Short Note

Diversity and frequency of visual defensive behaviours in a population of *Hypsiboas geographicus*

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Defensive behaviours against potential predators are a common and diverse survival mechanism employed by many amphibians. During a field course conducted in the vicinity of Madidi National Park, Bolivia, in April 2006, we observed several distinct defensive behaviours displayed by individuals of *Hypsiboas geographicus*. Here we assess the diversity of defensive behaviours displayed and quantify the frequency distribution of visual defensive behaviours across a sample of the population. We also discuss some of these behaviours in a phylogenetic context.

Key words: amphibian, Bolivia, boo behaviour, death feigning

Defensive behaviours against potential predators are a well known and diversified survival mechanism in amphibians. The variety of these responses, either on their own or combined with others, includes biting (Duellman & Trueb, 1994; Hartmann et al., 2003), body puffing and/or elevation of lower half of body (Duellman & Trueb, 1994; Kwet & Solé, 2002), curving the body and placing forearms close and parallel to the head (Andreone, 2002; Das et al., 2004), dorsal recumbency, death feigning (Russell, 2002; Hartmann et al., 2003) and possible death feigning variants, including flattening the body, distending limbs and remaining motionless (Toledo & Zina, 2004) and "boo behaviour" (Angulo & Funk, 2006), gaping (Duellman & Trueb, 1994), odour production (Duellman & Trueb, 1994; Andreone, 2002; Das et al., 2004), production of skin secretions (Duellman & Trueb, 1994; Kwet & Solé, 2002), sheltering underwater (Toledo, 2004a), snapping into position (Channing & Howell, 2003), "tilting" (Toledo, 2004b) and vocalizing (Duellman & Trueb, 1994; Andreone, 2002).

During a field course conducted near Madidi National Park in Bolivia, we observed several distinct defensive strategies displayed by *Hypsiboas geographicus* individuals. Field work was conducted from 16 to 19 April 2006 (end of the rainy season) at San Miguel del Bala Ecolodge (14°32'11"S; 67°29'54"W, elevation 280 m), municipality of San Buenaventura, department of La Paz, Bolivia. The lodge is located on the banks of the Rio Beni. Observations were made in the evening (1930–2200), most on 18 April 2006 (n=101), on a river beach (Playa San Miguel), during a rainless night and at an ambient temperature of 18 °C and relative air humidity of 95%. Other observations were conducted in a secondary forest and in the shrubby vegetation along the river bank, again without precipitation. *Hypsiboas geographicus* uses Playa San Miguel as a breeding site, where individuals congregate to reproduce (>160 individuals). This open area was created by a lowered water level and was slightly less than one hectare in area. Individuals could be found sitting on rocks, in shallow pools, perched on shrubs and on the sand. Other anuran species observed and/or heard at this site include *Hypsiboas boans* and *Chaunus marinus*.

We initially observed the behaviours displayed by *Hypsiboas geographicus* upon capture, and then proceeded to record their frequency of occurrence with each capture. We recorded the initial reaction to hand capture, although on some occasions also noted changes that occurred within the first few seconds of capture. Although in some instances individuals also released an odour, given the difficulty in positively identifying when an odour was released due to sensory variation in olfactory cues among us, we decided to concentrate on visual signals. We only tested those individuals that were awake and were not in amplexus. Captured animals were temporarily collected to avoid counting the same individuals more than once; most were released immediately after observations were concluded.

Observations on the diversity and frequency of initial postural strategies were made on 106 adult *Hypsiboas geographicus* (see Table 1). We observed at least four postures being displayed, which we categorized as follows: 1) no apparent reaction, 2) boo behaviour (*sensu* Angulo & Funk, 2006; Fig. 1a,b), 3) death feigning (Fig. 1c,d) and 4) open arm display (Fig. 1e shows partially extended arms). If we consider, in addition, the non-visual strategy of odour release, our observations encompass up to five potential behaviour strategies. We did not hear any acoustic signals being emitted upon capture.

Death feigning can take several possible postural forms in a diversity of anuran species. Duellman & Trueb (1994) pointed out that in some species of *Hyla* and *Phyllomedusa* (*sensu lato*), individuals tuck their limbs close to the body and remain motionless on their backs; this was also observed in several *Hypsiboas geographicus* individuals. While boo behaviour is similar to this form of death feigning, it differs from it in that the

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Table 1. Frequency of postural strategies displayed by individual *Hypsiboas geographicus*.

Postural strategy	*n*	%
No apparent reaction	4	3.8
Boo behaviour	32	30.2
Death feigning	65	61.3
Extended arms	5	4.7
Total	106	100.0

hands of the individual are placed next to the face and close to the eyes, with fingers outstretched.

In the individuals we observed, death feigning was the most frequent initial defensive behaviour (61%), being twice as frequent as boo behaviour (30%). The other two behaviours represented less than 5% of observations each. One of the individuals that adopted a death-feigning strategy was also a call (advertisement call) voucher, and was collected (field number CCF 98, to be deposited at the Colección Boliviana de Fauna (CBF)). When handled for longer periods, we noted that three individuals changed their defensive behaviour. One individual, upon capture, extended its arms, arching backwards with its eyes closed, and a few moments later adopted a death-feigning position. Finally, after several nudges, it adopted a boo behaviour position. Another individual also initially adopted an extended-arms position, and a few moments later adopted a death feigning position. Yet another individual initially adopted a boo-behaviour strategy, but progressively began to scrunch its fingers and tuck its hands under its chin, until it reached a death-feigning position. All of these changes suggest plasticity in the adoption of different anti-predator strategies.

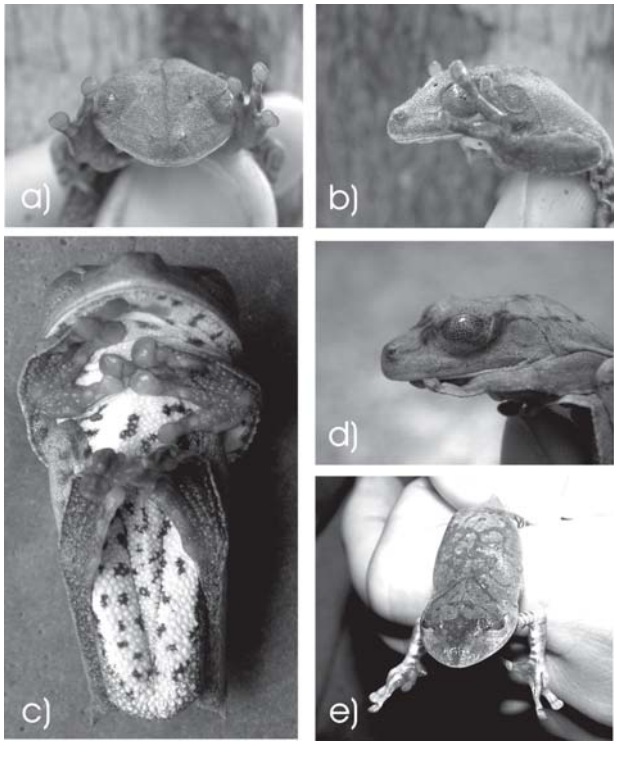

Fig. 1. The different visual displays adopted by *Hypsiboas geographicus*: a) frontal view and b) lateral view of boo behaviour display; c) ventral view and d) lateral view of death feigning display; e) open arm display (figure shows partially extended arms).

Azevedo-Ramos (1995) described the defence behaviours displayed by a treefrog considered to be *Hyla geographica* (= *Hypsiboas geographicus*) at Juréia Ecological Station in São Paulo state, Brazil. Subsequently, this Atlantic forest domain species has been considered to be *Hypsiboas semilineatus* (see Frost, 2007).

The results obtained in Faivovich et al.'s (2005) study support a sister-group relationship for these two taxa. They also support a sister-group relationship between *Hypsiboas calcaratus* and *Hypsiboas fasciatus*. The defensive behaviour shared by these two species supports the notion that they are closely related (Angulo & Funk, 2006).

Azevedo-Ramos (1995) reported six potential defensive behaviours in *Hypsiboas semilineatus*, of which death feigning was the most frequently observed (68.2% of 85 observations, *n*=79 adult males), followed by lung inflation (12.9%). In the illustration provided for the death-feigning posture, however, the forelimbs appear to be next to the face and eyes with fingers outstretched, and this is also noted in the figure legend. The death-feigning posture of Azevedo-Ramos (1995) would appear to be more similar to Angulo & Funk's (2006) boo behaviour (and see Fig. 1a,b in this study) than to our death feigning posture for *H. geographicus* (Fig. 1c,d).

While it is difficult to assign a character state to these behavioural features without knowing their distribution across other related taxa, and assuming Faivovich et al.'s (2005) hypothesis of the sister-group relationship between these two taxa, we can, however, say that 1) *H. geographicus* and *H. semilineatus* display a suite of potential defensive behaviours, at least two of which are common to both species (boo behaviour and odour release), 2) these potential behaviours are plastic in nature, with the capacity to change or co-occur in the same capture episode, and 3) the most frequent defensive behaviours chosen by these species involve immobility, limbs tucked close to body and closed eyes. In addition, boo behaviour appears to be a more widespread defensive postural strategy, occurring both in the *Hypsiboas albopunctatus* group and the *Hypsiboas semilineatus* group.

Death feigning by immobility, tucked limbs and closed eyes is a behaviour that is shared with some species of *Phyllomedusa*. Given Faivovich et al.'s (2005) placement of the Pelodryadinae and Phyllomedusinae as the sister group of the Hylinae (to which *H. geographicus* and *H. semilineatus* belong), and in order to test for a phylogenetic signal across defensive behavioural features, it may be worth exploring whether other Hylinae also exhibit similar death-feigning postures as potential defensive mechanisms, and to note the occurrence and distribution of boo behaviour as a variant of this posture, but one which could have taken on a different function – e.g. protecting the eyes, as suggested by Azevedo-Ramos (1995), or sending an antisignal, increasing the head size, or making ingestion difficult (see Angulo & Funk, 2006). Future research could also explore any po-

tential gender effects that could be related to specific defensive strategies.

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