Anti-predator behaviour in the Brazilian lizard *Tropidurus itambere* (Tropiduridae) on a rocky outcrop

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ABSTRACT - We recorded anti-predator behaviour in the Brazilian saxicolous lizard *Tropidurus itambere* on a rocky outcrop in southeastern Brazil. The lizards used cryptic colouration associated with immobility as primary defence but when discovered employed locomotor escape. When handled a variety of defensive behaviours were displayed: gular expansion, forced escape, cloacal discharge, threat display (the lizard opening the mouth and trying to bite), tail wave, death-feigning and bite. All individuals displayed gular expansion but only males bit the researcher. Females showed higher frequency of autotomized or regenerate tails than males, however, this difference was not statistically significant. There was no significant difference between the number of adults and juveniles with autotomized or regenerate tails.

Predation risk is a key factor in the lives of animals and to understand risk and the behaviours used to avoid predators requires detailed studies of different behaviour repertoires in different species. Lizards are a particularly useful group to study in this respect, partly because they are prey for a wide range of predators (see Mckinney & Ballinger, 1966; Greene, 1988; Rocha, 1993; Rocha & Vrcibradic, 1998; Ávila & Morando, 2002; López et al., 2003; Shepard, 2005) and also because they have evolved a variety of defensive strategies (Rocha, 1993). Two basic defensive behaviours have been observed: a primary defence that involves behaviour and morphological characteristics that decrease the chance of discovery followed by behaviour e.g. flight, biting or cloacal emissions, initiated when the primary defences have failed (Edmunds, 1974). Understanding such behaviours are key for insight into the relationship between predator avoidance/behaviours and the environment they are used in - for instance behaviours employed in closed structurally complex habitats may be differ from those used in open less structurally complex habitats.

This paper describes anti-predator behaviour in the lizard *Tropidurus itambere* Rodrigues, 1987, a *Tropidurus* of the *Torquatus* group (Frost et al., 2001), that commonly occurs in open, sometimes rocky, areas in central and southeastern Brazil (Rodrigues, 1987). It is a diurnal medium-sized (mean snout-vent length adult = 71.8 mm) sit-and-wait forager (Van Sluys, 1992) mostly feeding on ants (Van Sluys, 1993a). Although several studies on the general ecology of *T. itambere* have been carried out (Van Sluys, 1992, 1993a, b, 1995, 1997, 1998, 2000, Van Sluys et al., 1994) details of behaviour is largely unknown.

MATERIALS AND METHODS

We recorded anti-predator behaviour of 109 individuals of *T. itambere* (48 females, 39 males and 22 juveniles) between February and November 2007, in a rupestrian field situated in the Ibitipoca State Park (21°41'48"S, 43°53'21"W), Minas Gerais state, southeastern Brazil. The Park presents an area of 1488 hectares and varies in altitude from 1200 to 1800 metres (Cetec, 1983). The climate of the area is classified as Cwb (Köppen classification): humid mesotermic, with rainy summers and dry winters. The mean annual precipitation is 1530 mm and mean temperature 18.9ºC (Cetec, 1983). The average minimum temperature at summer is 21.5ºC and maximum 36°C, in winter these temperatures are from 2 to 14.5°C (Dias et al., 2002). The vegetation of the Park is dominated by Orchidaceae, Velloziaceae, Bromeliaceae, Cactaceae, Poaceae and Compositae families.

Defensive Behaviour	Males (N = 39)	Females (N = 48)	Juveniles (N = 22)	Sexual difference (N = 87)	Ontogenetic Difference (N = 109)
Gular expansion	100%	100%	100%	*	*
Forced escape	61.5%	29.2%	27.3%	$\chi^2 = 9.16$; p = 0.00	$\chi^2 = 1.96$; p = 0.16
Cloacal discharge	46.2%	45.8%	36.4%	$\chi^2 = 0.00$; p = 0.97	$\chi^2 = 0.65$; p = 0.41
Threat display	28.2%	12.5%	13.6%	$\chi^2 = 0.37$; p = 0.07	$\chi^2 = 0.40$; p = 0.52
Tail wave	15.8%	8.3%	9.1%	$\chi^2 = 1.05$; p = 0.30	$\chi^2 = 0.10$; p = 0.74
Death feigning	10.2%	10.4%	4.5%	$\chi^2 = 0.00$; p = 0.98	$\chi^2 = 0.70$; p = 0.40
Bite	7.7%	0%	0%	$\chi^2 = 3.82$; p = 0.05	$\chi^2 = 0.78$; p = 0.37

* We did not apply the chi-square test for gular expansion behaviour because all lizards exhibited it.

Table 1. Frequency of males, females and juveniles of *Tropidurus itambere* that exhibited defensive tactics during the handling in Ibitipoca State Park, southeastern Brazil: sexual and ontogenetic differences.

We conducted fieldwork monthly in three-day trips per month and searched for lizards between 07:00 and 18:00 hrs during the wet season (February, March, September, October and November 2007) and between 08:00 and 17:00 hrs during the dry season (April, May, June, July and August 2007). When one individual was found, we recorded its initial behaviour at a distance of 3-4 meters, with the aid of binoculars, without disturbing the lizard. Afterwards, to simulate an attack, one of the researchers, always the same and always wearing similar clothes, approached the lizard and then its behaviour was registered again and the type of refuge selected after the flight. The lizards were then captured with a nylon noose and snout-vent length (SVL) measured to the nearest 1.0 mm with a manual calliper and then weighed with a Pesola micro line/30g to the nearest 0.25g. Lizards were classified as adults if SVL equalled or exceeded 57.3mm for males and 56.1mm for females (Van Sluys, 1993b). Sex was determined using body ventral area condition, which in adult males shows black ventral patches on the thighs, pre-cloacal flap and abdomen (Rodrigues, 1987). Juveniles were not sexed.

To avoid recapture and pseudo-replication elastic hair bands were attached to the lizards as necklaces in the way described by Ribeiro & Sousa (2006) and the tail base painted using nail varnish. The necklaces were not removed after the completion of the study. However monitoring of the study population indicated the collars dropped of after around five months. The necklaces did not appear to have influenced behaviour which is in agreement with other studies (e.g. Ribeiro & Sousa, 2006). Defensive behaviours exhibited during handling were quantified and converted to frequencies for males, females and juveniles. We also recorded the number lizards with autotomized tails. Lizards were released at the point of capture and their behaviour recorded.

We used the chi-square test (Zar, 1999) to test for differences defensive behaviour between males and females and between adults and juveniles. The significance level was set at p = 0.05.

RESULTS

After initial contact the lizards remained motionless on the substrate using cryptic colouration as the primary defence mechanism. After discovery the lizards initiated locomotor escape but this varied: (1) they ran either towards rock crevices (65.1%; N = 71), (2) towards vegetation (15.6%; N = 17), (3) they ran certain distance, stopped and remained

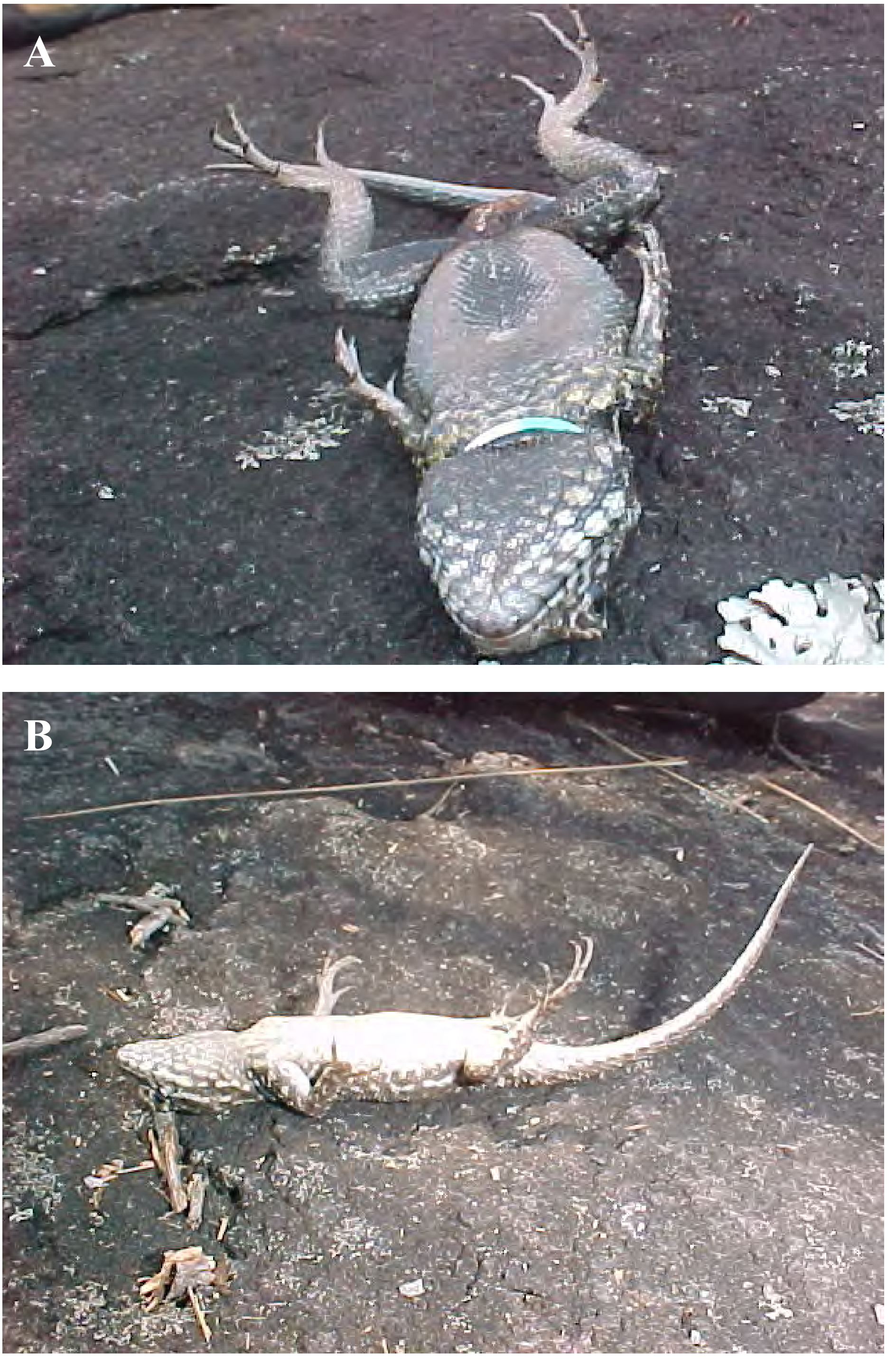

Figure 1. Individuals of *Tropidurus itambere* exhibiting death-feigning after liberation on the ground in the Ibitipoca State Park, Minas Gerais state, southeastern Brazil: (a) adult male (89.8 mm SVL) and (b) juvenile (50.5 mm SVL) with closed eyes.

motionless again (12.9%; N = 14) or (4) they made several short runs alternated with brief stops, during which exhibited head bobs and push ups and then became motionless (6.4%; N = 7).

When handled the lizards displayed a variety of defensive behaviours: gular expansion, physically attempting to break free, cloacal discharge, threat display (mouth opened and trying to bite), tail wave, death-feigning and bite. All individuals displayed gular expansion but only males bit the researcher (Table 1). Tail waving always preceded attempting to escape. Males attempted forced escape and bite behaviours more frequently than females but there was no significant difference in the frequency of defensive behaviours exhibited during handling between adults and juveniles (Table 1).

The lizards did not attempt to tail break during handling, however, 13.7% of those examined showed autotomized or regenerate tails. Females had higher frequency of autotomized or regenerate tails (20.8%; N = 10) than males (7.7%; N = 3), but the difference was not (χ^2 = 2.9; p = 0.087; N = 87). Two juveniles (9.1%) showed autotomized tails. There was no significant difference between the number of adults (pooled male and female data) and juveniles with autotomized or regenerate tails (χ^2 = 0.5; p = 0.47; N = 109).

After the handling released lizards either immediately exhibited locomotor escape, running towards rock crevices (77.1%; N = 84) or vegetation (13.7%; N = 15) or remained motionless (9.2%; N = 10). The lizards that remained motionless were those that exhibited death-feigning during handling and released on the ground. Eight remained in thanatosis for several minutes (1-5 min). Two individuals recovered after 10-20 sec and fled rapidly. During thanatosis, the lizards lay on their backs with all four legs and sometimes the tail, extended upward but their eyes were open (Figure 1a) except in a death-feigning juvenile where the eyes were closed (Figure 1b).

DISCUSSION

The defensive behaviours displayed by *T. itambere* in this study were observed in response to the presence of human researchers. It has been proposed that this could alter experimental results because coexistence with humans may affect behavioural and physiological anti-predator behaviour in lizards (Labra & Leonard, 1999). However, the use of humans as a surrogate predator to assess the anti-predator behaviour can still provide useful information (see Schall & Pianka, 1980; Snell et al., 1988; Machado et al., 2007; Martín et al., 2009). An additional factor that may interact with anti-predator behaviour is social behaviour since lizards must also be aware of not only potential predators but also with competitors for territory (Díaz-Uriarte, 1999; Machado et al., 2007). However, in this study, we did not evaluate the influence of the social context on the defensive behaviours exhibited by *T. itambere*.

The individuals of *T. itambere* of the Ibitipoca State Park used cryptic coloration and immobility as primary defense mechanism. This has been observed in other sit-and-wait foraging lizards that inhabit open environments (e.g. Rocha, 1993; Galdino et al., 2006; Machado et al., 2007). According to Rocha (1993) lizards that inhabit open environments are more at risk to visually oriented predators and hence cryptic coloration is adaptive increasing chances of survival. Foraging mode may also influence defence behaviour (Cooper, 1994): active foraging lizards use locomotor escape as the primary defence mechanism, while sit-and-wait foraging lizards generally use cryptic coloration for primary defence and only use locomotor escape when risk is greatest. When discovered, *T. itambere* usually ran directly towards rock crevices (65.1%; N = 71) and therefore the abundance granite rocks present on the study site plays a key role in escaping from predators.

Defensive behaviours exhibited by *T. itambere* during handling were similar to those displayed in the congeneric *T. montanus* (Machado et al., 2007) in a rocky outcrop area, however with differences; *T. itambere* did not inflate the body and *T. montanus* did not exhibit gular expansion. Gular expansion was the most frequent defensive behaviour exhibit by *T. itambere*. It is an aggressive display used during agonistic interactions and may be used as a behavioural modifier to enhance information conveyed by lizards (Ord et al., 2002; Labra et al., 2007).

During handling lizards exhibited threat display (mouth open and attempting or threatening to bite). *T. itambere* exhibited tail waving during handling. This behaviour is well known and, for example, has been described in *L. lutzae* by Rocha (1993), in *Eurolophosaurus nanuzae* by Galdino et al. (2006) and in *Tropidurus montanus* by Machado et al. (2007) However, there was no difference in the frequency that adults and juveniles of *T. itambere* using the behaviour.

The observation of tail waving in *T. itambere* is well known and, for example, has been described in *L. lutzae* by Rocha (1993), in *Eurolophosaurus nanuzae* by Galdino et al. (2006) and in *Tropidurus montanus* by Machado et al. (2007). It is a well known method of diverting the attention of predators by exposing the tail to reduce the risk of potential injury to vital parts of the body lizard (Vitt, 1983; Rocha, 1993). No lizard exhibited tail break during handling, however, 13.7% of those examined showed autotomized or regenerate tails. This value is smaller than found for another *T. itambere* population living in grassland in Valinhos, São Paulo (Van Sluys et al., 2002), where 23% showed autotomized or regenerated tails. We believe that this difference is due to Valinhos grassland population to be more susceptible to predation and to agonistic interactions due to a smaller number of refuges compared to a rupestrian field. Many factors play a role in the frequency of tail autotomy in lizards including prevalence and type of predators, type of habitat and frequency of intraspecific aggression (Bellairs & Bryant, 1985).

In *T. itambere* the absence of a significant difference in frequency of tail autotomy between the sexes may relate to the presence of agonistic territorial behaviour in both males and females (Van Sluys, 1997; Van Sluys et al., 2002; Nunes et al., 2008). Both sexes are therefore equally susceptible to injuries as found in *E. nanuzae* (Galdino et al., 2006). Tail break frequency may also differ between juveniles and adults (Vitt et al., 1977; Daniels et al., 1986; Brandl & Volkl, 1988, Rocha, 1993) but we could not obtain a significant result for this in our study. Tail autotomy may have physiological and behavioural impacts that differ according the age of a lizard and stage of development. Tail loss in a juvenile incurs not only an energy cost for regeneration but impacts on somatic growth; the behavioural and physiological impact of tail loss may therefore be more extreme for juveniles than for adults (Bateman & Fleming, 2009).

Thanatosis (death feigning) has been observed in other *Tropidurus* (see Bertoluci et al., 2006) and is a frequent behaviour among lizards (and snakes) and considered a primitive characteristic in tropidurids (Bertoluci et al., 2006). Death feigning can inhibit predator attack through loss of interest by the predator increasing the possibility of escape (Edmunds, 1974; Rocha 1993). Bertoluci et al. (2006) recorded death-feigning for *T. itambere*, but did not make clear if it was exhibited by adults and/or by juveniles and did not describe the behaviour in detail.

The great number of defensive behaviours used by *T. itambere* of Ibitipoca State Park indicates that this species has evolved a variety of mechanisms to avoid or to escape from different types of predators in an open environment. Although no lizards were observed being predated during the study period, there was a constant presence of potential predators including birds of prey, snakes and other lizard species.

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