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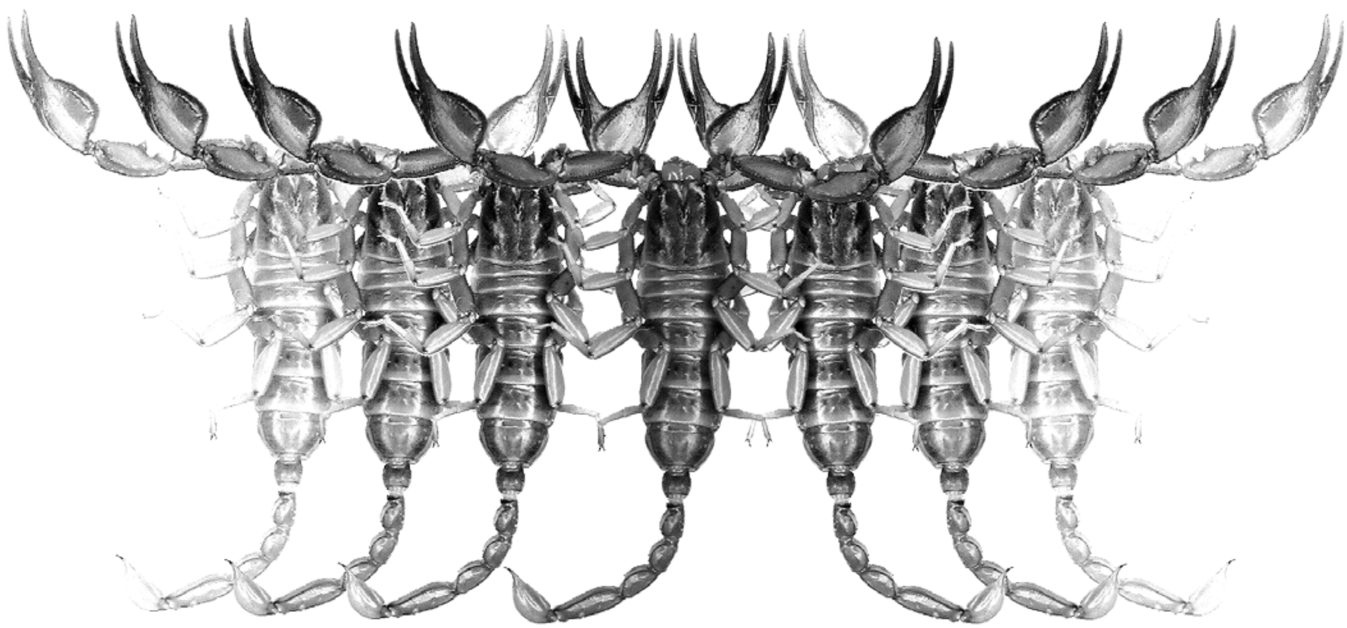

Prey Capture Behavior in *Heterometrus petersii* (Thorell, 1876) (Scorpiones: Scorpionidae)

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Prey capture behavior in *Heterometrus petersii* (Thorell, 1876) (Scorpiones: Scorpionidae)

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Summary

Prey capture by *Heterometrus petersii* (Thorell, 1876) (Scorpionidae) was observed in the laboratory. The behavior components displayed in prey capture were identified, compiled into a flow chart, analyzed and discussed.

Introduction

Scorpions are usually considered as generalist predators on a variety of prey, such as insects, spiders, and other small animals. Scorpions may use sensory systems other than vision or audition to locate prey (Polis & McCormick, 1986; McCormick& Polis, 1990). Depending on the distance between prey and the scorpion, prey is sensed by tarsal organs or by trichobothria, the long and very thin sensory hairs located on the pedipalps (Le Berre, 1979; Brownell, 2001). Already Pocock (1893) conducted a qualitative study on *Parabuthus capensis* (Ehrenberg, 1831) (Buthidae) and *Euscorpius carpathicus* (Linnaeus, 1767) (Euscorpiidae) feeding to them two common cock-roaches. The first quantitative study on prey capture behavior was conducted by Hadley & Williams (1968) for *Hadrurus hirsutus* (Wood, 1863) (Caraboctonidae), *Hoffmannius confusus* (Stahnke, 1940), *Smeringurus mesaensis* (Stahnke, 1957), and *Paruroctonus baergi* (Williams et Hadley, 1967) (Vaejovidae; taxonomy current) and *Centruroides sculpturatus* Ewing, 1928, (Buthidae). Subsequently, Bub & Bowerman (1979) identified and discussed different behavioral components involved in prey capture by the North American *Hadrurus arizonensis* Ewing, 1928, (Caraboctonidae) and presented these behaviors as a flow chart (ethogram). Casper (1985) studied prey capture and sting behavior of the African *Pandinus imperator* (C. L. Koch, 1841) (Scorpionidae). In this scorpion species, young usually sting prey, whereas adults only use their pedipalps. Recently, Rein (1993, 2003) analyzed and discussed behavioral components of prey capture by two buthid species from East Africa, *Parabuthus leiosoma* (Ehrenberg, 1828) and *P. pallidus* Pocock, 1895. Stewart (2006) observed prey capture behavior of *Androctonus crassicauda* (Olivier, 1807) (Buthidae) in the indoor and outdoor laboratory in Iraq. The effect of environmental conditions on prey capture behavior was also analyzed.

In this experimental study, prey capture behavior of *Heterometrus petersii* (Thorell, 1876) (Scorpionidae) was observed. All the behavioral components involved in prey capture were identified and analyzed. In two events when scorpions were injured by their prey, we observed behavior that could indicate a short-term memory.

Material and Methods

Species studied

Heterometrus petersii (Thorell, 1876) is found in Southeast Asia and is not native to China, Our specimens were purchased from pet suppliers in China who obtain scorpions from Tay Ninh Province, Vietnam. *Heterometru*s scorpions are frequently bred for pets and the dining table and have many common names; “tropical forest scorpion”, “red forest scorpion”, “Asian forest scorpion”, “Malaysian forest scorpion”, etc. (Zhu & Yang, 2007).

Materials

Studied specimens were adults (20 males, 20 females) from 90 to 120 mm in length. The adults vary in body color from greenish-black to black. They were housed individually in terraria (60×20×40cm), with a substrate of loam. The room temperature was maintained at 26 to 29°C, and the daylight was 10 to 14 hours. Two different types of prey were used in the experiments: mealworms (larvae of *Tenebrio molitor*) (28–32 mm, ca. 0.1 g), and “superworms” (larvae of *Zophobas morio*) (48–52 mm, ca. 1.0 g) (Coleoptera: Tenebrionidae).

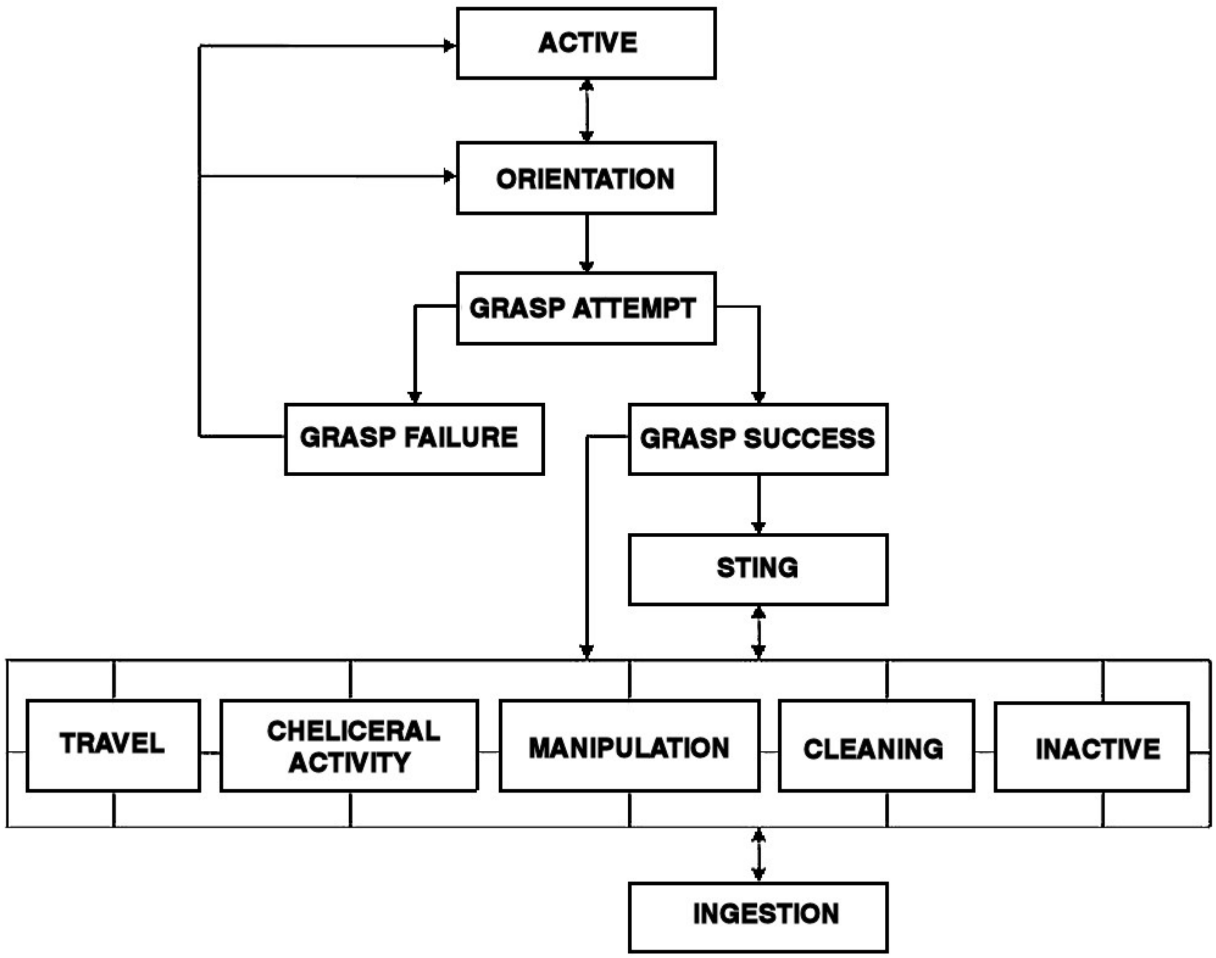

Figure 1: A flow chart modified from Bub & Bowerman (1979), Rein (2003), and Stewart (2006) showing prey capture behavior of *Heterometrus petersii*. The phases of Travel, Inactive, Cheliceral Activity, Manipulation and Cleaning show no particular temporal order, and are united in a frame.

These prey items were chosen principally because of availability and cost.

Experiment

In order to observe prey capture behaviors of scorpions effectively, specimens were starved for four weeks. During the starvation period, water was provided by misting, and scorpions were not fed until tested. Feeding and observations were conducted under low-intensity red light conditions which apparently do not affect the scorpion's behavior (Machan, 1968). When testing began a prey item was offered to a scorpion when the predator was observed moving on the substrate or remained motionless in an alert posture. A total of 50 feedings from 40 specimens were recorded. From April to July 2008, 20 experiments were conducted on capturing mealworms and 30 experiments were conducted on capturing superworms. On any given night of feeding only one or two scorpions were observed. Each terrarium was individually isolated and observed during the entire sequence of behaviors. As a scorpion was seen to be active a prey worm was offered and data taken till complete ingestion.

Terminology of prey capture phases and their descriptions are modified from Bub & Bowerman (1979), Rein (2003), and Stewart (2006) (Table 1).

Results and Discussion

Prey capture sequence

The behavioral components observed in the experiments were identified and compiled into a flow chart (Figure 1). Not all scorpions displayed all of the components in one experiment. For example, a quicker prey capture sequence involved orienting toward the prey, successful grasping, manipulating the prey, and

Prey Capture Phase	Description
Active	Scorpion travels within the terrarium prior to contact with prey, or remains alert: standing motionless with the trunk raised above the substrate, pedipalps outstretched in front of the body, movable fingers of its chela and/or pectines touching the substrate. Metasoma is curved above the dorsal surface of mesosoma.
Orientation	Scorpion detects the prey and the anterior portion of the body is moved directly towards the prey.
Grasp Attempt	After orientation, scorpion moves towards prey and attempts using one or both chelae to seize and hold the prey, staying within the range of touching the prey with chelae.
Grasp Failure	Scorpion does not capture the prey successfully after a grasp attempt, regardless of whether there has been any contact with prey or not.
Grasp Success	Scorpion holds the prey firmly with one or both chelae and controls prey when it struggles.
Sting	Forward movement of metasoma and telson as the aculeus probes and penetrates soft parts of prey.
Inactive	After successful grasp or sting, scorpion stays motionless.
Travel	Scorpion moves throughout the terrarium, holding the prey in its chelae or chelicerae
Manipulation	Scorpion reorients the prey using chelae and/or legs I, sometimes assisted by chelicerae before and/or during ingestion.
Cleaning	During prey capture, manus of chelae are cleaned by claws of legs I, or pectines are cleaned by claws of legs II; after ingestion, movable and fixed fingers of chelae are combed alternately by chelicerae.
Cheliceral Activity	Protraction of one chelicera and retraction of another, alternating with retraction of the first and protraction of the second.
Ingestion	Intake of the predigested prey, as indicated by cyclical movements of coxae I.

Table 1: Prey capture phases and their descriptions.

on-site ingestion of captured prey. The slower prey capture sequence involved all phases presented in the flow chart.

Once prey was detected, the anterior portion of the scorpion body was positioned facing the prey. Then the predator either moved towards the prey attempting to grasp it with one or both chelae or stayed motionless and ignored the prey regardless of contact. After the scorpion detected the prey and attempted capture, the frequency of the first grasp success was high (96%). When grasp failure happened (4%), the scorpion either attempted grasping the prey a second time (estimated at 75%), or paid no further attention to the prey. Prey resistance to capture was often observed but very few worms escaped.

After a successful grasp, 14% of scorpions stayed inactive up to 5 min, holding the prey with one or both chelae. Some scorpions (10%) traveled (even extensively and some even attempted to climb the walls), with prey in their chelae or (infrequently) in the chelicerae after successfully capturing prey. We speculate that nearby human activity may have promoted some or all of this traveling activity.

Scorpions used stings only in a few cases (7.5 %), all following successful grasping of superworms only. Stinging of mealworms was never observed. Only actively struggling superworms were stung. Scorpions did not sting passive prey.

Ingestion was indicated by cyclical movements of leg I coxae. During ingestion, most scorpions displayed a posture similar to the rest posture. Both prosoma and mesosoma contacted with the substrate, and metasoma was not curved above the dorsal surface of mesosoma but was placed on the legs or substrate. Chelae were positioned on the surface of the substrate. Legs II were placed forward, and legs III and IV backward so that legs I were free to assist feeding. In this feeding posture, the scorpion maybe used the substrate to support body weight in order to decrease energy consumption.

Scorpions often preferred to start the ingestion of the worm from the anterior (46%) rather than posterior (36%) end, possibly avoiding injury from a biting worm. It is also true that the anterior end of the worm (head and legs) may offer an improved gripping surface as the posterior worm body is hard and smooth. Regardless of prey orientation, there were no apparent differences between ingestion of *Tenebrio* or *Zophobas* larvae.

Prey	Period	Tool	Object	N*
Tenebrio molitor	After ingestion	Chelicerae	Movable and fixed fingers of chelae	5(20)
Zophobas morio	Prior to ingestion	Legs I (claws)	Internal keel of chela manus	2(30)
		Legs II (claws)	Pectines	1(30)
	After ingestion	Chelicerae	Movable and fixed fingers of chelae	13(30)

* N, number of cleaning events; the number of trials is in parentheses.

Table 2: Cleaning behaviors of *Heterometrus petersii* displayed during prey capture and after ingestion.

However, a firm crushing of *Zophobas* larvae by chelae was usually observed before feeding.

Cleaning behavior

Two different types of cleaning behaviors during two phases were observed (Table 2). In the first phase, immediately before ingestion, during prey capture a few scorpions apparently cleaned the internal keel of the chela manus by scratching with the claws of leg I. Also, very few scorpions scraped their pectines, both lamellae and teeth, using claws of legs II. In the second phase, after ingestion, some scorpions combed the movable and fixed fingers of chelae in turn with both chelicerae. Most cleaning behaviors (61.9 %) were observed after ingestion of large *Zophobas* larvae, while only a few scorpions displayed cleaning behaviors after ingestion of the *Tenebrio* larvae (23.8 %). Even fewer showed cleaning behavior during prey capture of *Zophobas* larvae (14.3 %).

Bub & Bowerman (1979) observed for the first time a cleaning behavior of scorpions which they characterized as “sand thrust”, but they did not discuss it in detail. Later, Rein (2003) also reported a similar type of cleaning behavior when studying prey capture by two African buthid species: fingers of one or both chelae and/or aculeus were pushed into the substrate and frequently moved back and forth a few times. We observed *Heterometrus* to use leg claws as cleaning tools: legs I to clean pedipalp chelae, or claws of legs II to clean the pectines during prey capture. After ingestion, *Heterometrus* also used chelicerae in turn to comb movable and fixed fingers of pedipalp chelae. Different types of cleaning behavior could be related to scorpion habitats. The formerly observed species of Buthidae inhabit semi-arid areas, where a direct “sand thrust” of pedipalp fingers into the substrate could serve as a cleaning-behavior adaptation. *Heterometrus*, on the contrary, lives on the red loam of tropical rainforests where thrusting an appendage directly into ground would just accumulate more dirt.

Possible short-term memory of injuries

Two injuries inflicted by the larvae of *Zophobas morios* were observed during prey capture on two different scorpion specimens. Both injury events occurred after the scorpions successfully grasped the worm. Both times, as the larva was being directly delivered to the chelicerae for ingestion, the prey bit the intersegmental membrane of the scorpion’s pedipalp. After being bitten by their prey, the two scorpions exhibited different behaviors. One specimen released its prey at once, convulsed a few times, “treated” the injury by combing it alternately with chelicerae for about 60 s, and then stayed motionless. Even though prey contacted this scorpion during the motionless period, the scorpion ignored the prey and did not react. The other specimen released the prey only after prey struggled twice; the scorpion convulsed for a few times, “treated” the injury combing it alternately with chelicerae for about 20 s, and then moved through the terrarium and seemed to search for the prey. Once this scorpion detected the prey again, it opened both chelae at a larger angle, which could indicate a stronger attempt to capture. As prey contacted scorpion chela for an instant, it was strongly grasped by chelae. Scorpion then crushed the anterior portion of prey’s body alternately by each chela six times, compared to two or three times observed in most capture experiments.

We can speculate that injured scorpions appear to remember events within a short time after being bitten. Either the injured scorpion ignored prey and did not attempt a re-capture to avoid being bitten a second time, or it used a stronger effort to capture the resistant prey and then crushed it numerous times before ingestion. Of course, just two occasional injury events are insufficient for interpreting this behavior as a short-term memory; a further study should be done in the future.

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