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SHORT COMMUNICATION

New defensive behaviour of the false coral snake *Oxyrhopus rhombifer* Duméril, Bibron & Duméril, 1854 (Serpentes, Dipsadidae) in south-eastern Brazil

Novos comportamentos defensivos da falsa-coral *Oxyrhopus rhombifer* Duméril, Bibron & Duméril, 1854 (Serpentes, Dipsadidae) no sudeste do Brasil

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Abstract

Anti-predator mechanisms are essential for species survival and the description of defensive behaviour may improve our understanding about the ecology, biology and evolution of species. Herein, we describe new anti-predator behaviour for the False Coral Snake *Oxyrhopus rhombifer* in south-eastern Brazil, through direct observation of a juvenile specimen under laboratory settings. We recorded 10 types of defensive behaviour, seven of which are new records for this species and one of them (body vibration) is the first report for Brazilian snakes. Such behaviour may be explained by ontogeny or physical constraints. We highlight that *O. rhombifer* may be capable of recognising different threat levels imposed by predators and, accordingly, adjusting its defensive behaviour.

Resumo

Mecanismos antipredadores são essenciais para sobrevivência das espécies e descrever comportamentos defensivos pode melhorar nosso entendimento sobre a ecologia, biologia e evolução das espécies. Aqui, fornecemos dados sobre novos comportamentos antipredadores para a falsa-coral *Oxyrhopus rhombifer*

no sudeste do Brasil, através de observação direta de um jovem espécime sobre condições laboratoriais. Registramos 10 comportamentos defensivos, sete dos quais são novos registros para esta espécie, e um deles (vibração do corpo) é o primeiro registro para serpentes brasileiras. Tais comportamentos podem ser explicados por ontogenia ou limitações físicas. Destacamos que *O. rhombifer* pode ser capaz de reconhecer diferentes níveis de ameaça impostos pelo predador e ajustar propriamente seu comportamento defensivo.

Keywords
Anti-predator mechanisms, aposematic colouration, Atlantic Forest, Squamata

Palavras-chave
Mecanismo anti-predação, coloração aposemática, Mata Atlântica, Squamata

Predatory pressures evolutionarily shaped the responses of prey, which can display either avoidance mechanisms by removing themselves from the predators foraging field or anti-predator mechanisms to reduce the odds of predation when occupying the same habitat (Brodie et al. 1991). Several anti-predator mechanisms are known for snakes, which aim to avoid detection, injuries and, ultimately, death (Greene 1988). The current knowledge about anti-predator mechanisms are still scarce for many species, but has increased annually with descriptions of, for example, new defensive behaviour (e.g. Pereira et al. 2018, Fiorillo et al. 2019, Guedes et al. 2017). The availability of such data is crucial for a better understanding of species ecology, biology and evolution (e.g. Greene 1988; Sazima and Abe 1991, Pereira et al. 2018).

The genus *Oxyrhopus* (Serpentes: Dipsadidae) is comprised of 14 species with coral-like colouration, distributed across Central and South America (Costa and Bérnils 2018, Uetz et al. 2019). Amongst them, *O. rhombifer* Duméril, Bibron & Duméril, 1854 is known to occur in Argentina, Paraguay, Uruguay, Bolivia and in all Brazilian biomes (Nogueira et al. 2019). This species is a terrestrial snake, mainly found in the Cerrado, dirty fields and forest borders (Sawaya et al. 2008). Besides its aposematic colouration, this species exhibits other anti-predator mechanisms, such as cloacal discharge, body flattening, struggling (Sawaya et al. 2008), erratic movements and hiding the head (Marques et al. 2015). Herein, we describe a new defensive behaviour displayed by *O. rhombifer* in south-eastern Brazil.

On 27 November 2017, a juvenile male *Oxyrhopus rhombifer* was collected by local collectors in the municipality of Paula Cândido (precise locality unknown; the following coordinates refer to the municipality's centroid: 20.8508S, 42.9806W, WGS84), state of Minas Gerais, Brazil. The region is part of the Atlantic Forest biome (*sensu* IBGE 2019) and the dominant vegetation type is classified as seasonal semi-deciduous forests, currently composed of small secondary forest fragments embedded in a matrix of pastures and eucalyptus plantations (Veloso et al. 1991). The specimen was donated to the Museu de Zoologia João Moojen at Universidade Federal de Viçosa, state of Minas Gerais, Brazil (MZUFV 2485; 336 mm SVL). The observations occurred under laboratory settings (air temperature 18 °C), on the same day as the capture of the individual, which had recently preyed on a liz-

ard *Hemidactylus mabouia* Moreau de Jonnès, 1818 (69 mm SVL). We simulated a predation attempt (Fig. 1A) with an increasing threat level (see Roth and Johnson 2004) by first letting the specimen notice our presence, then approaching it with our hands and finally handling the animal.

Afterwards, we released the snake on to the laboratory bench and let it notice our presence. The animal remained motionless at first, then performed a pronounced dorsoventral flattening of the anterior part of the body (Fig. 1B), raised its tail, adopted an S-shaped posture (Fig. 1C, D), raised the first third of the body and performed brief body vibrations. Then we approached the snake, which remained with the same posture and body vibrations. When we touched the animal (not handling), it remained with the S-shaped posture, keeping the first third of the body elevated and the dorsoventral flattening (however, less accentuated) and started to display erratic movements, false strikes and locomotor escape. When handled, the snake only struggled. We filmed just a few of these types of behaviour, which are deposited in the Fonoteca Neotropical Jacques Vielliard (ZUEC-VID 783). The specimen was euthanised by an intraperitoneal injection of 2% lidocaine, fixed in formalin 10%, preserved in 70% alcohol and deposited in the herpetological collection of the MZUFV.

We observed a great variation in the defensive repertoire of the juvenile *Oxyrhopus rhombifer*, where, amongst the ten types of behaviour recorded, only three were already known for this species. Amongst the five types of behaviour described in literature, only two of them were not shown – cloacal discharges and hiding the head (Table 1). Recent feeding can influence the snake's defensive behaviour (Herzog and Bailey 1987) and the fact that the specimen had recently fed upon a lizard may have caused physical limitations and affected its response to the predation risk. Moreover, defensive responses in snakes decrease as body size increases – i.e. generally, juveniles exhibit a broader set of defensive behaviour than adults (Sweet 1985, Gutzke et al. 1993, Shine et al. 2002; Roth and Johnson 2004), considering that small predators, that could easily kill a small snake, may not be able to capture, subdue and feed on a large one (Carrier 1996, Roth and Johnson 2004). Therefore, some types of behaviour, described in this study, may be either explained by physical constraints or ontogeny (e.g. being exclusive to juveniles)

Some types of behaviour reported for *Oxyrhopus rhombifer*, such as erratic movements, tail display, dorsoventral flattening and immobility, are typical of coral snakes of the genus *Micrurus* (Sazima and Abe 1991; Marques et al. 2019). These similarities might represent behavioural convergences, as *O. rhombifer* also shares an aposematic colour pattern similar to the true coral snakes colouration patterns, reinforcing the mimicry hypothesis between these two groups of snakes (Sazima and Abe 1991). Regarding body vibrations, this is yet an unknown anti-predator behaviour for Brazilian snakes, this being the first record to the best of our knowledge. There are fossorial snakes that, when threatened, produce low frequency body vibrations that can rapidly propagate through the soil, reaching other snakes and acting as an alarm system (Young et al. 2014). However, *O. rhombifer* is a terrestrial snake and, maybe, such behaviour could actually represent a defensive signal against non-visually orientated predators.

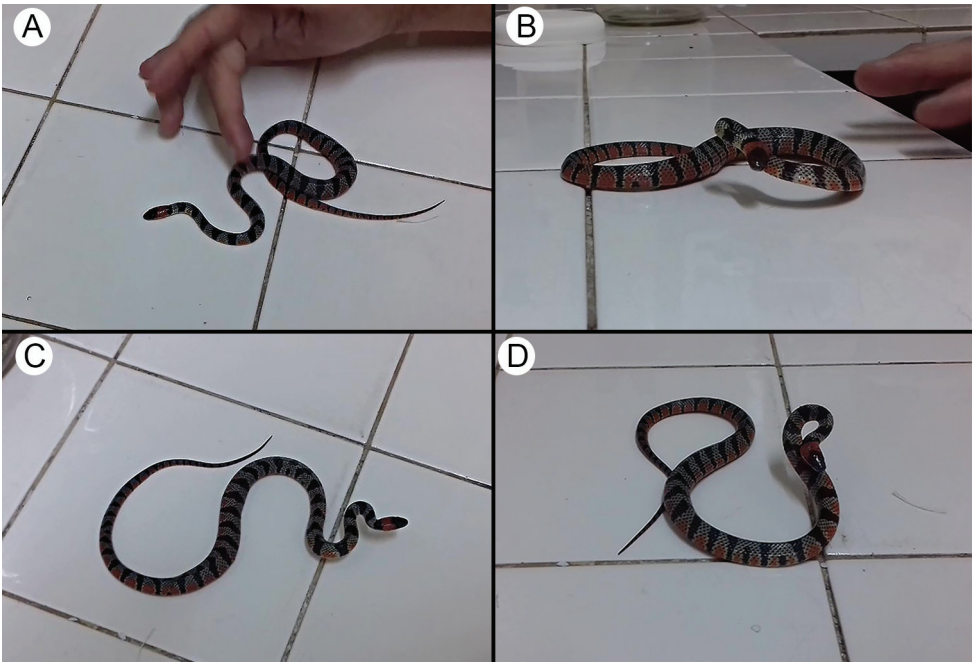

Figure 1. Some defensive types of behaviour displayed by the juvenile *Oxyrhopus rhombifer* (MZUFV 2485). **A**) simulation of a predation attempt; **B**) elevation and dorsoventral body compression of the anterior portion of the body; and **C, D**) S-shaped posture.

Table 1. Defensive types of behaviour reported for *Oxyrhopus rhombifer*.

Defensive mechanisms	Reference
Immobility	Present study
Dorsoventral body compression	Sawaya et al. 2008, present study
Tail display	Present study
Elevation of the first third of the body	Present study
Body vibration	Present study
S-shaped posture	Present study
Erratic movements	Marques et al. 2015, present study
False strike	Present study
Cloacal discharges	Sawaya et al. 2008
Hiding the head	Marques et al. 2015
Locomotor escape	Present study
Struggle	Sawaya et al. 2008, present study

We observed differences in defensive strategies by the specimen *Oxyrhopus rhombifer* according to the threat level imposed. While only observing the snake, it made what is known as warning displays (Sazima 1992) – e.g. dorsoventral flattening and S-shaped posture – which is reinforced by the aposematic colouration pattern. The dorsoventral flattening behaviour, for example, creates an illusion of having a larger body size (Tozetti et al. 2009), which may discourage predators from striking

at their prey. Behaviour such as false bites, erratic movements and locomotor escape, exhibited after we touched the animal, are actions more related to an offensive defence (Gehlbach 1970; Greene 1988; Sazima 1992). These types of behaviour may either warn predators about the dangers of making contact or that the prey will not be easily captured, thus discouraging any predation attempt (Dugatkin 2013). Therefore, we highlight that *O. rhombifer* may be capable of recognising different threat levels imposed by predators and adjusting its defensive behaviour accordingly.

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