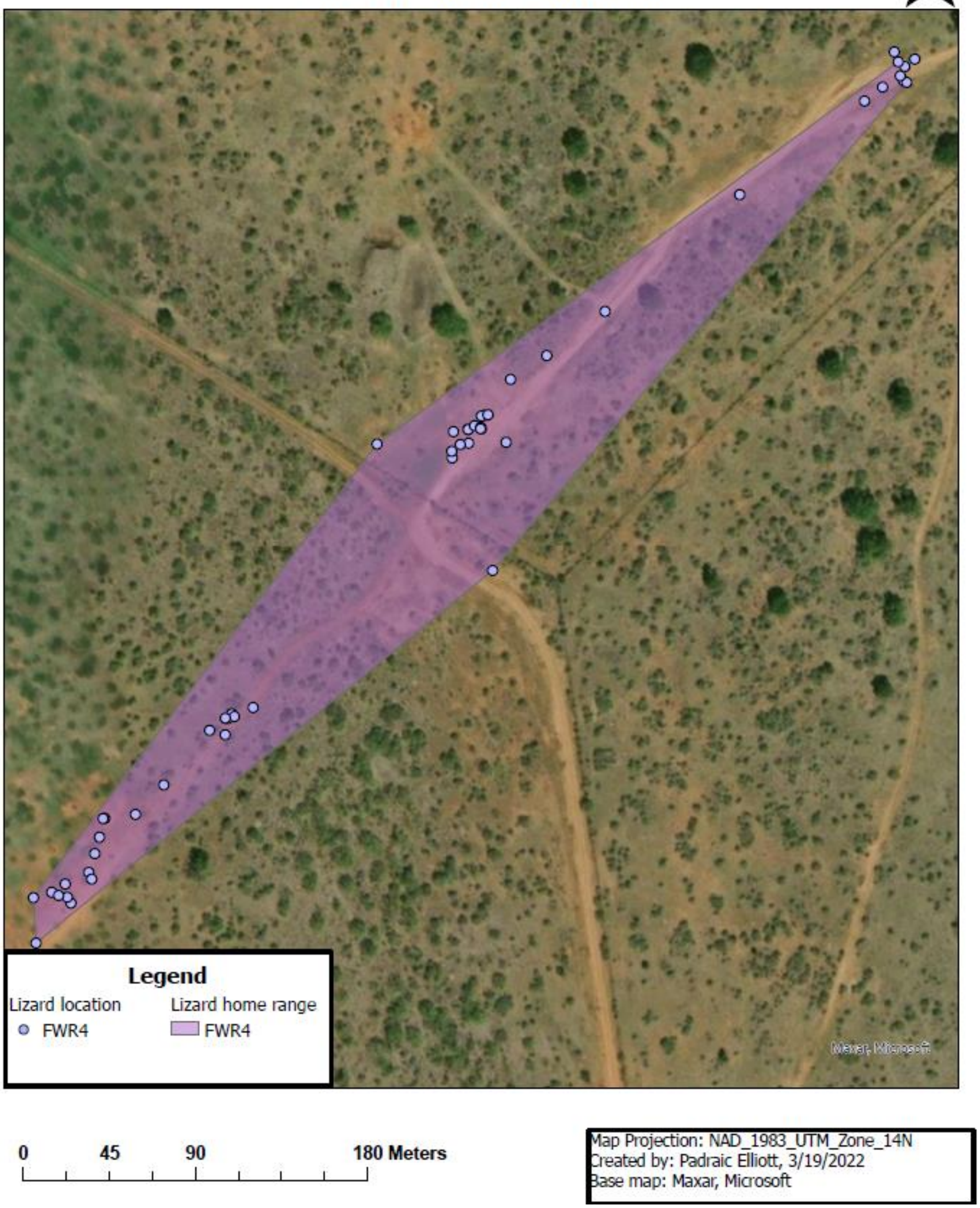
Appendices

Appendix I: Home range sizes (95% Minimum convex polygons) and relocation points for lizards tracked more than 10 times at the White Ranch. General location obscured to protect privacy of owners. N = 6 lizards

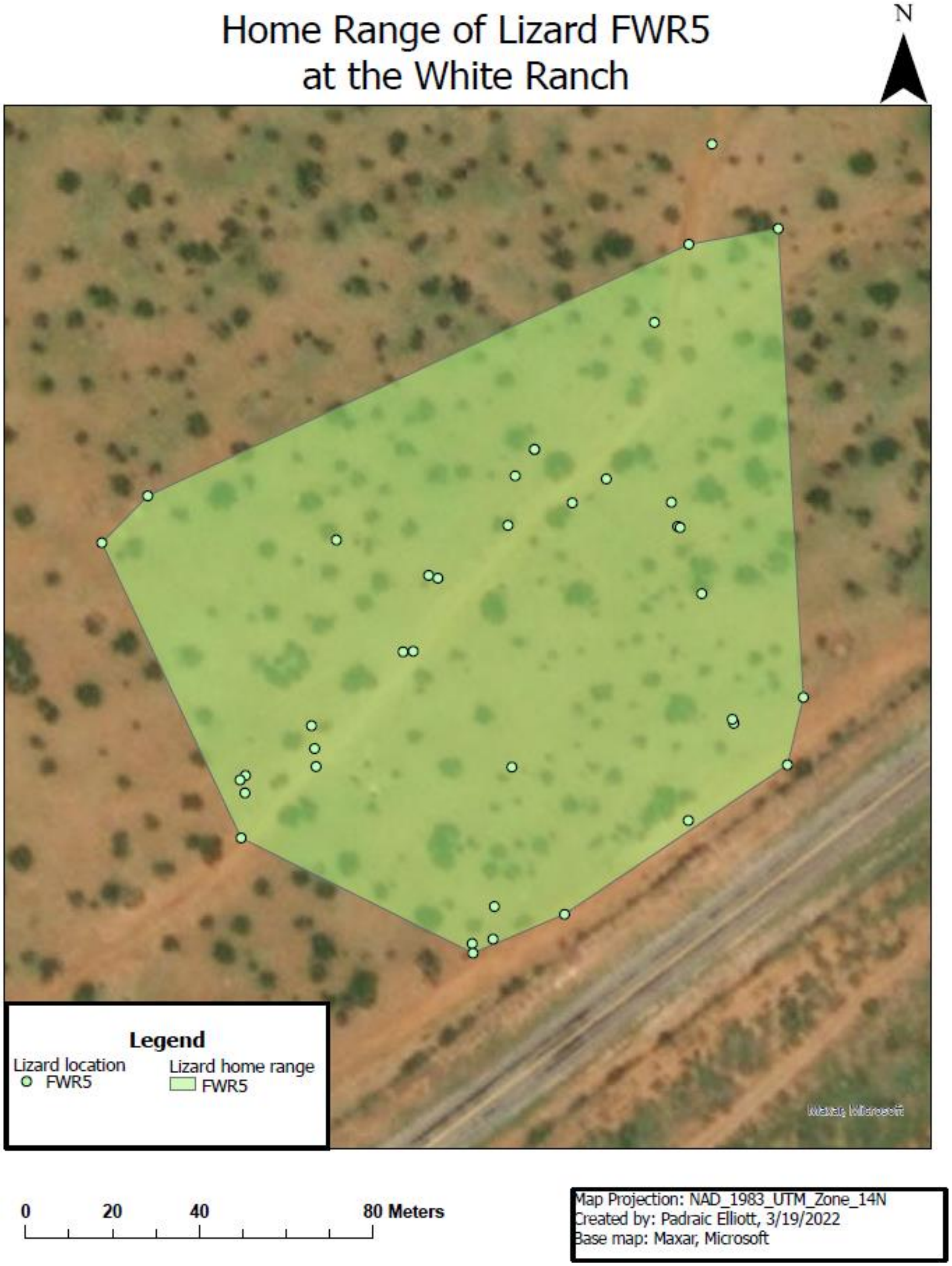


Home Range of Lizard FWR4
at the White Ranch

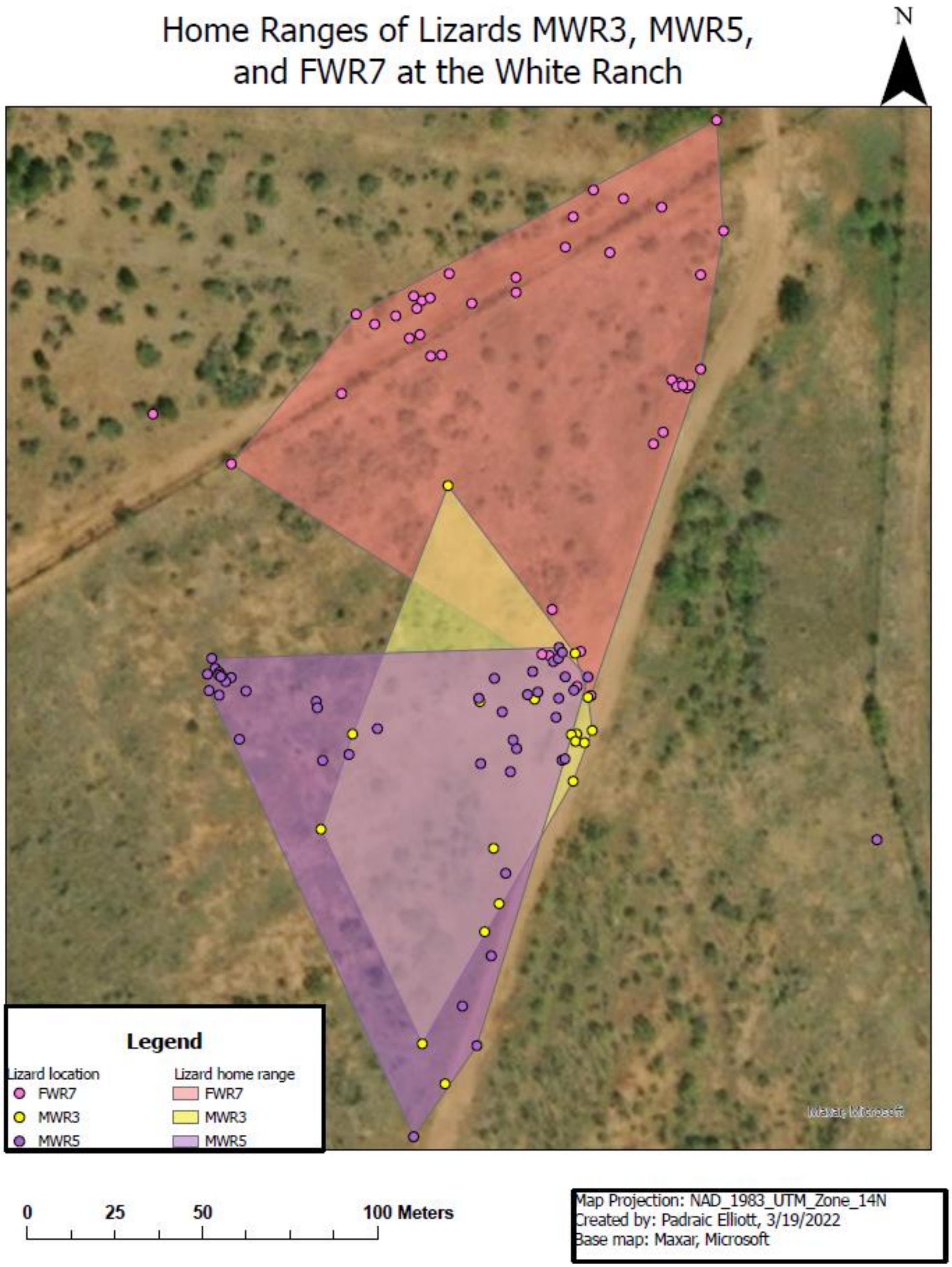
N



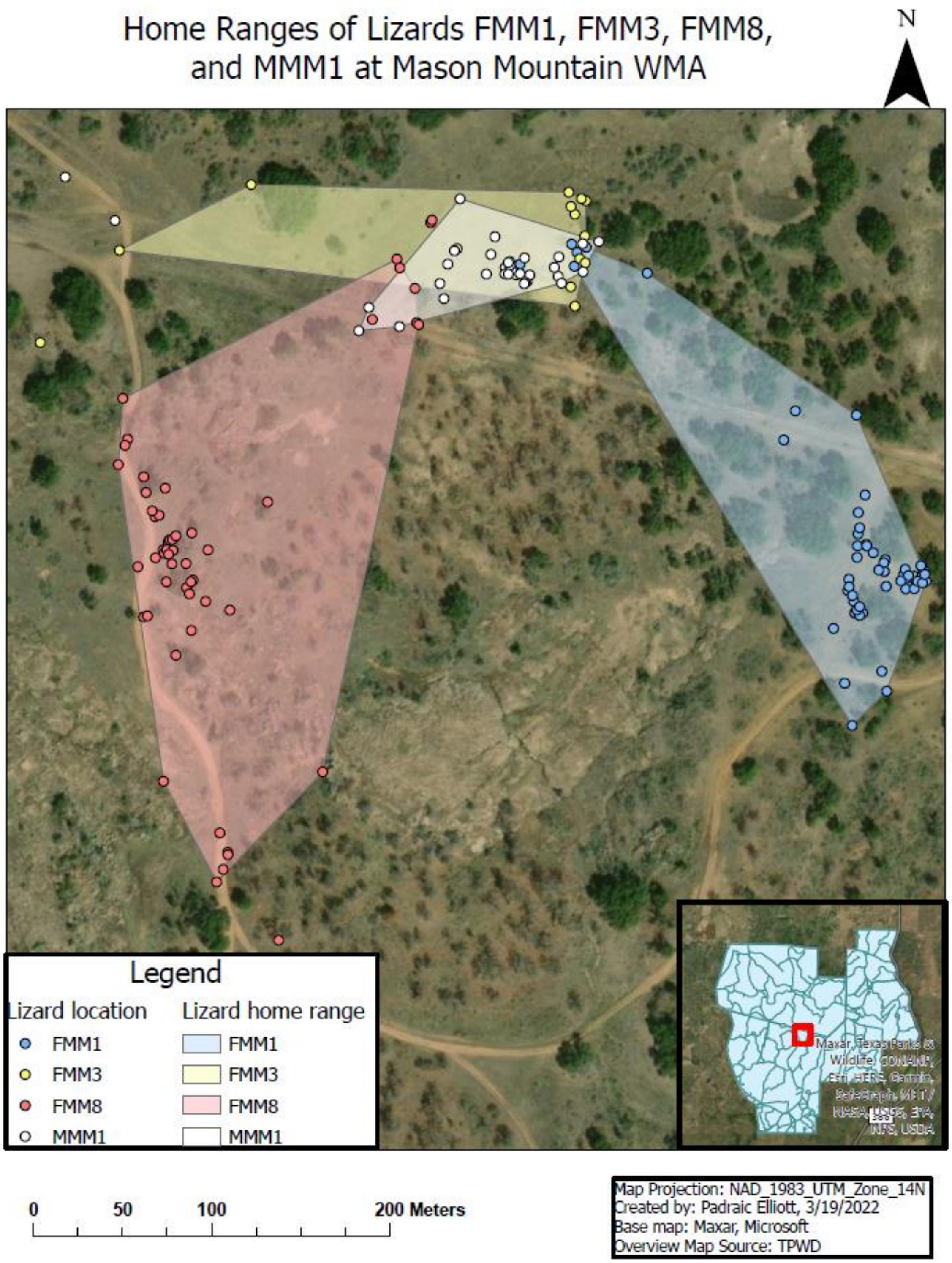
Home Range of Lizard FWR5
at the White Ranch



Home Ranges of Lizards MWR3, MWR5, and FWR7 at the White Ranch



Appendix II: Home range sizes (95% minimum convex polygons) and relocation points for lizards tracked more than 10 times at Mason Mountain Wildlife Management Areas. N= 4 lizards



Appendix III: Generalized linear model (GLM) selection for pooled Texas horned lizard's microhabitat selection for Texas horned lizards from June to August 2021 using bias-corrected Akaike's information criterion (AICc). k represents the number of parameters in the model.

Model	k	AICc	ΔAICc
Selection ~ ID	2	844.1143	42.4223
Selection ~ ID + Compaction + Forbs + Grass + Litter + Soil + Woody	8	804.272	2.58
Selection ~ ID + Compaction + Grass + Litter + Soil + Woody	7	802.2213	0.5293
Selection ~ ID + Compaction + Grass + Litter + Woody	6	801.692	0
Selection ~ ID + Compaction + Grass + Woody	5	803.1283	1.4363

Appendix IV: Generalized linear model (GLM) selection for Texas horned lizard's microhabitat selection within MMWMA from June to August 2021 using bias-corrected Akaike's information criterion (AICc). k is the number of parameters in the model.

Model	k	AICc	ΔAICc
Selection ~ ID	2	288.2449	4.9148
Selection ~ ID + Compaction + Grass + Litter + Soil + Woody	7	286.2678	2.9377
Selection ~ ID + Compaction + Grass + Soil + Woody	6	284.5109	1.1808
Selection ~ ID + Compaction + Soil + Woody	5	283.3301	0
Selection ~ ID + Compaction + Woody	4	283.6655	0.3354

Appendix V: Generalized linear model (GLM) selection for Texas horned lizard's microhabitat selection within WR from June to August 2021 using bias-corrected Akaike's information criterion (AICc). k is the number of parameters in the model.

Model	k	AICc	ΔAICc
Selection ~ ID	2	559.9317	53.3417
Selection~ Lizard ID + Compaction + Grass + Forbs + Litter + Woody + Cow	8	508.5038	1.9138
Selection~ Lizard ID + Compaction + Grass + Litter + Woody + Cow	7	506.59	0
Selection~ Lizard ID + Grass + Litter + Woody + Cow	6	506.6575	0.0675
Selection~ Lizard ID + Grass + Litter + Woody	5	507.865	1.275
Selection~ Lizard ID + Grass + Forbs	4	514.3034	7.7134
Selection~ Lizard ID + Compaction + Forbs + Litter + Soil + Woody + Cow	8	508.466	1.876
Selection~ Lizard ID + Forbs + Litter + Soil + Woody + Cow	7	508.2325	1.6425
Selection~ Lizard ID + Litter + Soil + Woody + Cow	6	511.5593	4.9693
Selection~ Lizard ID + Litter + Forbs + Soil	5	516.2135	9.6235
Selection~ Lizard ID + Litter + Forbs	4	537.687	31.097

Appendix IV: Generalized linear mixed effects model (GLM) selection for Texas horned lizard's microhabitat selection during the evening compared to morning and afternoon using bias-corrected Akaike's information criterion (AICc). Data taken from June to August 2021. k is the number of parameters in the model.

Model	k	AICc	ΔAICc
Selection ~ ID	2	370.947	9.08
Selection ~ ID + Compaction + Forbs + Grass + Litter + Soil + Woody	8	369.263	7.39
Selection ~ ID + Compaction + Forbs + Litter + Soil + Woody	6	365.637	3.77
Selection ~ ID + Compaction + Forbs + Litter + Woody	5	363.629	1.76
Selection ~ ID + Forbs + Woody	4	361.87	0.00
Selection ~ ID + Woody	3	364.668	2.80

Appendix VII: Generalized linear mixed effects model (GLM) selection for Texas horned lizard microhabitat selection during the afternoon compared to morning and evening using bias-corrected Akaike's information criterion (AICc). Data taken between June and August 2021. k is the number of parameters in the model.

Model	K	AICc	ΔAICc
Selection ~ ID	2	396.33	0.00
Selection ~ ID + Compaction + Forbs + Grass + Litter + Soil + Woody	8	404.08	7.75
Selection ~ ID + Forbs + Grass + Litter + Soil + Woody	6	403.38	7.05
Selection ~ ID + Grass + Litter + Soil + Woody	5	401.75	5.42
Selection ~ ID + Grass + Soil + Woody	4	399.97	3.64
Selection ~ ID + Grass + Woody	3	398.29	1.96

Appendix VIII: Generalized linear mixed effects model (GLM) selection for Texas horned lizard microhabitat selection during the morning compared to afternoon and evening bias-corrected Akaike's information criterion (AICc). Data taken between June and August 2021. k is the number of parameters in the model.

Model	K	AICc	ΔAICc
Selection ~ ID	2	398.7519	7.42
Selection ~ ID + Compaction + Forbs + Grass + Litter + Soil + Woody	8	396.9249	5.60
Selection ~ ID + Compaction + Forbs + Grass + Litter + Soil	7	394.8502	3.52
Selection ~ ID + Compaction + Grass + Litter + Soil	6	392.847	1.52
Selection ~ ID + Grass + Litter + Soil	5	392.0538	0.72
Selection ~ ID + Grass + Soil	4	391.3289	0.00

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Vita

Personal Background

Padraic James Elliott
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Education History

Diploma, Florida State University Schools, Tallahassee, Florida. 2013

Bachelor of Science, Biological Science, Florida State University, Tallahassee, Florida, 2017

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Experience

Texas Christian University, Fort Worth, TX. Graduate Teaching Assistantship
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St. Marks NWR, *US Fish and Wildlife*, St. Marks, FL. Fire Technician
Dec 2017-Present

The Orianne Society, Lumber City, GA. Land Management Technician
Jan 2020-Jul 2020

Joseph Jones Ecological Research Center, Newton, GA. Plant Technician
Jul 2019-Nov 2019

Oklahoma State University, Stillwater, OK. Bobwhite Technician
Feb 2019-Jul 2019

Tall Timbers Research Station, Tallahassee, FL. Bobwhite Technician
May 2018-Aug 2018

Robert K. Godfrey Herbarium, *Florida State University*, Tallahassee, FL. Intern
Oct 2016-May 2018

Philmont Scout Ranch, *Boy Scouts of America*, Cimarron, NM, Trail Crew Foreman
May 2016-Aug 2016

Philmont Scout Ranch, *Boy Scouts of America*, Cimarron, NM, Conservationist
May 2014-Aug 2014

Professional Memberships

Magnolia Chapter of the Florida Native Plant Society, 2017-Present

Coastal Plains Institute, 2018-Present

Herpetologist League, 2021-Present

Society for the Study of Amphibians and Reptiles, 2021-Present

Horned Lizard Conservation Society, 2021-Present

Abstract

MICROHABITAT USE AND RANGE SIZE OF NATIVE AND REINTRODUCED POPULATIONS OF TEXAS HORNED LIZARDS (*PHRYNOSOMA CORNUTUM*)

By Padraic James Elliott M.S., 2022
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Texas horned lizards (*Phrynosoma cornutum*) have declined throughout much their range. Although multiple private and state institutions have made reintroducing this species to restored habitat a high priority, previous efforts have been met with low success and the reasons for outcomes were unknown. The purpose of this study was to compare microhabitat use between reintroduced lizards and a natural population. For three months, I tracked eighteen lizards daily and quantified microhabitat features such as vegetation cover and soil compaction at lizard locations and random points. I compared these data within and between populations to determine if lizards were using microhabitats non-randomly and if they differed in their habitat utilization. Native and reintroduced Texas horned lizards had similar home ranges and daily movement lengths. Microhabitat use differed by time of day and by location. Management for reintroductions should include prescribed burns and increasing the size of the reintroduction site that is managed for this species.