BEHAVIORAL ASPECTS OF THE COMMON STRIPED SCORPION, CENTRUROIDES VITTATUS (SAY) (BUTHIDAE)

by

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INTRODUCTION

This study concerns the behavior of the common striped scorpion, Centruroides vittatus (Say), and compares its behavior with that reported in the literature for other species of scorpions. Laboratory and field observations on C. vittatus were made at Kansas State University, Manhattan, Kansas, and the immediate vicinity between March, 1961 and March, 1962.

Centruroides vittatus probably has a greater distribution in the United States than any other scorpion. Stahnke (1956:14) reports it ranges from New Mexico to Florida and northward to include Colorado, Oklahoma, Arkansas, Kansas, Missouri, and southern Illinois. In Kansas, C. vittatus has been collected throughout most of the state but appears to be most common where there are limestone outcrops. Although it is closely related to the two lethal species, C. sculpturatus Ewing and C. gertschi Stahnke, occurring in the southwest, C. vittatus is only a minor nuisance. Its sting is painful but not dangerous to man.

Most publications on scorpions deal with taxonomy, morphology, and venom; and research on behavior has been done primarily on species not found in the United States. Information relating to the behavior of C. vittatus has been published by Smith (1927) and Ewing (1928).

Scorpions are sometimes referred to as living fossils as they are one of the oldest forms of life still to be found on the surface of the earth. Scorpions have remained essentially unchanged morphologically for hundreds of millions of years.

Vachon (1956:2-3) theorizes that while great climatic and ecological changes were occurring, scorpions were able to survive with little apparent evolution because of their ecological plasticity and subterranean habitat. "Largely unaffected by extremes, they are virtually independent of their surroundings; herein lies the most certain guarantee of the immortality of their race."

Scorpions belong to the phylum Arthropoda characterized by jointed appendages, bilateral symmetry, segmented body, external skeleton, dorsal heart, and ventral nerve cord. This phylum also includes the millipeds, centipedes, crustacea, spiders, mites, insects, and a few other related groups. Members of the class Arachnida to which scorpions belong possess no antennae and have two body regions, a celpalothorax, which corresponds to a union of the head and thorax regions of insects, and an abdomen. This class also includes the spiders, harvestmen, ticks, and mites. Scorpions occupy the order Scorpionida by themselves. The cephalothorax is unsegmented dorsally and broadly joined to the abdomen. The cephalothorax bears a pair of large pedipalps terminating in stout chelae or claws in addition to four pairs of walking appendages terminating in small tarsal claws rather than large chelae used for grasping. Dorsally, the cephalothorax bears a pair of median eyes and two to five pairs of eyes, termed the lateral eyes, on the anterolateral margins. The abdomen is subdivided into two parts, a thickened preabdomen composed of seven segments and a more slender "tail" or postabdomen of five segments and a terminal sting. On the ventral surface of the second abdominal segment are a pair of comb-like organs, the pectines, which are probably tactile organs. On the ventral surfaces of the third to sixth abdominal segments are found four pairs of booklungs.

Only about 650 species of scorpions are described with 40 species occurring in the continental United States. Throughout the world, adult scorpions range in length from three-fourths inch (20 mm.) to eight inches (204 mm.). In the United States, they range from one inch (25 mm.) to five inches (125 mm.) (Stahnke, 1956:5).

Centruroides vittatus belongs to the family Buthidae which is characterized by: a triangular-shaped sternum with sides strongly convergent anteriorly; two unbranched spurs at the base of the last tarsal segment; and the arm of the chelicerae is void of a ventral tooth (Ewing, 1928:15).

Adults of C. vittatus have a total body length (anterior edge of carapace to end of fifth postabdominal segment) averaging one and three-fourths inch (45 mm.) for females and two and three-fourths inch (68 mm.) for males.

The dorsal plate of the cephalothorax, the carapace, is broad at the base and tapers to one half this width on the anterior margin. This plate is divided into right and left halves by a deep furrow. Along each anterolateral margin are located three lateral eyes in a straight line. On both sides of the medial groove and a little forward of the center of the carapace is situated a pair of median eyes in a small convexity, the ocular tubercle. Two furrows leading from the posterior end of the ocular tubercle to just behind the posterior pair of lateral eyes form an ocular triangle which is dark brown contrasting with a yellowish field. The posterior and lateral boarders of the carapace are also darkened.

Adults of C. vittatus possess two broad, dark, longitudinal stripes on the dorsum of the abdomen. These stripes are usually entirely interrupted at the middle of each abdominal tergite.

The appendages and postabdomen of both sexes are yellowish brown except for the distal portion of the stinger, which is black. The relative length of the postabdomen compared with the preabdomen is much greater in males (44 mm. to 12 mm.) than in females (29 mm. to 10 mm.).

In the immature specimens the dark longitudinal bands are usually continuous. The chelae and the fifth segment of the postabdomen are black, and three longitudinal black stripes run the length of the venter of the postabdomen. The median stripe is wider than the lateral ones.

METHODS

Collecting and Rearing

Scorpions used for the following study were obtained in two ways: those collected by the investigator and other members of the Department of Entomology from an area surrounding Manhattan, Kansas; and those mailed to the department by interested persons throughout the state.

Collecting was done by turning over stones, picking the scorpions up with forceps, and placing them individually in plastic bottles. When two scorpions were found under the same cover they were placed together.

Specimens were shipped in cardboard mailing tubes furnished by the investigator to anyone who would collect scorpions for this project. Included in the tube were return address labels and postage, instructions for packing and shipping, data or specimen sheet, and two numbered pint plastic bags with strips of paper inside. The data sheet requested the following information: collector's name and address; and habitat, location, date, and time when the scorpion was collected. The directions for mailing were to moisten the paper strips, seal the bag with a rubber band, place in the mailing tube, and ship. The scorpions could be shipped by regular third-class mail from anywhere in Kansas and arrive in Manhattan alive and well if sufficient moisture was added to the paper strips. The data reports were returned separately. This method of shipment was obtained from the Poisonous Animals Laboratory, Tempe, Arizona.

When the scorpions reached the laboratory, they were placed in jars with the date collected written on the outside. Many types of holding containers were tried during the preliminary studies, and only the most satisfactory will be described. Widemouth gallon jars were used as containers, with a fine gravel about one inch deep covering the bottom, and with one or two large stones for cover. In some jars, no stones were provided so the scorpions would be in constant view of the observer.

Water was provided in a small petri dish filled with cleansing tissue and saturated several times a week as it became dry.

No more than two adult scorpions were generally placed in any one jar; however, in a few small aquaria (31 by 20 by 22 cm.) as many as six to eight adults or immatures were held with no apparent conflict. These aquaria made excellent holding and observation containers, but were too spacious and expensive to be used exclusively.

Food was made available at all times by keeping live arthropods in the containers. The scorpions fed on several species of cockroaches, grasshoppers, and spiders; but more readily ate domestic crickets, Acheta domesticus (L.). Because the latter species was also most easily reared in the laboratory, it was the primary food used.

All containers with scorpions were kept in dark cabinets with no attempt made to control humidity or temperature.

Experimental Techniques

Light. Because scorpions frequently remain under stones when in low intensity white light, observations were frequently made using red light. By using red filters or covering the containers with red glass or plactic, the scorpions remained active throughout the day.

Marking. When scorpions had to be marked for identification, small spots of colored lacquer were painted on the cephalothorax or abdomen.

Removal of Pectines. In order to remove the pectines, scorpions were first anesthetized with carbon dioxide and placed on their backs. The pectines were cut off at the edge of the basal plate using a pair of straight iridectomy scissors. Because the wounds were found to bleed profusely after amputation of the pectines, the area was sealed with a low melting point wax (a distilled acetylated monoglycerides product manufactured by the Eastman Kodak Company under the trade name, "Myvacet"). Even though the genital aperture as well as the wounds were sealed by the wax, this material was satisfactory because the wax was worn off in about one week. By this time the wound had healed.

Removal of Trichobothria. The trichobothria, long sensory hairs on the pedipalps, were removed by singeing them with a small soldering iron. Directly after treatment and one month later the pedipalps were examined using a stereoscopic microscope (22X), and no trichobothria could be found.

Anesthetization. Scorpions were inactivated by using carbon dioxide gas. The scorpions were held in an airtight container of the gas for a period of up to one hour. After a period of one hour in this chamber, a scorpion usually remained quiet for only about ten minutes. If a longer period of anesthesia was needed, a steady stream of carbon dioxide was kept flowing over the scorpion.

Carbon dioxide was compared with ethyl ether as an effective anesthetic. When carbon dioxide was used, several scorpions were simultaneously anesthetized in a bottle; but when ether was used, each scorpion was anesthetized in a five-dram vial. The polyethylene cap of the vial contained a cotton plug on which 0.5 ml. of ether was placed. Ten individuals were used for each anesthetization period.

The scorpions were removed from the anesthetic and placed on their backs in an open dish. The point of revival was considered to be when the scorpions righted themselves. The results (Fig. 1) show that although a shorter exposure time is required and the scorpions remain quiet longer using ether, the exposure time is less critical for carbon dioxide. Due to this critical exposure time and the violent reactions by the scorpions when exposed to ether, carbon dioxide was the anesthetic of choice.

HABITAT

Although scorpions are similar morphologically, they are found in diverse habitats. Some frequent damp places (Euscorpius); others live in forested areas (Pandinus and Palamnareus); while others inhabit dry and desert regions (Scorpio, Buthus, and Androctonus) (Cloudsley-Thompson, 1958a:73). Scorpions are found under almost any kind of object where it is dark and moist. This habitat is also ideal for the small animals which are food for scorpions.

Lankester (1883:455) correlated body carriage with the type of habitat. Androctonus funestus, an Algerian species, which lives entirely in burrows, was observed to carry its body well raised from the ground with the tail recurved over its back.

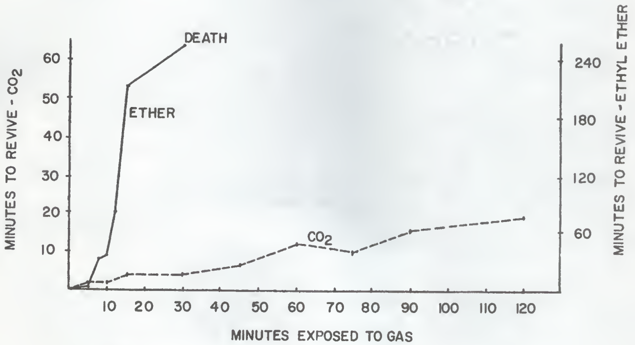

FIG. I COMPARISON OF ETHYL ETHER AND CARBON DIOXIDE AS ANESTHETICS.

Euscorpius sp., which occurs in Italy, carries its body much flatter with its tail rarely curved forward. This flatter carriage is probably connected with its habit of running under objects rather than burrowing. *Euscorpius carpathicus* was observed (Pocock, 1893:104) to have similar habits while *Parabuthus capensis* behaves similarly to *A. funestus* (Lankester, 1883:455).

Although *C. vittatus* is most frequently found under objects, it usually walks with its body raised about one half its thickness from the ground. Sometimes the postabdomen is curved over its back; but when the scorpion runs rapidly its pedipalps are extended forward and the sting points straight back.

Two closely related burrowing species can differ in their habitats and behavior as shown by two Australian scorpions. *Urodacus abruptus* lives in loamy soil in shallow tunnels opening under stones, and *U. armatus* lives in sand or sandy soil in tunnels with openings not covered by objects (Southcott, 1954: 145).

Fabre claimed that if two scorpions are found under the same object, they are either mating or one is devouring the other (Cloudsley-Thompson, 1958a:73). However, Schultze (1927:73) stated that one usually finds two or more individuals of *Palamnaeus longimanus* Herbst together. Two almost full-grown nymphs or a nymph and an adult of *Centruroides vittatus* have been found under the same stone several times in Kansas. Young nymphs with or without their mother are commonly found.

The _Centruroides_ spp. are referred to as bark scorpions (Stahnke, 1956:17) because of their frequency under the bark of trees such as cottonwood, pepper, and eucalyptus as well as in crevices in palm trees. _Centruroides vittatus_ has a habit of clinging to objects lying on the ground, so when the latter are turned over, it is possible to press them and get stung (Ewing, 1927:19). Ewing (1928:19) also stated this species sometimes moved into human dwellings in Texas. In Arkansas, Smith (1927:64) has observed _C. vittatus_ on dry hillsides under stones and similar shelter. Stahnke (1956:17) recorded _Centruroides_ spp. live in similar environments in Arizona but are found mostly in cool damp places where they escape the extreme heat and low humidities of the Southwest.

Scorpions collected by the investigator were found almost entirely under small stones. A population of _C. vittatus_ was located on the southern end of K-Hill, Manhattan, Kansas. The foot of this hill was encircled by a narrow creek which at the time had only scattered pools of water and was boarded on both sides by mixed hardwoods for about 20 yards sloping upward. Above the trees was a level ungrazed pasture grown up in mixed grasses and composites. This level strip was about 40 yards wide and was boarded on the other side by scattered cedar trees. The area with cedar trees was rocky and rose abruptly for about 50 yards to a grass covered summit where the trees ended. This summit was semicircled from south to west by a continuous limestone outcropping about ten yards wide and 100 yards long. From this small area of rock, about 75 scorpions were taken over a period from the first of August to the middle of September, 1961. The numerous cracked rocks partially covered by the soil provided natural tunnels which led far back into the hill. Scorpions were quick to retreat to these tunnels and were impossible to dig out as the rock surfaces made a catacomb of escape routes beneath the surface.

In the early morning while it was still cool, few or no scorpions were seen under the rocks; however, after midmorning when the sun reached these slopes, scorpions were readily taken from beneath the same rocks.

The soil beneath the stones varied from dusty to near mud during the collecting period, but the soil within the tunnels was always moist.

Rocks, logs, and dead trees located around the base of this hill yielded no scorpions.

Scorpions have been recorded in Kansas from Greenwood, Elk, Geary, Ellis, Cowley, Osborne, and Riley Counties. Data from sheets returned with the scorpions are summarized in the following list and show that scorpions in Kansas frequent a wide range of habitats both inside dwellings and outdoors.

List of places where scorpions have been found in Kansas.

A. Outdoors under the following objects:

Boards	3
Rocks	57
Sheet Metal	2
Bricks	2
Old logs	1
Canvas	6

B. Outdoors not under objects:

On man's leg	1
In or on tent	7
In drinking cup	1
Deck of swimming pool	2
Outdoor toilet	2
On screens of buildings	5
On tool chest	1
On lawn	1

C. Inside buildings:

In sink	8
On or in bed	2
In fireplace	2
In cellar	2
On walls	9
On ceilings	4
On floors	6

LIFE HISTORY

The gestation period varies from four and one-half months to seven and one-half months in *Centruroides insulans* in Jamaica (Baerg, 1954:275) and averages five months in *Leiurus quinquestratus* (Thornton, 1956:92).

Fabre recorded that certain European scorpions lay eggs, and the female breaks eggs and devours the shells (Smith, 1927:64). Smith (*loc. cit.*) has shown that *C. vittatus* is ovoviviparous. The eggs hatch within the mother, and the young develop for several months before they are born.

The young of *Buthotus alticola* and *B. occitanus* are assisted by the mother in escaping from the envelope of chorion enclosing them at birth (Serfat and Vachon, 1950:217). The young of *Euscorpius flavicaudis* escape by using their stinger to tear the chorion without any help from the mother (Cloudsley-Thompson, 1958a:84). *Centruroides vittatus* also frees itself from the chorion (Smith, 1927:64).

Some species are born at night, sometimes in two batches during successive nights, while other species are born during the day (Cloudsley-Thompson, 1958:84). *Palamnaeus longimanus* gave birth to 11 individuals on July 25 and on July 26. In some cases, Schultze (1927:381) believed that the unnatural environment in the laboratory made the female interrupt birth during daylight because in nature this species moves to a dark area such as the interior of a rotten log to give birth (Schultze, 1927:381).

Litters of Centruroides insulanus born from December to June ranged from six to 105 scorpions, but the small litters can probably be attributed to cannibalism (Baerg, 1954:275). Thornton (1956:92) dissected gravid females and found 41 to 63 embryos, and observed three births in L. quinquestriatus with litters of 42, 77, and 82. The births took place in April, September, and October which led Thornton to believe that in Sudan this species has no definite mating season. Euscorpius germanus and E. italicus were each observed to have litter sizes of 13 (Cloudsley-Thompson, 1951:105) in captivity. The latter were born in late August.

Centruroides vittatus kept in the laboratory were never seen to mate, and no young were born during the course of this study. However, the dissection of gravid females that had died and were preserved in alcohol revealed a number of embryos in various stages of development as shown in Table 1.

Table 1. Embryos found in preserved females.

Date of death	Number of embryos	Age class of embryos
July 15, 1961	20	dorsal tergites pigmented
July 16, 1961	24	dorsal tergites pigmented
July 19, 1961	24	eyes pigmented
July 23, 1961	38	eyes pigmented
July 25, 1961	22	no pigment
July 31, 1961	41	eyes pigmented
July 31, 1961	36	eyes pigmented
July 31, 1961	26	no pigment
August 3, 1961	27	dorsal tergites pigmented
August 28, 1961	22	eyes pigmented

From data shown in Table 1 it appears that C. vittatus in Kansas probably gives birth to young at least from July 15 to September 15 with a litter size of about 28 young.

After hatching, the young crawl onto the back of their mother aided by a "specially modified pad" located on the tarsi. This process may take up to two hours depending upon the condition of the young at birth and the temperature (Cloudsley-Thompson, 1958a: 84). The female C. vittatus "assists" the young in mounting her back shortly after birth (Smith, 1927:64).

Cloudsley-Thompson reported (1951:105) if a young scorpion fell off the back of E. italicus in artificial light, it remained motionless and made no attempt to remount; however, in darkness the scorpion would crawl back onto the parent. One scorpion climbed onto a dead scorpion in the container. Further study showed that if the surface of a cork was curved, the young scorpions would climb onto it; but on a flat surface they would cling to the side. This thigmokinetic response of climbing onto the mother's back is restricted to first instar nymphs. In this species the young molted in from ten to 12 days and left the back of the female with their skins remaining attached to her back. The young retained their tendency to aggregate for about one week. The young fed, but were also very cannibalistic; and none lived for a second molt. The young of E. germanus had a difficult time holding onto the back of the female, and the first molt came in about 16 days with their cast skins falling off the parent (Cloudsley-Thompson, 1956:193). As in E. italicus, no young were reared to maturity. In some other species the young may remain on the back of the female after their first molt for a period of up to 16 days (Cloudsley-Thompson, 1958a:85). The young C. vittatus molt for the first time after three to six days but remain on the back of the female for five to 15 days (Smith, 1927:64).

The first molt of Palamnaeus longimanus came in eight days, third molt in 38 days, fourth molt in 68 days, fifth molt in 168 days, sixth molt in 248 days, and the final molt in 333 days. This seventh instar lasted 85 days (Schultze, 1927:387).

In C. insulanus, the first molt came from seven to nine days after birth (Baerg, 1954:275). There are thought to be eight stadia in Palamnaeus longimanus and seven in Androctonus australis. This number probably varies even within the same species (Cloudsley-Thompson, 1958a:85).

Smith (1927:64) estimated C. vittatus required three to four years to reach maturity. A few nymphs of vittatus molted during this study, but none molted twice, indicating that the larger nymphs do not molt for more than eight months.

DAILY RHYTHM

During the day, scorpions stay in their burrows or under stones or other objects. They were never observed feeding except at dusk or in the night (Lankester, 1883:456). However, Pocock (1893:104) found it easy to arouse scorpions during the day by artificially warming their cage.

In the laboratory, scorpions could be observed moving about and feeding at any time of day or night when the doors of their dark cabinet were opened. However, when exposed to artificial white light, they retreated under stones. When kept in red light and even when they were not moving about, the scorpions stayed on the surface of the substrate rather than under an object.

From these observations it appears that scorpions are found under objects during the daytime primarily because of their response to light rather than humidity. In the field it was found that scorpions moved from their burrows to the undersides of stones after midmorning presumably due to the warming of the stones.

FEEDING BEHAVIOR

Food

All scorpions are almost exclusively carnivorous, with insects and other small arthropods being their primary source of food. Scorpions at birth possess yolk material within their bodies which furnishes them nourishment until they are capable of capturing food (Stahnke, 1956:17). When the young begin feeding in captivity, they readily eat termites (Smith, 1927:64).

Although adults generally feed on small insects (e.g., flies, crickets, cockroaches, and grasshoppers) and other arthropods (e.g., spiders, millipedes, and centipedes), under conditions of starvation they have been observed to feed on hard beetles (Cloudsley-Thompson, 1958b:229). In captivity they have been observed feeding on small lizards and semidried manure (Stahnke, 1956:14) and newborn white mice (Lankester, 1883:457). Smith (1927:64) reared specimens of _C. vittatus_ by feeding them raw lean beef along with insects.

Scorpions in the laboratory at Kansas State University ate adults of the following insects: differential grasshopper (_Melanoplus differentialis_), two-striped grasshopper (_M. bivittatus_), field cricket (_Acheta assimilis_), domestic cricket (_A. domesticus_), brown-banded cockroach (_Supella supellectilium_), German cockroach (_Blattella germanica_), and several species of small spiders. _C. vittatus_ did not eat a black ground beetle (_Harpalus_ sp.), a black reduviid (_Melanolestes picipes_), or a boxelder bug (_Lepticoris trivittatus_). The latter three species have strong odors which appeared to repel the scorpions. The hind legs were removed from the two species of grasshoppers to make it easier for the scorpions to catch them. The scorpions were usually fed _Acheta domesticus_ because it could be most easily reared in large numbers in the laboratory. Adult scorpions would eat dead crickets (_A. domesticus_) but refused raw hamburger meat.

Immature scorpions were offered termites (_Reticulitermes_ sp.) and Collembola (_Sinella curviseta_) but were never observed feeding.

In nature, scorpions have a wide range of prey as shown by the great number of arthropods and other small animals listed in the literature as food. However, when given a choice between _A. domesticus_ and other food in the laboratory, _C. vittatus_ usually feed on this cricket.

Cannibalism

Scorpions are cannibalistic and will prey on other smaller species, smaller scorpions of their own species, and individuals of their own size if caught right after molting when their integument is soft. A female often devours her young shortly after birth (Stahnke, 1956:14), and young scorpions sometimes eat their litter mates (Cloudsley-Thompson, 1951:105). Southcott (1955:148) reported a high rate of cannibalism in Urodacus abruptus when not fed more than once a month.

Only one act of cannibalism was noticed during this study. A dead scorpion which had been partially eaten was found; but since the scorpion was an adult and the kill was not witnessed, it probably was only fed upon after death. This low incidence of cannibalism may have been due to the small number of scorpions per container and the constant presence of food.

Mrs. James E. Flinn, Jr. of Ellis, Kansas, wrote the author that her children had found a scorpion under a rock "with what appeared to be small ones clinging to its back." The scorpions were placed in a jar, but within a few days the parent had eaten all the young.

These data suggest that cannibalism is probably overstressed in the literature because of observations made in the laboratory on scorpions kept in overcrowded and underfed conditions.

Detection of Prey

How scorpions detect their prey has not been positively determined.

Pocock (1893:105) agreed with Lankester (1883:460) that sight is too poorly developed in Euscorpius and Parabuthus to be effective in prey detection. This theory is further supported by the nocturnal habits of scorpions (Vachon, 1953:135; Cloudsley-Thompson, 1956:75). In this study, C. vittatus was able to capture prey in the dark, in red light, or with both its lateral and median eyes covered with paint. Therefore, vision must not be essential and probably plays little or no role in the detection of prey.

I know of no data regarding chemoreception by scorpions, but there are data suggesting tactile senses are important for detection of prey. Scorpions carry the pedipalps well in front of the body and use them like insects use antennae. These pedipalps are equipped with long, thin, sensory hairs or trichobothria which are richly supplied with nerves and respond to minute air currents (Pocock, 1893:105). Southcott (1955:147) believes that scorpions are able to distinguish scorpions from prey by direct contact because scorpions will release another scorpion after seizing it but will retain their hold on prey. Southcott further reported that the movement of another scorpion does not arouse Urodacus abruptus whereas the movement of potential food does. It is not known whether vision or chemoreception play any role in this behavior. In the laboratory, C. vittatus shows similar behavior in grabbing and releasing other scorpions. However, if the trichobothria are singed off the pedipalps, they are still able to capture prey.

Pocock (1893:106) has suggested that the pectines play a tactile or chemical sense role in prey detection. He saw Parabuthus walk over a dead cockroach, stop when about half way across, back up, and begin feeding on the cockroach. He believed that no portion of the ventral surface of the scorpion touched the fragment except the pectines. C. vittatus with both pectines amputated was able to locate and devour the dead and living crickets. Moreover, this species frequently was seen walking over dead insects which were touched by the pectines without any response shown by the scorpion to the food.

From the above discussion, it seems that scorpions may detect prey at a distance by vibrations of the air or substrate. Table 2 shows that even though eyes, pectines, and trichobothria may play some role in prey detection, these organs are not essential for scorpions to capture prey in a gallon jar. The data are not adequate to show whether the ability of scorpions to capture prey is diminished without the use of these organs.

Capture and Stinging of Prey

Prey is seized with the pedipalps and is not necessarily stung. In some species such as Urodacus abruptus the prey is not eaten while still struggling and may be stung several times (Southcott, 1954:147). Palamnaeus longimanus was never observed stinging prey but held its prey off the ground so that the prey could not get hold of anything (Schultze, 1927:379). If the sting is employed, it is not thrust quickly at random but probes repeatedly until a soft spot is found. A sudden stab against a hard exoskeleton could easily break off the point of the sting (Pocock, 1893:106).

Centruroides vittatus is not very aggressive and frequently remained quiet while crickets or other potential prey ran over the backs of the scorpions. Many times scorpions were seen to run away from insects which might be attacked at other times under similar conditions.

After seizing the prey, *C. vittatus* either stung it or did not, depending upon the size of the victim or more probably upon the amount it struggled. In some instances such as when holding large cockroaches, the scorpion stung almost immediately by slowly bringing the tail over its cephalothorax and stinging the ventral surface of the cockroach's abdomen. If the prey was small, the scorpion began feeding on it immediately and only stung the prey if it began to struggle. A scorpion holding a twitching leg which had broken off its prey, will make stinging motions toward an area immediately in front of the chelicerae where an insect would usually be if attached to the leg. If the prey did not struggle it was not stung at any time by *C. vittatus*.

Effect of Venom on Prey

Most reports on the effect of scorpion venom on prey emphasize that the venom paralyzes rather than actually killing the prey.

The period of time between stinging by C. vittatus and the actual immobility of the prey varied greatly. Small spiders with soft integuments became quiet within seconds. Larger prey such as cockroaches and crickets showed effects within seconds but actual immobility did not occur until after one minute. Usually the scorpion started to feed before complete immobility of the prey.

Fifty adult Acheta domesticus were artificially stung using one adult scorpion. The mean body weight for the crickets was 0.36 gram and that of the scorpion was 0.47 gram. As the sting was thrust into the venter of the abdomen of the cricket, the bulb of the sting was squeezed between the thumb and the forefinger; and the sting was immediately withdrawn. There was no way of assuring that poison was injected or that an equal amount was injected in all crickets. Each cricket was then placed in a shell vial. Two immature scorpions (body weight of 0.05 gram and 0.13 gram) were tested against five adult crickets in the same manner. Observations on the behavior of the crickets were made at five minutes, 30 minutes, and one hour on the first 25 crickets, and additional readings at eight hours and 24 hours were made on the second 25 crickets.

Thirty-four of 50 crickets showed no ill effects and presumably received no venom. The other crickets showed effects of the poison in a few seconds. When a poisoned cricket tried to walk, its legs would not support it; and it fell on its side or back. A slow twitching motion was observed in the legs, antennae, and mouth parts. The abdomen pulsed in and out deeply for about five minutes. After 15 minutes all motion stopped but begin again for a minute or two if the cricket were probed. One-third of all crickets showing effects after stinging never recovered. The others returned to normal after 30 to 45 minutes. This period of immobilization is adequate for the scorpion to kill or severely damage a cricket under normal feeding conditions.

Devouring of Prey

The appendages used for feeding are the pedipalps, chelicerae, and endite lobes of the coxae of the first pair of legs. The "hands" or chelae of the pedipalps are used for defense and grasping prey, and the basal segments or coxae are used to compress the prey. The preoral cavity is bounded dorsally by the chelicerae, laterally by the coxae of the pedipalps, and ventrally by the endite lobes of the coxae of the first pair of legs. The mouth is a small opening leading to the pharynx which may be modified into a sucking chamber (Tembe and Arvat, 1942, from Bender, 1959:262-63.

The prey is picked to pieces by the small chelate mandibles. These two jaw-like structures are thrust out and retracted alternately each time, crushing the body wall. This action of the chelicerae was compared with that of milking by Lankester (1883: 458). This crushing exposes the body fluids and tissues which are sucked into the minute mouth by the action of the pharynx (Pocock, 1893:105).

Baerg (1954:272-3) mentioned a fluid which comes out of the scorpion's mouth and is mixed by the chelicerae with the body fluids of the prey. Vachon (1956:136) thought this fluid was a powerful enzyme providing the scorpion with a type of external digestion and might be regurgitated from the middle intestine. By the time the food is taken into the mouth it has a consistency of thick soup (Baerg, 1954:273).

The feeding on insects by C. vittatus usually begins just behind the mandibles with only the head capsule, wings if present, and portions of the body wall discarded. Feeding is slow and may take up to two hours, depending upon the scorpion and type of prey (Pocock, 1893:105). During feeding, C. vittatus keeps its ventral surface against the ground, the tail curved and flat on the ground, and the legs folded to the side of the body. The pedipalps are held open when not holding the prey.

A scorpion began feeding on a small-bodied spider at the anteroventral end. The chelicerae began working alternately on the spider's integument, chewing and mixing in the exodigestive fluid and looking like two hands mixing dough. The cephalothorax was separated from the body and was consumed in its entirety including the legs. The abdomen was held by the extended left pedipalps and was eaten sometimes after the scorpion finished the cephalothorax. The chelicerae stopped their feeding action at times and both moved laterally in unison. The first pair of walking legs were held under the body and met at the tips. The front coxa pumped simultaneously throughout the feeding. At times the scorpion stopped feeding on the cephalothorax and appeared to regurgitate fluid onto the abdomen. While the scorpion was feeding on the ventral side, the dorsal part was sometimes passed down between the scorpion's legs. When the scorpion reached the abdomen, the pedipalps pulled the abdomen away; and the chelicerae consumed the remaining dorsal material. When this had been eaten, the scorpion continued the pumping motion of the coxa and the moving of the chelicerae. It took one hour and 15 minutes for the scorpion to consume just the cephalothorax of the spider.

Feeding on insects is similar except generally only the body juices of mature crickets and cockroaches are consumed through an incision just behind the mandibles, leaving the rest of the insect intact. If the scorpion had not fed recently, it sometimes consumed part of the exoskeleton. When only the body fluids are consumed, the chelicerae serve only to cut the tissue and hold the prey. The in and out movements of the chelicerae are not in evidence, but the pumping action of the front coxae continues through the feeding. Such feeding lasts no more than about 30 minutes.

If a scorpion is feeding in the dark and then is placed under a bright light, such as a microscope light, it immediately crawls under any available cover or runs around the container until it reaches a dark area. Scorpions fed usually on tops of rocks when in red light. They will even catch and sting a cricket and then drag it while moving backward up a rock.

As soon as the scorpion's body is level, it begins to feed even though the cricket may be perpendicular.

A scorpion becomes quiet after feeding, and other scorpions and crickets crawling over it do not seem to disturb the scorpion; however, light causes the scorpion to run under cover.

Pocock (1893:106) described two scorpions feeding on the same cockroach at opposite ends. When the larger scorpion discovered the presence of the other one, it used its tail to "beat off" the intruder with no attempt made to sting. I observed similar behavior which appeared to be more a tug of war with the tails used only as levers. They were waved back and forth over the back as to give momentum and a swinging motion that would throw the other scorpion off balance.

According to the literature and observations made during this study, feeding by all species of scorpions seems to be more similar than most other kinds of behavior.

Frequency and Amount of Feeding

In captivity, scorpions feed very irregularly even in the presence of food (Bender, 1959:263). The amount of food eaten by a scorpion depends upon the quantity available (Schultze, 1927: 376). Centruroides insulanus was observed to eat about once in two weeks (Baerg, 1954:272).

Records kept on C. vittatus as they were received in the laboratory showed feeding on grasshoppers or cockroaches at a rate of two to three insects the first week in captivity but averaged about one per week over a four-week period.

The number of insects eaten by experimental scorpions is shown in Table 2. During the first four weeks, when crickets and cockroaches were put in the container with scorpions at a rate of one cricket and one cockroach per week, 18 crickets but only seven cockroaches were eaten. Before crickets were used, cockroaches and grasshoppers were provided as food for several months. This comparison may be biased in that many cockroaches climbed the walls of the container where scorpions could not reach them. No difference in the frequency of feeding among the scorpions can be attributed to the treatments.

Table 2. Summary of results obtained from feeding experiments.

Scorpion No.	Treatment	No. of insects eaten		No. of weeks tested	
		Crickets	Cockroaches	Crickets	Cockroaches
1-A	none	7	0	16	4
1-B	same	8	2	16	4
2-A	no pectines	8	0	16	4
2-B	same	12	2	16	4
3-A	eyes painted	6	1	16	4
3-B	same	9	1	16	4
4-A	eyes painted no pectines	13	0	16	4
4-B	same	8	1	16	4
5-A	lateral eyes painted	6	0	10	0
5-B	same	3	0	10	0
6-A	singed off trichobothria	3	0	8	0

DRINKING

It is often stated that scorpions do not drink (Millot and Vachon, 1949:420); but Schultze (1927, 32:375) pointed out that the large Philippine forest scorpion, Palamnaeus longimanus, drinks large amounts of water daily. No doubt desert species (e.g., Scorpio, Buthus, Androctonus, and Centruroides spp.) do not normally drink, but obtain sufficient moisture for their needs from the blood of their prey (Cloudsley-Thompson, 1958b:229).

Cook (1959:95) believed that the generally held view that drinking by scorpions is unusual is due entirely to the absence of published accounts to the contrary. Cook published his observations on drinking by three species. Pandinus imperator was kept in a cage in which water was provided from a glass tube filled with cotton-wool. After a scorpion was seen on several occasions with its chelicerae close to the wet cotton-wool, a petri dish filled with water was used to determine whether the scorpion was drinking. The scorpion climbed halfway into the dish, completely immersed the chelicerae, and then made typical feeding movements. There was considerable body movement during drinking, but the pectines remained motionless and pressed close to the body. Another species, Bothriurus flavidus, was seen drinking from wet cotton-wool; but unlike P. imperator, there was no body movement, and the chelicerae did not perform their typical in and out motion. Mesobuthus gibbosus, unlike the latter two species, was actively attracted to water. While drinking, Mesobuthus gibbosus immersed its chelicerae completely as did

Centruroides insulanus (Baerg, 1954:273). Southcott (1955:148) described Urodacus abruptus drinking by tearing at cotton-wool, giving the impression of eating rather than drinking. Euscorpius italicus was not observed drinking, but it required a damp environment (Cloudsley-Thompson, 1956:105). Lankester (1883:455) reported that Androctonus funestus never visited a pan of water in its cage; but after being kept without water for over a year, A. australis, a closely related species, was observed drinking water off a wet stone and from droplets on the side of the container (Cloudsley-Thompson, 1958b:229).

C. vittatus was seen to drink many times from petri dishes filled with wet cleansing tissue. The scorpion placed the first pair of walking legs in the dish, and the second, third, and fourth pairs were placed on or below the rim of the dish. At times the second pair was held in the air. The tail, curved over the back, appeared to offer balance as no part of the scorpion was touching the ground which was about one centimeter below the rim of the dish. The pedipalps were bent bringing the tips close to and in front of the chelicerae, and sometimes the chelae grasped the cleansing tissue. Both chelicerae held onto the cleansing tissue and moved irregularly but the characteristic in and out motion as occurs in feeding was not seen. Except for the chelicerae, the scorpion remained motionless for the several minutes it remained at the dish.

While supporting themselves by their tails and the side of the container, scorpions were also observed stretching up the side and drinking water droplets which had splashed onto the glass.

Scorpions desiccated in "Dri-rite" for 17 hours were placed in a dish filled with cleansing tissue saturated with an aqueous solution of methylene blue. Although the scorpion drank, none of the stain was absorbed by the pectines. Desiccated scorpions were also placed in petri dishes, the floor of which was covered by a sheet of filter paper. The paper had been dipped in paraffin, leaving a nontreated strip down the center. This strip was saturated with water but the scorpions showed no attraction for this moist strip.

The experimental scorpions included in Table 2 showed attraction for water in a dish and drank frequently. *C. vittatus* could be induced to drink by allowing the water dish to remain dry for a few days.

SUMMARY AND CONCLUSIONS

Behavioral aspects of the common striped scorpion, *Centruroides vittatus*, were studied at Kansas State University from March, 1961 to March, 1962.

C. vittatus is the only species of scorpion known to occur in Kansas, and it is quite common in some localities. In nature, it is almost always found under some object where it is dark and moist. However, when red light was used in the laboratory, *C. vittatus* seldom if ever went under stones and was active during night and day. It appears that light rather than moisture is responsible for the habit of remaining under objects.

Scorpions were kept alive in the laboratory for almost a year in gallon jars provided with water and food. The domestic cricket, Acheta domestica, was supplied for food because it could be reared in large quantities, could not avoid the scorpions by climbing up vertical glass surfaces, and was readily eaten. Even though as many as eight adult scorpions were kept together in the same container, there was no problem with cannibalism.

Carbon dioxide and ethyl ether were compared as anesthetics for scorpions. Even though carbon dioxide required a longer exposure time and its effects lasted a short period, the author feels it is the better anesthetic. When the scorpions were exposed to ether they reacted more violently, and the exposure time was so critical that the scorpions were more likely to be killed. One third of the crickets which were immobilized died, and the remaining crickets revived in 30 to 45 minutes. Feeding followed the same pattern stated in the literature for other species. An average of about one insect per week was eaten at very irregular intervals.

C. vittatus was attracted to water and often drank. It could be induced to drink by depriving it of water for several days.

During the study, C. vittatus was never seen to mate nor were any young born. Ten preserved females contained an average of 28 embryos per female in various stages of development. Judging from these embryos, scorpions in Kansas give birth at least from July 15 to September 15.

The detection of prey was not dependent upon eyes, pectines, or trichobothria when scorpions and prey were confined in gallon jars. It could not be positively decided whether these organs assist in detecting prey. The scorpions stung the prey only if it struggled. Thirty-four of 50 crickets artificially stung showed no effects and the remainder were immobilized.

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BEHAVIORAL ASPECTS OF THE COMMON STRIPED SCORPION, CENTRUROIDES VITTATUS (SAY) (BUTHIDAE)

by

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A study was undertaken at the Department of Entomology, Kansas State University to investigate the behavior of the common striped scorpion, Centruroides vittatus (Say). Observations and qualitative tests were made between March, 1961 and March, 1962. The scorpions were collected in the area around Manhattan, Kansas, and several other localities in the state. All specimens of vittatus collected by the investigator were found under small stones. None were found under the bark of trees which is a common habitat for this species reported in the literature.

Scorpions sent to the laboratory from other parts of the state were collected under numerous objects both inside dwellings and outdoors. Many were also reported crawling across screens, floors, walls, and ceilings in houses. Although scorpions were collected under a number of different objects, they all provided the scorpions with a place void of light.

Two scorpions were kept per gallon jar provided with sand, stones, and a source of water. Unless tests were being conducted, a constant source of food, the domestic cricket (Acheta domesticus), was provided in each jar. These jars were marked and catalogued according to the locality and date of collecting the scorpions. Jars were kept in dark cabinets.

Carbon dioxide and ethyl ether were compared as anesthetics. Carbon dioxide required an exposure of at least one hour to anesthetize a scorpion for 15 minutes. Exposure to ether for 20 minutes would anesthetize scorpions for about one hour, but the scorpions reacted violently to the gas and were killed if exposed to it for about 30 minutes. A constant stream of carbon dioxide kept the scorpions anesthetized for three hours.

C. vittatus was never seen mating nor did any specimens give birth during the study. However, ten preserved females contained an average of 28 embryos in various stages of development.

In nature, scorpions are probably active only at night. In the laboratory when light was passed through a red filter, they could be seen walking about both day and night; and they did not crawl under objects. Apparently, light is the primary reason they are found under objects in the field.

C. vittatus ate several species of spiders and about six species of insects, but refused others. The common domestic cricket seemed to be preferred to German or brown-banded cockroaches.

The exact method of detecting prey is not dependent upon eyes, pectines, or trichobothria when scorpions were confined in gallon jars with crickets. Scorpions without these organs ate as many cockroaches and crickets as normal scorpions over a period of 16 weeks. It could not be positively decided whether these organs assist in detection of prey. After capturing prey, the scorpion employs its sting only if the victim struggles. Artificially inserting the sting in 50 adult crickets showed that one third of the affected crickets died and two thirds revived in 30 to 45 minutes.

Feeding by C. vittatus is similar to that reported for other species of scorpions. It masticated the prey by using its chelicerae, and the coxae of the pedipalps and first pair of legs assist in mixing the food with a secreted fluid. The resulting viscous fluid was sucked into the oral opening. Although crickets were constantly present in the jars, the scorpions fed very irregularly. Individual scorpions would feed weekly at times and then would go three to four weeks without eating.

C. vittatus was frequently observed drinking and could be induced to drink by allowing the water dish in the container to remain dry for a few days. During the drinking process no characteristic feeding motion of the chelicerae was observed.