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Defensive displays of Speckled Kingsnake, *Lampropeltis holbrooki* Stejneger, 1902

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A repertoire of defensive behaviours is often essential for the survival of snakes as they may face different types of predators in a variety of environmental settings (Lorenz, 1971; Martins, 1996; DuVal et al., 2006). These behaviours may be influenced by many factors such as the snake's habitat, body size, temperature, perception, and previous experience (Greene, 1979; Hertz et al., 1982; Yoerg and Shier, 1997; Senter, 1999). Various defensive responses in snakes have been documented in the literature, including balling, head hiding, thanatosis, vertical head display, tail display (Greene, 1979; Castro-Expósito et al., 2017; Tozetti et al., 2021), and the use of habitat for crypsis (Menezes et al., 2017). This study aims to describe eight distinct defensive behaviours of *Lampropeltis holbrooki* Stejneger, 1902.

Lampropeltis holbrooki is a terrestrial snake with a diurnal or crepuscular habit, which can be found on the ground or beneath surface structures from southern Iowa south to the Gulf Coast of Louisiana, and west to southeastern Colorado and west Texas (Ernst and Ernst, 2003; Powell et al., 2016; Boundy and Carr, 2017). This species inhabits a wide range of habitats from forests, shrublands, and rocky hillsides in the Ozark and Ouachita mountains to floodplains and muddy wetlands in the Mississippi Delta and Gulf Coastal Plain (Trauth et al., 2004). Younger *L. holbrooki* are black at the top of the body, with narrow, diagonal cream or yellow bars that extend to the back (Boundy and Carr, 2017). As the snakes get bigger, some of the black scales develop yellow spots that give the perception that snakes have a lot of yellow or white speckles (Boundy and Carr, 2017). The maximum length of this species is 1829 mm, with adults reaching usually from 694 to 1423 mm (Boundy and Carr, 2017). *Lampropeltis holbrooki* diet is based on other Squamata, rodents, and chelonian eggs (Boundy and Carr, 2017).

On 8 April 2023, at ~18:30 h, we lifted a stone and found a juvenile *L. holbrooki* (Fig. 1; https://youtu.be/20cp2lK5sas) underneath, in a part of the Ouachita Mountains called the Sans Bois Mountains (35.0873°N, 95.3268°W) in southeastern Oklahoma, USA. As we approached the individual, it immediately coiled itself, and after we handled it, it displayed eight defensive behaviours. First, the individual balled itself while simultaneously hiding the head and exposing the tail with slow movements of the tail towards the tip. At the same time, the snake performed erratic movements, during which it also did a cloacal discharge while performing a cloacal eversion. Lastly, the observed individual performed thanatosis, becoming motionless, with all muscles relaxed and the venter exposed. From the beginning of its manipulation, when the snake promptly initiated its defensive behaviours, until the thanatosis performance, approximately 90 seconds elapsed until we returned the individual beneath the same rock.

Some species protect their heads in the middle of the body when balling (Bustard, 1969; Dirksen et al., 1998). *Lampropeltis holbrooki* employs constriction during feeding (Trauth et al., 2004), which may contribute to its ability to execute balling behaviour. This behaviour may be very useful when snakes are found in burrows, making it difficult to the predator to reach the snake inside it (Mitchell, 1978). Since *L. holbrooki* individuals are usually found beneath surface structures (Boundy and Carr, 2017), a balling formation could make it difficult for some predators to catch the individual.

Head hiding and tail displays have been observed

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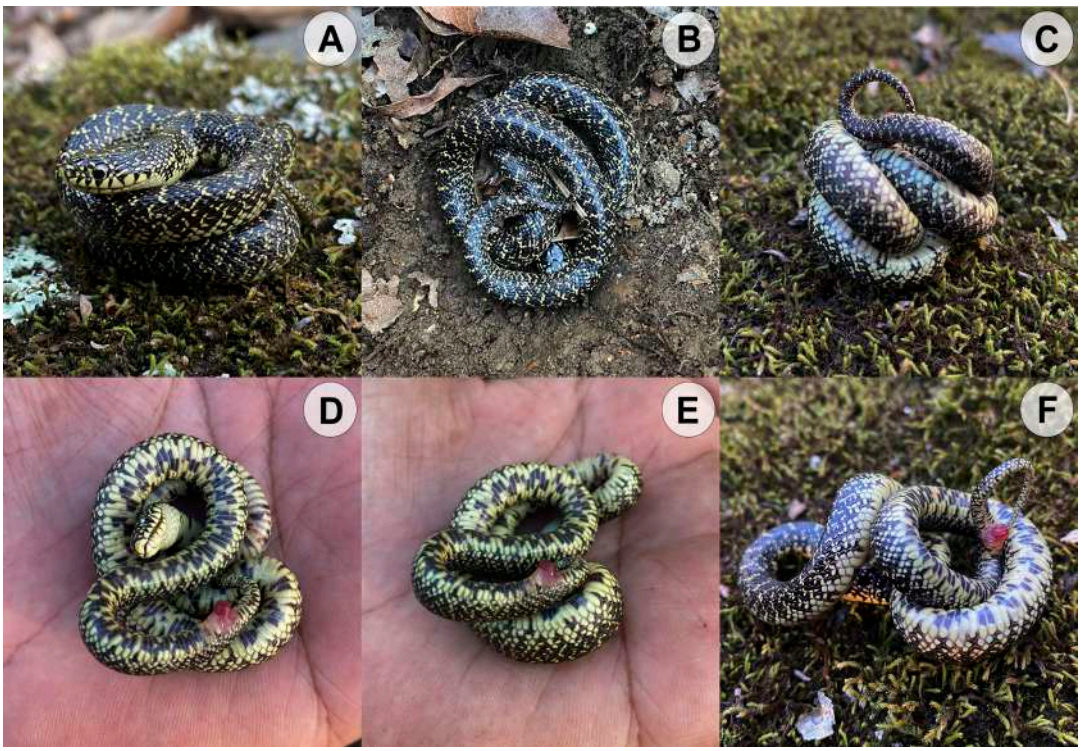

Figure 1. Defensive behaviours displayed by the observed male of *Lampropeltis holbrooki* in the Sans Bois Mountains, southeastern Oklahoma, USA: (A) coiled, (B) balled while simultaneously hiding the head, (C) exposing the tail with slow movements of the tail, (D–E) individual performing thanatosis, and (F) cloacal discharge while performing a cloacal eversion. Video available at https://youtu.be/20cp2lK5sas. Photos and video by Diego J. Santana.

in other colubrid snakes (Greene, 1979; Tozetti et al., 2021). In *Storeria dekayi*, head hiding is commonly observed after contact (Gray, 2015). The tail is the body part of an escaping animal that is more likely to get caught by a predator, providing the snake with an opportunity to escape or launch an offensive manoeuvre against the predator (Greene, 1973). It may also help to avoid direct attacks on the head and deflect them to a less vulnerable part of the body (Carbajal-Márquez et al., 2018).

Erratic movements, such as those described here for *L. holbrooki*, are a commonly observed defensive behaviour in many snake species (Gehlbach, 1970; Tozetti et al., 2009). These movements may serve to protect the head, and/or may demonstrate strength and energy (Cavalheri et al., 2021), possibly to intimidate predators.

Snakes can also make themselves distasteful, or unappetising, for predators by using cloacal discharge (Tozetti et al., 2009), which we observed in *L. holbrooki*. Previous studies have shown that cloacal discharge occurs only when the snake is being manipulated (Tozetti et al., 2009; Gray, 2015). Because we handled the individual, the cloacal discharge could be interpreted as a sign the snake perceived the situation as having been caught by a predator.

Handling has also been shown to strongly influence death-feigning behaviour, i.e., thanatosis, in snakes (Gehlbach, 1970; Gregory et al., 2007). This behaviour has been documented in several species of colubrid snakes (Sannolo et al., 2014; Castro-Expósito et al., 2017; Nadolski et al., 2020). In our observation, thanatosis served as the ultimate response to perceive danger, potentially effective in discouraging predators by leading them to believe the snake was deceased. Cloacal eversion and discharge may also occur simultaneously with thanatosis (Gregory et al., 2007). These behaviours occur late in the predation sequence and are thought to dissuade predators from continuing their attack and subjugation attempts (Humphreys and Ruxton,

2018). As previously reported in the literature and also observed by us, some defensive behaviours were displayed after handling, which could be interpreted as the snake responding with defensive movements only after direct contact.

A predation sequence consists of several steps and different defensive behaviours are often aimed at disrupting one or more steps in the sequence (Vitt and Caldwell, 2014). Smaller and younger snakes, like the *L. holbrooki* we observed, are potential prey for a broad range of predators and are also less experienced, which may explain the diversity of defensive behaviours displayed.

The diverse and rapid defensive responses observed in young *L. holbrooki* may be vital for their survival, given their possible vulnerability due to their smaller size. However, the effectiveness of these defences varies, as some predators may be deterred or confused, while others remain undeterred. Nevertheless, these behaviours, encompassing coiling, balling, head hiding, tail displays, erratic movements, cloacal discharge, cloacal eversion and thanatosis, highlight the adaptability and resourcefulness of young *L. holbrooki* snakes in the face of threats, considering that the younger the snake, the more antipredator responses it will demonstrate (Shine et al., 2002; Roth and Johnson, 2004). This multifaceted strategy may confuse or deter predators, buying valuable time for the juveniles to escape danger. To fully comprehend the role of these behaviours in the survival of *L. holbrooki* individuals in their natural habitat, further research and observation are imperative. Such studies can unveil the intricate interplay between these defence mechanisms and the predators that challenge the young snakes' survival in the wild.

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