THERMAL ECOLOGY OF REINTRODUCED AND NATIVE TEXAS HORNED LIZARDS (*PHRYNOSOMA CORNUTUM*)

by

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INTRODUCTION

Reintroductions are used to bolster wild populations of threatened species by placing captive bred individuals into their historic range or translocating individuals from one wild population to another (Santos et al., 2009). A major component of reintroduction success is habitat quality and suitable resource availability (Neuwald & Templeton, 2013; Mccoy et al., 2014; Miller et al., 2020;). Quality habitat will provide the basic needs for survival for an organism such as food, water, shelter from predators and the elements, etc. (Forsman et al., 2008). For ectotherms, an important resource contributing to habitat quality is suitable thermal habitat because of their dependence on the temperature of their environment to regulate their own body temperature (Neuwald & Templeton, 2013; Taylor et al., 2021). This means that environmental temperatures affect most aspects of the daily lives of these organisms from movement to metabolism (Taylor et al., 2021). Other studies looking at ectotherm reintroductions noted that higher quality habitat consisting of both high thermal quality and food availability greatly increased the reintroduction success at those sites(Santos et al., 2009). This is because the importance of thermal habitat quality is of greatest consequence when it forces a balance between maximizing time in habitats that meet thermoregulatory needs and habitats that are best for requirements such food acquisition and avoiding predators (Huey, 1991). Ideally, quality habitat would allow for an ectotherm to meet their thermoregulatory requirements while being in habitat that meets food and other resource requirements (Blouin-Demers & Weatherhead, 2002). Therefore, while an ectotherm may be able to maintain an optimal body temperature through a variety of means such as behavior and morphology, thermal regimes in different locals will affect what habitats are suitable for an organism and where it can occur (Grbac & Bauwens, 2001).

Thermal ecology studies of wildlife have increased in recent decades as the biodiversity crisis and climate change have been more thoroughly linked (Taylor et al., 2021). Due to their reliance on environmental temperatures, amphibians and reptiles are often used as model organisms for studies of thermal ecology and environmental quality (Taylor et al., 2021). The acceleration of research in this field of ecology has led to a standardization of indices and best practices, many of which are relevant to this study. To understand thermal ecology and thermal habitat, it is important to understand the preferred body temperature of the organism in question (T_{sel}; Table 1), as this is often where the physiological processes of the organism are most efficient (Brewster et al., 2020; Huey, 1991). This preferred body temperature, measured in laboratory conditions, is often compared to field body temperatures (T_{b}; Table 1). This is measured in the field to see how closely individuals can get to their preferred body temperature in their habitat. Microhabitats are often analyzed using models to record environmental temperatures (T_e; Table 1) to see how they compare to preferred body temperature of an organism (Taylor et al., 2021). This comparison tells us the thermal quality (d_e; Table 1) of a given habitat.

Table 1: Metrics and indices of thermal ecology (Hertz et al., 1993).

Index	Definition
T_{sel}	Preferred body temperature: central 50% of body temperatures measured in thermal gradient.
T_e	Operative environmental temperature, measured by models in microhabitats.
d_e	Thermal quality of habitat, measured as mean absolute deviation of T_e from T_{sel}.
T_b	Field active cloacal temperature.

The Texas horned lizard (*Phrynosoma cornutum*) has a high preferred body temperature of 34.2 - 38.5 ^{o}C and a high upper critical temperature (CT_{max}), the temperature at which they lose the ability to move, of 45.9 - 48.1 ^{o}C compared to sympatric species of lizards (Prieto & Whitford, 1971; Pianka & Parker, 1975; Lara-Reséndiz et al., 2015). This allows them to be active over longer periods of time(Pianka & Parker, 1975). These high temperature tolerances allow them to be well adapted to semi-arid regions with mixed ground cover, where they can remain in direct sun exposure for extended periods of time eating ants (Pianka & Parker, 1975; Guyer & Linder, 1985).

The Texas horned lizard is declining across its historic range in the state of Texas, resulting in it being listed as a threatened species in the state (Texas Conservation Action Plan - TCAP 2012). This is due to a variety of factors including habitat loss due to urbanization and agriculture, the population decline of their preferred prey harvester ants (*Pogonomyrmex spp*.), introduction of the red imported fire ant (*Solenopsis invicta*), and the pet trade (Dixon, 1993; Donaldson et al., 1994; Henke, 2003). This has resulted in increased efforts by Texas Parks and Wildlife, universities, and zoos from around Texas to try and save this iconic Texas reptile. These efforts include reintroducing lizards into areas where Texas horned lizards disappeared and where the habitat has been restored to a more natural state through the reduction of overgrazing and prescribed burns. Texas Parks and Wildlife, the Fort Worth and Dallas Zoos have been conducting reintroduction experiments at Mason Mountain Wildlife Management Area since 2015. So far, success has been minimal, although in 2022 there was evidence of breeding by several individuals that were introduced as hatchlings in previous years (Alenius pers. comm.).

The aim of this study was to assess the thermal habitat quality at the Mason Mountain Wildlife Management Area reintroduction site and a nearby site with a natural population of Texas horned lizards. By measuring the temperatures of lizards and using model lizards to record environmental temperatures, we calculated thermal indices to assess thermal habitat quality and differences between the two sites. If the reintroduction site has lower thermal quality than the site with a natural population of horned lizards, then it may be possible to manage the habitat to make it more favorable for reintroductions.

METHODS

Study Site

This study was conducted at two locations in Mason County, Texas. One location was at Mason Mountain Wildlife Management Area (MM) which is operated by Texas Parks and Wildlife (TPW) and has been the site of previous reintroduction attempts and research on Texas horned lizards (Fink, 2017; Alenius, 2020). The other location was at the White Ranch (WR) which is a private ranch ~32km to the southwest of MM. MM consists of 2,146 ha and was a private exotic game ranch before being acquired by TPW in 1997. TPW now uses it for the management and research of native and exotic wildlife with several species of exotic ungulates remaining on the property (Fink, 2017). MM is characterized by hills with granite and limestone outcrops, and soils ranging from clay loams to sand and gravel (Singhurst et al., 2007). Vegetative cover at MM consists of various grass species (*Bothriochloa ischaemum* and *Bothriochloa laguroides*) with shrubs (*Prosopis*) and trees (*Quercus virginiana*) throughout with some areas of exposed bare ground creating a mix of oak woodlands and savannas (Singhurst et al., 2007). The other site, WR, currently has a naturally occurring population of Texas horned lizards. Historically, the property was subjected to heavy grazing by cattle that eventually led to overgrazing. In recent years the ranch has shifted towards ecotourism and habitat management with minimal cattle grazing. Past grazing has led to compact soils and a more heterogeneous landscape in terms of vegetative cover with areas covered by interspersed grass (*Bothriochloa ischaemum* and *Bothriochloa laguroides*) and bare ground. Dominant vegetation types include savannas, oak/juniper, and mesquite. Both sites occur in the Llano Uplift ecoregion of Texas (Singhurst et al., 2007).

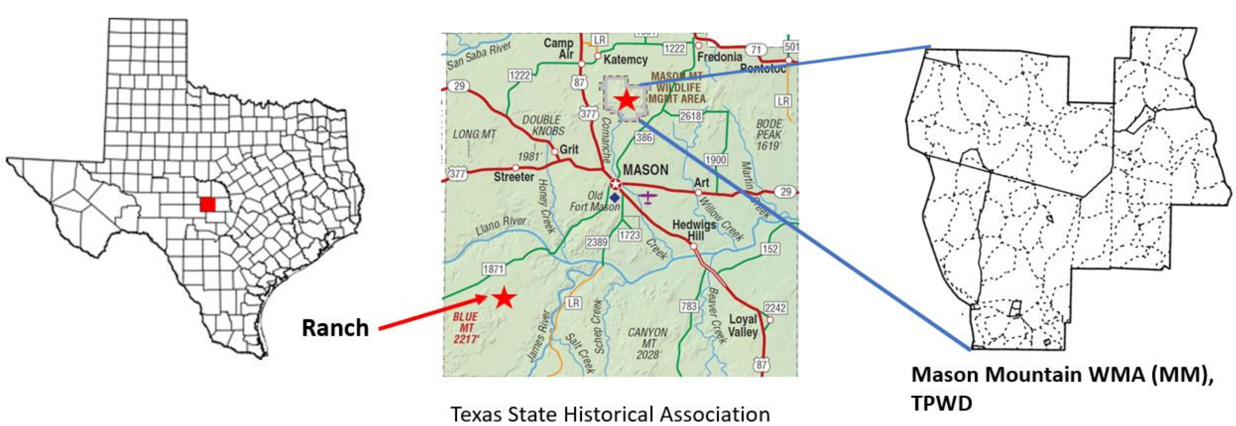


Figure 1: Map of Texas showing the location of Mason County and the locations of MM and WR.

Fieldwork

Texas horned lizards were captured by hand using a combination of walking and driving visual surveys, as well as captured opportunistically in the field. Upon capture, each lizard was weighed in grams (g) and snout to vent length (SVL) was measured in millimeters (mm) to obtain a body condition score by dividing the SVL by the weight of the lizard(Sion et al., 2021). Each lizard was examined to determine sex (M/F), age (juvenile or adult), and had a picture taken of its belly to identify individual lizards (Williams pers comm.). A DNA sample was obtained by swabbing the cloaca with a small Puritan® cotton-tipped applicator (Williams et al., 2012). Lizards that weighed between 10 and 20 g were given a 0.5-gram BD2 radio (Holohil Systems Inc.). Individuals that weighed over 20 g were attached a BD2 radio weighing 1.4-grams (Holohil Systems Ltd). At the end of the field season, the transmitters were removed and their morphometrics were remeasured. Radios were attached to each lizard using Mega Pro-Bonding Glue (JB Cosmetics Group) and were secondarily secured via a collar that was looped around the neck made of fishing line contained within intravenous tubing. Following ecdysis (shedding of the old skin in reptiles) or before the radios failed, the radios were reglued to the lizard.

Figure 2: Female Texas horned lizard affixed with radio-transmitter.

Lizards were tracked daily (weather permitting) using a handheld R-1000 telemetry and R-150 receiver and a yagi directional antenna (Communication Specialists Inc.). The lizards were located once a day at one of three different time periods classified as morning (700-1000), afternoon (1100-1500), and evening (1700-2000) corresponding with their hours of daytime activity (Moeller et al., 2005). We made sure to rotate what time of day the lizards were found to ensure that we obtained data from the three time periods for each lizard. For each lizard, GPS coordinates were taken and an Etekcity Lasergrip 774 infrared thermometer was used to obtain the temperature of the ground at the location of the lizard and at a random point ~10 meters (m) away to evaluate thermal habitat selection (Aarts et al., 2008). The direction of the random point from the location of the lizard was generated using a random number generator app to provide a compass bearing (Pretty Random – RNG). The infrared thermometer was also used to record the outside body temperature of a lizard. All infrared thermometer temperatures were taken ~30 cm away from the target for standardized readings. I then used a small temperature probe connected to a digital thermometer; (GDEALER Model DT8, accuracy ± 1 ^{o}C, resolution ± 0.1 ^{o}C) to take the lizard's cloacal temperature within 30 seconds of capture. All lizard data was entered and stored in the app ArcGIS Collector. ®

Figure 3: Left) Horned lizard model equipped with a DS1922L Thermochron™ temperature logger embedded in the belly area and secured with black self-fusing repair tape in open ground. Right) Model with temperature logger to approximate T_e available to lizards (Photos by MR Tucker).

A total of 24 3D printed horned lizard models equipped with DS1922L Thermochron™ temperature loggers were deployed between MM and WR with 12 models at each site (WR lost one model before any data could be collected). Models were deployed from June 22-July 6, 2021, July 8-21, 2021, and July 25-August 7, 2021. To record temperatures across the different microhabitats that horned lizards utilize, models were placed on open ground, under vegetation (cover), and buried ~2cm under the soil (Dzialowski, 2005). The models were programmed to take a temperature recording every 10 minutes (Lara-Reséndiz et al., 2015). I placed the models within the home ranges of the monitored Texas horned lizards. A previous study found a significant linear relationship (R^2 = 0.89, P = 0.02) between model temperatures and cloacal temperatures of the lizards, that did not differ from a slope of 1 (Tucker, 2021).

Thermal Indices and Statistical Analysis

Thermal indices such as T_{sel}, are typically determined in a laboratory thermal gradient. We utilized the results from a study going on at the same time in the towns of Kenedy and Karnes City, Texas (Taylor et al., 2021; Tucker, 2021). T_{sel} is the preferred body temperature of an individual lizard and is calculated from the average T_{sel} values from all the individual lizards in a laboratory study. T_{sel25} and T_{sel75} refer to the T_{sel} range and represent the 25th and 75th percentiles respectively. T_{sel}, T_{sel25}, and T_{sel75} from Tucker (2021) was similar to the results of two other studies of Texas horned lizards in different areas (Table 2). Models placed in different microhabitats throughout the study sites were used to record T_e data. Thermal quality (d_e) was calculated by using the following equations: if $T_e < T_{sel}$, then $d_e = T_e - T_{sel25}$, and if $T_e > T_{sel}$ then $d_e = T_e - T_{sel75}$,. If the T_e values were within the T_{sel} range, d_e was equal to zero.

Table 2: Preferred body temperatures (T_{sel}) of Texas horned lizards and T_{sel} range (25 and 75 quartiles) in ˚C. Mean ± standard error reported for T_{sel} from two other studies on Texas horned lizards done in different areas. ND means standard error was not determined.

N	T_{sel}	T_{sel25}	T_{sel75}	References
10	38.5 ± ND	37.5	39	Prieto & Whitford, 1971 - Central New Mexico
97	34.2 ± 0.1	32.5	36	Lemos-Espinal and Smith 2009; Lara-Reséndiz et al., 2015 - Chihuahuan Desert, Mexico
19	35.7 ± 0.3	33.5	38.5	Tucker, 2021 - Kenedy and Karnes City, Texas (used in this study)

Home ranges were calculated using 95% minimum convex polygons (MCPs) using the package “adehabitatHR” in the program R v.4.0.0 (Calenge, 2006). Only lizards with 20+ relocations were utilized in home range analysis. A two-sample independent T-Test was done to compare differences in home range size between MM and WR. A Shapiro-Wilks test was done on the data to test for the assumption of normality. To test the assumption of equal variance between groups, a Bartlett's Test was performed. All home range data analysis was done in the program R v.4.0.0.

Regression analysis was done using Minitab® Version 19 for the surface temperatures of the lizards vs the field cloacal temperatures of the lizards (T_b), T_b vs the ground temperature at the location of the lizard, and the ground temperature at the location of the lizard vs the surface temperature of the lizard. For linear regressions, a student's T-Test was performed to see if the slope was significantly different than one. A general linear mixed model (GLMM) was done in Minitab® Version 19 to look at the impact of time of day, microhabitat, and site on body temperature, and were followed with a Tukey-Kramer post hoc test to see what time of day specifically had a significant impact on body temperature. Individual ID was set as the random variable with the fixed variables being the time of day when the measurement was taken, the microhabitat the lizard was found in, site (MM or WR), and the interaction of time of day and microhabitat. I ran a binomial general linear mixed model (GLMM) between lizard location and the random location, in Program R (v. 4.1.2, The R Foundation) to ask whether Texas horned lizards were associated with ground temperatures that differed from random. Multiple packages were used including lme4, Matrix, and MuMIN. Lizard ID was a random factor, and site, time of day, and ground temperature were fixed effects.

Comparisons between sites, microhabitats, temperature datalogger data, and indices were done in program R v.4.0.0 and Minitab® Version 19. The assumptions of normality and equal variance were tested using a Shapiro-Wilks Test and F-Test respectively. If these assumptions weren't met, an independent 2-group Mann-Whitney U-Test was performed. To assess differences across microhabitats for time spent in optimal and critical ranges, a one-way ANOVA Test was performed.

RESULTS

Home Ranges

A total of 8 lizards were used in home range analysis (MM = 3, WR = 5). Overall, the average home range size for the lizards using 95% MCPs was 1.27 ± 0.88 ha and there was no significant difference in home range size between the two sites (Fig. 4; $t = 0.32$, $p = 0.76$).

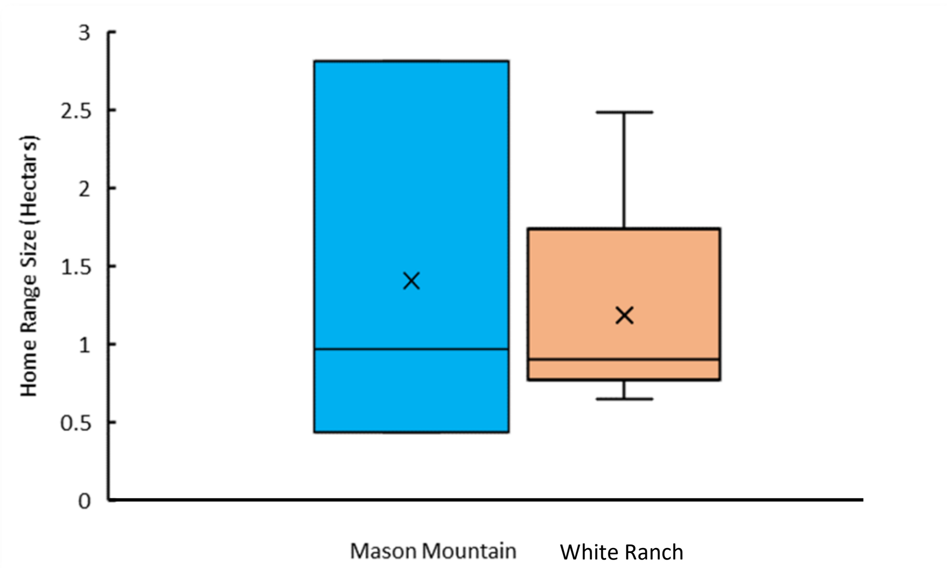


Figure 4: Box plot showing difference in home range areas for the Texas horned lizards between MM and WR calculated using 95% MCPs.

Regression Analysis

The field cloacal (internal) temperature of the lizard and the surface temperature of the lizard obtained by the infrared thermometer had a strong positive relationship ($y = 0.99x + 0.58$, $R^2 = 0.92$, $p < 2.16e\text{-}16$, N = 18 lizards; Fig. 5A) and the slope was not significantly different from 1.0. There was also a strong nonlinear relationship between the field cloacal (internal) temperature of the lizard and the ground temperature at the location of the lizard obtained by the infrared thermometer ($y = 0.03x^2 + 2.64x – 23.66$, $R^2 = 0.86$, $p < 2.16e\text{-}16$, N = 18 lizards; Fig.

5B). Finally, there was a strong nonlinear relationship between the surface temperature of the lizard obtained by the infrared thermometer and the ground temperature at the location of the lizard obtained by the infrared thermometer ($y = 0.03x^2 + 2.57x – 22.72$, $R^2 = 0.86$, $p < 2.16e-16$, N = 18 lizards; Fig. 5C). To account for resampling of individual lizards, these same regresions were done on each lizard individually and the results were similar to what we found with all of the points together (all p-values < 0.05 and all R^2 values between 76.4 – 98.1).

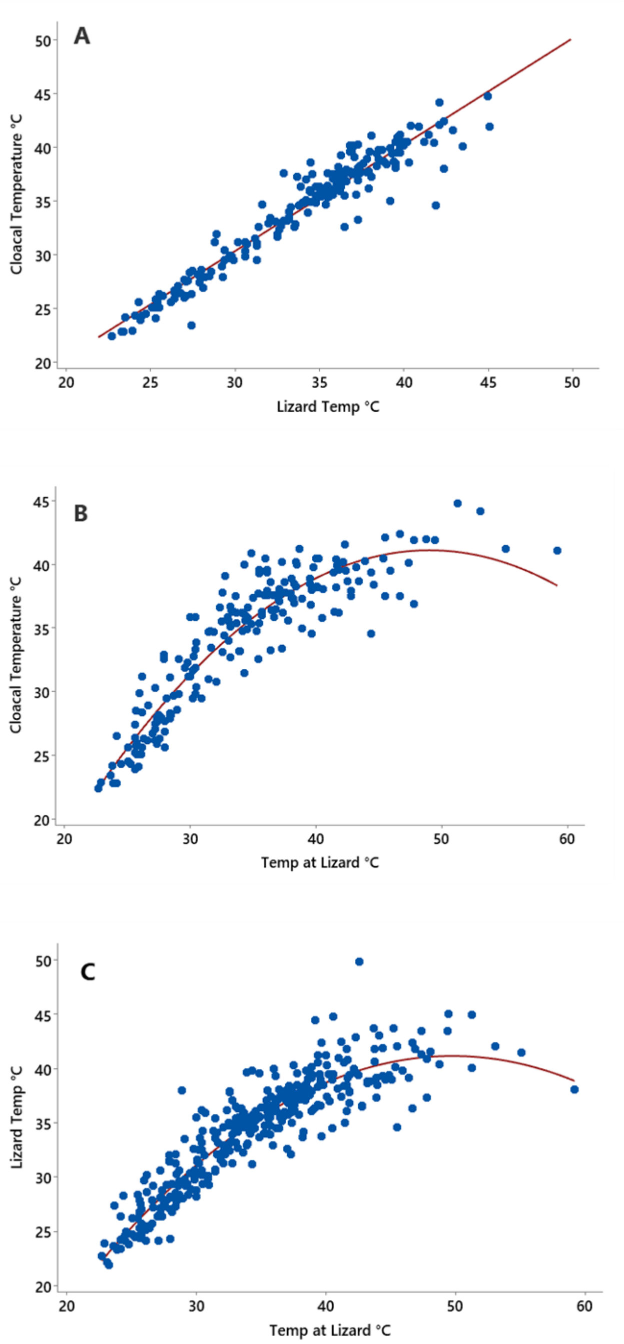


Figure 5: Relationships between lizard temperatures and ground temperature. A) The relationship between the field cloacal (internal) temperature of the lizard and the surface temperature of the lizard obtained by the infrared thermometer. B) The relationship between the field cloacal (internal) temperature of the lizard and the ground temperature at the location of the lizard obtained by the infrared thermometer. C) The relationship between the surface temperature of the lizard obtained by the infrared thermometer and the ground temperature at the location of the lizard obtained by the infrared thermometer.

Lizard Thermal Data

Table 3: Results from a binomial GLMM to show how ground temperature impacted probability of selection for a location on the ground by a Texas horned lizard.

Selection Category	Estimate	Std. Error	z - value	p - value
(Intercept)	-4.32393	0.87484	-4.943	7.71E-07
Evening Selection	1.51309	1.24409	1.216	0.223903
Morning Selection	4.53297	1.2213	3.712	**0.000206**
Temperatures	0.10382	0.02086	4.976	**6.48E-07**
Evening Selection*Temperature	-0.02882	0.03143	-0.917	0.35915
Morning Selection*Temperature	-0.11106	0.03588	-3.095	**0.001967**

Table 4: Analysis of variance from a GLMM looking at the impact of different variables on T_b.

Source	DF	Adj SS	Adj MS	F	P
Lizard ID	13	344.15	26.47	1.78	0.05
Time of Day	2	458.59	229.30	14.76	**0.000001**
Microhabitat	2	35.29	17.64	1.14	0.32
Study Site	1	51.99	51.99	3.35	0.07
Time of Day*Microhabitat	4	125.26	31.31	2.02	0.09

Table 5: Analysis of variance from a GLMM looking at the impact of different variables on body surface temperature using the temperature gun.

Source	DF	Adj SS	Adj MS	F	P
Lizard ID	13	479.7	36.90	2.86	**0.001**
Time of Day	2	1304.5	652.27	50.63	**< 0.01**
Microhabitat	2	111.8	55.90	4.34	**0.01**
Time of Day*Microhabitat	4	104.1	26.01	2.02	**0.01**

The plots lizards were found in differed in their ground temperature compared to random plots, especially in the morning (Table 3). In the morning, lizards were found in plots with higher ground temperatures. Cloacal temperature only varied significantly with time of day with morning temperatures being significantly lower from afternoon and evening temperatures (Appendix 2; Tukey $F = 73.48$, $p < 0.01$). There was a trend for the two study sites to be different (P = 0.07) with higher Tb at the WR (Table 4). Body surface temperature varied significantly with time of day, microhabitat and an interaction between time of day and microhabitat (Table 5, Appendix 3). Lizards in the open habitat were warmer in the morning than covered or buried habitats and then as the day progressed lizards in both open and covered habitats had higher temperatures than buried lizards.

Lizard Thermal Microhabitat Selection

We found no significant difference between sites in microhabitat use (p = 0.40). Covered and open microhabitats were used more than buried ones (F = 28.46, p < 0.01).Only covered microhabitats were more often in the optimal temperature range than the critical range (Fig. 6; n = 14 lizards, t = 3.29, p = 0.006).

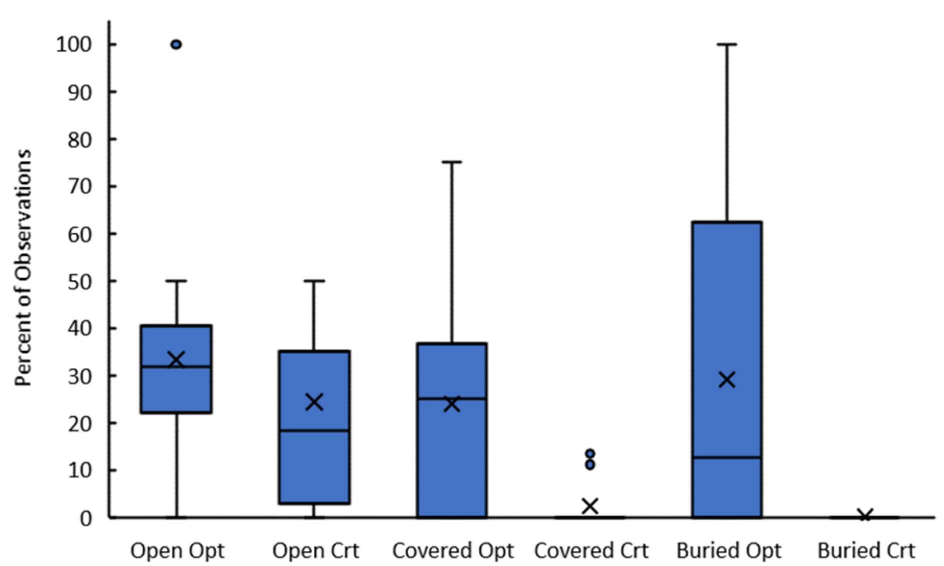


Figure 6: Boxplots of percent of time microhabtats lizards were found in were in the optimal or critical range. Optimal and Critical are refered to as ‘Opt’ and ‘Crt’.

Thermal Microhabitats (T_e)

Environmental temperatures (T_e) did not differ between the sites for any of the microhabitats (P >0.10 for all comparisons). Overall, T_e was in the critical temperature range more than it was in the optimal temperature range for Texas horned lizards in open microhabitats (n = 8 dataloggers, F = 11.08, p = 0.001), and buried ones (n = 7 dataloggers, F = 11.08, p = 0.001). Covered microhabitats were in the optimal range more often than the critical range for Texas horned lizards (n = 7 dataloggers, F = 11.08, p = 0.001). There was a significant difference beween microhabitats in the amount of time each microhabitat was in the optimal range with covered being in the optimal range the most, followed by buried, then open microhabitats (Fig 7; n = 22 dataloggers, H = 14.26, p = 0.001). There was also a significant difference beween microhabitats in the amount of time each microhabitat was in the critical range, with open being in that range the most, followed by buried, then covered microhabitats (Fig. 7, 8; n = 22 dataloggers, H = 11.96, p = 0.003). Covered microhabitats at WR were in the optimal range more than the covered microhabitats at MM during the afternoon period (Fig. 8; T = 4.62, p = 0.00005).

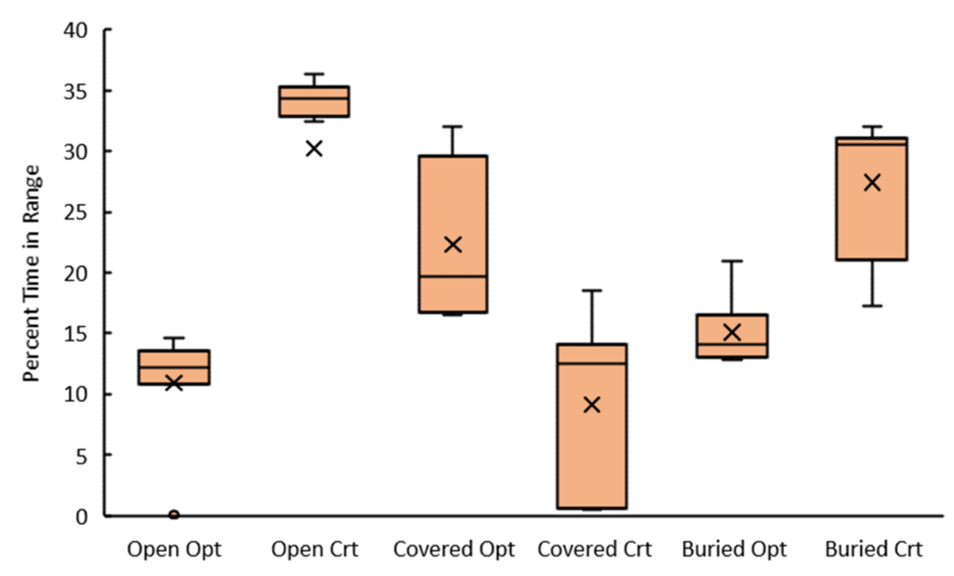


Figure 7: Boxplots for percent of time models in different microhabitats were in the optimal or critical range. Optimal and Critical are refered to as ‘Opt’ and ‘Crt’.

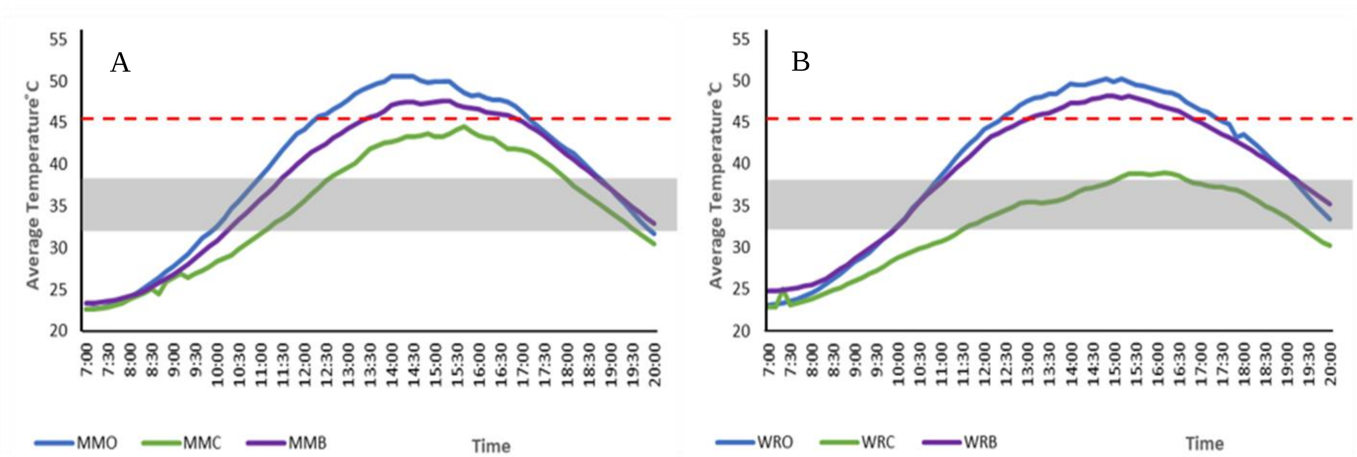


Figure 8: Average temperture from dataloggers in different microhabitats across different times of the day. A) Average temperatures over time at MM. B) Average temperatures over time at WR. Open microhabitats are MMO and WRO, covered microhabitats are MMC and WRC, and buried microhabitats are MMB and WRB. The red line represents the lower end of the critical temperature range and the grey box represents the optimal temperature range.

Habitat Thermal Quality

Thermal habitat quality (d_e) (n = 12 occurences for open, n = 12 occurences for covered, and n = 3 occurences for buried) didn’t differ significantly between sites (Table 6, W = 137.00, p

= 0.51). Thermal habitat quality (de) did differ significantly between the three microhabitats (F = 25.67, p < 0.01). Cover had the highest thermal quality while open and dirt microhabitats had the lowest thermal quality (Table 6, Fig. 9).

Table 6: Average thermal quality scores (d_e) ± standard error, across the two study sites and microhabitats.

Study Site	d_e
MM	6.84 ± 0.43
WR	6.36 ± 0.33
Open	7.99 ± 0.19
Covered	4.94 ± 0.35
Buried	6.67 ± 0.38

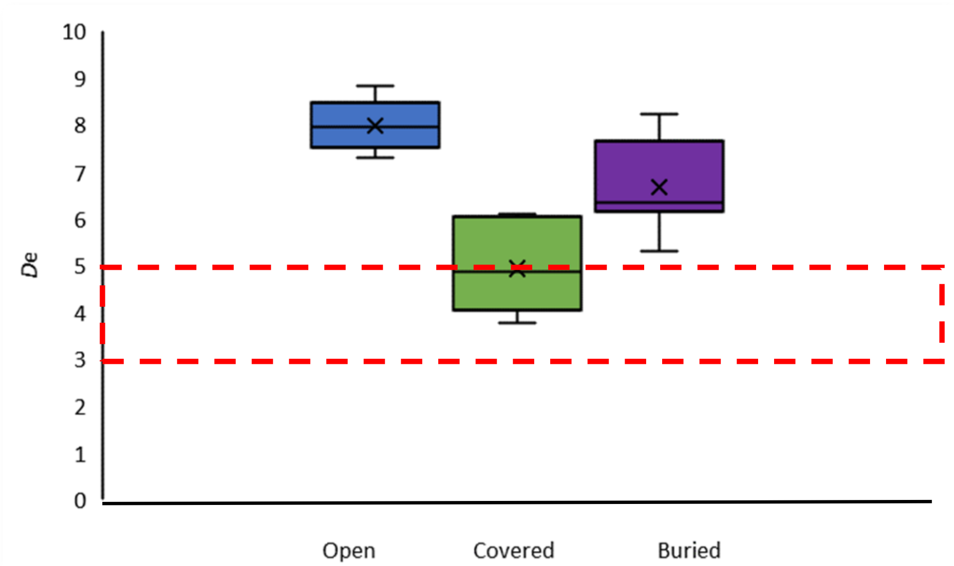


Figure 9: Boxplot of the d_e values across microhabitats. The dashed red box represents the range of scores that represents high quality habitat.

Discussion

Lizard body temperature (T_b) was influenced by time of day but not by the microhabitat it was found while body surface temperature was determined by a time-of-day x microhabitat interaction. Body surface temperature might be expected to change more quickly than internal temperature and so was more impacted by the microhabitat. Our regression analysis showed that using a thermal temperature gun on the surface of the lizard can provide an accurate indicator of the internal body temperature (T_b) of a Texas horned lizard similar to a study conducted in Kennedy and Karnes City, Texas ($y = 1.07x – 1.32$, $R^2 = 0.95$, $P = 0.002$) (Tucker, 2022). Nevertheless, at higher temperatures there is more variability around the regression line suggesting that body surface temperature may be a less accurate indicator of internal body temperature at higher temperatures. Our two polynomial regressions comparing the T_b and surface temperatures of the lizards to the ground temperature indicate that as the ground temperature approaches their critical temperature limit, the lizards' body temperatures level off close to the upper part of their optimal range suggesting they are actively thermoregulating. Lizards were also found in plots with warmer ground temperatures than random plots in the mornings as might be expected for an ectotherm that needs to increase its body temperature.

There were no differences between MM and WR in the temperatures of microhabitats the lizards were found in, although there was a trend for body temperatures to be greater at WR. The temperatures in different microhabitats as measured by temperature loggers did not differ between the sites, although covered habitat at WR was within the optimal range during the afternoon period while MM temperatures were significantly higher for covered habitat. Thermal quality (d_e) of a habitat is regarded as high quality when $3 < d_e < 5$ and low quality when outside this range (Hertz et al., 1993;Vickers et al., 2011)). These scores did not differ between sites, with all microhabitats being of low quality except for covered microhabitat (d_e = 4.99) similar to a study of Texas horned lizards in Kenedy and Karnes City, Texas (Tucker, 2022). The 95% MCP home range sizes were also similar between sites and previous studies done on lizards in central Texas (Granburg, 2014; Fink, 2017). These data suggest that the reintroduction site has suitable thermal habitat for Texas horned lizards.

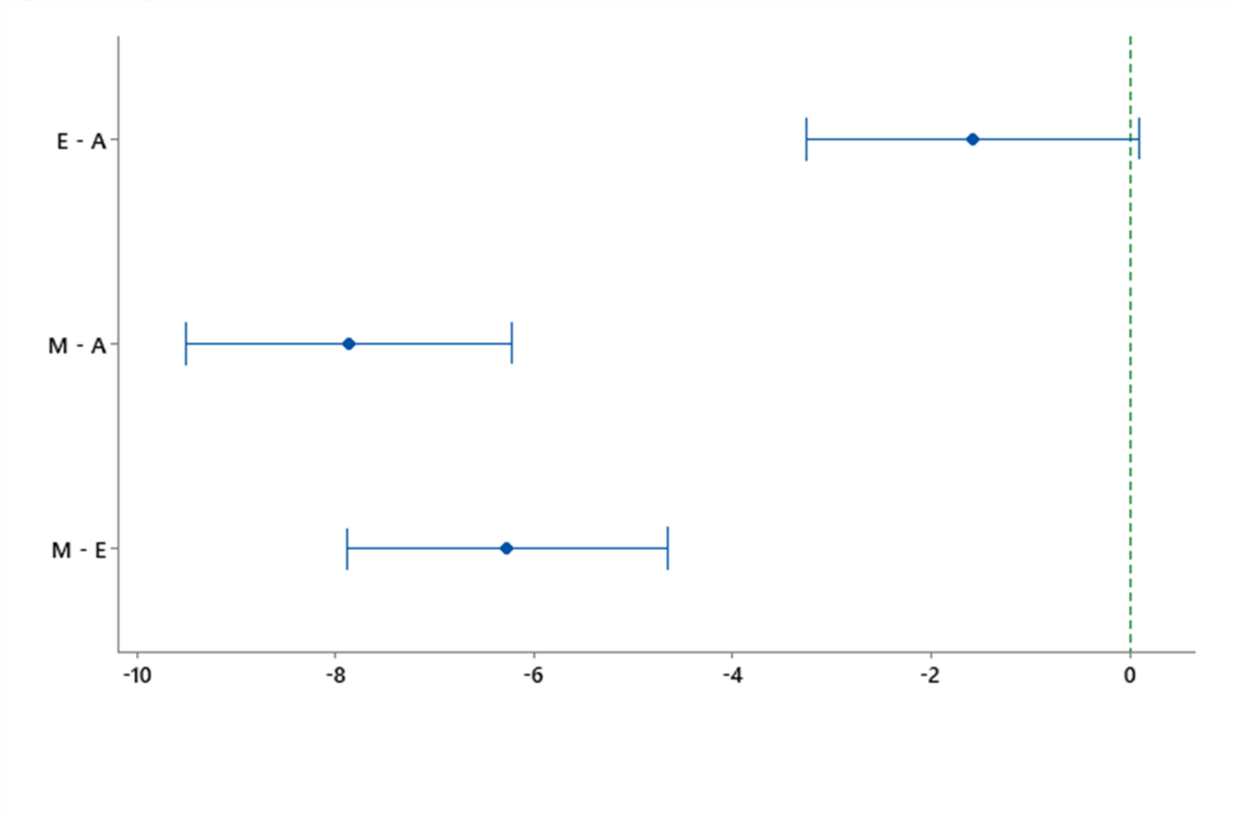
Future studies should be conducted on the configuration of microhabitats in the landscape which could become more important as the reintroduced population grows and spreads into new areas. The configuration is important because it could allow the lizards to keep themselves in an optimal temperature range without having to move too far to get food and increasing their risk of predation and over exertion (Attum et al., 2006; Schreuder & Clusella-Trullas, 2016; Neel & McBrayer, 2018). Further study of cover microhabitats utilized by Texas horned lizards would be useful since this is the microhabitat that has temperatures most often in the optimal range during the day. There was also an indication that covered habitat at MMWMA had higher than optimal temperatures during the afternoon compared to WR. Whether this was due to the type of cover available at each site is unknown. A concurrent microhabitat study indicated that overall, MMWMA had more cover than WR and less open soil and that lizards utilized areas with less grass suggesting it might be useful to conduct more prescribed burns at MMWMA (Elliott 2022). Previous studies on Texas horned lizards have confirmed the importance of a mixed mosaic of microhabitats and vegetative cover for thermal refugia that allow Texas horned lizards to thrive, although the scale at which this mosaic is optimal is unknown ((Munger, 1984; Tucker, 2021).

APPENDECIES

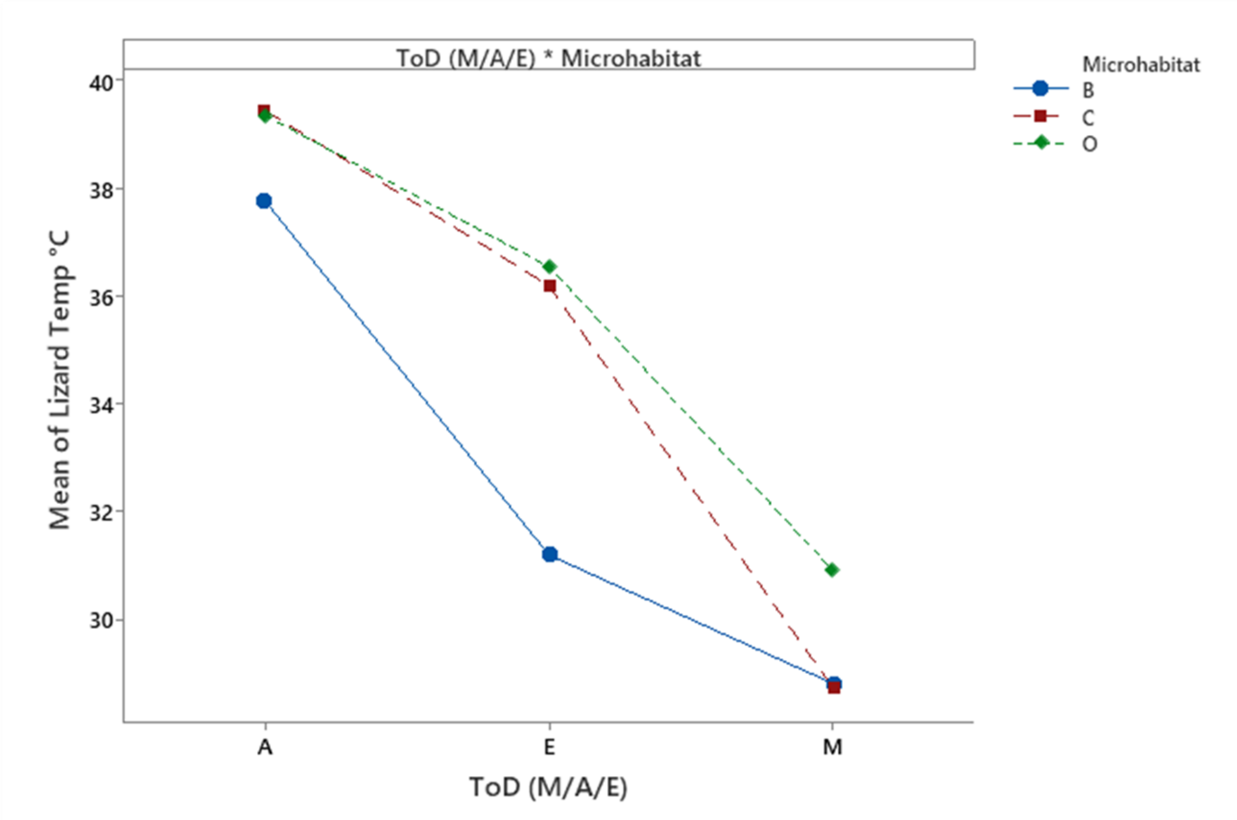
Appendix 1: Generalized linear model (GLM) selection comparing lizard location plots to random plots using bias-corrected Akaike's information criterion (AICc). k is the number of model parameters. ΔAICc is the difference between the best model and the comparison model. Temperature is ground temperature, ToD is time of day (early, mid, late), and study site is MM or WR.

Model	k	AICc	ΔAICc
Selection ~Lizard ID	2	1002.143	30.1433
Selection ~Lizard ID + Study Site + ToD + Temperature + ToD*Temperature	8	973.1814	1.1816
Selection ~Lizard ID + ToD + Temperature + ToD*Temperature	7	971.9998	0
Selection ~Lizard ID + Study Site + ToD + Temperature	4	989.633	17.6332
Selection ~Lizard ID + ToD + Temperature	5	977.6476	5.6478

Appendix 2: 95% confidence interval grouping of time of day using a Tukey-Kramer post hoc test to see which time of day had the greatest impact on temperature. Morning, afternoon, and evening are represented by M, A, and E respectively. Intervals not containing a zero differ significantly from one another.



Appendix 3: Interaction plot for lizard body temperature from the temperature gun looking at the interaction between time of day and microhabitat. Morning, afternoon, and evening are represented by M, A, and E respectively. Open, covered, and buried microhabitats are represented by O, C, and B respectively.



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ABSTRACT

The Thermal Habitat Selection of reintroduced Texas Horned Lizards (*Phrynosoma cornutum*)

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Due to habitat loss the Texas horned lizard (THL) (*Phrynosoma cornutum*) population has declined across its historic range. To date, reintroduction attempts for the species have been unsuccessful, calling into question the suitability of the habitat. Texas horned lizards require suitable thermal habitat to meet their thermoregulatory needs, because of this, understanding the thermal habitat requirements of THLs is important. The objective of this study was to determine thermal habitat preferences of reintroduced THLs at Mason Mountain WMA compared to a nearby natural population of THLs on the White Ranch. We also compare the thermal conditions of different microhabitats between the two sites. To do this, we used thermal dataloggers to record the temperatures in different microhabitats throughout the day at each study site, then compared how much of the time these data loggers were within the lizard's optimal and critical temperature range. The ground temperature selection by the lizards versus random points on the ground were assessed to see what factors affected selection the most such as, study site, time of day, and microhabitat. It was found that the two sites did not differ from each other in terms of microhabitat thermal quality and for the temperature and microhabitat measurements taken for the lizards. Similar to other studies on THLs, vegetative cover seems to play an important role in providing quality thermal habitat and thermal refugia. These findings suggest that habitat management should focus on maintaining vegetative cover for THLs and more work should be done to look at the impacts of microhabitat configuration on overall habitat quality.