

Additional defensive behaviours of *Dipsas mikanii* (Schlegel, 1837) and *Taeniophallus occipitalis* (Jan, 1863) (Serpentes: Dipsadidae)

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Snakes evolved defensive behaviours to avoid being detected, injured or killed by predators, and they possess an array of such behaviours (see a review in Greene, 1988). The family Dipsadidae is widespread in the New World and exhibits a high species diversity in Central and South America, and the West Indies (Zaher et al., 2009; Vidal et al., 2010). Previous studies have reported different defensive tactics used by several species of this family (e.g. Martins and Oliveira, 1998; Martins et al., 2008; Maia-Carneiro et al., 2012; Menezes et al., 2015, 2017; Atkinson, 2018; Fiorillo et al., 2018). However, there is still much to discover about defensive behavior in snakes, and the description and documentation of new defensive behaviours can help us gain a better understanding of the ecology and evolution of defensive strategies in snakes (Martins, 1996; Martins et al., 2008). Here, we present observations of novel defensive behaviors of two species of dipsadid snakes from Brazil, *Dipsas mikanii* and *Taeniophallus occipitalis*.

Dipsas mikanii is widely distributed in central and eastern Brazil, as well as in the Misiones region of Argentina and adjacent Paraguay, and occurs in diverse habitats, from forests to open savannas in the Brazilian Cerrado, where it is commonly found (Franco, 1994; Cacciali, 2006; França et al., 2008; Sawaya et al., 2008; Freitas et al., 2014; Marques et al., 2015, 2017). It has terrestrial habits and is primarily nocturnal (Sazima and Manzini, 1995; Sawaya et al., 2008; Marques et al.,

2015). Its diet is specialized in gastropods (Oliveira, 2001; Marques et al., 2015).

Taeniophallus occipitalis is a terrestrial, diurnal species that is found in leaf-litter (Sawaya et al., 2008; Morato et al., 2011; Marques et al., 2015) of open vegetation types of the Cerrado (Scrocchi and Giraudo, 2005; França et al., 2008; Sawaya et al., 2008). It does not seem to persist in disturbed areas (Sawaya et al., 2008). Its diet is composed mainly of anurans and lizards (Yanosky et al., 1996; Cechin, 1999; Marques et al., 2009).

Known defensive behaviours of *D. mikanii* are head triangulation, hiding the head, cloacal discharge, and striking (Marques et al., 2015). For *T. occipitalis*, body depression and cloacal discharge have been described (Marques et al., 2015). Here we report additional defensive behaviours for these species. On 19 July 2018 at Santa Bárbara Ecological Station, Águas de Santa Bárbara Municipality, São Paulo, Brazil (22.8244 S, 49.2264 W), we captured an individual *D. mikanii* (juvenile, snout-vent length ca. 20 cm) that displayed hooding, flattening itself while keeping the anterior portions of its body elevated (Fig. 1). This behaviour was observed repeatedly every time its path was blocked (about four times) by the researcher during escape attempts. On 25 July 2018, at the same study area, we captured an individual *T. occipitalis* (male, snout-vent length ca. 25 cm). This individual was placed inside a glass cup to be photographed. The glass cup containing the snake was then put upside-down on a tray filled with sand where photographs were taken. The snake fell upside-down on the sand and remained static in this position after we removed the glass cup, in a behaviour similar to thanatosis. After touching and moving the snake a couple of times, it rotated itself upright and tried to flee. We then repeated the process of turning the snake upside-down within the glass cup three more times without the snake presenting thanatosis, but at the fourth time we repeated the process the individual

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Figure 1. Different views of *Dipsas mikanii*, from Santa Bárbara Ecological Station, Águas de Santa Bárbara (São Paulo, Brazil), displaying hooding behaviour. Photos by Bruno Ferreto Fiorillo (A), Matheus Januário Lopes de Sousa (B) and Giordano Novak Rossi (C).

displayed the behaviour again and a photograph was taken (Fig. 2).

The hooding behaviour reported here for *D. mikanii* has already been recorded for its sister species *D. newwedii* (Martins *et al.*, 2008), as well as other species of the family Dipsadidae (e.g. in the genera *Erythrolamprus*, *Hydrodynastes*, *Thamnodynastes*, *Xenodon*; Greene, 1979; Martins and Oliveira, 1998; Franco *et al.*, 2003; Young and Kardong, 2010; Kahn, 2011; Menezes *et al.*, 2015). This defensive behaviour is commonly performed by species of Old World elapids, specifically cobras (e.g. *Naja* spp., *Hemachatus* spp., *Ophiophagus*

spp. and *Aspidelaps* spp.) when they are facing a threat (Greene, 1997; Kahn, 2011). It is well accepted that hooding increases the apparent size of the individual and alerts the predator about a potential risk (Greene, 1988, 1997; Young and Kardong, 2010).

Thanatosis has been observed in a great diversity of snakes, including colubrids, natricids, dipsadids, and elapids (Gerald, 2008; Mirza *et al.*, 2011; Bhosale and Thite, 2013; Marques *et al.*, 2013; Sannolo *et al.*, 2014). However, thanatosis is rarely reported among dipsadids (Marques *et al.*, 2013; Durso and Mullin, 2014; Muscat *et al.*, 2016). A number of different hypotheses have been



Figure 2. *Taeniophallus occipitalis*, from Santa Bárbara Ecological Station, Águas de Santa Bárbara (São Paulo, Brazil), displaying death feigning behaviour. Photo by Bruno Ferreto Fiorillo.

suggested to explain the exact function of this behaviour, such as the loss of interest of predators specializing in live prey (Rovee et al., 1976) or enhanced escape opportunity (Ratner and Thompson, 1960; Rovee et al., 1976). Nevertheless, the exact mechanisms by which thanatosis deters predation are still unclear, particularly among vertebrates. Many snake species that invert their bodies defensively expose brightly or highly-contrasting ventral patterns or coloration, and the ventral side of *T. occipitalis* is a moderately bright yellow, in contrast to its brown dorsum. This “flash coloration” may play a role in startling potential predators (e.g. McCallum et al., 2006).

The behaviours described here have in common that they are secondary defences that occur during the encounter with the predator (Edmunds, 1974) and are targeted to visually oriented predators (Martins et al., 2008). They act through different mechanisms (to intimidate and feigning death, respectively) but have the same ultimate goal (to survive a predation attempt). Moreover, both are widespread not only among the Dipsadidae but in several other groups of snakes, suggesting convergence and relative success of these strategies.

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