Effect of Temperature on the Defensive and Predatory Stinging Behavior of the Scorpion *Hadrurus obscurus*

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INTRODUCTION

- Scorpions display stinging behavior in both predatory and defensive context, while presenting variation in behavior due to their morphology, prey size and struggle intensity, and/or scorpion metabolism(Coelho et al., 2017,Carlson & Rowe 2009).
- Larger scorpion species with more powerful pedipalps rely more on their grasp and less on stinging while the opposite is true for smaller species with smaller pedipalps, due to greater struggle (Rein, 1993). As sit-and-wait predators, scorpions do not expel large amounts of energy actively hunting for their prey. They rely on vibration transmission through the substrate to feel prey in close proximity to strike (Stewart, 2006). This results in low energy expenditure overall.
- Other arachnids have also displayed a positive relationship between temperature and physiological performance; the mite species *Paratarsotomus macropalpis* has been shown to reach larger sprint speeds in higher temperatures (Wu et al. 2010), and the tarantula *Aphonopelma hentzi* had a sprint speed that more than doubled when body temperature is raised from 15 to 40°C (Booster et al. 2015).
- This trend applies to scorpions as well. Carlson & Rowe (2009) demonstrated that Striped bark scorpions *Centruroides vittatus* exhibited significantly shorter sting latencies, higher sting rates, and faster sprint speeds at warmer temperatures. Similarly, the *Paruroctonus marksi* scorpion was shown to have the greatest sprint speed when its body temperature nears 28 °C, which correspond to about their ideal preferred temperature (Nisani et al. 2022a).
- The present study was conducted to determine if body temperature affects defensive stinging and prey-capture behavior in the desert hairy scorpion, *Hadrurus obscurus*. We hypothesized that higher body temperatures will increase *H. obscurus* strike time (time from initial probe to first sting) and decrease the number of probes needed to elicit first sting. Finally, we aim to determine if the prey-capture sequence of this species and the success rate is affected by environmental conditions such as temperature.

METHODS

PREDATORY BEHAVIOR

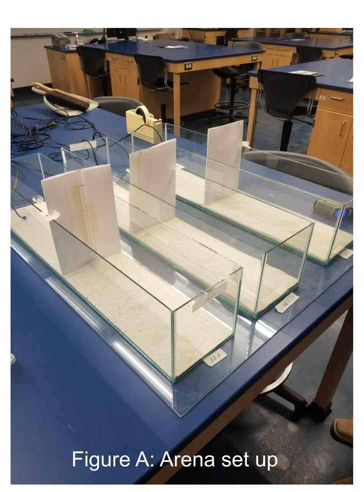


Figure A: Arena set up

- Scorpions were placed in a small glass arenas with sand substrate, (Figure A). Each arena was set up on a heating strip, set to different temperature (22°C, 32°C, or 42°C).
- Each scorpion was allowed to acclimate for five minutes. Their body temperature was checked with an infrared thermometer.
- A cricket was added to the opposite side of the arena.
- Scorpions predatory behavior was recorded and analyzed (Table 1, Figure B).

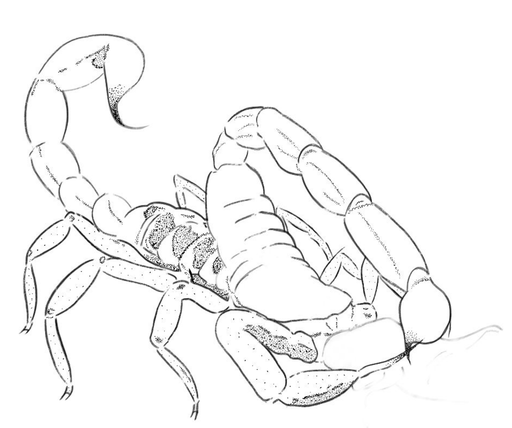
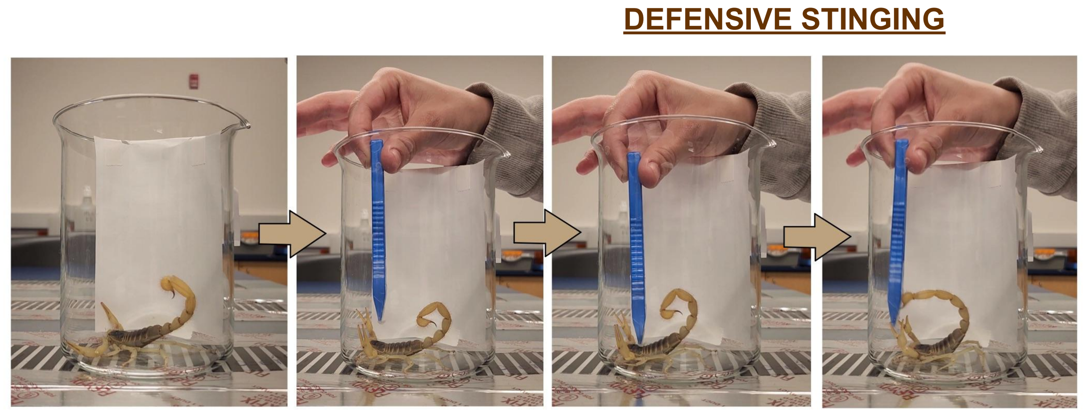


Figure B: Scorpion grasped cricket firmly, stinging in the above motion.

DEFENSIVE STINGING



- Tweezers were opened and wrapped tightly in parafilm,in order to prevent injury to scorpions. The parafilm was disposed of and re-applied between each trial.
- Three 800 mL beakers were set on the high temperature strip (26 - 28°C) and the other three were set on the low temperature strip (21-22°C). The desired temperature of each beaker was confirmed using an infrared thermometer.
- Scorpions were randomly selected and placed into two separate temperature ranges, low and high
- Scorpions were allowed to acclimate for 15 minutes before experiment began.
- Their body temperatures were confirmed using an infrared thermometer.
- Once a timer was started, a probe was lowered down touching the mesosoma (Highlighted in figure C).
- Scorpions were tapped gently but firmly enough to elicit a stress response in order to observe any potential defensive behavior.
- Probing continued until a sting was elicited.
- The amount of time required for sting (time to sting) and number of probes until the first sting were recorded.

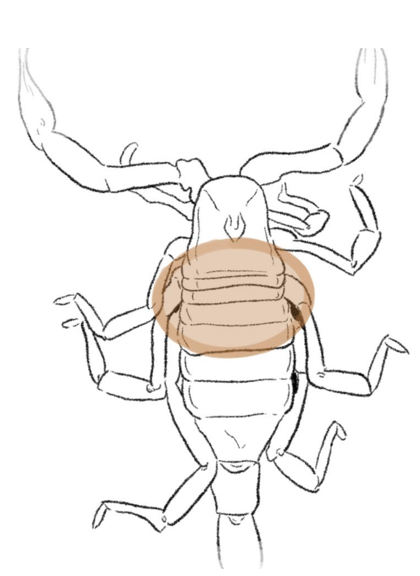


Figure C: The mesosoma, located at the top of the segmented tail & below scorpion head, was tapped with the tweezer.

RESULTS

Prey-Capture Sequence

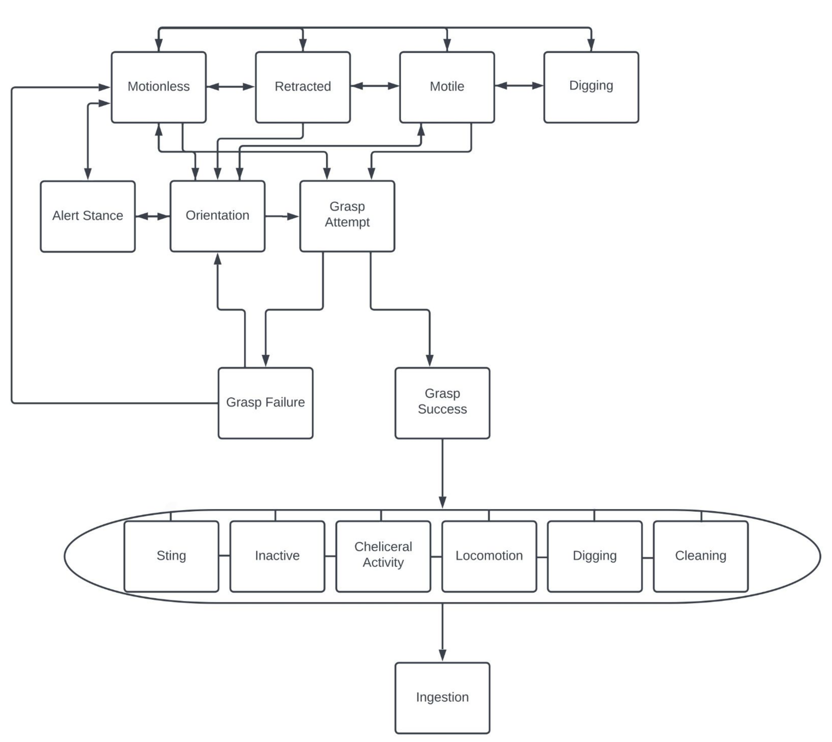


Figure 1: Flow chart ethogram showing prey-capture behavior sequences for *Hadrurus obscurus*. The behaviors observed flowed in the direction of the arrows. The oval with six behaviors inside indicates that those behaviors can precede or follow the others.

Table 1: Ethogram modified from Bub and Bowerman (1979) and Stewart (2006). Description of behaviors.

Behavior	Description
Motionless	Prior to catching prey, the scorpion's relaxed, motionless state with its body raised above the substrate
Motile	Ambulation prior to feeding
Alert Stance	Body is raised above the substrate while the pedipalps are extended anteriorly and raised up
Retracted	Body in contact with the substrate, metasoma and appendages drawn in
Digging	Movement of sand using the pedipalps or legs of the scorpion
Orientation	Movement of the anterior part of the scorpion toward detected prey
Grasp Attempt	Attempt to capture prey in one or both pedipalps
Grasp Failure	Unsuccessful attempt at capturing prey, whether there is contact or not
Grasp Success	Successful attempt at capturing prey with one or both pedipalps
Sting	Metasoma and telson move forward toward prey, probing, then penetrating the prey
Inactive	After catching its prey, scorpion remains motionless
Cheliceral Activity	Protraction and retraction of chelicera as they open and close respectfully
Locomotion	Ambulation of scorpion with prey after catching it
Cleaning	Repeating insert of either pedipalps or telson into the sand after prey capture

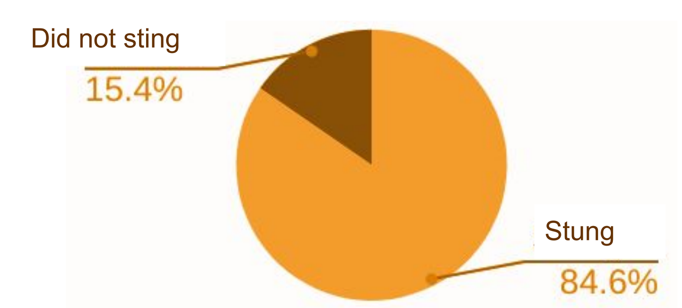


Figure 2: Percentage of scorpions that stung their prey post-capture.

How Temperature Effects Prey-Capture Behavior

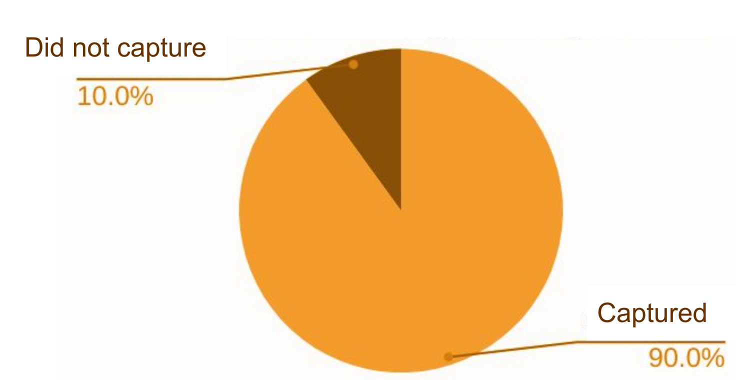


Figure 3: Scorpions with high body temperature (26.6-33.8°C) prey capture success.

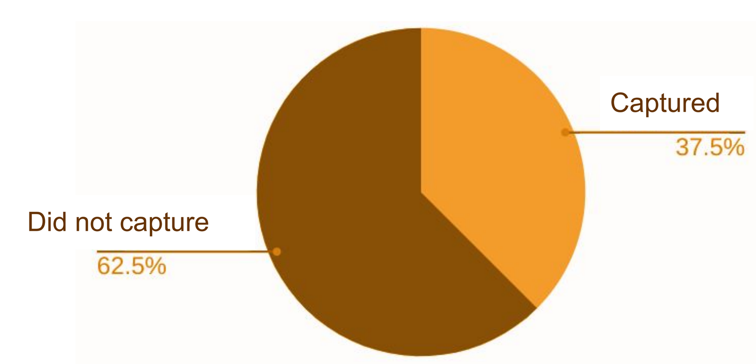


Figure 4: Scorpions with low body temperature (20.6-22.9°C) prey capture success.

How Temperature Effects Defensive Stinging Behavior

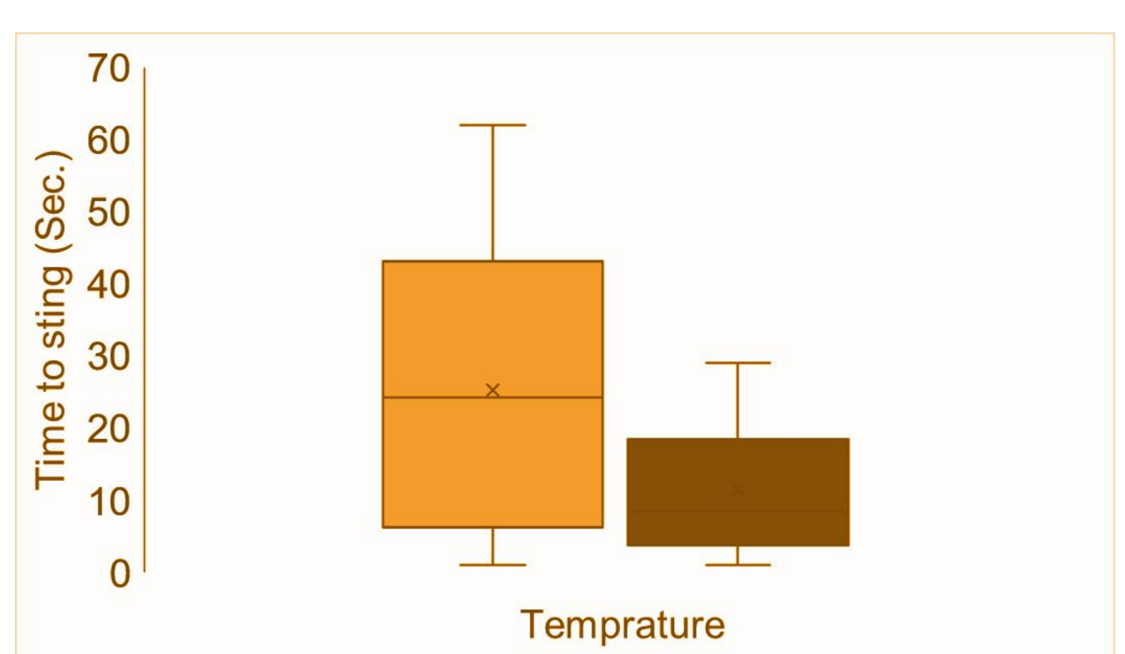


Figure 5: Scorpion defense response time by temperature (Low & High) treatment. The line in the box designates the median and the X is the mean. The reaction time was significantly shorter under high temperature, 11.5 ± 8.88 seconds, compared to low temperature, 25.29 ± 19.19 seconds, $t(10) = 3.19$, $p = 0.01$. It took fewer probes (mean ± SE) for scorpions to sting under high temperature conditions, 6.64 ± 1.34 probes, than cooler treatment, 17.27 ± 3.72 probes.

CONCLUSIONS

- **Both defensive and predatory behavior in the H. Obscurus is affected by temperature. This allows for more information into the thermal ecology of desert ecosystems and for further understanding on how temperature-dependent behavioral adaptations may contribute in scorpion survival in general.**

Predatory

- **Temperature affected prey capture success (Figures 3 and 4)**. This may be explained by their enhanced metabolism and hence muscle function when warm. Environmental temperatures can have a significant effect on the biology of terrestrial ectotherms (Angilletta, 2009). Scorpions tend to be faster at warmer temperatures (Carlson & Rowe, 2009; Nisani et al., 2022a),
- **Scorpions in a 27°C environment had the quickest capture time but no correlation between stinging and temperature when it came to prey capture.** More efficient movement at 27°C may contribute to quicker capture of prey (Nisani et al., 2022a). In Mojave desert scorpions were most active at this temperature (Nisani et al., 2002b)
- **Cleaning of the pedipalps and the telson were only observed after prey capture**. It may be grooming behavior.
- **Scorpions ate the prey in whichever direction it was caught**, contradicting the observed behavior to eat prey head-first and the hypothesis that this is preferred for brain damage or avoidance of rear chemical defenses. This behavior may be species-dependent due to the differing natural prey that may or may not need these advantages to be subdued easily.

Defensive

- **Temperature affected strike time and the number of probes required to provoke a defensive sting (Figure 5).** This supports similar findings, such as the shorter latency and faster sting rates found at higher temperatures (Carlson and Rowe, 2009), as well as the increase of scorpion sting incidences during warmer temperatures or summer (Hurtado-Díaz et al. 2017).

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