

Thermal utility of desert vegetation for the Egyptian tortoise and its conservation implications



Omar Attum^{a,*}, Andrew Kramer^a, Sherif M. Baha El Din^b

^a Department of Biology, Indiana University Southeast, 4201 Grant Line Rd. New Albany, IN 47150, USA

^b Nature Conservation Egypt, 3 Abdalla El Katib St., Dokki, Cairo, Egypt

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ABSTRACT

We examined the monthly shrub use and the thermal utility of the desert shrub, *Artemisia monosperma*, by the globally endangered Egyptian tortoise, *Testudo kleinmanni*, in Sinai, Egypt. *A. monosperma* is a common desert shrub that is often used by the Egyptian tortoise as a refuge. Egyptian tortoises had the highest mean carapace temperature and lowest carapace temperature range during summer months, which coincided with the aestivation period and the Egyptian tortoise's use of larger shrubs. Our results suggest that the thermal characteristics of larger shrubs are important to the microhabitat use of the Egyptian tortoise and likely long-term survival. Larger shrubs were effective as thermal refuges that ameliorated and stabilized micro-climatic variation. Smaller shrubs were not an adequate thermal refuge in the summer because the mean temperature, and its fluctuation range beneath them was too high to offer adequate refuge during aestivation. The tortoises used the smaller shrubs in the fall, winter, and spring seasons for basking, thermoregulation, and concealment and used shrubs with a cover diameter greater than one meter during the aestivation season. The future conservation of the Egyptian tortoise should focus on protecting and restoring existing habitat by maintaining large perennial shrubs for refuge and aestivation sites.

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1. Introduction

Plants in arid ecosystems often act as thermal and biodiversity 'islands' (Brown and Porembski, 1997; El-Bana et al., 2002, 2003; Moro et al., 1997a, 1997b; Vetaas, 1992). Desert shrubs create microclimates that ameliorate environmental conditions by decreasing solar penetration and surface temperature extremes and increasing soil moisture (El-Bana et al., 2002; Moro et al., 1997b, 1997a; Qin et al., 2004; Tracol et al., 2011). Individual plants also provide leaf litter, shelter from predators, improved soil nutrients, and buffer against aeolian process by acting as fine particulate traps which can lead to the formation of *nabkhas* or phytogenic mounds (El-Bana et al., 2002, 2003; Moro et al., 1997a, 1997b). In addition, larger shrubs often support high plant density and richness within their immediate vicinity (El-Bana et al., 2002, 2003); however, for some species an inverse relationship exists between shrub size and species richness (Moro et al., 1997b).

Desertification, the reduction of vegetation cover in arid lands, often results in a reduction of species diversity and an increase in

aeolian processes due to human activities and/or climate change (Brown, 2003; Geist and Lambin, 2004; Verón et al., 2006). As desertification in the Middle East and North Africa is likely to increase in the future, ecologists are attempting to predict the effects of these impacts on species survival and diversity (Attum et al., 2006; Barrows, 2011; Sears et al., 2011; Sinervo et al., 2010; Verón et al., 2006). Overgrazing and vegetation cutting, which contribute to desertification, are detrimental to many vegetation communities because such practices reduce species diversity, vegetation height, and percent vegetation cover (Attum et al., 2006; El-Bana et al., 2003; Fleischner, 1994; Milchunas and Lauenroth, 1993). Given the widespread effects of anthropogenic disturbances on vegetation cover, one would expect consequential negative impacts on associated animal communities that depend upon vegetation. Wildlife declines often occur when vegetation complexity decreases, which causes a reduction in thermal refuge and food availability, while increasing environmental severity and predation risk (Attum and Eason, 2006; Attum et al., 2006; Bentley et al., 2000; Laurance, 1994; Saunders et al., 1991). The use and availability of thermal refuges may represent one of the fundamental mechanisms that allow wildlife to survive in arid environments (Beck and Jennings, 2003; Bulova, 2002; Lagarde et al., 2012).

* Corresponding author. Tel.: +1 5028107861.

E-mail address: oattum@ius.edu (O. Attum).

Reduced activity, such as aestivation, is an important strategy for wildlife in arid environments during prolonged periods of food reduction or unfavorable environmental conditions, such as high ambient temperatures or drought (Hailey and Loveridge, 1997; Kennet and Christian, 1994; Roe et al., 2008; Seidel, 1978). Chelonians that undergo prolonged reduced activity may experience a reduction in field metabolic rates, with or without physiological adjustments (Roe et al., 2008; Seidel, 1978). A reduced field metabolic rate allows animals to conserve water, conserve energy stores, and remain inactive until environmental conditions or food availability improves (Hailey and Loveridge, 1997; Henen, 1997; Kennet and Christian, 1994; Loehr et al., 2009; Roe et al., 2008).

The Egyptian tortoise *Testudo kleinmanni* is one of the smallest and most endangered tortoise species in the world, having the most restricted range of all tortoises in the Mediterranean Basin (Baha El Din et al., 2003). Chelonians of arid lands have evolved in environments that experience long term, potentially lethal temperatures and low resource availability (Barrows, 2011; Loehr et al., 2009). Small body size is an adaptation to environments with low productivity because smaller animals typically have lower resource demands (Nagy, 2005). In addition, being small allows animals to use the smaller refuges, such as rodent burrows, crevices, or underneath vegetation in landscapes characterized by limited availability of larger refuges (Attum and Eason, 2006; Attum et al., 2006; Bonnet et al., 2001; Geffen and Mendelssohn, 1989; Loehr, 2002; Loehr et al., 2009). Egyptian tortoises typically aestivate or experience prolonged dormancy in the summer months, starting from the middle of May to early June until the end of September to the beginning of October – a period characterized by extremely high ambient temperatures, no rainfall, and the lowest food availability (Attum et al., 2006, 2007b, 2008; Geffen and Mendelssohn, 1989).

Habitat loss, fragmentation, and the illegal pet trade have led to dramatic declines in wild populations of *T. kleinmanni* over the last few decades. In Egypt, much of the Mediterranean coast has been altered by urban development and large-scale agriculture. Suitable Egyptian tortoise habitat now exists only in a few protected areas, which are inhabited by local pastoralists who use the existing vegetation for livestock grazing and fuel (Attum et al., 2007a; Baha El Din et al., 2003).

The objective of this study was to examine shrub use and the thermal utility of desert shrub, *Artemisia monosperma*, to the Egyptian tortoise. We first examined the thermal attributes of different sized *A. monosperma* shrubs over the course of a year by studying the relationship between shrub size (maximum diameter) and the mean temperature and temperature range beneath a shrub. We then examined the patterns of Egyptian tortoise use of differently sized *A. monosperma* shrubs throughout the year. Finally, we examined the monthly variation in Egyptian tortoise carapace temperature.

2. Methods and materials

2.1. Location & vegetation selection

This study took place in Zaranik Protected Area (ZPA) in North Sinai, Egypt. ZPA is located 30 km west of the town El Arish (N 31° 05', E 33° 25'), occupies 250 km², has an altitude range of sea level to 30 m, is characterized by stable and unstable sand dunes, and receives 50–100 mm rainfall per year. The perennial vegetation within ZPA mostly consists of 5–10% coverage and is dominated by the shrub *A. monosperma*. We chose the shrub *A. monosperma* as our model species to examine the relationship between shrub size and substrate temperature because *A. monosperma* is the most common shrub at our study site and widely used by the Egyptian tortoise as a refuge. We, however, were not able to examine the

relationship between shrub size and substrate temperature for each shrub species used by the Egyptian tortoise because of financial constraints.

2.2. Data collection – vegetation and ambient temperatures

We used 29 Thermochron ibutton temperature loggers (DS1921G) to record temperature beneath differently sized shrubs, and one temperature logger was used to record the temperature just beneath the surface of bare ground. Temperature loggers were placed on the southern side of the shrub at the base of the trunk and submerged in the sand, with the top of the temperature logger being covered by 3 mm of sand. Temperature of the bare ground, located approximately 3 m from the nearest shrub, was estimated by submerging and covering a temperature logger with 3 mm of sand. The ibutton records temperatures within a range of –40 °C to 85 °C, with an accuracy of ±1 C°, and resolution of 0.5 °C. The ibuttons were programmed to record temperatures between 11/1/06 and 10/8/07 every four hours at the following time intervals: 03:00, 07:00, 11:00, 15:00, 19:00, and 23:00. The maximum diameter for each shrub was recorded with a tape measure to the nearest cm. The temperature loggers were checked weekly to ensure that they were covered with the above described levels of sand. The data from one temperature logger placed beneath a 1.7 m diameter shrub was removed from the analysis due to malfunction. We, therefore, used data from only 28 temperature loggers. Ambient air temperature was determined by the publicly available historic weather data from the 623370 (HEAR) weather station in El Arish, Egypt (31.08° N, 33.83° E, Alt: 31 m) located approximately 30 km away.

2.3. Data collection – vegetation use

We examined monthly variation in the vegetation use (maximum shrub diameter) by five Egyptian tortoises (one male and four females), utilizing data collected from a previous radio-telemetry study at the same site (Attum et al., 2008). The mean carapace length was 97.7 mm ± SE: 3.2, and the mean weight was 205.5 g ± 13.5 for the five tortoises. Tortoises were located weekly between February 2005 and May 2006. We recorded the vegetation species and corresponding maximum diameter for each shrub used by the animal. We only included Egyptian tortoise refuge use of *A. monosperma* in our final analysis, as our data on shrub diameter and temperature were only collected from *A. monosperma*.

2.4. Data collection – tortoise carapace temperature

We recorded the daily tortoise carapace temperature of fourteen tortoises at the above described times by attaching temperature loggers onto the lateral-posterior end of the carapace in the field with an epoxy glue (Edwards and Blouin-Demers, 2007). We attached ibuttons onto 10 females (mean ± SE: carapace length 106.3 mm ± 2.9, weight 213.7 g ± 19.1) and four males (mean ± SE: carapace length 93.1 mm ± 4.8, weight 133.5 g ± 9.8). We painted the ibuttons' exterior to match the carapace color. The combined mass of the ibuttons and epoxy was between three and four grams, which was less than 5% of tortoises' body mass. The majority of the tortoises were captured the week prior to the first programmed temperature-recording event. Two tortoises were captured on 11/19/06, and we used data starting on 11/20/06 for those individuals in the analysis. The temperature loggers were removed from the tortoises during a mark-recapture study during the following December 2007 and 2008. Two temperature loggers did not have stored data, and four temperature loggers had fallen off the tortoises during the course of the study. We, therefore, used data from

eight individuals (seven females, one male) in our final analysis, combining the data from both sexes to increase sample size. We were not able to concurrently study the vegetation refuge use of the Egyptian tortoise through the use of radio-telemetry, along with recording carapace temperature because of concerns that the combined weight of the radio-transmitters and temperature loggers would exceed 5% of the tortoise body mass. We assumed that the tortoises with attached temperature loggers behaved similarly to the tortoises from the radio-telemetry study because they were studied in the same location.

2.5. Data analysis – vegetation temperature

We examined the overall relationships between shrub diameter and daily mean temperature, daily temperature range, daily maximum temperature, and daily minimum temperature. These relationships were determined separately for the spring months (March, April, May), summer months (June, July, August, September), fall months (October, November), and the winter months (December, January, February) through the use of eight linear mixed-model analysis using individual shrubs as the subjects, day as the repeated effect, shrub diameter as the fixed effect, and daily mean temperature, daily temperature range, daily maximum temperature, or daily minimum temperature as the dependent variable. The relationships were considered significant if $p < 0.05$. Once the relationships were determined, the diameter threshold at which the effect stabilized was determined by calculating Akaike's information criterion (AIC) for all possible thresholds for each of the eight relationships and by determining the lowest AIC value for each relationship. Lastly, we examined the strengths of the relationships between shrub diameter and daily mean temperature, daily temperature range, daily maximum temperature, and daily minimum temperature for each season individually through the use of 4 separate linear regressions for each relationship. We used Bonferroni corrections to minimize Type I errors by adjusting the p values for the multiple regression tests. Linear regression tests were significant if $p < 0.013$. All analyses were conducted using SPSS 19.

2.6. Data analysis – vegetation use & tortoise carapace temperature

We tested whether the monthly mean diameter of vegetation refuges used by the Egyptian tortoise changed each month, as well as whether the monthly mean daily range (monthly mean daily maximum carapace temperature – monthly mean daily minimum carapace temperature) and monthly mean daily carapace temperature of the Egyptian tortoise differed among months. We did these tests using repeated measures ANOVA, and corrected the degrees of freedom using Greenhouse–Geisser estimates of sphericity ($\epsilon = 0.20$, $\epsilon = 0.27$ and $\epsilon = 0.20$, respectively). The ANOVAs were significant if $p < 0.05$. We had to remove one individual tortoise from the repeated measures analysis of vegetation refuge size used by the Egyptian tortoise because that individual did not use *A. monosperma* in some months.

3. Results

3.1. Vegetation temperature

The highest temperature recorded on the open ground was 54.5 °C; this temperature was recorded on 10 June 2007. The lowest temperature recorded on the open ground was 3.0 °C; this temperature was recorded on 18 December 2006. The highest temperature recorded beneath any of the shrubs was 52.0 °C; this

temperature was recorded on 10 June 2007 beneath a shrub with a 0.2 m diameter. The lowest temperature beneath any of the shrubs was 4.5 °C; this temperature was recorded on 16 December 2006 beneath a shrub with a 0.3 m diameter and on 18 December 2006 beneath three shrubs with diameters of 0.2 m, 0.3 m, and 0.4 m.

For all seasons, there was a significant relationship between shrub diameter and daily mean temperature, daily temperature range, daily maximum temperature, and daily minimum temperature (Table 1). The shrub size threshold at which temperature began to stabilize ranged from 0.5 m to 0.8 m, depending upon season and temperature category (Table 1). Shrubs with a larger diameter experienced significantly overall lower mean temperatures until reaching their respective size threshold (Table 1), where mean temperatures appeared to have stabilized around 19 °C in the spring, around 30 °C in the summer, 17 °C in the fall, and around 12 °C in the winter (Fig. 1A). Daily temperature range significantly decreased as shrub diameter increased until reaching their respective size thresholds (Table 1), where temperature range appears to have stabilized at around 8 °C in the spring and summer and around 6 °C in the fall and winter (Fig. 1B). Daily maximum temperature significantly decreased as shrub diameter increased until reaching their respective size threshold (Table 1), where the daily maximum temperatures appears to have stabilized at around 24 °C in the spring, around 34 °C in the summer, around 21 °C in the fall, and around 15 °C in the winter (Fig. 2A). Daily minimum temperature significantly increased as shrub diameter increased until reaching their respective size threshold (Table 1), where daily minimum temperatures appeared to have stabilized at around 15 °C in the spring, around 25 °C in the summer, around 14 °C in the fall, and around 11 °C in the winter (Fig. 2B).

The regression tests reiterated the significance of the relationships between shrub diameter and daily mean temperature, daily temperature range, daily maximum temperature, and daily minimum temperature in all seasons. The p value was 0.010 or less for all relationships. Shrub diameter size explained more of the variation (r^2) of all of the relationships in the summer months than in the other seasons (Table 1).

Table 1

The results of linear mixed analysis examining the relationship between shrub diameter and temperature beneath the shrub. Individual shrubs were treated as the subjects, day as the repeated effect, shrub diameter as the fixed effect, and daily mean temperature, daily temperature range, daily maximum temperature, or daily minimum temperature as the dependent variable. Size threshold represents the minimum shrub diameter in which the measured temperatures begin to stabilize. Threshold was calculated using Akaike's information criterion. The r^2 values were generated by separate linear regressions.

Test	F values	Significance	r^2	Size threshold
Spring				
Mean	$F_{16, 346.6} = 135.59$	$p < 0.001$	0.038	0.6 m
Range	$F_{16, 2007.0} = 635.78$	$p < 0.001$	0.447	0.6 m
Max	$F_{16, 1147.1} = 310.24$	$p < 0.001$	0.227	0.5 m
Min	$F_{16, 656.0} = 98.76$	$p < 0.001$	0.050	0.8 m
Summer				
Mean	$F_{16, 1750.4} = 667.54$	$p < 0.001$	0.226	0.6 m
Range	$F_{16, 2878.6} = 1310.17$	$p < 0.001$	0.540	0.6 m
Max	$F_{16, 2438.2} = 1096.83$	$p < 0.001$	0.468	0.6 m
Min	$F_{16, 1698.3} = 325.95$	$p < 0.001$	0.137	0.8 m
Fall				
Mean	$F_{16, 272.4} = 39.60$	$p < 0.001$	0.006	0.6 m
Range	$F_{16, 683.7} = 227.25$	$p < 0.001$	0.338	0.6 m
Max	$F_{16, 441.4} = 218.27$	$p < 0.001$	0.140	0.5 m
Min	$F_{16, 430.3} = 45.22$	$p < 0.001$	0.031	0.8 m
Winter				
Mean	$F_{16, 663.4} = 37.25$	$p < 0.001$	0.005	0.5 m
Range	$F_{16, 1585.2} = 532.22$	$p < 0.001$	0.361	0.6 m
Max	$F_{16, 877.6} = 293.92$	$p < 0.001$	0.181	0.5 m
Min	$F_{16, 945.7} = 58.04$	$p < 0.001$	0.077	0.8 m

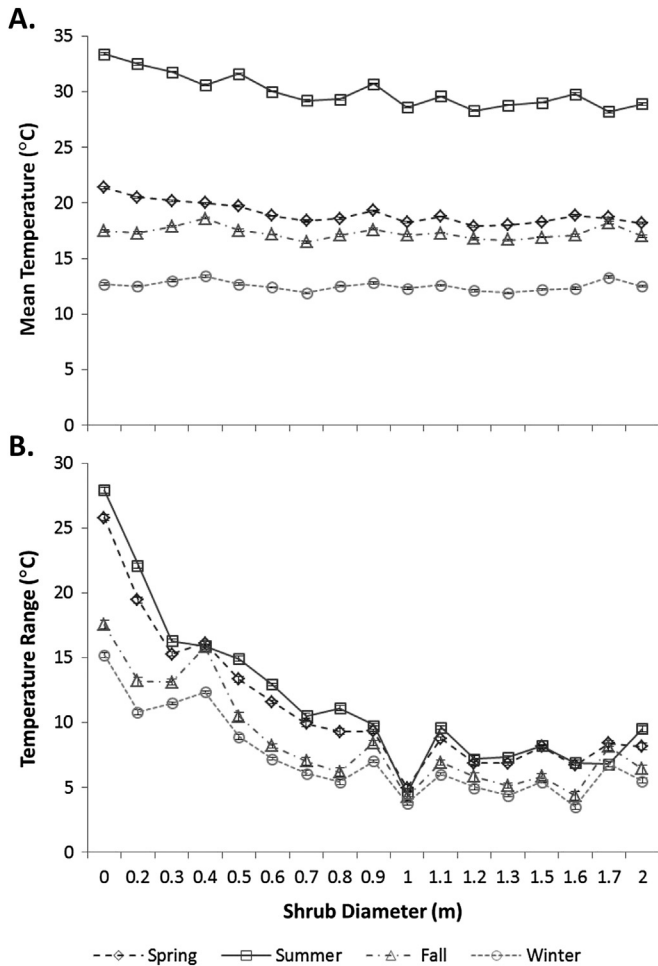


Fig. 1. The relationship between shrub size and mean daily temperature (A.), and the relationship between shrub size and mean daily temperature range (daily maximum temperature – daily minimum temperature) (B.) beneath the shrub for each season.

3.2. Vegetation use

The vegetation size used by the Egyptian tortoise was significantly different among months, with the largest shrubs used during the summer months and the smallest shrubs used during the winter months ($F_{2,2, 6.7} = 14.45, p = 0.003$; Fig. 3).

3.3. Tortoise carapace temperature

Both the mean carapace temperature and mean carapace temperature range of the Egyptian tortoise were significantly different among months (respectively: $F_{2,2, 15.4} = 617.54, p < 0.001$; $F_{2,9, 20.6} = 40.42, p < 0.001$). Egyptian tortoises had the highest mean carapace temperature and lowest mean carapace temperature range during summer months, and the lowest mean carapace temperature and the highest mean carapace temperature range during the winter months (Fig. 4). The low fluctuation and high carapace temperatures coincided with the aestivation period of the Egyptian tortoise. The mean daily temperature experienced by the tortoises during the aestivation period from 1 June to 30 September was $(28.5 \pm \text{SE } 0.23)^\circ\text{C}$, and the mean daily temperature range experienced during this time was $(9.6 \pm \text{SE } 0.77)^\circ\text{C}$. The mean carapace temperature was higher than the bare ground and ambient air temperature between November and March and the carapace temperature was lower than the bare ground temperature between May and October (Fig. 4). The highest carapace

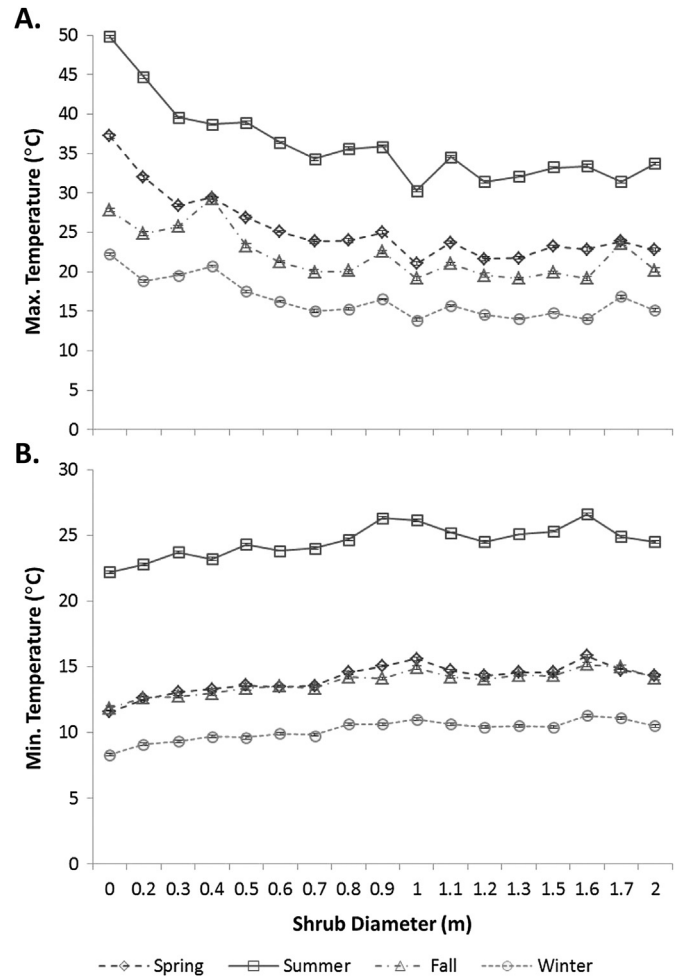


Fig. 2. The relationship between shrub size and mean daily maximum temperature (A.), and the relationship between shrub size and mean daily minimum temperature (B.) beneath the shrub for each season.

temperature recorded was 45.0°C ; this temperature was recorded for one tortoise on 9 March 2007. The lowest carapace temperature recorded was 3.0°C ; this temperature was recorded for three tortoises on 18 December 2006.

4. Discussion

4.1. Benefit of large shrubs

Our results suggest that the thermal buffering of larger shrubs is important to the Egyptian tortoises' likely long-term survival. Extreme temperatures are an evolutionary force that limits species distribution and survival (Sinervo et al., 2010). Thermal heterogeneity is important for a species' survival because it determines the costs of behavioral thermoregulation during fluctuating environmental conditions (Angilletta, 2009; Huey, 1991; Huey and Slatkin, 1976; Sears et al., 2011). The availability of thermal retreats that ameliorate extreme temperatures is critical for a species survival, especially during seasons that are thermally challenging (Beck and Jennings, 2003; Bulova, 2002; Huey, 1991). The suitability of a microhabitat as a thermal retreat is often correlated with microhabitat size (Huey, 1991; Huey et al., 1989; Lagarde et al., 2012).

Smaller shrubs are not adequate thermal refuges for Egyptian tortoises in the summer, as the daily temperature and temperature

fluctuation under them are probably too extreme (Figs. 1–3). Larger shrubs serve as thermal refuges that ameliorate and stabilize micro-climatic variation, which are especially important to Egyptian tortoises during the aestivation season. Larger shrubs are more valuable as thermal refuges during the summer months because shrub size was responsible for explaining more of the variation in mean temperature, temperature range, and daily maximum temperature than the non-summer months (Table 1). The summer months are characterized by daily, potentially lethal maximum daytime temperatures; therefore, the benefits of the shade provided by large shrubs as thermal refuges would be more valuable during this period when the tortoises aestivate.

Temperature fluctuations appear to stabilize when *A. monosperma* shrubs have a diameter greater than 0.6–0.8 m (Table 1). However, during the aestivation season, Egyptian tortoises used shrubs that had a diameter greater than 1 m. The discrepancy between the proposed size threshold and size of shrubs used by the Egyptian tortoises may be due to other confounding factors. Our diameter measurement was intended as a relative measure to compare sizes of different shrubs but does not take into account the patchiness in vegetation cover and shrub shape. For example, some shrubs have different sized gaps of exposed surface within their canopy, and there are slight deviations in the circular shape of shrubs, which potentially reduce the thermal buffering in the summer (Lagarde et al., 2012). In addition, tortoises could be choosing shrubs larger than the threshold size due to larger shrubs having better concealment or higher humidity levels that assist in water conservation (Bulova, 2002).

Shrub size explained less variation in all the temperature metrics outside of the summer months possibly because the temperature dichotomy between highs and lows is not as extreme during non-summer months, and therefore the temperature beneath the shrub may be less dependent upon shrub size and more dependent upon environmental conditions (Figs. 1–3). In addition, large shrubs appear to have greater insulation properties than smaller shrubs, allowing the large shrubs to retain some heat at night during the winter months, which would make the canopy of larger shrubs cooler than the surrounding desert during the day but slightly warmer at night relative to the bare ground (Niachou et al., 2001; Fig. 2B).

4.2. Vegetation importance during aestivation

The aestivation period of the Egyptian tortoise in our study coincided with the period of the lowest carapace temperature range, highest carapace temperatures, and highest surface temperatures (Fig. 4). High non-lethal body temperatures may be important for triggering metabolic depression during physiological aestivation as some reptiles have a reduced metabolic rate at high body temperatures (Dawson and Bartholomew, 1956; Kennet and Christian, 1994; Moberly, 1963). The use of large shrubs as aestivation sites helps to reduce the range of temperature fluctuation, which in turn would assist in maintaining relatively stable carapace temperatures. Stable body temperatures are important for reducing metabolic costs of prolonged inactivity by reducing basal metabolic rates (Beck and Jennings, 2003; Kennet and Christian, 1994).

4.3. Vegetation importance outside of aestivation

Tortoises in arid environments often use shrubs with smaller diameters during the cooler months to increase potential temperature exposure (Douglas and Rall, 2006). Egyptian tortoises use smaller shrubs as refuge in the fall, winter, and spring seasons, when the threat of overheating is reduced due to the overall cooler ambient air temperatures (Figs. 3 and 4). The use of small shrubs as refuge outside of the summer months may also be advantageous for

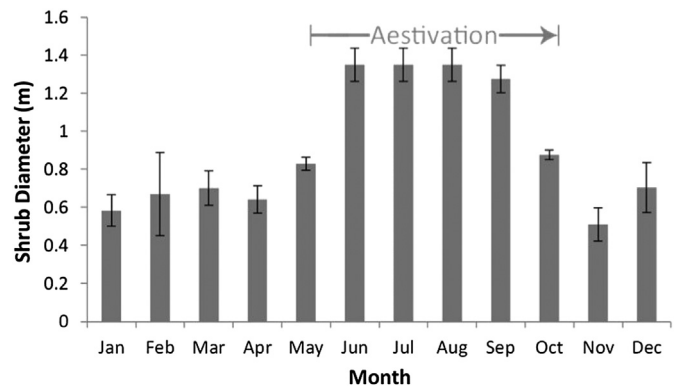


Fig. 3. The mean \pm SE diameter of *A. monosperma* used by the Egyptian tortoise. Sample size (n) of the number of shrub measurements per month: January = 12, February = 12, March = 23, April = 30, May 28, June 18, July = 17, August = 24, September = 24, October = 18, November = 13, December = 10.

thermoregulatory purposes by allowing tortoises to bask and be exposed to sunlight while being partially concealed from predators. Our results suggest that the Egyptian tortoise is actively thermoregulating as the mean carapace temperature was higher than the bare ground and ambient air temperature from November until March. Many reptiles and amphibians use structural microhabitats to cryptically conceal themselves from predation while thermoregulating (Cunnington et al., 2008; Huey et al., 1989; Jennings, 2007; Rittenhouse and Semlitsch, 2007; Seebacher and Alford, 2002; Steen et al., 2007).

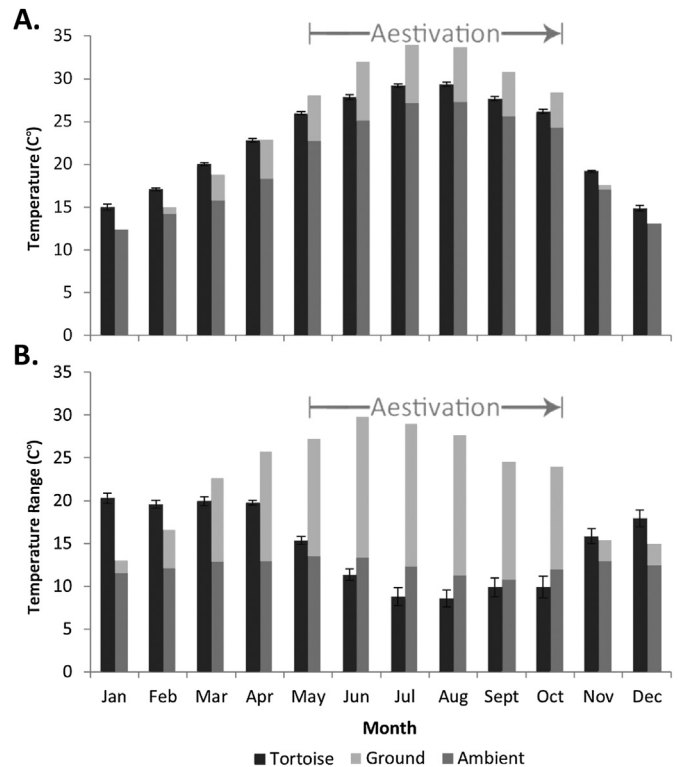


Fig. 4. The monthly carapace temperature of the Egyptian tortoise compared to the monthly recorded ground and ambient temperatures. A.) The mean \pm SE carapace temperature, mean recorded ground temperature, and mean recorded ambient air temperature. B.) The mean \pm SE daily carapace temperature range (daily maximum temperature – daily minimum temperature), mean recorded ground temperature range, and mean recorded ambient air temperature range.

4.4. Conclusion

The future conservation of the Egyptian tortoise in Egypt is dependent on protecting and restoring existing habitats. Desertification, characterized by a reduction in vegetation cover by overgrazing and vegetation removal, increases the severity of an already harsh environment, which may drive the local extinction of many desert generalist species that are not adapted to extreme desert conditions, while desert specialists may be able to persist because of adaptations to hyper-arid deserts (Attum and Eason, 2006; Attum et al., 2006; Sinervo et al., 2010). We believe that the Egyptian tortoise would not be able to persist through any desertification and reduction of vegetation cover, just like other chelonians in arid environments (Lagarde et al., 2012). Habitat protection and restoration of sand dune vegetation is possible as past studies have shown that the sand dune habitats of the region can recover fairly quickly from degradation if given the opportunity (Attum et al., 2006; Seifan, 2009). We recommend that these restoration efforts should include maintaining thermal heterogeneity by including the presence of large perennial shrubs as an important component for the long term survival of the Egyptian tortoise (Lagarde et al., 2012).

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