

SHORT COMMUNICATION

The South American false coral snake *Erythrolamprus aesculapii* (Serpentes: Dipsadidae) as a possible mimic of *Micrurus averyi* (Serpentes: Elapidae) in Central Amazonia

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Mimicry among coral snakes is a controversial issue in evolutionary biology (Dunn 1954, Hecht and Marien 1956, Wickler 1968, Gelbach 1972, Greene and McDiarmid 1981, Brodie III and Brodie Jr. 2004). There is some evidence that a coral-snake color pattern might offer some protection against predators such as birds or mammals (Brodie III 1993, Brodie III and Janzen 1995, Pfennig *et al.* 2007, Kikuchi and Pfennig 2010, 2012). However, the assertion that specific coral-snake patterns may confer different levels of protection requires further investigation. Many studies have elucidated the ways in which coral-snake mimicry operates in nature (Kikuchi

and Pfennig 2010, Davis-Rabosky *et al.* 2016, França *et al.* 2017, Akcali *et al.* 2019), but the role of the mimicry process that produces this coevolutionary pattern must be explored in more depth. The first step in evaluating mimetic complexes is to describe the color patterns of the different species occurring in a given region.

Color patterns among the species of neotropical coral snakes of the genus *Micrurus* Wagler, 1824 vary significantly with respect to the sequence and width of rings (Savage and Slowinsky 1992). In Amazonia, where many species of *Micrurus* occur, snakes with different color patterns may be sympatric. Thus, there may be a wide array of potential models for other snakes to mimic; most of the potential mimics are members of Dipsadidae Bonaparte, 1838 (Martins and Oliveira 1998, Campbell and Lamar 2004, Almeida *et al.* 2014).

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South American false coral snakes of the genus *Erythrolamprus* Boie, 1826 often are associated with mimicry complexes involving sympatric species of *Micrurus* (Greene and McDiarmid 1981, Marques and Puerto 1991, Starace 1998, Almeida *et al.* 2016), including cases of concrete homotypy (*sensu* Pasteur 1982) with perfect and imperfect mimics. For instance, the monad-patterned (*i.e.*, one black band/ring separating red bands/rings) specimens of *Erythrolamprus aesculapii* (Linnaeus, 1758) in the Brazilian Atlantic Forest, as well as melanistic *E. guentheri* Garman, 1883 in Peru, seem to represent precise mimics of their respective models, *Micrurus corallinus* (Merrem, 1820) and *M. margaritiferus* Roze, 1967 (Greene and McDiarmid 1981, Marques and Puerto 1991). In contrast, *Erythrolamprus* with a diad pattern (*i.e.*, two black bands/rings separating red band/rings) may be imprecise mimics of triad patterned venomous coral snakes (Marques and Puerto 1991), because the similarities among mimics and models may vary, but the number and combinations of black and white rings never match.

The variations of color pattern in the false coral snake *Erythrolamprus aesculapii aesculapii* (Linnaeus, 1758) (Dipsadidae: Xenodontinae) has been documented in Amazonia with the co-occurrence of several different morphotypes (Starace 1998, Campbell and Lamar 2004, Almeida *et al.* 2016). Such Amazonian populations are remarkably polytypic across the broad distribution of the species, and include specimens with monads, triads and tetrads, as well as different degrees of melanism (Martins and Oliveira 1998, Curcio 2008, Almeida *et al.* 2016) occurring in sympatry different species of *Micrurus*. Presumably this favors the successful establishment of imperfect mimics (Almeida *et al.* 2016, Sherratt and Peet-Paré 2017, Akcali *et al.* 2019).

The Black-headed Coral Snake *Micrurus averyi* Schimdt, 1939 is a moderately slender species (nearly 700 mm in total length) occurring in the central and northern parts of Amazonia, in

southern Guyana, southern Suriname, and northern Brazil (Martins and Oliveira 1998, Campbell and Lamar 2004, Silva Jr. *et al.* 2016). It is unique having an almost entirely black head, as well as a conspicuous body pattern combining monads with narrow black and white rings, interspaced by distinctively long red rings (Martins and Oliveira 1998, Campbell and Lamar 2004, Silva Jr. *et al.* 2016).

Herein we report the co-occurrence of specimens of *Erythrolamprus aesculapii aesculapii* with distinct color patterns, one of which is a precise mimic of the syntopic venomous coral snake *M. averyi*. From January to March of 2006, one of us (HAA) surveyed snakes for 45 days in an area of dense, ombrophilous forest in the Anavilhanas National Park (Figure 1) (02°23'41" S, 60°55'14" W; 50 m a.s.l., 350.018 ha), lower Rio Negro, Brazilian Central Amazonia (Hudson 2007).

The methods employed a combination of 22 pitfall traps and 46 funnel traps connected by 300 m of drift fences (Greenberg *et al.* 1994, Cechin and Martins 2000, Enge 2001). Twenty-two snakes of 10 species were collected and included the following: one *Micrurus hemprichii* (Jan, 1858); two *M. averyi* (CHUFJF 000390: total length = 550 mm; CHUFJF000377: total length = 330 mm); and two *Erythrolamprus aesculapii aesculapii* (MNRJ 014183: total length = 920 mm; MNRJ 014185: total length = 800 mm) captured in funnel traps. Vouchers are housed at the Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro state (MNRJ), and Universidade Federal de Juiz de Fora, Minas Gerais state (CHUFJF).

The specimens of *Micrurus averyi* (Figures 2, 3A) have the typical color pattern of the species (Campbell and Lamar 2004); the color patterns of the two *Erythrolamprus aesculapii aesculapii* (Figures 2, 3B–C) differ from each other. Both snakes have long red rings, but one of them has black rings arranged in monads (Figures 2, 3B) and the other in diads (Figures 2, 3C). These two individuals differ from one of

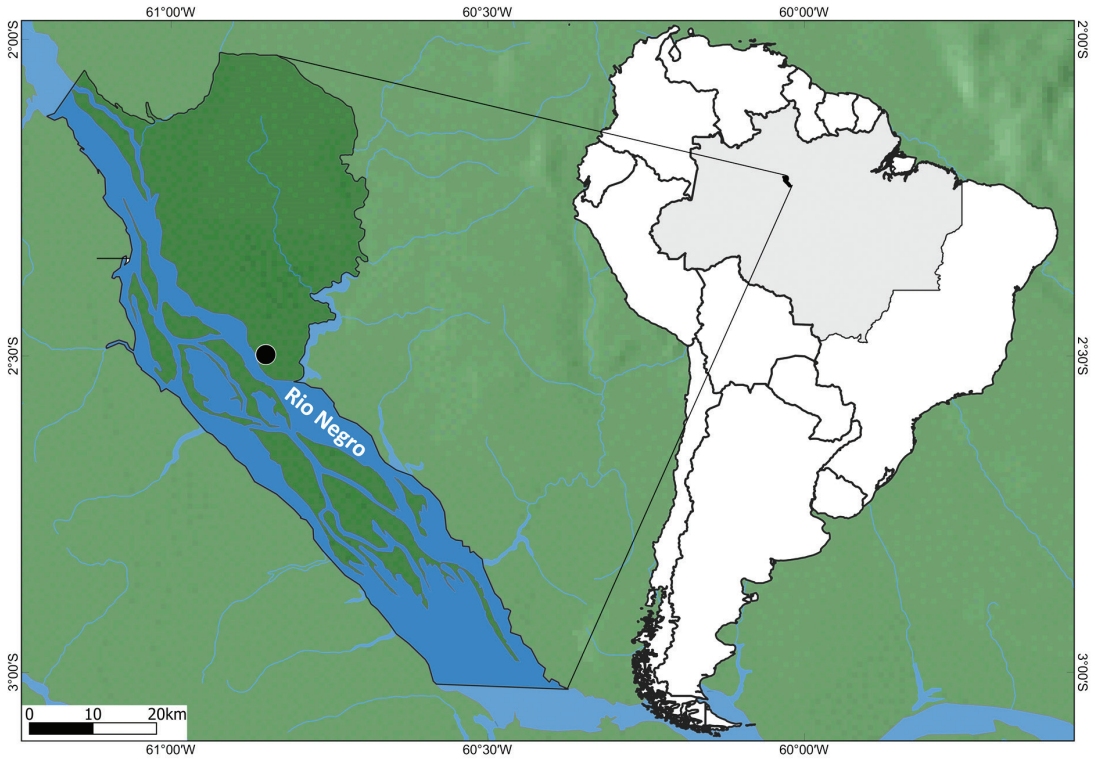


Figure 1. Locality of the sampling site (black circle) of *Erythrolamprus aesculapii* and *Micrurus averyi* at the margin of Rio Negro, Anavilhanas National Park. The gray area on map of South America represents the limits of the Brazilian Legal Amazonia.

most common patterns of *E. aesculapii* found throughout Amazonia (diads usually equal in length or longer than red rings Figures 2, 3D). The monad-patterned specimen (Figures 2, 3B) closely resembles the general coloration of *M. averyi*, not only with respect to dorsal pattern with monads, but also by having an almost entirely black head. The black rings of the tail, usually composed of diads even in monad-patterned specimens of *Erythrolamprus*, tend to fuse dorsally; however, the similarities with the bicolored tail pattern of *M. averyi* are superficial.

The two specimens of *Erythrolamprus aesculapii aesculapii* in our sample promote discussion of instances of precise and imprecise

mimicry in cases of concrete homotypy. Concrete homotypy applies to cases in which the level of resemblance between mimics and models allows prompt association of the latter to a particular taxon at the generic level (Pasteur 1982). This is the case of most snakes with a coral-snake pattern, independent of the sequence and length of dorsal rings. In Amazonia, not only *E. aesculapii aesculapii* (Figures 2, 3D), but also most *Atractus latifrons* (Günther, 1868) have populations with diads on the body (Almeida *et al.* 2014, 2016) that differ of all triad- and monad-patterned *Micrurus* with respect of the sequence of rings. Nonetheless, the scattered presence of specimens with tricolor monads



Figure 2. (A) *Micrurus averyi* (CHUFJF000377, TL = 330 mm), Anavilhanas. (B) *Erythrolamprus aesculapii aesculapii* with larger red ring and monad (MNRJ 014183, TL = 920 mm), Anavilhanas. (C) *E. a. aesculapii* with larger red ring and diads (MNRJ 014185, TL = 800 mm), Anavilhanas. (D) *E. a. aesculapii* showing narrow red ring and diads, a pattern frequently found in other regions in Amazonia.

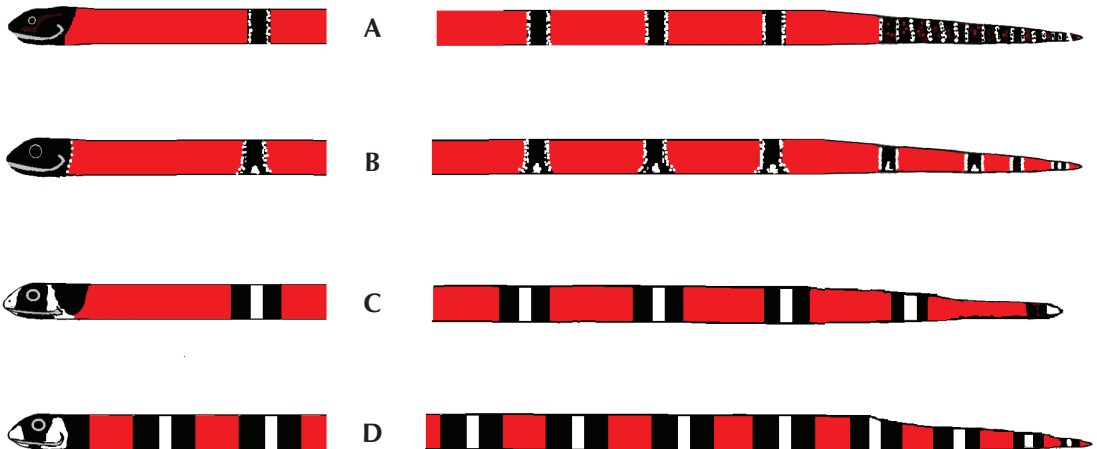



Figure 3. Coloration of the different snakes, showing the different color patterns and arrangement of the rings of the head, body and tail in coral snakes and their possible Batesian mimics. (A) *Micrurus averyi* (the model). (B) *Erythrolamprus aesculapii aesculapii* (the possible precise mimic). (C) *E. a. aesculapii* (the possible imprecise mimic). (D) *E. a. aesculapii* (the pattern frequently found in other regions in Amazonia).

(also bicolor in the case of *Atractus*) may reflect instances of perfect mimics involving monad-patterned species of *Micrurus* (e.g., *M. paraensis* Cunha and Nascimento, 1973; *M. averyi*, and *M. albicinctus* Amaral, 1925) (Almeida *et al.* 2016). The sparse records of monad-patterned *E. aesculapii aesculapii* in Amazonia (Almeida *et al.* 2016) do not necessarily coincide with the distribution of *M. averyi*; nevertheless, none of these records includes mimics as perfect as the specimen recorded here.

The existence of presumed mimics that only superficially resemble their potential sympatric models of the genus *Micrurus* is supported by the “multiple models hypothesis” (Edmunds 2000, Sherratt 2002), in which the mimics would benefit from a mosaic of features that may reflect similarities shared with more than one dangerous species. On the other hand, the similarities shared by mimics and models tend to increase when the mimic co-occurs with one single model species, often producing instances of precise mimicry (Akcali *et al.* 2019). Other *Micrurus* have been recorded in the region of the Anavilhanas National Park, e.g., *M. hemprichii*, *M. lemniscatus* (Linnaeus, 1758), *M. spixii* Wagler, 1824 (Hudson 2007), but *M. averyi* seems to be the mimetic model for the *E. aesculapii aesculapii* described here. The two individuals from Anavilhanas National Park have long red rings, that match the general pattern of *M. averyi*, but one of them has body monads and a mostly black head to accommodate the strict definition of a perfect mimic. Their syntopic occurrence with *M. averyi* suggests that, independent of the general polymorphism of the mimic species, precise mimicry may play a role in the selection of particular phenotypes. Although the precise mimics (monads and long red rings) can be more difficult to distinguish from the model by humans, the imperfect mimic (diads and long red rings) may also provide more effective protection against natural enemies than the usual pattern of *E. aesculapii aesculapii* (diads and short red rings). This is because the proportions of red and black (long red rings, in this case) may be more important than the

arrangement of the rings as a sign to identify the highly poisonous model (Kikuchi and Pfennig 2010, França *et al.* 2017). Experimental studies using plasticine models (e.g., Brodie III 1993, Hinman *et al.* 1997, Kikuchi and Pfennig 2010, França *et al.* 2017, Banci *et al.* 2020) would be a useful tool to test such assumptions.

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