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Shadowboxing Salamanders: Defensive Behavior in Two Amazonian *Bolitoglossa* Species (Amphibia: Plethodontidae).

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Abstract

Salamanders employ diverse anti-predator strategies, yet many tropical species remain poorly documented. We describe a previously unreported defensive display in two Amazonian plethodontids, *Bolitoglossa equatoriana* and *B. altamazonica*. During nocturnal surveys in the Apayacu Reserve, Ecuador, an individual of *B. equatoriana* perching on a leaf performed a striking "shadowboxing" display when lightened: it repeatedly raised and waved its forelimbs while swaying from side to side for several minutes. A comparable behavior was observed in *B. altamazonica* in Peru after gentle handling for photography. Neither species exhibited skin secretions or bright warning colors during the display, although anecdotal reports suggest mild cutaneous reactions to *B. altamazonica* secretions. Shadowboxing may therefore function as a visual deterrent, complementing chemical defenses documented in other species of *Bolitoglossa*. Similar posturing is rare in salamanders, previously noted only in a few species such as *Cryptotriton nasalis*. These records expand knowledge of antipredator behavior in neotropical salamanders and underscore the importance of detailed natural-history observations for understanding behavioral diversity and survival strategies in Amazonian amphibians.

Keywords. *Antipredator behavior***,** *Defensive display, Plethodontidae*

Salamanders use a lot of different ways to avoid being eaten, and these ways vary across species, individuals, and environmental contexts (Brodie, 1977). These strategies include behavioral responses, physical adaptations, and chemical defenses (Brodie, 1977; Arrivillaga and Brown, 2018). For instance, the Northern two-lined salamander, *Eurycea bislineata* (Green, 1818), responds to predator cues such as snake tongue-flicks by running, jumping, or staying still (Dowdey and Brodie, 1989). Running is the most common strategy in areas with a lot of predators (Ducey and Brodie, 1983). Savage (2002) described body-flipping as a defensive behavior shown by salamanders of the genus *Oedipina*, especially in reaction to violent disruptions or direct physical contact. To protect important body parts from predators, many salamanders take defensive positions. They commonly focus on their tails, which they can give up to escape (Myette, 2019). Some species also have bright colors on their bellies that act as a warning sign that their skin secretions are poisonous or unpleasant (Brodie et al., 1979). Although the chemical composition of the skin of most Caudata species is unknown (de Vasconcelos et al., 2021), the cyan newt, *Hypselotriton cyanurus* (Liu, Hu, and Yang, 1962) rolls onto its back to prominently display its warning colors (Brodie, 1977).

The genus Bolitoglossa, part of the family Plethodontidae, is the biggest group of salamanders. It can be found all over tropical America (Frost, 2024). These salamanders live in a wide range of places, from grasslands at high elevations to rainforests in lowlands, and may display a lot of genetic and phenotypic variety (Jaramillo et al., 2020). Many species, including *B. ramosi, B. rostrata*, and *B. subpalmata*, produce potent skin toxins that deter predators (Brodie et al., 1991; Medina et al., 2022). Other species in the genus secret viscous substances that may be toxic (*B. diaphora, B. conanti, B. dunni*; Arrivillaga and Brown, 2018). However, the chemical and behavioral anti-predator strategies of this genus are still not well documented.

This study documents an antipredator behavior not yet described for *Bolitoglossa equatoriana* and *B. altamazonica* in the Amazon rainforest of Ecuador and Peru, respectively. The Ecuadorian climbing salamander, *Bolitoglossa equatoriana (*Brame and Wake, 1972), is endemic to the western Amazon basin and is found in several provinces of Ecuador, including Napo, Orellana, Pastaza, Sucumbíos and Morona Santiago (Almendáriz et al., 2004). This species is common at night in the eastern forests of Ecuador (Raffaëlli, 2013). On the other hand, *B. altamazonica* (Cope, 1874) is restricted to just a few localities in Loreto, Peru (Cusi et al., 2020). The behavior of these species remains poorly understood, highlighting the need for natural history observations to be documented.

During a field expedition to the Apayacu Reserve (-1.067222° S, -77.670278° W, 400 m a.s.l.) in Tena Province, Ecuador, in November 2023, we found an individual of *Bolitoglossa equatoriana* during an active search for amphibians at night. The salamander was perched on a leaf, and as we approached with the light of a headlamp to observe it more closely, it began to perform a fascinating behavior, resembling shadowboxing movement (Fig. 1, Supplementary material Video 1). Shadowboxing refers to the act of striking into the air without an opponent, typically used to practice movements, refine technique, and simulate combat scenarios. The salamander individual raised both front legs and swayed back and forth while holding them up. This behavior continued for several minutes, during which the salamander intermittently rested its legs before starting the movement again. We observed this sequence on at least three occasions, totaling six minutes during the same encounter.

We observed the same behavior in *Bolitoglossa altamazonica* on 18 February 2014 in the Allpahuayo-Mishana National Reserve (03.965° S, 73.421° W, 132 m a.s.l.). After handling the individual for laboratory photography (Figure 2), it exhibited the same defensive shadowboxing behavior. The display did not last more than a couple of minutes, and no secretions or other responses were observed after handling.

The present record represents a novel behavior for these species. Similar posturing has also been observed in the Cortes salamander, *Cryptotriton nasalis* (Dunn, 1924), which adopts and maintains an elevated defensive posture when threatened (Arrivillaga and Brown, 2018). In many terrestrial salamanders, defensive postures are closely tied to the use of skin secretions. These may involve revealing bright warning colors on the underside or directing specialized skin glands toward the predator (Brodie and Gibson, 1969). Although these species lack bright colors, we have anecdotal evidence of allergic reactions to the secretions of *B. altamazonica*. After handling the reported individual, a localized sensation of heat appeared in the hand, which triggered redness. The sensation lasted from a few minutes to an hour, depending on the length of contact with the animal (*comm. pers*. Giussepe Gagliardi-Urrutia). This shadowboxing behavior suggests that these species rely on physical positioning to deter predators, emphasizing the role of different strategies in salamander survival. This finding not only enhances our understanding of the behavioral ecology of *B. equatoriana* and *B. altamazonica* but also emphasizes the importance of continued field research to uncover the hidden complexities of amphibian life in the Amazon rainforest.

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SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found at:

https://drive.google.com/file/d/1xEZYyGi0Gxs4h6tkV6roYMqNS1HoH690/view?usp=drive_link

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138 FIGURES

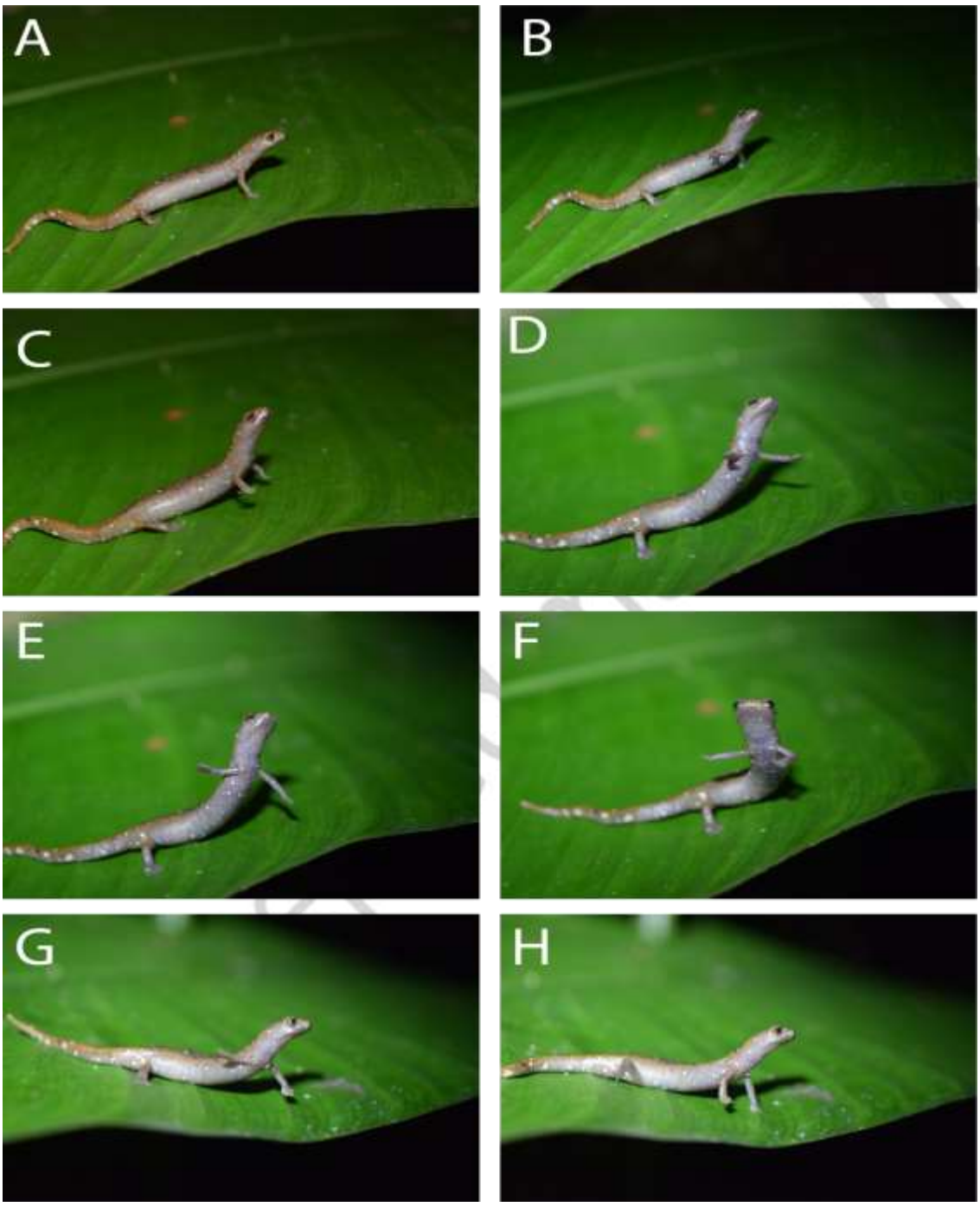

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Figure 2. Shadowboxing posture in *Bolitoglossa altamazonica*.