Distribution and population estimates of the Borrego sand scorpion (*Paruroctonus borregoensis*)

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ABSTRACT

Scorpions are important to the desert biome as prolific prey items, predators, and habitat modifiers. Our study set out to fill in the knowledge gap pertaining to the abundance and homing behavior of the Borrego dune scorpion, *Paruroctonus borregoensis*. A mark and recapture was conducted to determine if Borrego sand scorpions display site fidelity and as well as estimate population density in the Anza Borrego Desert in California. The Borrego sand scorpion displays no evidence of site fidelity. Additionally, females were found closer to shelter and in lower numbers than males, indicating that females take less risks. Borrego sand scorpion’s lack of site fidelity could have key implications in the modification of subterranean habitat for other desert species and further studies are needed to examine if fidelity changes with microbiome.

Keywords: scorpion, *Paruroctonus borregoensis*, desert, site fidelity, distribution

INTRODUCTION

Deserts cover over one fifth of the earth’s land surface and are spreading (Zeng and Yoon 2009). However, they are understudied due to their vast size and characteristically harsh conditions (Peel et al. 1974). Within the desert biome there are many habitats that vary drastically in climate, organisms present, as well as geological and hydrological processes (Zeng and Yoon 2009). However, each of these desert ecosystems feature scorpions as an important component of the food web (Hadley 1974, Polis and McCormick 1986). Scorpions owe their extensive distribution and high abundance to the numerous adaptations which they have accumulated to survive in harsh desert climates (Hadley 1974). Many of the adaptations of scorpions are centered around the retention of water. Physiologically, scorpions have a low metabolic rate which translates to slowed respiration and low levels of water loss (Hadley 1974). Scorpions are nocturnal and live in subterranean burrows where the temperature is lower and humidity is higher (Hadley 1974). They are also able to withstand higher temperatures and levels of desiccation than other arthropods (Hadley 1974). Most scorpions are sit-and-wait predators which acts as another method for...
conserving energy (Brownell and Farley 1979). Their large population and wide distribution also mean they are a staple prey item in many organisms’ diets (Polis 1991). Scorpions prey upon many surface-dwelling organisms including spiders, insects, small reptiles, small mammals, and other scorpions (Polis and McCormick 1986, Bradley 1989). In addition, they are prey to many desert mammals as well as large centipedes, tarantulas, lizards, and birds (Polis 1991). Many animals living in arid environments obtain the majority of their water through the consumption of other organisms (Polis and McCormick 1987). Scorpions are between 1–20 kg per hectare of the desert wet biomass (Polis and McCormick 1986) and have an advanced ability to retain nutrients in the hepatopancreas—a gland that stores and digests food (Hadley 1974). This ability to conserve large amounts of food and their high water retention make them important prey items in the dry desert. Scorpions are also an important prey for other scorpions, both in the same species and between species (Polis and McCormick 1987). Due to their high incidence of cannibalism, scorpions tend to avoid one another (Polis and McCormick 1987). Despite their propensity to avoid contact, scorpions can occur in high densities between 1,000–5,000 individuals per hectare (Polis and McCormick 1986).

The majority of research to date on desert scorpions focuses on the dune scorpion, Paruroctonus mesaensis (Polis 1991). The dune scorpion is known to be a pervasive species throughout California that exhibits site fidelity (Gaffin and Brownell 1992). By returning to the same burrow each evening, dune scorpions preserve energy that would otherwise be spent digging a new burrow (Switzer 1993). Due to the high risk of predation that scorpions face throughout their lifetime, they often stay within one meter of their burrow to avoid time spent in the open (Brownell and Farley 1979, Switzer 1993). Additionally, the desert environment is often heterogeneous and unpredictable, so dune scorpions are more likely to stay in their high-quality home range in lieu of seeking out another territory (Switzer 1993).

The dune scorpion’s life history may also play a role in their exhibition of site fidelity. It takes two years for this species to reach sexual maturity and they have a one-year gestation period (Warburg 2011). Females are iteroparous and will likely show more cautious behavior when gravid (Warburg 2011), so it is likely that males and females will display different behavior. A closely related species, the Borrego sand scorpion, P. borregoensis, has no studies to date on its population size or dynamics. All that is known about the Borrego sand scorpion is its phenotype, its burrowing behavior, and that it occurs from the northern Mojave Desert to the southern Vizcaino Desert in North America (Haradon 1984). However, its distribution and abundance has not been studied. Based on knowledge of the dune scorpion we predicted that the Borrego sand scorpion would also return to the same home territory each evening. Additionally, we predict that due to the behavioral differences in male and female scorpions, male Borrego sand scorpions will participate in more risk-taking behavior. Cautious behavior could be described as not coming out of their burrow every night or staying closer to a burrow or cover in general. It is important to understand the behavior and distribution of Borrego sand scorpions because they likely comprise an important
METHODS

We set up an observational and experimental study between late October and early November of 2018, at the Anza Borrego desert research center in Borrego Springs, California. We set out to study Borrego sand scorpion’s home fidelity and population size. Data was collected from an area of 5 hectares on the west side of the reserve in a desert shrubland. The flora present consisted mainly of cholla cacti (*Cylindropuntia* sp.) and creosote bush (*Larrea tridentata*).

2.1 Observational Methods

To search for Borrego sand scorpions and record basic data on their habitat and physiology, our research team walked as a group, each researcher approximately 3 meters apart, from 18:20–20:20 from October 31 to November 6 2018. We used ultraviolet lights to locate scorpions. We measured scorpion size (from head to the last body segment), sex (based on pectine size and comb number), time, gps location, and distance from drip line of the nearest shrub (proxy for distance to nearest cover).

2.2 Manipulation Methods

Body text. A mark-recapture study was utilized to test for home fidelity and an estimation of population size. Scorpions were numbered on their ventral surface with permanent marker and released approximately 15 m from their original location in a pseudo-random direction. GPS coordinates were taken of the capture and release locations. Recaptured scorpions had their new GPS coordinates taken and were identified by the numbers. Recaptured scorpions were not relocated a second time. Google Earth Pro was used to analyze if recaptured scorpions were found closer to the original or release locations.

2.3 Statistical Analysis

JMP Statistical Software V.14 was used to conduct the statistical analysis. To test whether scorpions demonstrated site fidelity, we used a paired t-test to examine the relationship between the distance from the location they were moved to and the recapture location in relation to the original site. A t-test was used to identify the relationship between the sex of the scorpion and the distance to cover. Furthermore, to estimate population size the following mark-recapture equation was used: \( N = Mn \).

RESULTS

We sampled 97 scorpions in total, 35 were females and 62 males. The range of movements was 65.1 meters to 5.67 meters per night with an average of 27.3 meters per night. There was a greater distance between the recapture point and the home territory, than there was between the point that individuals were originally moved to and the home territory (Paired T-test, \( N=12, t=2.31, p=0.04 \), Figure 1). There is no correlation between body size and distance traveled per night (\( N=12, t=0.28, p=0.78 \)). Based on mark-recapture data, the population estimate of the Borrego sand scorpion population was 88–195 individuals per hectare. On average, females were found closer to cover (\( N=97, t=2.21, p=0.02 \), Figure 2).
Figure 1. **Relationship between distances traveled before and after recapture.** There was a greater distance between the recapture point and the home range than there was between the point that individuals were originally moved to and the home range. Indicates lack of site fidelity. Bars represent +/- 1 S.E.M. p=0.04

Figure 2. **Distance to cover based on sex.** Females were found to be 0.3 m closer to cover than males. Bars represent +/- 1 S.E.M. p=0.02.

**DISCUSSION**

We found that Borrego sand scorpions do not exhibit preference for a home range based on our twelve recaptured specimens. In order to show home fidelity, the distance from the origin that scorpions were found during recapture should have been smaller than the distance they were moved originally. The distance they were moved from their original site averaged at 15 m while the distance from their home range at which they were recaptured was around 50 m. There are numerous explanations for this behavior. Because they were transported by hand and removed from their pheromone trails, they may have not been able to find their way back along the scent trail (Gaffin and Brownell 1992). However, scorpion homing behavior is more complex than the simple use of pheromone trails (Gaffin and Brownell 1992). They may be able to use their sensitivity to humidity and temperature to return to their burrows, which are more humid and cooler than above-ground (Gaffin 2011). However, the scorpion would have to be relatively close to their burrow to detect it in this way (Gaffin 2011). Another explanation is that during our study the burrows of our recaptured scorpions were trampled by researchers, causing them to seek a new location. Burrow quality is positively correlated with site fidelity (Day et al. 2015). However, it is unlikely that the burrows of all twelve recaptures were destroyed. Behavior demonstrated by the Borrego sand scorpions in our study infer that they do not have home fidelity. However, there were some noticeable differences in the behavior of male and female scorpions.

The population estimate generated for Borrego sand scorpions in the study area likely represents only a fraction of the actual population in this area. This is because scorpions tend to spend the majority of their time in their burrows (Polis 1991). Nights spent outside burrows depend heavily on
the species and age of scorpions. Scorpions in the genus *Paruroctonus* spend anywhere from 1–50% of nights outside of their burrows (Bradley 1989). In addition, females are not properly accounted for since they were underrepresented in our study, possibly due to being sheltered in their burrows.

Females were found closer to the dripline than male Borrego sand scorpions. This response to seek shelter should reduce predation risk. Scorpions may prefer to dig burrows at or near the base of vegetation due to the optimal soil conditions created by the plant (Hadley 1974). Therefore, a closer distance to dripline most likely translates to proximity to a burrow. Scorpions mate in fall from August to September (Warburg 2011), so females that were of reproductive size may have been gravid. Gravid females are less active than other adult females (Warburg 2011), so the larger proportion of females near cover may have been indicative of their reproductive status. Additionally, other male scorpions from the genus will travel further distances from their burrow during mating season to find females (Gaffin and Brownell 1992). The closely-related dune scorpions will follow pheromone trails left by females in order to locate them during mating season. Therefore, it follows that males may still be exhibiting mate-seeking behavior and that is what caused the behavioral discrepancy between the sexes. It should be noted that only 35 females were found while 62 males were captured in our study. This would further indicate that females are exhibiting cautious behavior by not leaving their burrows as frequently as males.

It is well-documented that scorpions in the *Paruroctonus* genus participate in cannibalism and interspecies predation (Polis and McCormick 1987). Scorpions comprise an average of 12–46% of other scorpions’ diets, depending on the availability of other prey items. Because the various species of this genus occupy similar niches and trophic levels, they compete for food as well as territory (Warburg 1998). However, competition between scorpions ends in one of them being depredated upon more often than not (Warburg 1998). Therefore, the result that gravid females would have a higher likelihood of staying closer to their burrow for protection is supported by our findings (Polis and McCormick 1987). Documenting cautious behavior that is typical of gravid females also indicates that the Borrego sand scorpions may mate during the fall.

Since Borrego sand scorpions are known to dig burrows (Haradon 1984), they are creating potential habitats for other organisms. Through the digging of burrows, they may also be increasing soil drainage, decomposition rates, and can therefore affect plant populations and community composition (Jones et al. 1994). By not returning to the same burrow, Borrego sand scorpions would be creating more burrows than a species with site fidelity. Understanding the nuances of the life history of the Borrego sand scorpion can aid in further studies of this species or other organisms that interact with it. Their lack of site fidelity in a desert shrub community may not be a ubiquitous result for the species across all desert microhabitats. One route of future research could be examining the persistence of our results in other desert habitats such as dunes or desert grasslands. The presence or lack of site fidelity may have greater implications on the surrounding
habitat. Understanding how Borrego sand scorpions interact with the organisms around them is pertinent based on our estimates of their high abundance in the Anza Borrego Desert.

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REFERENCES


