PREY CAPTURE BY THE SCORPION *HADRURUS ARIZONENSIS* EWING (SCORPIONES: VAEJOVIDAE)

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ABSTRACT

Prey capture behavior of the desert scorpion *Hadrurus arizonensis* Ewing has been studied in the laboratory. Information about the behavior was obtained from analysis of ten 8mm movie films, and 50 direct observations of individual prey capture sequences. An ethogram was constructed which depicts the interrelationships between the discrete behavioral components; e.g., alert stance, grasp success, and sting. Most individuals also exhibit a pedipalpal sand thrust, which may function in a cleaning capacity.

INTRODUCTION

Scorpions are best known for their dramatic stinging behavior, which can be associated either with prey capture or with defense. Still, scorpion prey capture behavior has not been studied to any appreciable extent. Many previously published descriptions have been anecdotal in nature (Lankester 1883, Pocock 1893, Fabre 1911, Smith 1927). Several more recent articles do include brief descriptions of prey capture for various scorpion species (Vachon 1953, Baerg 1961, Cloudsley-Thompson 1961, Williams 1963, Stahnke 1966). Hadley and Williams (1968) maintained several species in the laboratory, and described the prey capture behavior of *Paruroctonus mesaensis* Stahnke as representative. Palka and Babu (1967) described the ballistic defensive movements of the scorpion *Heterometrus* spp.

Robinson and co-workers have studied the prey capture behavior of several tropical web-building spiders (Robinson 1969, Robinson and Mirick 1971, Robinson and Olazarri 1971, Robinson et al. 1971, Robinson and Robinson 1973, 1974). Ethograms of the predatory sequence were designed and intraspecific variations noted. Prey capture by a primitive web-builder (Valerio 1974) and by jumping spiders (Forster 1977) have also been studied.

This paper represents the results of a study similar to the above on the predatory behavior of a species of desert scorpion, *Hadrurus arizonensis* Ewing. The prey capture sequence is depicted in an ethogram, and the behavioral components are described.

METHODS

Individuals of *H. arizonensis* were collected in August 1977 near Palo Verde, California. The scorpions were maintained individually in 25 cm x 35 cm terraria, with 15 cm deep sandy-soil substrate, which permitted them to burrow. The individuals were of unknown age, ranging in length from 5 to 10 cm (prosoma to aculeus), and weighing from 0.89 to 7.36 grams. In the holding room, fluorescent lights and two heat lamps were on fourteen hours and off ten hours, daily. Temperatures ranged respectively between 20° and 29° C. Water was provided weekly by misting the substrate and by saturating a sponge, upon which the scorpions were seen to knead with their chelicerae, presumablly extracting the moisture. Individuals were removed from their terraria for observation only after onset of the dark period, when they were out of their burrows. The observation and filming chamber was semicircular, with a 50 cm diameter.

Nymphs and adults of the American cockroach, *Periplaneta americana*, and adults of the common house cricket, *Acheta domesticus*, were offered to the scorpions as prey. Orthoperan species have been identified as natural prey for *H. arizonensis* (Hadley and Williams 1968). Time between feedings varied from one week to one month.

Ten prey capture sequences were filmed with a Beaulieu 4008 Zm 11 Super 8mm movie camera, at 24 frames per second and analyzed with a Kodak stop action projector. No overt differences were noted between the behavior when filmed under white lights and that observed under red light. The spectral sensitivities of *H. arizonensis* photorecep-tors have not been described, so it is not known whether or not the red light can be perceived.

The next stage of the study involved 50 prey capture sequences by fourteen individuals, viewed under two 40W red tungsten light bulbs. Each scorpion was transferred with forceps to the observation chamber and after a thirty-minute acclimation period, the cockroach or cricket was introduced. Subsequent activities were recorded on a cassette tape recorder for later transcription.

RESULTS AND DISCUSSION

The prey capture sequence, as observed and analyzed in the laboratory, is represented by the composite ethogram (Fig. 1). The terms used in the ethogram are defined as follows:

Motile—locomotion within the chamber, prior to contact with the prey.

Retracted—body in contact with the substrate, metasoma and appendages drawn in.

Alert Stance—a posture in which the scorpion is supported above the substrate by the legs, the pedipalps are extended anteriorly, with the movable fingers of the pedipalpal chelae and the pectines in contact with the substrate (Fig. 2).

Orientation—movement of the scorpion resulting in the anterior aspect being directed towards the prey.

Grasp Attempt—an effort to obtain a hold on the prey with the pedipalpal chelae.

Grasp Failure—the prey escapes after a grasp attempt, whether there is contact or not.

Grasp Success—the scorpion obtains a firm hold on the prey with at least one pedipalp.

Sting—a behavioral unit consisting of a forward sweep to the metasoma, telson contact with the prey and subsequent probing movements, and aculeus penetration with presumed venom injection.

Inactive–following a grasp success; no visually detectable activity of chelicerae, pedipalps or walking appendages.

Manipulation–handling of the prey by the pedipalps and first pair of legs, including turning of the prey for head-first ingestion.

Cheliceral Activity–protraction of one chelicera and retraction of the second, alternating with retraction of the first and protraction of the second. The chelicerae are opened during protraction and closed during retraction.
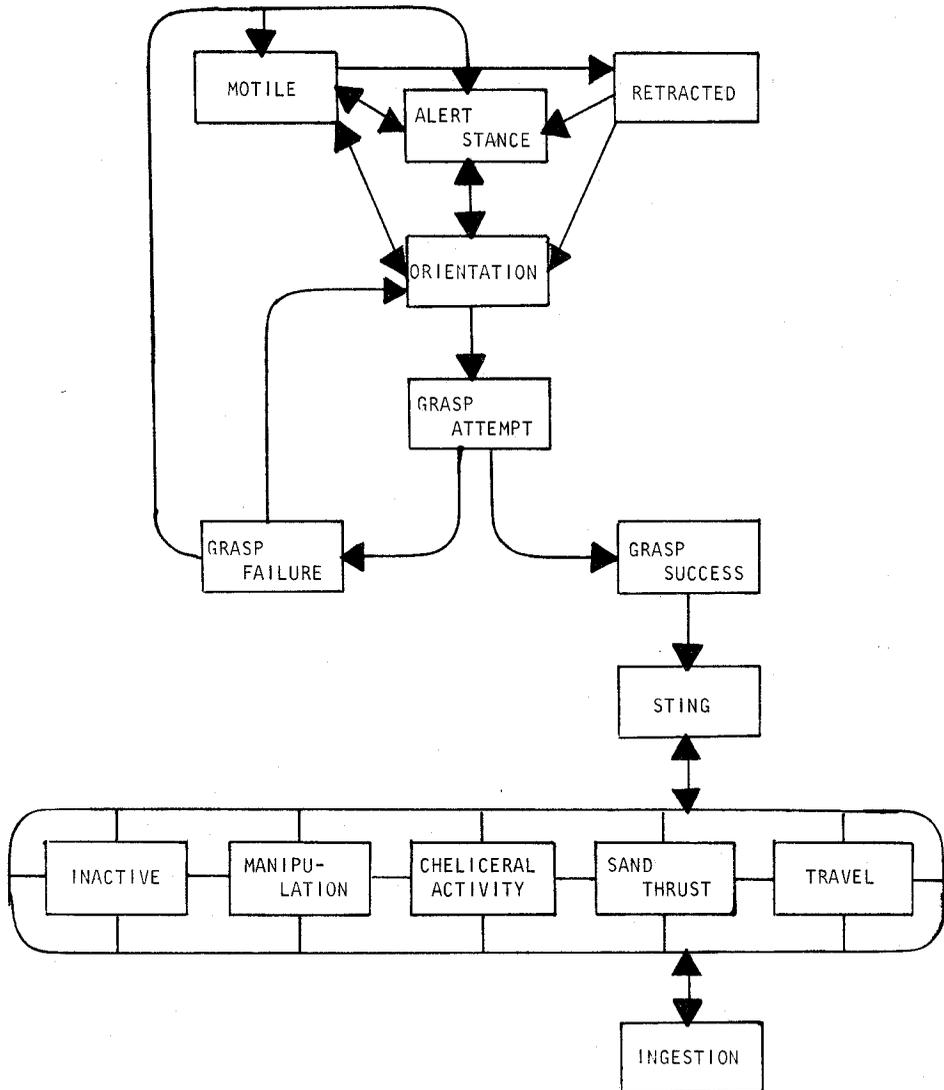

Fig. 1.–Ethogram of the prey capture sequence and its constituent behavioral units for the scorpion *Hadrurus arizonensis*. Individual terms are defined in the text. Behavior observed in this study was seen to flow in the direction of the arrows. The box circumscribing five of the behavioral units indicates that any of these units can precede or follow any of the others.

Sand Thrust—a pedipalp is pushed into the substrate, withdrawn, and frequently brushed off by the distal segments of the first and second pair of legs.
Travel—moving throughout the chamber, holding the prey in a pedipalp and/or chelicerae.
Ingestion—the intake of the pre-digested fluid prey, as indicated by cyclical movements of the coxae of the first legs.

The Prey Capture Sequence.—Many individuals, when first placed in the observation chamber, moved around the area in an exploratory fashion before settling. A potential prey encountered during this motile stage, either was ignored by the scorpion, or induced orientation and a grasp attempt. When a scorpion ceased to move around the chamber, it usually adopted one of two postures. In some sequences (20%), the scorpions took on a retracted posture with the ventral surface resting on the substrate, and the pedipalps, legs and metasoma drawn in against the body. In a few cases, scorpions in a retracted posture completely ignored prey. At other times, however, the scorpion responded to nearby prey by taking an alert stance or by making an immediate grasp attempt.

In most instances (80%), the scorpion adopted an alert stance (Fig. 2) soon after being placed in the observation chamber. In this posture, the prosoma and mesosoma are supported slightly above the substrate by the four pairs of legs and the metasoma is curled dorsomedially. The pedipalps are extended anteriorly, slightly bowed. The chelae are open, with the very tips of the movable fingers in contact with the substrate. The distal aspects of the pectines are also touching the ground. Occasionally, scorpions would lift their pedipalps and pectines, reorient by moving forward or pivoting, then re-adopt the alert stance. This activity often results in directed orientation of the scorpion towards nearby prey.

A scorpion in the alert stance was able to detect and orient to moving prey and to make a grasp attempt before there was direct contact. Immobile prey did not elicit either orientation or grasp attempts. On several occasions, a scorpion and prey would both stand perfectly still within a few centimeters of each other for several minutes. Should the prey move first, the scorpion would lunge and often successfully grasp it, but when the scorpion moved first, the prey would usually avoid capture. The use of substrate-borne vibrations for prey detection by *H. arizonensis* seems quite possible. Brownell (1977) demonstrated the ability of another vaejovid desert scorpion, *Paruroctonus mesaensis*, to detect compressional and surface waves generated by digging activity of prey up to a distance of 50 cm. Electrophysiological recordings showed that compound slit-sensilla on the basitarsal leg segments, and tarsal hairs responded to these prey-generated, substrate vibrations. Analogous sensory mechanisms may be operating in *H. arizonensis*, possibly with auxillary input from mechanoreceptors on the pedipalps and pectines, which are both in contact with the substrate during the alert stance.

The alert stance of *H. arizonensis* brings legs, pedipalps, and pectines in contact with the substrate simultaneously. The stereotyped placement of these appendages in this behavior may be critical in permitting central nervous system integration of environmental information concerning prey location. Another arthropod, the water strider *Gerris remiges*, utilizes a comparable stereotyped posture during prey orientating behavior (Murphy 1971). Localization of a stimulus and subsequent responses by this organism are determined by which of the six legs are closest to the stimulus.

Even though the mechanical senses may be of highest importance, the prospect that the visual system plays a role in prey location should not be discounted without direct experimentation. Recent studies (Fleissner 1977a,b), demonstrate the high sensitivity of scorpion photoreceptors, particularly the lateral eyes.
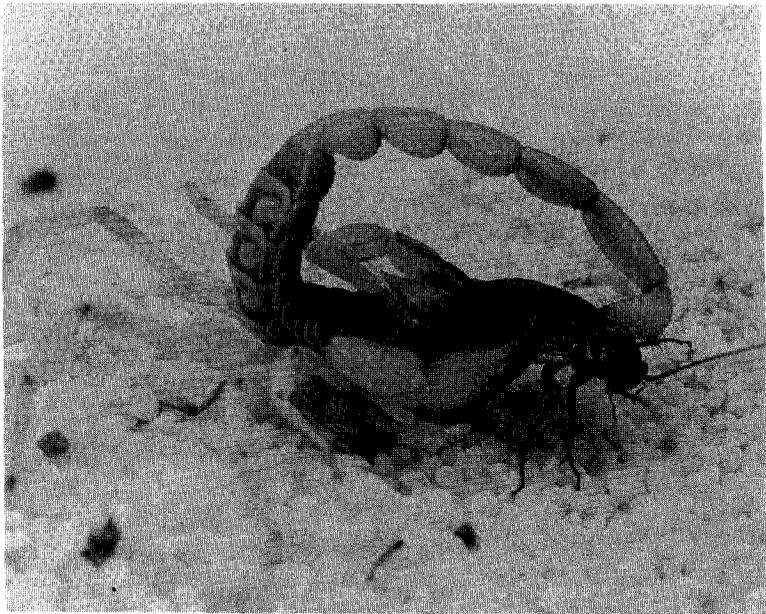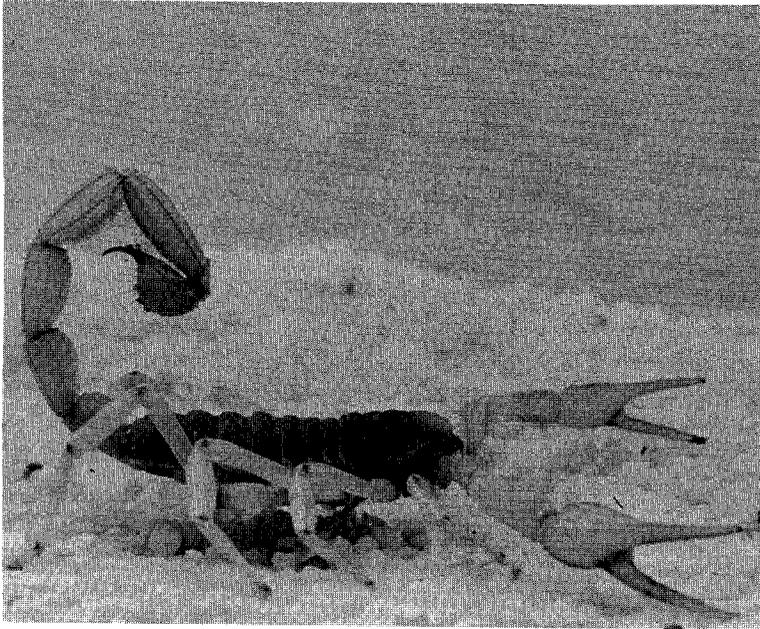
Fig. 2.–The alert stance of *Hadrurus arizonensis*, in which the distal aspect of the pectines and the tips of the movable fingers of the pedipalpal chelae are in contact with the substrate.

Fig. 3.–*Hadrurus arizonensis* stinging an adult cockroach on the ventral surface. Note the involvement of both the mesosoma and metasoma in telson placement, and the supportive positioning of the legs.

In grasp success, both pedipalps are employed, with one or both gaining a firm hold of the prey. In 61% of the sequences, the first grasp attempt was successful, while in the other 39%, two or more attempts were necessary. The attempt was considered a grasp failure if the prey was missed altogether, or was held only momentarily before escaping. Under natural conditions, should the scorpion fail in a grasp attempt, it is most likely that the prey, unless injured, would move from the vicinity and thereby reduce the prospects for a second attempt. In this study, where escape was not possible, the scorpions were allowed unlimited grasp attempts.

The prey was stung at least once in all sequences observed. When stinging prey, *H. arizonensis* maintains postural stability by extending the second, third and fourth pairs of legs in a characteristic pattern (Fig. 3). The first pair of legs may be supportive as well, but more frequently assists the pedipalps in the manipulation of the prey. The thrashing legs of the victim may be held or moved aside by these anterior most legs. The pectines remain inactive during stinging, being withdrawn against the ventral mesosomal surface. The telson is initially brought forward dorsomedially in a slow precise movement (Fig. 4). The posture of the mesosoma during stinging ranges from a slight convex bowing
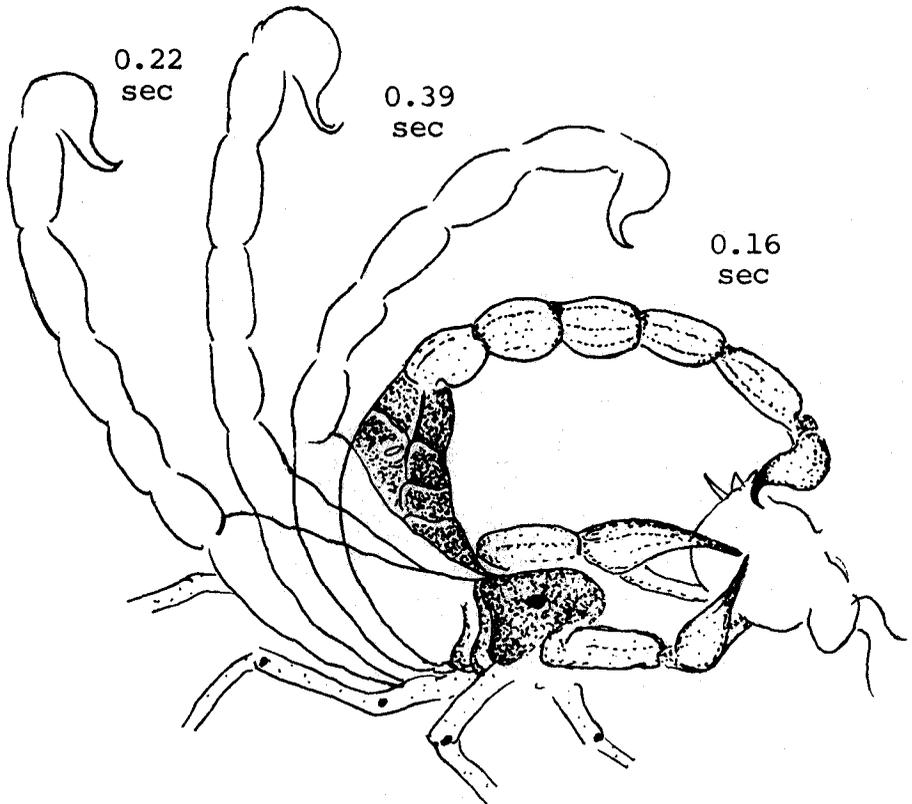

Fig. 4.—Progressive movements of the opisthosoma from point of grasp success to telson contact. Tracings are from selected frames of an 8mm movie taken at 24 fps. Time periods between positions are given, the entire movement taking approximately 0.75 seconds.

involving every segment (Fig. 5A), to a more angular deflection (Fig. 5B). It is the metasoma, however, which demonstrates the greatest flexibility. As opposed to the more or less uniplanar curving of the mesosoma, the first four joints of the metasoma have a considerable rotational ability (Bowerman 1972). When the telson is brought forward, the aculeus first contacts that part of the prey's body in direct line with the sweep. If soft tissue of the prey is met, penetration and presumably venom injection occur immediately. However, if hard chitinous plates are contacted first, the telson must then be repositioned to locate a penetrable tissue.

Some species of scorpion (e.g., *Euscorpius italicus* and *Anuroctonus phaiodactylus*) seldom, if ever, employ a sting during prey capture (Schultz 1927, Cloudsley-Thompson 1955a, Baerg 1961, Williams 1963, McDaniel 1968). Baerg (1961) points out that scorpions with large pedipalps and reduced metasoma probably do not use the sting for immobilizing prey. In the current study, *H. arizonensis* stung every prey offered. It is possible that *H. arizonensis* may not sting prey below a certain size, or under different conditions, but these were not investigated.

The time from telson contact to actual penetration by the aculeus, i.e., that time spent locating soft tissue, ranged approximately from one to 50 seconds. In some cases, extensive telson movements occurred throughout this period.

Steiner's (1976) mapping of predatory digger wasp sting sites on cricket prey showed clumped distribution, positively correlated with the location of major ganglia. There appears to be no such correlation in the sting sites of *H. arizonensis* on either cricket or cockroach prey. Rather, the sting site distribution appears to reflect the sites of the first penetrable tissue encountered. Adult cockroaches, for example, received 94% of the
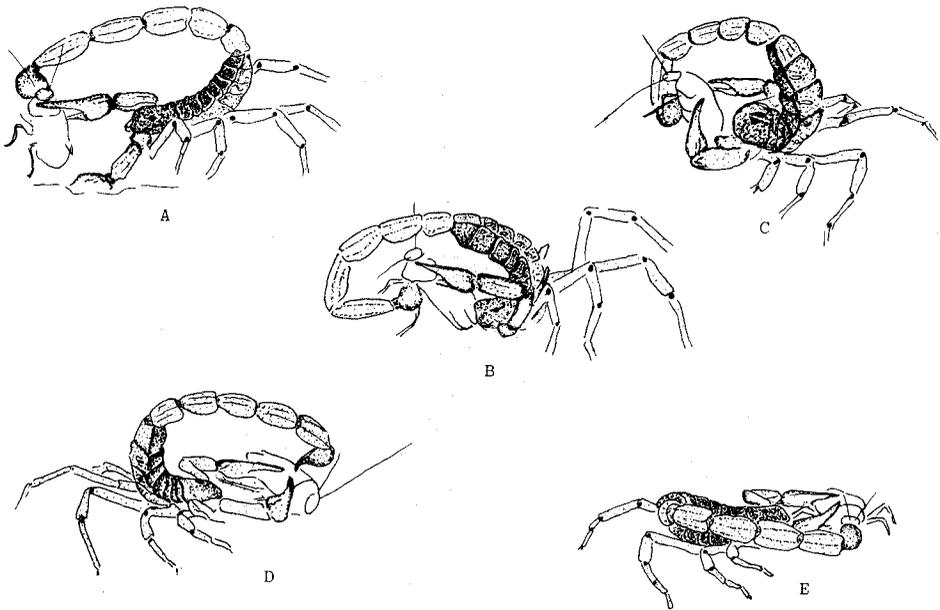

Fig. 5.–Postures demonstrated by *Hadrurus arizonensis* when stinging prey. Drawings are from single frames of 8mm movies.

stings on their ventral surface, even though the dorsal surface was usually encountered first by the telson. The heavy wings and thoracic sclerites appear to prevent dorsal penetration. Adult cricket prey, however, received 75% of their stings dorsally. The dorsal aspect was again usually encountered first, but since the relatively small cricket wings do not extend over the abdomen, immediate penetration could often occur.

Any one of the behavioral units following the sting, may follow any other as shown by the box and interconnections in the ethogram (Fig. 1). For example, the initial sting may be followed by inactivity, manipulation, cheliceral activity, sand thrusts or travel. Subsequent stings occurred in 52% of the sequences, usually in response to struggling of the prey.

Within this part of the prey capture sequence an interesting behavior termed the sand thrust occurs which heretofore has not been described. The sand thrust (Fig. 6) was observed in 81% of the sequences and appears to be a fundamental part of prey capture in this species. Only one individual repeatedly failed to exhibit the sand thrust. Four other scorpions failed to exhibit the sand thrust in one of several observed sequences. The remaining nine scorpions invariably performed the sand thrust during the prey capture sequence.

Either simultaneously with, or following a sting, the scorpion releases one pedipalpal chela from the prey while retaining hold with the other. The free pedipalp is thrust into the sandy substrate up to the base of the chela. Usually, it is withdrawn immediately, but at other times it is kept buried for several seconds. Repetitive thrusts frequently occur, and prior to regrasping the prey, the chela is often brushed off by the distal segments of the ipsilateral first and second legs. A sand thrust by one pedipalp is sometimes immedi-
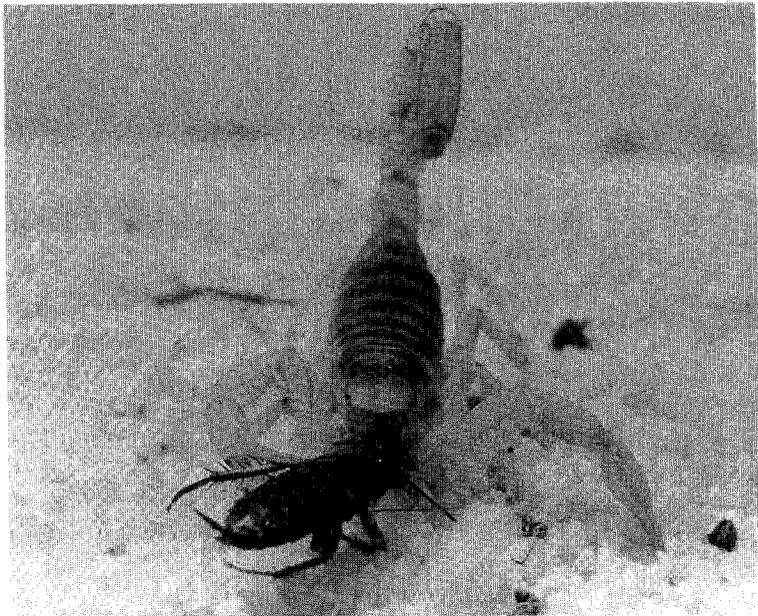

Fig. 6.—The sand thrust behavior demonstrated by *Hadrurus arizonensis* following the capture of prey.

ately followed by a sand thrust with the other pedipalp. The function of the sand thrust behavior is unknown. It may well be a grooming or cleaning behavior, as hemolymph from the prey often contacts the pedipalps during capture.

In the majority of the sequences (75%), the scorpions remained to feed at the site where the prey was captured. In the other sequences, they traveled throughout the observation chamber with the prey held in one pedipalp or the chelicerae. This activity continued occasionally interspersed with digging behavior, until the scorpion eventually settled to feed.

Cheliceral mastication began at the head end of the prey in 89% (39/44) of the sequences. In 30 of the sequences, this required that the prey be reoriented by manipulation with the pedipalps. In each of the other nine sequences, the prey was caught in such a way that the head was already directed toward the chelicerae. Other manipulations involved displacement or removal of the prey's wings, leg and/or antennae. The head first prey consuption seen in *H. arizonensis* has been described in *Opisthophthalmus latimanus* Koch by Alexander (1972), who identified the position of the prey's legs as being one of the clues used by the scorpion for feeding orientation. The possible advantages underlying this specific head-first ingestion were not discussed in her article. Head-first consumption may assist in subduing the prey by immediately damaging the brain. Alternatively, the scorpion may be avoiding the posterior aspect of the prey, since many orthopterans have large powerful legs which could greatly interfere with the feeding activities of the scorpion. Similarly, chemical defenses in some prey such as tenebrionid bettles are extruded from the rear, and would be avoided by starting at the head.

The scorpion's first pair of walking legs aid the pedipalps in manipulating prey, which is not an unusual characteristic among the arachnids. Within the Solifugae and Amblypygi, the first pair of walking legs are secondarily segmented for use as tactile organs, and are not used for locomation (Savory 1970). Certain Araneae are known to use their first pair of legs for display during courtship, as well as for walking. Bowerman (1975) in a study on the control of walking in *H. arizonensis*, noted that the first pair of legs exhibited different stepping patterns than the more posterior legs, i.e., they were elevated for longer periods during stepping. It was suggested that these legs functioned, in part, in a tactile capacity. A closer investigation of these appendages in several scorpion species would be of interest.

The chelicerae are activated prior to their actual contact with, and use in, mastication of the prey. The activity consists of reciprocating movements of left and right appendages. One chelicera is protracted with open chela, at the same time that the other chelicera is retracted with closed chela. Then, each chelicera performs the motion just completed by the other. The reciprocate grasping and retraction by the two chelicerae slowly tears the prey's exoskeleton, exposing the inner tissues to the digestive enzymes of the scorpion (Snodgrass 1948). Rhythmic movements of the coxae of the first pair of legs help in transporting the predigested prey into the scorpion's oral cavity by means of a pumping action (Shrivastava 1955). Observations on the prey capture sequences were terminated when the rhythmic movements of the coxae signaled that ingestion had commenced.

Predation strategies of several species of desert scorpions have been observed in the field. In general, the majority of these scorpions employ a sit and wait strategy (Williams 1963, Stahnke 1966, Hadley and Williams 1968, Enders 1975), ambushing prey that blunders into the vicinity (Pianka 1973). Some large diplocentrid species wait in the entrance of their burrows, while most of the vaejovid species move a distance from the

burrow before settling. *H. arizonensis* appears to utilize a sit and wait strategy involving the alert stance. The presumption that the prey capture sequence of *H. arizonensis* unfolds similarly in the field to the way it does in the laboratory observation chamber awaits verification. However, given that the just stated presumption is reasonably sound, the current study provides an informational foundation for further studies on the feeding behavior of *H. arizonensis* as well as for comparative studies of other species of scorpion, both closely and distantly related.

ACKNOWLEDGMENTS

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