INTERACTIONS BETWEEN TARANTULAS *(APHONOPELMA HENTZI)* AND NARROW-MOUTHED TOADS *(GASTROPHYRNE OLIVACEA)*: SUPPORT FOR A SYMBIOTIC RELATIONSHIP

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ABSTRACT

The Great Plains narrow-mouthed toad, *Gastrophryne olivacea* often shares burrows with other vertebrates (lizards) and invertebrates (spiders and insects). The association with large tarantulas (*Aphonopelma hentzi*) is particularly interesting because these spiders are opportunistic feeders that readily attack and consume vertebrate prey including anurans. We show that *A. hentzi* will attack and consume the cricket frog (*Acris crepitans*) which is similar in size to *G. olivacea*. In trials where *G. olivacea* and more palatable A. *crepitans* and invertebrates were presented simultaneously to tarantulas, the presence of *G. olivacea* did not appear to affect the predatory response of the tarantulas. However, when placed in a confined space with *G. olivacea* or *G. carolinensis*, the tarantulas never initiated a predatory response. Because we were using wild caught, adult tarantulas, this may be a learned response towards *G. olivacea*. We have no field records that tarantulas share burrows with *G. carolinensis*. The laboratory experiments suggest that tarantulas are sensitized to *Gastrophryne* spp. and may be able to detect chemicals secreted by the toads.

Key words: *Gastrophryne olivacea*, *Gastrophryne carolinensis*, tarantulas, *Aphonopelma hentzi*, burrow-commensals, toxic skin secretions, predatory response

INTRODUCTION

Spiders are important predators of amphibians (Sharma and Sharma, 1977; Groves and Groves, 1978; Littlejohn and Wainer, 1978; Formanowicz et al., 1981). However, certain anurans are capable of avoiding this predation (Szelistowiski, 1985). Three theraphosid spiders (tarantulas) have been shown to have commensal relationships with specific anurans (Blair, 1939), which may protect both associates from predators (Hunt, 1980; Mulvany, 1983). In these associations, anurans are not only

tolerated around the burrow, but also take refuge within the burrow. Blair (1936) found up to nine *Gastrophryne olivacea* with a single tarantula burrow under a stone and Dundee (1999) found 22 *G. olivacea* with a tarantula in a burrow under a stone. Although tarantulas are opportunistic feeders capable of subduing and consuming large prey items, including vertebrates, certain amphibians probably are immune from predatory attacks because their toxic skin secretions (Garton and Mushinsky, 1979) make them unpalatable. The presence of myrmecophagous anurans such as *G. olivacea* may benefit tarantulas by reducing ant predation on the spiders' eggs (Hunt, 1980). In return, anurans may benefit from a microenvironment which reduces the risk of desiccation (Cocroft and Hambler, 1989; Hunt, 1980) and/or provides protection from predators (Hunt, 1980; Mulvany, 1983).

This paper explores the association of the Great Plains narrow-mouthed toad *Gastrophryne olivacea* and the tarantula, *Aphonopelma hentzi* which are sympatric from Kansas to Texas and small areas of Missouri to northeastern Louisiana. In particular, we observed the predatory feeding responses of tarantulas towards vertebrate and invertebrate prey and compared this with the behavior that tarantulas exhibit towards *G. olivacea*.

Aphonpelma hentzi are fossorial tarantulas which live in a silk-lined burrow. They are sedentary, sit-and-wait predators that emerge at dusk and wait near the burrow entrance for suitable prey to pass by. Females may remain in the same burrow for most of their lifetime whereas males abandon their burrows once they reach sexual maturity. Tarantulas, in general, have poorly developed eyesight and are more dependent on tactile and chemical cues for prey recognition (Foelix, 1996). As with other spiders, they have numerous contact ("taste") and airborne ("smell") chemoreceptors which are capable of determining chemical properties of substrates and substances (Foelix, 1970, Drews and Barnard, 1976; Foelix, 1996). The taste or contact chemoreceptors are located on the distal segments of the legs and palps but the exact location of the olfactory receptors is still uncertain (Foelix, 1996).

Gastrophryne olivacea is a small, myrmecophagus narrow-mouthed toad that, because it is an inefficient digger (Freiburg, 1951; Fitch, 1956), often shelters in burrows of lizards, insects, or spiders (Freiburg, 1951). Garton and Mushinsky (1979) examined the distribution of skin secretory glands in *G. olivacea* and the closely related *G. carolinensis*. The two *Gastrophryne* species are partially sympatric and hybrids are not infrequent (Nelson, 1972). Both species have numerous secretory glands and poison glands in all regions of the skin and copious skin secretions that may form an effective antipredator defense (Garton and Mushinsky, 1979). Predators include garter snakes *Thamnophis sirtalis* (Wright, 1932), short-tailed shrews (*Blarina brevicauda*) (Freiburg, 1951), and copperheads (*Agkistrodon contortix*) (Anderson, 1942, Freiburg, 1951). In the laboratory, Gorton and Mushinsky (1979) found that *G. carolinensis* were eaten by *Thamnophis sirtalis*. However, snapping turtles (*Chelydra sepentina*) that they used ate *G. carolinensis* but often regurgitated them. They also noted that black-crowned herons (*Nycticorax nycticorax*) would bite *G. carolinensis*, but would then release them. In addition, these toads are primarily myremecophagous so their skin secretions may also protect them from counterattacks by ants (Wood, 1948; Freiburg, 1951; Fitch, 1956; Garton and Mushinsky, 1979).

Although anuran-arachnid associations have been reported for several different species of both spiders and anurans, little information exists on interactions between these unusual burrow-commensals. The objectives of this study were: 1) to observe narrow-mouth toads in tarantula burrows in the field, 2) to observe behavior of *A. hentzi* towards potential prey items including invertebrates (cockroaches, grasshoppers, and crickets) and anurans (*Acris crepitans* and *G. olivacea*) and, 3) to determine if the presence of *G. olivacea* affects the predatory behavior of *A. hentzi* towards other prey. Because adult, wild-caught tarantulas were used in these experiments, it is possible that the lack of a predatory response towards *G. olivacea* is a learned behavior as a result of previous contact. Thus, the final objective 4) was to observe and compare interactions between *A. hentzi* and *G. carolinensis*. *G. carolinensis* is closely related to *G. olivacea*; it is similar in size and also has toxic skin secretions. However, although *G. carolinensis* occurs within the same habitant as *A. hentzi* no report of tarantulas sharing a burrow with *G. carolinensis* is known.

Materials and Methods

Field Observations: The field site encompassed approximately 1.62 ha of savanna type habitat on an upland limestone outcrop adjacent to Red Bud Valley Nature Preserve, approximately 5 km west of Catoosa in Rogers County, Oklahoma. This area has abundant flat stones. Woody vegetation included many small persimmon trees (*Diopyros virginiana*), aromatic sumac (*Rhus aromatica*), and hawthorn (*Crategus reverchonii*). Observations of tarantulas and narrow-mouthed toads were made at this site from June-August 1977. Tarantulas from a site in McCurtain County, Oklahoma were checked for several years and no *Gastrophryne* were discovered there, nor were breeding choruses of the toad ever heard.

Laboratory Trials: *A. hentzi*, *G. olivacea*, and the hylid species *A. crepitans* were collected from several counties in Oklahoma (Delaware, Okmulgee, Payne, Rogers, and Tulsa) and Texas (Dimmit and La Salle). *G. carolinensis* were collected from the vicinity of Spavinaw Creek, in Delaware County, Oklahoma. All tarantulas used in this study were mature females. They were maintained in individual containers and were fed a diet of cockroaches, grasshoppers, and crickets. The anurans were housed in groups but separated by species. They were fed pinhead crickets for the duration of the study.

To observe the behavior of *A. hentzi* towards potential prey, three species of orthopterans (cockroaches, crickets, and grasshoppers) were placed individually in a covered glass finger-bowl with tarantulas. The finger-bowls were approximately 6.5 cm deep and 21 cm in diameter. Interactions between tarantula and prey were recorded. These interactions were compared with observations of either *G. olivacea* or *G. carolinensis* together with *A. hentzi* under similar conditions.

To demonstrate that tarantulas eat anurans, but were choosing not to eat *G. olivacea*, tarantulas were placed into one gallon plastic shoe-box containers with either *A. crepitans* or *G. olivacea* for three days. *A. crepit*ans is similar in size to *G. olivacea* but is not reported to have toxic skin secretions although they do have a warty skin (pers. comm.. R. Kazmaier). Two experimental groups of tarantulas were established.

Tarantulas in group 1 were first exposed to *A. crepitans*, while those in group 2 were exposed to *G. olivacea* first. Containers were checked daily to determine if the anurans had been consumed by the tarantulas. After three days, live anurans were removed from the containers and new frogs and toads were introduced but in reverse order (i.e., group 1 now received *A. crepitans* and group 2 received *G. olivacea*).

Finally, to determine if the presence of *G. olivacea* affects predation by tarantulas on other potential prey, tarantulas were again divided into two groups. Those in group 1 were placed in a finger-bowl with *G. olivacea* together with either *A. crepitans* or a cricket while those in group 2 were placed in finger-bowls with the prey species but without *G. olivacea*. The predatory response of tarantulas in each group was recorded. Chi square tests were performed to test for differences in the predatory responses of tarantulas toward potential anuran prey.

Tarantulas from the McCurtain County, Oklahoma site, where no *Gastrophryne* were discovered, could be presumed to be naive. They also were placed into containers with *Gastrophryne* to determine their reactions.

RESULTS

FIELD OBSERVATIONS: On 23 trips to the Red Bud Valley area, 137 *G. olivacea* were observed under stones with occupied tarantula burrows. An additional 28 were found under stones with no burrows. No toad was found without a stone covering it. Fifteen of the 28 sighted in the absence of burrows were found on visits after substantial rain. Toads were not marked or removed during these observations, so the same individuals could have been observed during each visit. The majority of *G. olivacea* were discovered under seven stones, each with a tarantula burrow. Under one stone with a large burrow, 11 toads were found during one visit. By flooding these seven tarantula burrows with water, additional *G. olivacea* were recovered from five of the seven burrows.

LABORATORY TRIALS: Tarantulas (n=22) displayed four responses to contact with prey species; (1) quick, predatory response, (2) charging towards prey species but without grabbing the prey item, (3) rising to a defensive posture and possibly backing away, and (4) no response. Cockroaches were eaten most frequently and incidental contact between tarantulas and cockroaches in the finger-bowls usually resulted in a predatory response by the tarantula. Cockroaches that survived up to a day with the tarantula were usually found on the opposite side of the finger-bowl from the tarantula. Crickets and grasshoppers on the other hand, often wandered into the tarantula without effect.

When *G. olivacea* were introduced into finger-bowls with tarantulas, the anurans usually initiated contact within a few minutes. If the toad made sudden, forceful contact with the tarantula (i.e., hopping/jumping in the fingerbowl), tarantulas usually rose into a defensive position. If less forceful contact was made, this resulted in only minor postural adjustments by the tarantula. Usually introduction of tarantula and toad resulted in an initial period in which familiarization between the two species seemed to occur. After initial contact, the tarantula might slowly retreat a few steps, or walk slowly over the toad. After repeated, seemingly random contacts of this nature, the two

animals came to rest with the toad positioned under or slightly anterior to the cephalothorax of the tarantula. This occurred approximately 50% of the time. This positioning would usually occur within 20 minutes of introduction and lasted for a few minutes to several hours. Through the observation period, the two species were often found in this "hovering" position. On rare occasions, tarantulas rested the tips of their pedipalps on *G. olivacea*. In general, however, tarantulas avoided contact with the toad (e.g., if a tarantula came into contact with *G. olivacea* while walking around the finger-bowl, the tarantula would stop or recoil or adjust course to avoid the toad). Several times a tarantula was observed holding one leg aloft for several hours, which if lowered, would contact the anuran. No qualitative difference was noted between the interactions of *G. carlinensis* and *A. hentzi* and those of *G. olivacea* and *A. hentzi*. Resting of pedipalps on *G. carolinensis* was observed and instances of "hovering" occurred frequently.

When presented with either *G. olivacea* and *A. crepitans*, 72% of tarantulas (n = 16) ate *A. crepitans*, but none (0%) ate *G. olivacea*. Although both anurans are similar in size, *A. crepitans* had a significantly greater chance of being eaten by tarantulas compared with *G. olivacea* ($\chi^2 = 10.78$, df = 1, $P < 0.05$).

Finally, no difference in the predatory response of tarantulas towards crickets was noted (n = 6, ($\chi^2 = 1.33$, df = 1, $P < 0.05$) or *A. crepitans* (n = 8, ($\chi^2 = 2.5$, df = 1, $P < 0.05$) in the presence or absence of *G. olivacea*. Tarantulas were overall less likely to eat *A. crepitans* (50% of trials) compared with crickets (67% of trials), but sample size of tarantulas was small and no statistically significant difference was evident between either group ($\chi^2 = 0.89$, df = 1, $P < 0.05$).

Discussion

The first published account of the cohabitation of tarantulas and anurans was reported by Blair (1936) who examined over 100 occupied tarantula burrows. Of these, 75% included one to three toads living in the same burrow with the tarantula. In this study, we also observed numerous tarantula burrows and found up to 22 toads sharing the same burrow with the tarantula. The association may occur throughout the range of co-occurrence of *G. olivacea* and *A. hentzi* and the number of narrow-mouthed toads in any burrow apparently varies substantially.

We observed typical predatory response of tarantulas to invertebrate prey and also showed that tarantulas will eat some anurans but not *G. olivacea* and *G. carolinensis*. They readily attacked and consumed *A. crepitans*, but did not harm the similarly sized *G. olivacea* and *G. carolinensis*. Surprisingly, no initial attack was made by tarantulas towards either *Gastrophryne* species. Both Cocroft and Hamber (1989) and Szelistowiski (1985) reported that spiders attacked and quickly released toxic anurans that were introduced. The attack response occurred even though it was probable that the tarantulas had previously come into contact with other individuals of the same species. Thus these tarantulas are apparently relying on substrate vibrations or airborne pressure waves to initially locate prey (Foelix, 1996; Cocroft and Hamber, 1989; Szelistowiski, 1985). After the initial attack, contact chemoreceptors on the distal portions of the legs and palps (Foelix, 1996) were important to determine the toxicity of potential prey. Our observations of *A. hentzi* with *Gastrophryne* species did not follow

this pattern; *A. hentzi* never initiated an attack towards any of the narrow-mouthed toads. Although this could be a learned response towards *G. olivacea*, the same is not true for *G. carolinesis*. *G. carolinesis* are not known to share tarantula burrows even though the two species are sympatric. That the supposedly naive tarantulas from McCurtain County reacted similarly to those from Red Bud Nature Preserve suggests that the tarantulas react instinctively or that some form of chemical communication indicated that the toad was toxic. One reason that may explain the different responses of arachnids in our study compared with other studies, is the experimental setup. Both Cocroft and Hambler (1989) and Szelistowiski(1985) conducted experiments with spiders in their natural environment, whereas our observations took place in small, glass bowls. Within this restricted, artificial environment, *A hentzi* may have been able to determine the toxicity of the narrow-mouthed toads very quickly without physical contact via olfactory cues. Although *A. hentzi* ate *A. crepitans* in these experiments, more tarantulas attacked and ate invertebrate prey. Prior to the laboratory experiments, tarantulas were fed only invertebrate prey and this may have biased their initial response to introduced prey items. The reduced predatory response towards *A. crepitans* may simply be due to its novelty as a prey item rather than indicating a preference for invertebrate prey. In addition, because of a small sample size, determining if the predatory response of *A. hentzi* is influenced by the presence of *G. olivacea* is impossible. Rödel and Braun (1999) reported that skin toxins of one species of anuran can be transferred onto another less toxic species and provide protection for the latter from ants. This, however, involved physically rubbing the skins of the two anurans together. *A. crepitans* and *G. olivacea* were never in such close contact and under natural conditions the presence of *G. olivacea* in tarantula burrows probably has little impact on the tarantulas' feeding behavior.

The association between *G. olivacea* and *A. hentzi* appears to be a relationship of mutual benefit, although both species thrive outside the range of the other, and *G. olivacea* inhabits burrows of other animal species besides tarantulas. A potential benefit to the tarantula is the elimination of predatory ants by *G. olivacea* and consequently increased survival rates of young tarantulas. Hunt's (1980) observations on a captive *A. hentzi* showed that the tarantula tolerated *G. olivacea* around its egg case and the toads did not prey on small, newly hatched tarantulas. Baerg (1958) stated that the tarantula is "powerless to cope with ants, which are predators on the eggs and young with the cocoon. When ants tear open a cocoon of young, the female retreats to the far corner of her residence …. and later departs to seek a safer place to live." For *G. olivacea*, the tarantula burrow provides a favorable microenvironment that reduces the risk of desiccation (Blair, 1936; Powel et al., 1984). In addition, adult tarantulas may prevent potential anuran predators from entering the burrow, thus providing a safe retreat for the narrow-mouthed toads (Hunt, 1980). Thus, although this association is not critical for survival, it may be advantageous to both species.

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