SHORT COMMUNICATION

Predatory interactions between *Centruroides* scorpions and the tarantula *Brachypelma vagans*

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Abstract.   In the Yucatan Peninsula, the tarantula *Brachypelma vagans* Ausserer 1875 is commonly associated with human settlements, as are the scorpions *Centruroides gracilis* Latreille 1804 and *C. ochraceus* Pocock 1898. Nonetheless, scorpions are virtually absent from villages showing a high density of tarantulas. Predatory interactions between these predators could explain the lack of local overlap. To test this hypothesis, we observed the behavioral interactions between *B. vagans* and *C. gracilis* or *C. ochraceus* in experimentally controlled conditions, and we compared these interactions to interactions between the tarantula and two prey species: cricket and cockroach. For observations, a pre-adult tarantula was placed in an experimental arena in which we introduced either a scorpion or an insect. In all, 115 trials were performed. We recorded time elapsed and behavioral responses: avoidance, attack, escape, capture, and attack success. Tarantulas preyed on all prey with the same attack success ($63.8\% \pm 0.8\%$), but they attacked and captured cockroaches quicker and more often than the other prey (87% vs. 50%, and 57% vs. 30%, respectively). Scorpions attacked tarantulas in 25.5% of occasions, but they were never successful, and were killed in 9% of occasions. We conclude that tarantulas are potential predators of scorpions. Moreover, in villages where tarantulas are abundant they might prevent the presence of scorpions. Thus the presence of this non-aggressive tarantula may be beneficial from the human perspective.

Keywords: *Centruroides ochraceus*, *Centruroides gracilis*, cockroach, cricket, Yucatan Peninsula

The Mexican redrump tarantula, *Brachypelma vagans* Ausserer 1875 (Araneae: Theraphosidae), is distributed from Mexico to Costa Rica, and is also present in Florida (Valerio 1980; Edwards & Hibbard 1999). Despite its large range, most of its natural history is poorly known (but see Machkour-M'Rabet et al. 2005, 2007), particularly its predatory behavior, but for two studies describing cannibalism in the species (Hénaut & Machkour-M'Rabet 2005; Dor et al. 2008). One previous study by Marshall (1996) reported that free-ranging *Brachypelma* spiders are nocturnal and feed on ground-dwelling arthropods, and possibly on small vertebrates. It is also known how sensory channels are involved in prey detection in tarantulas (Blein et al. 1996).

Brachypelma vagans habits are similar to those of scorpions as sit-and-wait nocturnal predators (Hadley 1974; Skutelsky 1995; Pinkus-Rendón et al. 1999), except that *B. vagans*' predatory activities occur within or near the burrow. These burrows can be very densely distributed, as was found in rural settlements of the southern Yucatan (Machkour-M'Rabet et al. 2007). Like *B. vagans*, scorpions in the Yucatan Peninsula are commonly found in or around houses, where 80% of scorpion stings occur (Pinkus-Rendón et al. 1999). Therefore, tarantulas and scorpions are probably competitors, as well as each other's predators, in urban settings.

In the southern Yucatan, two scorpion species, *Centruroides ochraceus* Pocock 1898 (Scorpiones: Buthidae), locally called "yellow scorpion", and *Centruroides gracilis* Latreille 1804 (Scorpiones: Buthidae), locally called "black scorpion", regularly appear in houses and backyards. Our personal observations over several years indicate that approximately ten scorpions are found per house per year. The sting of *Centuroides* scorpions from Yucatan is rarely a source of complications for humans, and only a local reaction usually occurs (Pinkus-Rendón et al. 1999). However, peri-domestic scorpions in Mexico represent a real health problem, with more human deaths annually than in any other country (Ramsey et al. 2002).

Previous casual observations of scorpions in rural villages showed that anywhere that tarantulas are present, scorpions are absent, even if they are found in the surroundings of the villages (Y. Hénaut pers. observ., 2005–08). These observations were confirmed by local people in several villages of the southern Yucatan (A. Dor; S. Calmé, pers. observ.), including those where Machkour-M'Rabet et al. (2005, 2007) found high densities of *B. vagans*. We hypothesized that the absence of scorpions in areas of high density of tarantulas may be the result of predation of *B. vagans* upon scorpions. Spiders and scorpions might be involved in intra-guild predation relationships, as observed for the wolf spider *Schizocosa avida* Walckenaer 1838 with the scorpion *Centruroides vittatus* Say 1821 (Punzo 1997), and for the Mediterranean tarantula *Lycosa tarantula* Linnaeus 1758 with the Occitan scorpion *Buthus occitanus* Amoreux 1789 (Moya-Laraño et al. 2003; Williams et al. 2006).

In this paper, we test the hypothesis that the larger red rump tarantula successfully preys on scorpions by experimentally pairing individuals of *B. vagans* with individuals of the scorpion species *C. ochraceus* and *C. gracilis*, and recording the behavioral response of both arthropods. Additionally, we observed the predatory behavior of *B. vagans* upon two common prey insects, which provided a basis for comparison.

METHODS

Field observations.—We assessed the spatial segregation between tarantulas and scorpions by recording sporadically the presence of scorpions and tarantulas in several areas of the southern Yucatan: Calakmul Biosphere Reserve nucleus area, three villages (11 de Mayo, Zoh-Laguna and Raudales) and

the city of Chetumal on January 2005–September 2007. In daylight, we actively searched resident tarantulas (occupying a burrow), errant adult tarantulas, juvenile tarantulas (body size ≤ 1.0 cm) and scorpions, to record their presence. We searched underneath stones, fallen trunks, and into burrows. Second, we interviewed local people about the presence of the organisms of interest. Because of the nature of these data, no statistical analysis could be performed.

Collection and care of arthropods.—We collected 25 individuals of black scorpions, 30 individuals each of yellow scorpions, crickets and cockroaches, and eleven pre-adult tarantulas. We reared the latter in the laboratory from several days to several weeks on June 2005–January 2006. All arthropods were maintained under the following laboratory conditions: one individual per plastic cylinder (13 cm diam. × 5 cm height) containing a cup filled with water to keep the humidity high. Water was changed weekly. Room temperature was maintained at 26° C, similar to natural conditions. Spiders were fed with *Zophobas morio* (Coleoptera: Tenebrionidae) larvae. All voucher specimens are deposited in the Collection of the Museum of Zoology of El Colegio de la Frontera Sur, Chetumal, Quintana Roo, Mexico.

Interaction trials.—Besides tarantulas (*B. vagans*) and the two aforementioned species of scorpions (*C. ochraceus* and *C. gracilis*), the arthropods used during the experiments were cockroaches (*Periplaneta americana*) and crickets (*Acheta domesticus*). Body size was determined by measuring the distance from the extreme anterior point of the prosoma (arachnids) or the head (insects) to the hindmost part of the opisthosoma (arachnids) or abdomen (insects). These distances were measured for a sample of each group of arthropods to ensure that prey were of comparable size: crickets (1.98 ± 0.16 cm, $n = 20$), cockroaches (2.08 ± 0.31 cm, $n = 20$), yellow scorpions (2.60 ± 0.18 cm, $n = 30$, and black scorpions (2.68 ± 0.04 cm, $n = 25$). Tarantulas had a mean size of 3.45 ± 0.43 cm ($n = 11$), which was significantly larger than individuals of both scorpion species (Mann Whitney U test: yellow scorpion $U = 2.89$, $df = 1$, $P < 0.01$; black scorpion $U = -4.33$, $df = 1$, $P < 0.001$).

Each tarantula/prey encounter was repeated 30 times, except in the case of black scorpions, for which there were 25 repetitions. All individuals were used once, except tarantulas, since only 11 were available; thus, each tarantula was used about 10 times. Before any trial, all tarantulas were starved for two weeks and randomly paired with a prey item. As soon as an encounter was finished, the tarantula was removed from the arena and starved again if it succeeded in catching and eating the prey. Otherwise, the tarantula was fed with *Zophobas morio* before being starved. Because of the time elapsed between repetitions using the same tarantula (≥ 14 da), each trial was considered independent with respect to any change that could come from experience. The whole experiment lasted 6 mo. All the predation experiments were conducted in plastic boxes (29.5 cm width × 44 cm length × 23.5 cm height). A tarantula was released into the box, and after one minute, the second individual was introduced approximately 10 cm from the spider. Each experimental trial occurred for a maximum duration of 30 min or finished when an arthropod was captured. During the trials we characterized the motion behavior of the second individual before it met the tarantula as follows: quick, slow, or immobile.

We recorded the following behaviors for both arthropods during the trials: 1) Avoidance: when an individual kept its distance from the other following a tentative approach of the latter; 2) Attack: if an individual moved quickly toward the other and made contact with it; 3) Capture: when an individual was bitten or stung after an attack; 4) Escape: when an individual ran away from the other after the latter attacked, without having been bitten or stung; 5) Non-agonistic behaviors (NAB), such as no activity or no movement, which were recorded and classified as a single category. Based on the frequencies of behaviors, we constructed flow diagrams. We also estimated the attack success of tarantulas as being the number of successful captures divided by the number of attacks. The latency before an attack was recorded from the time the second individual was introduced into the experimental arena until the attack occurred.

Data analysis.—The frequencies of avoidance, attack, capture were compared by log likelihood tests (G test) among the four types of encounters (tarantula vs. cockroach, tarantula vs. cricket, tarantula vs. yellow scorpion, and tarantula vs. black scorpion). The frequencies of trials ending with the capture of the individual that first attacked (reverse fate), and attack success (the proportion of prey attacked actually captured) were also analyzed using G tests. Latencies before attack were compared among the four types of encounters using a multiple comparisons Kruskal-Wallis test.

RESULTS

Confirming our previous anecdotal observations, active searches in the field and interviews indicated that scorpions were absent locally when burrowing tarantulas were present. However, the presence of errant adult or juvenile (body size ≤ 10 mm) tarantulas did not prevent the presence of scorpions (Table 1).

The interactions we provoked experimentally between tarantulas and scorpions differed from those of tarantulas with insects mainly because both scorpions and tarantulas were capable of attacking each other, whereas crickets and cockroaches never attacked tarantulas (Fig. 1). The attack behavior of both scorpion species toward a tarantula was similar ($G = 0.05$, $df = 1$, $P = 0.82$), and tarantulas behaved similarly regardless of the scorpion species ($G = 0.002$, $df = 1$, $P = 0.96$). However, the frequency of attacks of tarantulas on scorpions was significantly higher than that of scorpions on tarantulas (43.6% vs. 25.5%, respectively: $G = 4.06$, $df = 1$, $P = 0.04$).

Another main difference between the four types of encounters was the lower number of non-antagonistic behaviors (NAB) during the interactions between cockroach and tarantula ($G = 10.00$, $df = 3$, $P = 0.01$). Tarantulas presented NAB in only 7% of encounters with cockroaches, compared with more than 30% for the confrontations with scorpions or crickets. Furthermore, the frequency of attacks was much higher for tarantula-cockroach interactions than for any other of the three interaction types ($G = 6.50$, $df = 3$, $P < 0.001$), with 87% of tarantula attacks on cockroaches compared with less than 55% on scorpions or crickets. Attack latency was similar for all prey (Kruskal-Wallis test: $H = 5.47$, $n = 42$, $df = 3$, $P = 0.14$), even if cockroaches were attacked more quickly (191 ± 61 s) than the other prey (cricket: $450 \pm$

Table 1.—Presence (+) and absence (−) of scorpions and tarantulas in several sites of the Southern Yucatán (11M: 11 de Mayo; R: Raudales; ZL: Zoh-Laguna), according to the status of tarantulas (resident, errant or juvenile) and data source (interview or active research).

Data source	Coordinates	Site	Scorpion	Resident tarantula	Errant tarantula	Juvenile tarantula
Interviews	18°29′58.73″N 88°18′09.54″W	Chetumal - South	+	−	−	−
	18°30′08.72″N 88°17′03.13″W	Chetumal - East	+	−	−	−
	18°32′48.69″N 88°16′16.67″W	Chetumal - North	+	−	+	−
	18°07′21.00″N 89°46′59.98″W	Calakmul	+	−	−	+
Active research	18°06′59.90″N 89°27′39.76″W	11M - Secondary forest	+	−	+	−
	18°42′35.32″N 88°15′20.44″W	R - Dirt track side	+	−	+	+
	18°42′27.12″N 88°15′21.74″W	R - Backyard	−	+	+	+
	18°35′24.06″N 89°24′59.09″W	ZL - 2 Houses and backyard	−	+	+	+
	18°05′27.55″N 89°27′38.15″W	11M - Backyard	−	+	+	+
	18°05′26.06″N 89°27′38.11″W	11M - Football camp	−	+	+	+

135 s; black scorpion: 567 ± 300 s; yellow scorpion: 570 ± 286 s). Cockroaches were the only prey to move constantly and quickly when introduced in the box, whereas tarantulas, crickets and both scorpion species stayed mainly immobile. Cockroaches were also the only prey that showed avoidance.

After an attack, the individual under attack (prey) could be captured or could escape, as was generally observed for insects, or might even attack in return, as observed with tarantulas when they were first attacked by scorpions. The frequencies of escape behavior, based on the number of attacks by tarantulas, were similar among the four types of

interactions ($G = 2.00$, $df = 3$, $P = 0.50$), with a tendency for the cockroach to escape more often. However, when a scorpion attacked, the tarantula almost never tried to escape (0% and 4% when attacked by yellow and black scorpions, respectively).

All captures were realized by tarantulas, without regard for the species they confronted. In other words, even when a scorpion attacked a tarantula, if none of the individuals escaped, the issue was always a win for the tarantula. However, the efficacy of tarantulas varied with the potential prey. The frequency of captures was higher with cockroaches
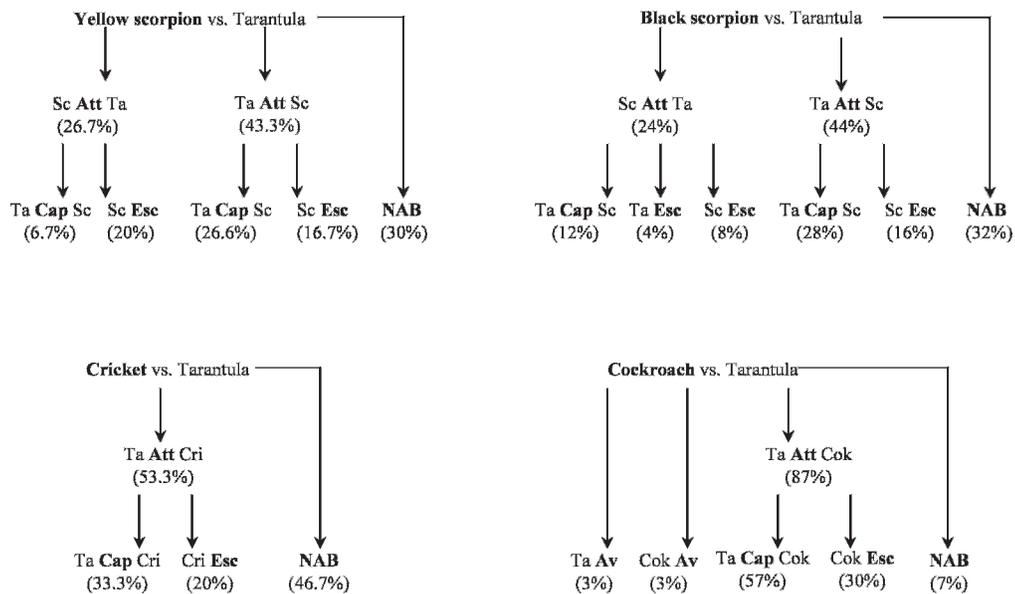

Figure 1.—Flow diagrams of the predation sequence of tarantulas (Ta) on yellow and black scorpions (Sc), crickets (Cri), and cockroaches (Cok). Behaviors as follows: non-antagonist behavior (NAB), avoidance (Av), attack (Att), escape (Esc) and capture (Cap). The sum of percentages at the bottom of each diagram equals 100%.

(half of the trials) than with crickets or scorpions (about one third of the trials) ($G = 16.50$, $df = 2$, $P < 0.001$). Nevertheless, the frequency of successful attacks by tarantulas was similar for all prey (yellow scorpion: 61.5%, black scorpion: 63.6%, cricket: 62.5%, cockroach: 65.5%; $G = 0.06$, $df = 3$, $P = 0.90$).

DISCUSSION

In laboratory conditions, we showed intraguild aggressive behavior between scorpions of two species, *Centruroides ochraceus* and *C. gracilis*, and *Brachypelma vagans* tarantulas. However, predation was only carried out by tarantulas, regardless of which species attacked first. Moreover, in response to an attack by a tarantula, scorpions' defense capabilities were not more effective than those of cockroaches or crickets. This predatory relationship between scorpions and tarantulas contrasts with that reported in previous studies, in which scorpions were predators of spiders (Polis & McCormick 1986; Punzo 1997; Moya-Laraño et al. 2003; Williams et al. 2006). In these earlier studies, however, scorpions were larger than spiders (Punzo 1997; Williams et al. 2006), whereas our experiment involved spiders that were larger than scorpions, with an inverse predation interaction. Body length is undoubtedly a critical factor accounting for the conflicting results of the interactions between these predators. As a matter of fact, in the context of intraguild predation, Polis et al. (1989) demonstrated that predation interaction could be mutual and was size dependent, with the larger individuals of any species always preying on smaller individuals of the other species.

This work offers the first description of this tarantula's interaction with prey, and allows us to conclude that *B. vagans* tarantulas have extensive capabilities of prey capture. *Brachypelma vagans* attacked the three types of prey offered to it, namely *Centruroides* scorpions, crickets, and cockroaches with similar success. Tarantulas, however, attacked and captured cockroaches more often than crickets or scorpions. This advantage was certainly related to the capacity of tarantulas to detect prey vibrations (Blein et al. 1996), as cockroaches were very active and mobile.

In peri-domestic environments where tarantulas are numerous, their ability to prey on scorpions may explain the lack of scorpions (as observed by the authors), even if these are considered common in this kind of environment (Pinkus-Rendón et al. 1999). It is noteworthy that only the presence of adult, resident tarantulas (occupying a burrow) was related to the absence of scorpions. Therefore, based on our laboratory observations, we hypothesize that spatial distribution of scorpions is limited by predation risk by adult resident tarantulas.

The presence of tarantulas in backyards might actually prove to be a good way to avoid scorpion intrusion into houses, and be used as an argument to protect these spiders. From the human perspective, *B. vagans* is less dangerous than scorpions, because it is not aggressive (Locht et al. 1999), its bite is harmless and not very painful (Hénaut et al. 2006), and it does not invade houses as scorpions do because it lives in burrows.

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LITERATURE CITED

Blein, W., K. Fauria & Y. Hénaut. 1996. How does the tarantula *Lasiodora parahybana* Mello-Leitaõ 1917 (Araneae, Theraphosidae) detect its prey? Revue Suisse de Zoologie Vol Hors Série 1:71–78.

Dor, A., S. Machkour-M'Rabet, L. Legal, T. Williams & Y. Hénaut. 2008. Chemically mediated burrow recognition in the Mexican tarantula *Brachypelma vagans* female. Naturwissenschaften 95:1189–1193.

Edwards, G.B. & L.H. Hibbard. 1999. The Mexican Redrump, *Brachypelma vagans* (Araneae: Theraphosidae), an exotic tarantula established in Florida. Florida Department of Agricultural & Consumer Services, Division of Plant Industry, Gainesville, Florida. May/June. Entomology Circular 394.

Hadley, N.F. 1974. Adaptational biology of desert scorpions. Journal of Arachnology 2:11–23.

Hénaut, Y. & S. Machkour-M'Rabet. 2005. Canibalismo y cleptobiosis en la tarántula *Brachypelma vagans*. Entomología Mexicana 4:30–32.

Hénaut, Y., R. Rojo, A. Dor & S. Machkour-M'Rabet. 2006. Peludas y mal amadas. Ecofronteras 29:4–5.

Locht, A., M. Yáñez & I. Vázquez. 1999. Distribution and natural history of Mexican species of *Brachypelma* and *Brachypelmides* (Theraphosidae, Theraphosinae) with morphological evidence for their synonymy. Journal of Arachnology 27:196–200.

Machkour-M'Rabet, S., Y. Hénaut, R. Rojo & S. Calmé. 2005. A not so natural history of the tarantula *Brachypelma vagans*: interaction with human activity. Journal of Natural History 39:2515–2523.

Machkour-M'Rabet, S., Y. Hénaut, A. Sepulveda, R. Rojo, S. Calmé & V. Geissen. 2007. Soil preference and burrow structure of an endangered tarantula *Brachypelma vagans* (Mygalomorpheae: Theraphosidae). Journal of Natural History 41:1025–1033.

Marshall, S.D. 1996. Evidence for territorial behavior in a burrowing wolf spider. Ethology 102:32–39.

Moya-Laraño, J., J. Pascual & D.H. Wise. 2003. Mating patterns in late-maturing Mediterranean tarantulas may reflect the costs and benefits of sexual cannibalism. Animal Behaviour 66:469–476.

Pinkus-Rendón, M.A., P. Manrique-Saide & H. Delfín-González. 1999. Alacranes sinantrópicos de Mérida, Yucatán. Revista Biomédica 10:153–158.

Polis, G.A. & S.J. McCormick. 1986. Scorpions, spiders and solpugids: predation and competition among distantly related taxa. Oecologia 71:111–116.

Polis, G.A., C.A. Myers & R.D. Holt. 1989. The ecology and evolution of intra-guild predation: potential competitors that eat each other. Annual Review of Ecology and Systematics 20:297–330.

Punzo, F. 1997. Leg autotomy and avoidance behavior in response to a predator in the wolf spider, *Schizocosa avida* (Araneae: Lycosidae). Journal of Arachnology 25:202–205.

Ramsey, J.M., L. Salgado, A. Cruz-Celis, R. Lopez, A.L. Alvear & L. Espinosa. 2002. Domestic scorpion control with pyrethroid insecticides in Mexico. Medical and Veterinary Entomology 16:356–363.

Skutelsky, O. 1995. Flexibility in foraging tactics of *Buthus occitanus* scorpions as a response to above-ground activity of termites. Journal of Arachnology 23:46–47.

Valerio, C. 1980. Arañas Terafósidas de Costa Rica (Araneae: Theraphosidae). 1. Sericopelma y Brachypelma. Brenesia 18:259–288.

Williams, J.L., J. Moya-Laraño & D.H. Wise. 2006. Burrow decorations as antipredatory devices. Behavioral Ecology 17:586–590.