

Chemosensory recognition of the marbled whiptail lizard, *Aspidoscelis marmorata* (Squamata: Teiidae) to odors of sympatric lizards (*Crotaphytus collaris*, *Coleonyx brevis*, *Eumeces obsoletus* and *Uta stansburiana*) that represent different predation risks

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Abstract: The ability of the whiptail lizard *Aspidoscelis marmorata* (Teiidae) to detect and discriminate chemical stimuli associated with the integument of a sympatric saurophagous lizard (*Crotaphytus collaris*) was tested. Females of *A. marmorata* were presented with cotton swabs containing chemical cues from *C. collaris* and three species of nonsaurophagous lizards, as well as water and cologne (pungency control), and total number of tongue-flick (TF) recorded. Other responses were assessed including directed TF rate, time from initial presentation of the stimulus to first TF (latency), time spent fleeing from the stimulus, and number of flight bouts. The number of TFs, directed TF rate, and number of attempts at fleeing exhibited by were significantly greater when females were presented with swabs containing cues from *C. collaris* as compared to nonsaurophagous lizards and both control treatments. *A. marmorata* required significantly less time to elicit their first TF when presented with cues from *C. collaris* as compared to all other treatments. Most previous studies have focused on the responses of lizards to cues associated with snake predators. This study provides the first available data on responses of a teiid to cues associated with a saurophagous lizard.

Key words: *Aspidoscelis marmorata*, Chemosensory recognition, Predator odor
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Introduction

An important component of antipredator behavior is the ability to detect and respond to the presence of potential predators (Lima and Dill, 1990; Kats and Dill, 1998; Punzo, 2005a, b). Prey animals have evolved a variety of sensory adaptations that allow them to detect predators (Lima, 1998). The nature of these adaptations is often associated with specific foraging modes and microhabitat conditions (Punzo and Gonzalez, 2003). Animals exhibit a variety of defensive adaptations for avoidance or defense against predators including morphological (armor plating, spines, autotomy of tail or limbs), physiological (repellent secretions, venom), and behavioral (ataxia, threat displays, flight (Punzo, 1997; Punzo and Kukoyi, 1997; Sih *et al.*, 1998).

Among lizards, a keen visual sense allows them to detect moving predators at a distance that is usually sufficient for avoidance of detection or evasion if a predator attacks (Cooper, 2005). However, because predators currently located near prey, or that are soon likely to be so, are not always visible, any sensitivity to chemosensory cues from predators should increase survivorship of prey (Amo *et al.*, 2004a, b). The tongue-vomer nasal system is well-developed in several lizard families (Cooper, 2000). The tongue is involved in sampling molecules in the external environment and transferring them to the vomeronasal organs for subsequent analysis (Rehorek *et al.*, 2000). This type of vomerolfaction allows lizards to recognize odors associated with shelter sites (Paulissen, 2006), conspecifics (Bissinger, 1981; Punzo and Parker, 2006), prey (Cooper, 2000;

Punzo, 2003), and predators (Dial *et al.*, 1989; Aragon *et al.*, 2003; Amo *et al.*, 2004a).

In contrast to studies analyzing the use of chemical cues by lizards in the detection of prey and conspecifics, their use in the detection of predators has received less attention (Punzo, 2000), but has also focused on saurophagous snakes (Dial *et al.*, 1989; Van Damme and Quick, 2001; Amo *et al.*, 2004b). However, lizards are often preyed upon by larger conspecifics or other species of lizards (Pianka and Vitt, 2003; Punzo, 2001, 2003, 2005c).

The marbled whiptail lizard *Aspidoscelis marmorata* (Teiidae) is a medium-sized lizard (snout-vent length, SVL: 5.9-11.7 cm). It is found in far west Texas and extends into southern New Mexico and eastern Arizona (Stebbins, 2003). In the desert southwest it prefers arid or semiarid habitats with sparse vegetation, open areas with sand and exposed rocks, (Garrett and Barker, 1987), and can also be found at higher elevations in montane forests (Stebbins, 2003). In Big Bend National Park (BBNP), which lies in the northern Chihuahuan Desert, it feeds on a variety of insects and spiders (Maury 1995; Punzo, 2000). Juveniles of *A. marmoratus* are preyed upon by adult eastern collared lizards (*Crotaphytus collaris*) having a SVL ranging from 7.6-11.5 cm (Best and Pfaffenberger, 1987; Punzo, 2000; Stebbins, 2003). Sympatric lizards that are exclusively insectivorous and pose no threat to *A. marmorata* include the desert side-blotched lizard (*Uta stansburiana*), Texas banded gecko (*Coleonyx brevis*) and great plains skink (*Eumeces obsoletus*).



Because few data are available on the ability of lizards to detect scents associated with other saurophagous lizards, the present study was conducted to assess the responses of *A. marmorata* to odors of several sympatric lizard species that pose different levels of risk.

Materials and Methods

Animals and housing conditions: All animals were housed under conditions that met guidelines for the use of animals in research as outlined by the Animal Behavior Society, Washington, D.C. (USA). All individuals of *A. marmorata* used in these experiments were females (SVL: 5.2–5.5 cm) and were captive-bred offspring of adults originally collected at Tornillo Flat in Big Bend National Park (BBNP, Brewster County, Texas) during the spring of 2004. Eleven female lizards from two different clutches ($n = 22$, egg deposition sites separated by a distance of 2.3 km) were chosen as subjects for experiments. Females were chosen due to availability at time of testing.

After hatching, lizards were housed individually in 30 x 30 x 20 cm reptile cages (Model C10S, Bush Herpetological Supply, BHS, Neodosha, Kansas) until subjected to testing at 10–11 months of age. The floor of each cage contained a milled sphagnum substrate (BHS, MISM) and was provided with fluorescent UV lighting (BHS, 8L48, 350 nm). Cages were provided with a section of tree bark for shelter and to allow lizards to climb. Cages were housed in a climate-controlled room (23.5–24.5°C; 35–40% relative humidity; 14L:10D photoperiod regime). Substrate and tree bark were changed on a weekly basis. Lizards were fed twice weekly on a diet consisting of lynx spiders (*Oxyopes salticus*), crickets (*Acheta* sp), and mealworms (*Tenebrio molitor*). All individuals of *A. marmorata* used in these experiments were 'naive' in that they had no previous encounter with any of the other predator (*C. collaris*) or non-predator lizards (*C. brevis*, *U. stansburiana*, *E. obsoletus*) used in this study. Predator and non-predator lizards were housed and maintained under conditions identical to those described above for *A. marmorata*.

Experiments on chemosensory recognition: Experiments were conducted to assess the differential responses of *A. marmorata* ($n = 22$) to various chemosensory cues. I compared the tongue-flick rates (TFR) of *A. marmorata* to cotton swabs impregnated with one of each of the following treatments: predator cues (high risk): (1) *C. collaris*; non-predator cues (no risk): (2) *C. brevis*; (3) *U. stansburiana*; and (4) *E. obsoletus*; (5) odorless control: deionized water; and (6) pungency control: cologne. Water was used to determine baseline TFR under experimental conditions. Chemosensory stimuli were prepared by dipping the tip of a cotton swab into deionized water. Other stimuli were added by rolling the moistened cotton tip over the body surface of other lizards or by dipping it into diluted cologne. A new cotton swab was used in each trial.

All subjects were exposed to each treatment stimulus in a counterbalanced order of presentation (Amo *et al.*, 2004a) for one trial/day. All experiments were conducted in another climate-controlled room (23.5–24.5°C; 35–40% RH) between 1130 and 1400 hr (Eastern Standard Time).

All experiments were conducted in a square-shaped vinyl test chamber (50 x 50 x 40 cm) provided with an open top. Before testing began, all subjects were placed individually into the chamber and allowed to explore it for 30 min/day over a 3-day period, thus allowing all lizards to become familiar with its interior. At the start of each trial, an individual lizard was placed in the center of the chamber and covered with an inverted opaque plastic bowl that prevented movement within the chamber and kept the subject in one place. After 1 min, the bowl was lifted and a cotton swab containing one of the 6 treatments was moved slowly toward the lizard to a position 1 cm anterior to its snout. The number of tongue flicks (TFs) directed toward the swab was recorded over a 60-sec period. I also recorded the time that elapsed between presentation of a cotton swab and the first TF (latency), time spent by a subject running away from the swab (fleeing) toward one of the walls of the chamber, and the number of times a lizard fled.

Statistical analysis: All statistical procedures followed methods outlined by Sokal and Rohlf (1995). All data were tested for normality using a Bartlett's test and for homogeneity of variances using a G test. I used a repeated-measures analysis of variance (ANOVA) with scent stimulus as the within factor to test for differences in number of total TFs among treatment conditions, number of TFs not directed toward a swab, time spent fleeing, and number of times that lizards fled from the stimulus. In some trials a lizard would move away from the stimulus a number of times which required that the swab be continuously repositioned in front of its snout. As a result, I calculated the rate of TFs directed to the swab in relation to the actual time that a lizard remained exposed to a stimulus (*i.e.* - directed TFR). I analyzed the directed TFR by using a repeated measures analysis of covariance (ANCOVA) with number of repositionings of the swab as a covariate to avoid any confounding effects of this variable. Data on directed TFR were arc-sine-transformed, while all other data were log-transformed. I used Tukey's honestly significant difference test (HSD) to conduct pairwise comparisons.

Results and Discussion

All subjects exhibited TFs to swabs regardless of treatment condition. There were significant differences among treatment conditions in total TFs (ANOVA: $F_{5,105} = 5.44$, $p < 0.001$) (Table 1, 2). Whiptails directed significantly more TFs toward swabs containing chemical stimuli from the saurophagous lizard (*C. collaris*) as compared to non-saurophagous lizards (CB: Tukey tests: $p < 0.01$; US: $p < 0.01$; EO: $p < 0.01$), cologne ($p > 0.60$), or water ($p > 0.55$) (Table 1). There were no significant differences in total TFs directed at non-saurophagous lizards and water or cologne ($p > 0.80$), between water and cologne treatments ($p > 0.77$), or in total TFs between the three non-saurophagous lizards ($p > 0.90$).

There was also a significant difference in the rate of TFs directed toward swabs among treatments (ANCOVA: $F_{5,100} = 9.01$, $p < 0.001$) (Table 1). Swabs containing chemical stimuli from a saurophagous lizard (Table 1, CC) elicited a significantly higher

Table - 1: Total number of tongue flicks (TFs), rate of TFs directed at cotton swabs in relation to the time exposed to the stimulus (directed TF rate), and latency (in sec) to the first TF by a lizard (*Aspidoscelis marmorata*). Data expressed as means (n = 22); values in parentheses represent (\pm SE). TFs in response to: W (deionized water); C (cologne; pungency control); scent from a predatory lizard, *Crotaphytis collaris* (CC), nonpredatory lizards (*Coleonyx brevis*, CB; *Uta stansburiana*, US; *Eumeces obsoletus*, EO)

	Stimulus					
	W	C	CB	US	EO	CC
Total TFs	10.3 (2.1)	12.2 (1.8)	21.7 (3.2)	23.9 (4.1)	22.4 (2.9)	34.3 (3.8)
Directed TF rate	6.8 (0.4)	7.4 (0.2)	7.7 (0.5)	7.3 (0.2)	7.8 (0.3)	12.6 (0.8)
Latency (s)	3.2 (0.2)	2.8 (0.3)	2.6 (0.3)	2.5 (0.2)	2.6 (0.4)	0.7 (0.1)

Table - 2: ANOVA table for effects of treatment conditions (chemical stimuli) on number of tongue flicks (TF), frate of TFs directed at cotton swabs (TF rate), and latency to the first tongue flick (see data and heading for Table 1). *p < 0.01

Source of variation	df	SS	MS	F
W	5	57116.13	28557.06	
C	5	55499.73	13885.41	
CB	5	48792.44	15413.55	
US	5	51214.66	20877.41	
EO	5	53477.92	17844.63	
CC	5	3022.71	433.66	5.44*

Table - 3: Behavioral responses of *Aspidoscelis marmorata* exposed to cotton swabs containing the following chemical stimuli: W (deionized water); C (cologne; pungency control); scent from a predatory lizard, *Crotaphytis collaris* (CC), nonpredatory lizards (*Coleonyx brevis*, CB; *Uta stansburiana*, US; *Eumeces obsoletus*, EO). Data expressed as means (n = 22); values in parentheses represent (\pm SE). TF (tongue flicks)

Treatment	W	C	CB	US	EO	CC
Non-directed TFs	6.9 (1.1)	6.4 (0.7)	8.8 (1.5)	13.5 (2.1)	9.5 (1.8)	8.9 (0.8)
Time spent fleeing	24.8 (4.1)	25.4 (2.8)	27.3 (3.3)	25.7 (2.7)	28.2 (2.2)	27.7 (3.8)
Number of flees	9.1 (1.2)	8.5 (1.8)	9.3 (2.3)	9.8 (1.9)	8.1 (0.9)	12.4 (2.4)

directed TF rate when compared to responses directed at swabs treated with water or cologne (Tukey's tests, p < 0.01). Rate of TFs directed toward swabs containing cues of non-saurophagous lizards were significantly lower when compared to responses directed to swabs containing cues of *C. collaris*.

Directed TF rate toward swabs containing odors of non-saurophagous lizards did not differ from water or cologne (p>0.70), and no differences were found between water and cologne (p>0.82).

There was no significant difference in the number of TFs not directed toward a swab (ANOVA: $F_{5,105} = 0.89$, p > 0.21; Table 3).

Although there was no significant difference in the time spent fleeing from a stimulus among treatments (ANOVA: $F_{5,105} = 0.92$, p > 0.35, Table 3), the number of times lizards fled from a stimulus differed significantly among treatments ($F_{5,105} = 4.11$, p < 0.01; Table 3). Whiptails showed a significantly greater tendency to flee when exposed to stimuli associated with a saurophagous lizard (CC) than they did toward water or cologne (Tukey's test: p > 0.50 and 0.60, respectively). There were no other significant differences in pairwise comparisons between any of the other treatments (p > 0.10).

There was a significant overall effect of treatment conditions on latency to first tongue flick (Table 1, ANOVA: P < 0.01). Latency to swabs containing stimuli associated with the saurophagous lizard (CC) was significantly shorter differed significantly among treatments (Tukey tests): W: p < 0.01; C: p < 0.01; CB: p < 0.01; US: p < 0.01; EO: p < 0.01. Latency to swabs containing stimuli associated with a saurophagous lizard (CC) was significantly shorter as compared to any of the other treatments. There were no significant differences in latency for whiptails exposed to water, cologne, or any of the non-saurophagous lizards (p > 0.60 in all cases).

To my knowledge, these experiments provide the first data on responses of any teiid lizard to chemical stimuli associated with a saurophagous lizard. Previous studies on responses of lizards to scents of predators have focused on snakes as predators (Dial *et al.*, 1989; Cooper 1990; Amo *et al.*, 2004a, b). Results of this study clearly demonstrate that females of the marbled whiptail *A. marmorata* have the ability to detect and differentially respond to chemosensory stimuli associated with a naturally-occurring, sympatric saurophagous lizard, *C. collaris*. In addition, because these whiptails had no previous encounter experience with *C. collaris*, this ability appears to have a genetic basis (innate).

The higher TFR of *A. marmorata* in response to body scents of *C. collaris* indicates that this whiptail can discriminate chemical cues of a predator from those associated with non-saurophagous lizards. This suggests that the discriminatory ability of *A. marmorata* in detecting a saurophagous lizard is specific and not merely a response to some generalized category of 'lizard scents'. Perhaps *A. marmorata* has evolved the innate capacity to recognize specific chemical compounds associated with the skin of *C. collaris* such as pheromones or hydrocarbon compounds associated with the epidermis. Future studies should attempt to ascertain the precise chemical nature of the chemical cues used in predator recognition.

The lack of differences between the directed TF rate and latency to first tongue flick when presented with non-saurophagous scents, as compared to water or cologne, suggests that either *A. marmorata* treated these cues as irrelevant, or were not able to recognize them. These results are in agreement with previous studies on responses of lizards to body scents from saurophagous and non-saurophagous snakes. For example, the lizard *Lacerta vivipara* exhibited a significantly higher TFR when placed in a cage that had



previously housed *Vipera berus*, a viper that feeds on *L. vivipara*, as compared to its TFR when placed in a cage that never housed an animal of any kind (Van Damme *et al.*, 1990). Similarly, wall lizards (*Podarcis* sp) have the ability to discriminate between scents of a saurophagous snake (high risk) from those associated with snakes which pose no threat to lizards (Van Damme and Quick, 2001; Amo *et al.*, 2004b).

During mid-spring to late summer at Tomillo Flat (TF; BBNP), the peak foraging activity period for *A. marmorata* and other whiptails is between 1030-1300 hr (Punzo, 2001). During this period, adults of *C. collaris* emerge from shelter sites in rock crevices and can be found using large rocks, logs, and boulders as perch sites from which they visually scan their immediate environment, looking for body movements of potential prey. Adult collared lizards typically feed on lizards and large arthropods (Banta, 1960; Stebbins, 2003), and occasionally on rodents (McAllister and Trauth, 1982). In desert regions of the southwestern U.S., collared lizards are known to feed on a variety of lizards, including whiptails (Best and Pfaffenberg, 1987; Pianka and Vitt, 2003). Thus, selection should favor lizards that can discriminate between odors of saurophagous versus non-saurophagous predators. Females of *A. marmorata* clearly possess this ability, and may rely on it to detect chemical cues left by *C. collaris* and avoid shelter sites in rock crevices formerly occupied by collared lizards. Stapley (2003) has shown that the skink, *Pseudemoia trecasteauxii*, can discriminate among shelter sites formerly occupied by saurophagous snakes from those formerly occupied by snakes that feed only on small mammals or amphibians.

Although there was no significant difference in the mean time spent moving away (fleeing) from the scent stimulus by *A. marmorata* when exposed to scents of any of the lizards, this whiptail exhibited a significantly higher number of flight bouts when exposed to scent of *C. collaris*. One possible explanation is that running is associated with high energetic costs and should only occur when the presence of a predator can be more accurately assessed (Helfman, 1989; Harvell, 1990; Lopez and Martin, 2001). A more accurate assessment might require not only chemical cues associated with predators but also visual confirmation. Perhaps flight is less likely in the absence of visual cues. A previous study showed that wall lizards (*Podarcis* sp.) exhibited a heightened degree of antipredator responses, including fleeing, when they encountered a combination of chemical and visual cues associated with a predator that when they encountered only one type of cue (Amo *et al.*, 2004b). However, in the present study, whiptails did exhibit an increased tendency to initially move away from a chemical stimulus associated with a predator even though any bodily movement may make a lizard more visible to predators and hence reduce fitness.

Many mammals and amphibians, as well as some species of reptiles, are known to exhibit other behavioral responses when presented with a cotton swab containing predator chemical cues (Lima and Dill, 1990; Kats and Dill, 1998). These can include increased vigilance, biting the swab before retreating, hissing, or adopting some kind of defensive posture (Lima, 1998; Lopez and

Martin, 2001). Many snakes exhibit a defensive posture as well as hissing when confronted by a potential predator (Weldon, 1982; Arnold and Bennett, 1984; Kats and Dill, 1998). Among lizards, once a predator has been detected, antipredator behavior may include ataxia, stereotypical threat postures, and/or running away (Greene, 1988; Pianka and Vitt, 2003). In this study, *A. marmorata* exhibited no threat posture when exposed to predator chemical cues. Additionally, in no case did these lizards bite the cotton swab, but they did exhibit a significant increase in total number of TFs, directed TF rate, and number of times they withdrew from the stimulus.

In their natural habitat, whiptail lizards (Teiidae) are typically wary (Benes, 1969) and maintain a certain distance between themselves and an intruder (Etheridge and Wit, 1993). Should another animal approach a whiptail at a closer distance, these lizards usually respond by running away at considerable speed (Punzo, 2001). However, when they are searching for prey, they typically move about, extruding their tongue which makes frequent contact with the ground and/or surrounding vegetation. Not only can teiids detect moving prey visually at the ground surface, but they can also use their well-developed vomeronasal sensory apparatus to locate insects that are submerged under sandy soils (Punzo, 2001; Paulissen, 2006). The results of this study suggest that *A. marmorata* possesses the ability to recognize and respond differentially to chemosensory cues associated with naturally-occurring predators, which may reduce risk of predation under natural conditions.

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