PREDATORY BEHAVIORS OF *BLARINA BREVICAUDA* TOWARD A FOSSORIAL EASTERN SPADEFOOT TOAD *(SCAPHIOPUS HOLBROOKII)*

THOMAS J. MAIER

ABSTRACT

Northern short-tailed shrews (*Blarina brevicauda*) have been reported to prey upon relatively large salamanders and anurans. Nevertheless, detailed observations of such behavior are rare, though important in providing insights into shrew foraging strategies, prey capture and handling, and possibly the coevolution of predator-antipredator mechanisms. Natural and staged interactions between multiple *B. brevicauda* and a fossorial eastern spadefoot toad (*Scaphiopus holbrookii*) were observed in western Massachusetts, August-November 2000. Routing the buried toad during laboratory trials via both surface and sub-surface contact (both resulting in the toad's eruption to surface), shrews attacked with varying success; less successfully when attacking the toad's cephalic region, more successfully when seizing the toad's hind limbs and dragging it backwards, thus circumventing numerous anuran antipredator mechanisms. Although *B. brevicauda* would seem adept at attacking adult *S. holbrookii*, its role as a common predator of this anuran remains uncertain.

INTRODUCTION

Northern short-tailed shrews (*Blarina brevicauda*) have successfully preyed upon relatively large salamanders and anurans during various laboratory trials (e.g., Brodie, 1978; Formanowicz and Brodie, 1979), and have occasionally been reported to prey upon amphibians in the wild (Babcock, 1914; Hamilton, 1930). Their ability to actively do so is often associated with their relatively large size, robust nature, and venomous saliva (Brodie et al., 1979; George et al., 1986; Churchfield, 1990 and references therein). Nevertheless, detailed observations of such predatory behavior are rare, although they may provide useful insights into shrew foraging strategies, prey capture and handling, and possibly the coevolution of predator-antipredator mechanisms.

Here I report observations of predator-prey interactions between multiple semi-fossorial *B. brevicauda* and a fossorial eastern spadefoot toad (*Scaphiopus holbrookii*) in the field and laboratory, and discuss the effectiveness of this shrew's predatory behaviors and its implications for the coexistence of these species. Eastern spadefoot toads are cryptic anurans (adult length: 44-57 mm) that spend much of their lifetime quiescently buried 5-30 cm in predominantly loose sandy soils. These toads come to the surface both at night to feed on insects, arachnids, and myriapods during moist air-soil conditions, and to breed during or after very heavy rainfall (Pearson, 1955).

METHODS

FIELD EVENTS

Two interactions between a northern short-tailed shrew (hereafter "shrew") and an adult eastern spadefoot (hereafter "toad") were observed in Hadley, Hampshire County, Massachusetts, U.S.A. (GPS: 42°22'04.27" N; 72°33'04.13" W) within a 3-week period during August 2000. Both events followed days of periodic rainfall and occurred between 0200-0400 h. Alerted in both cases by a sporadic series of abrupt, strident anuran vocalizations (Maier and Richmond, unpublished data), I traced these sounds to a window-well of my house where a shrew was observed harassing a toad that continued to vocalize loudly while maintaining an inflated defensive posture. The shrew, driven off by my light and activity, was not heard to make any sound during either interaction. No physical contact between the shrew and toad was noted, due to partially obstructing leaf debris in the window-well. Several hours after the first interaction (after daybreak), the sand-substrate bottom of the window-well was inspected, but no sign of either animal was found, although partially-filled burrow holes were noted.

During the second interaction on 25 August, an adult *S. holbrookii* was collected to assess any damage caused by shrew attacks and to determine if these vocalizations could be elicited from the toad under laboratory conditions. Examination revealed no physical damage. Subsequent handling of the toad during its examination and transfer to the Biology Department at the University of Massachusetts-Amherst failed to elicit any further sounds or other observable antipredator behavior.

LABORATORY TRIALS

The toad collected on 25 August 2000 was maintained in a 37.9-l glass terrarium containing ca. 8-cm of potting-soil substrate with food and water provided *ad libitum*, and allowed to acclimate for 6 weeks prior to the first of 2 arena trials. Two shrews (1 for each trial) were live-trapped 8-24 hours prior to trials and transferred via a small covered terrarium supplied with soil and leaf substrate, food, water, and bedding material. The first trial was conducted in a photographic darkroom under redlight at 1100 h on 14 October 2000 at a room temperature of 20 ± 2° C. A shrew was introduced into the toad's terrarium (potentially eliminating a territorial response by a shrew), with ensuing interactive behavior verbally documented on audiotape. In order to prevent injury to the toad, prolonged contact with the shrew was prevented. The second trial was held within a large quiet classroom under fluorescent light at 1400 h on 3 November 2000 at a room temperature of 20 ± 2° C. As with the first trial, a shrew was introduced into the toad's terrarium. We visually recorded this trial through the terrarium with a tripod-mounted Sony color digital movie camera and Panasonic DVM60 tape (speed: 30 frames/sec [60 fields/sec]). Written notes were made during this trial, with the behavior of both species documented verbally and audio-visually. Images harvested from the high-speed video were processed with Adobe Photoshop®.

RESULTS

Both trials began with the toad completely buried in the substrate of the terrarium. During the first trial, the shrew burrowed almost continuously, rarely foraging on the surface, but occasionally poking its head briefly above the surface. With the 1st subsurface contact between the animals, the toad erupted to the surface, jumped ca. 24 cm away from the shrew, and crouched motionless, exhibiting no other defensive behavior. Ultimately, the shrew surfaced beside the toad, seized one of the toad's hind limbs with its mouth, and tried to pull the toad beneath the surface backwards, whereupon the toad inflated and began producing the same loud calls heard in the field, while struggling to escape by attempting to jump (the animals were physically separated at this point). Following this attack, the shrew (now on the surface) continued to lunge at the toad and retreat without making contact. In response, the toad positioned its inflated body head-first towards the shrew, ventriflexed its head, retracted its eyes, and vocalized abruptly with mouth agape, occasionally jumping a short distance away from the shrew. The increasingly aggressive shrew eventually seized the toad's lip, at which point we broke contact and removed the shrew, ending the first trial. Subsequent examination of the toad revealed no physical wounds, and the shrew appeared to behave normally. Immediately after the shrew's removal, the toad re-buried itself; the first fossorial behavior exhibited by the toad since the trial's beginning.

The shrew used in the second trial foraged almost exclusively along the surface, covering the entire terrarium in ca. 3 min, whereupon it dug directly down to the buried toad. The toad immediately erupted from the soil with the shrew grasping it by a hind limb. The shrew tenaciously retained its bite on the leg of the toad (Fig. 1), occasionally dragging the toad backwards short distances over the surface, despite being repeatedly knocked off its feet by the jumping, loudly vocalizing toad, coupled with the distraction provided by our (eventually successful) attempts to dislodge and remove it from the arena; this ending the second trial. Soon after the shrew's removal, the toad again buried itself in the substrate. Physical examination of the toad revealed a bleeding wound on its thigh near the knee; however, the toad recovered completely from this injury in time.

We observed no evident glandular secretions from the toad (but see Bragg, 1965:30) during either trial or any behavior by either of the shrews that would indicate an adverse reaction to such noxious substances (i.e., mouth pawing, squeaking, avoidance), as observed with *Blarina* exposed to various other anurans by Formanowicz and Brodie (1979).

Fig. 1. – Northern short-tailed shrew (*Blarina brevicauda*) retaining bite on the hind limb of a jumping eastern spadefoot toad (*Scaphiopus holbrookii*) during arena trial, 3 November 2000.

DISCUSSION

Northern short-tailed shrews exhibited different foraging behaviors, having routed the buried eastern spadefoot toad both while burrowing beneath the loose substrate and by digging directly down to the quiescent anuran from the soil's surface. Such behavioral differences may have been those of individual shrews or may have been caused by differing trial conditions, the most apparent difference being variation in ambient light levels. Nevertheless, these behaviors were opposite of those expected if light were the motivating factor (i.e., where shrews would likely burrow under brighter light and move along the surface under dimmer redlight). More likely, if caused by trial conditions, the observer's proximity (i.e., closer during the redlight trial, providing more scent and activity) affected the shrew that burrowed.

Irrespective of approach, captive *B. brevicauda* demonstrated the ability to access and proclivity to attack a buried anuran. Most fossorial anurans bury themselves by digging backwards using their hind feet (Emerson, 1976); in the case of *S. holbrookii*, backing spirally until 5-30 cm in depth, with most toads found at depths of less than 20 cm (Pearson, 1955). This provides a tube of loose substrate that may facilitate access by potential predators. Given that *B. brevicauda* is capable of both excavating insect pupae from soil depths of 15 cm (Semel and Andersen, 1988) and detecting buried anurans from the surface (this study), the largely subterranean existence of *S. holbrookii* and similar fossorial anurans, alone, may prove an ineffective defense--perhaps even a liability – against this robust hypogeal shrew.

On routing the buried toad, *B. brevicauda* attacked with varying success; least successfully when attempting to grasp the cephalic region of the toad, most successfully when seizing the hind limbs. Similarly, *B. brevicauda* used by Brodie and Formanowicz (1981) bit and injured the hind limbs of captive treefrogs (*Hyla versicolor*); and small packs of least shrews (*Cryptotis parva*) incapacitated captive leopard frogs (*Rana pipiens*) by biting at the knees of frogs, eventually severing patellar tendons (Hatt, 1938). Of possible relevance, Pearson (1955) noted various injuries to both hind and fore limbs during his seminal study of eastern spadefoot toads, although such mutilation may have been caused by pre-metamorphic cannibalism by other *S. holbrookii* larvae (Ball, 1936).

Seizing the hind limbs of saltatory anuran prey and dragging them backwards and/or underneath substrate confers advantages to potential shrew predators. Biting may at least partially paralyze jumping muscles of the powerful hind limbs due to the bite's great pressure (T. Maier, personal observation on having been bitten by *B. brevicauda*). Pulling at such prey further unbalances attempted jumps (as observed in this study) and dragging prey even partially under some form of substrate (as described by Martin, 1980) would suppress attempted jumps and other abrupt movements that could lead to the prey's escape. Additionally, attacking hind limbs circumvents numerous other anuran defense mechanisms (e.g., chin-tucking, biting, head-butting, parotoid gland secretions). Conversely, such attack behavior suggests additional adaptive value in the almost universal anuran defensive response of body positioning headfirst towards threat stimuli – thereby impeding the seizure of hind limbs by small potential predators, such as shrews.

Northern short-tailed shrews would seem adept at attacking adult eastern spadefoot toads; yet, their role as common predators under natural conditions remains uncertain. First, captivity may have contributed to the success of *Blarina* in seizing the toad, given the loose shallow substrate, and the lack of surface cover and area available for the toad to hide and escape. Nevertheless, most eastern spadefoot toads live in loose soils and generally do not move very rapidly, even when on the surface (Pearson, 1955). Second, although these shrews possess venomous saliva containing toxins comparable to elapine venom (Lawrence, 1945; Kita et al., 2004)--a fact often associated with the inclusion of large prey in their diet--the venom's immobilizing effect is more evident on insects (Martin, 1981) than on anurans (Brodie and Formanowicz, 1981--where bitten frogs recovered, as did the toad in this study). Third, stomach analyses of these shrews (yielding mostly insects and annelids) have revealed relatively few vertebrates (George et al., 1986); yet, some shrews may prey upon salamanders and anurans seasonally (Hamilton, 1930; Wołk, 1976), thus dietary studies may be biased. Fourth, these shrews prefer consistently humid habitats provided by either heavy herbaceous cover or deep litter (George et al., 1986), whereas spadefoot toads prefer well-drained sandy soils without extensive accumulations of organic matter (Pearson, 1955). Nonetheless, these shrews and toads do come into contact (as observed in this study); at least, after periods of rain. Finally, the geographic distributions of these species are largely exclusive (Conant and Collins, 1998; Whitaker and Hamilton, 1998). Such segregation, however, might also be attributed to the effectiveness of *B. brevicauda* as a predator of these fossorial anurans. The southern short-tailed shrew (*B. carolinensis*) has practically the same geographical distribution as *S. holbrookii* (McCay, 2001); yet, this much smaller species of *Blarina* (total length: 72-105 mm) is not known to feed on vertebrates, with the exception of turtle eggs (Deitz and Jackson, 1979). Also, Altig (1972) was unable to elicit defensive behavior from *S. holbrookii* using *B. carolinensis* (thought at that time to be *B. brevicauda*). Other researchers have noted differences in temperament between *B. carolinensis* and the larger *B. brevicauda* (total length: 106-141 mm); the latter being more aggressive (E. Brodie, Jr.; personal communication).

To whatever extent *B. brevicauda* and *S. holbrookii* may interact as predator and prey (and/or competitors for common prey), the fact remains that they do come into contact with each other. The shrews in this study may have been displaying territoriality (despite methodological considerations, see above); however, their behaviors did not resemble those of agonistic conspecifics (Martin, 1980). Further, shrews elicited a wide array of anuran antipredator mechanisms from the toad used in this study (Maier and Richmond, unpublished data), as *Blarina* have with many other anurans (e.g., Altig, 1972; Formanowicz and Brodie, 1979; Brodie and Formanowicz, 1981); responses seldom evoked by other stimuli or predators, except snakes (Marchisin and Anderson, 1978). That *B. brevicauda* likely is and has been more abundant (Wrigley et al., 1979; Getz, 1989) than any other larger potential predator of *S. holbrookii* (e.g., southern hognose snake--*Heterodon simus*), and that these 2 species appear relatively evenly-matched as predator and prey, raises interesting questions regarding the possible coevolution of predator-antipredator mechanisms.

ACKNOWLEDGMENTS

I thank D. Kroodsma, W.-C. Liu, and A. Richmond for their assistance in recording behavior; E. Wilda for processing the video media, R. DeGraaf, K. Doyle, T. French, D. King, and 2 anonymous reviewers for their comments regarding the manuscript. The University of Massachusetts-Amherst Institutional Animal Care and Use Committee (IACUC) approved experimental procedures under protocol #21-02-04.

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