REPTILES & AMPHIBIANS

Notes on Defensive Behavior and Distribution of the Poorly Known Prado's Coastal House Snake, *Mesotes rutilus* (Dipsadidae: Xenodontinae: Tachymenini)

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Snakes exhibit a range of defensive behaviors that are fundamental for their survival and ecological interactions (Greene 1988). These behaviors are often classified as passive or active, depending on the ecological or threat context (Tozzeti et al. 2021; Miranda et al. 2022). Passive strategies such as camouflage, aposematism, and mimicry (Tozzeti et al. 2021; Miranda et al. 2022) are low-energy behaviors used to avoid detection or deter predators (Passek and Gillingham 1997; Durso and Mullin 2014). When escape is not possible, snakes resort to energy-intensive strategies, including cloacal discharge, hissing, aggressive posturing, body flattening, and biting (Tozzeti et al. 2021). These behaviors underscore the adaptability and evolutionary success of snakes across diverse environments (Greene 1979; Fanselow 2018).

Prado's Coastal House Snake, *Mesotes rutilus* (Prado 1942), is a small snake, with males reaching 477 mm snout-vent length (SVL) and females 414 mm SVL (Franco et al. 2017). Nocturnal and semiaquatic, this species feeds primarily on amphibians and fish (França et al. 2008). *Mesotes rutilus* can be distinguished from its congeners by distinctive red spots on the sixth infralabials (Franco and Ferreira 2002). The species is considered rare and potentially threatened with extinction throughout its known range (França and Araújo 2006), and reports on its life history and behavior are limited (Magalhães-Guedes et al. 2017).

Mesotes rutilus is distributed throughout central-southwestern Brazil, including the states of Distrito Federal, Goiás, Mato Grosso do Sul, Minas Gerais, Rio de Janeiro, and São Paulo, occurring in both Cerrado and Atlantic Rainforest biomes (Magalhães-Guedes et al. 2017). However, substantial gaps in its distribution exist, particularly in the northern part of its range. Species distribution modeling can help predict species' potential geographic distribution and enhance understanding of habitat use, ecological needs, and conservation requirements (Elith et al. 2006). Such modeling can also guide field surveys to areas more suitable for the species, facilitating research on rare species like *M. rutilus* (Fois et al. 2018).

In situ behavioral observations have enriched our understanding of the natural history and evolution of snakes (Greene 1988; Tozzeti et al. 2021), which emphasizes the

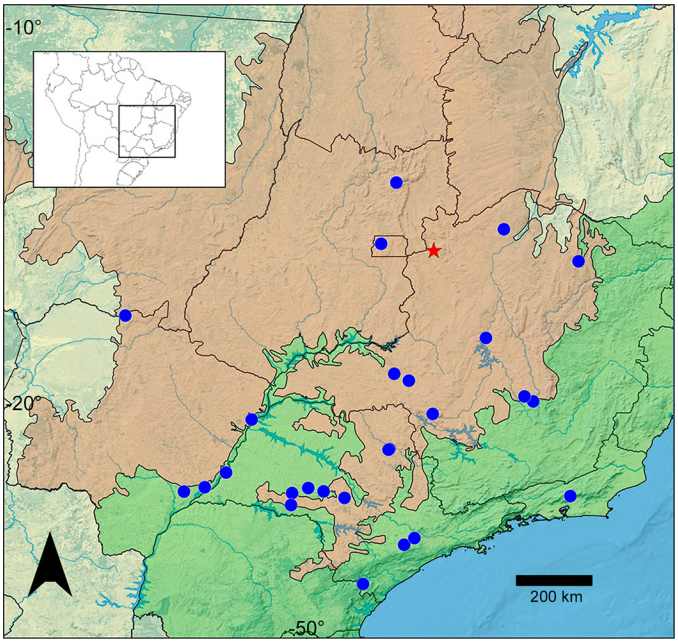

Figure 1. The known distribution of Prado's Coastal House Snake (*Mesotes rutilus*); records from the literature are marked by blue dots and the new record by a red star. Biome boundaries are represented by green (Atlantic Forest) and beige (Cerrado).

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importance of fieldwork. We herein present a new distribution record and a previously undescribed defensive display for *Mesotes rutilus*. Additionally, we constructed a species-distribution model to identify potential range extensions and to encourage further studies on the species' natural history and biogeography.

At 2000 h on 21 January 2023, we observed a female *Mesotes rutilus* (field number RAB03285; SVL = 211 mm; tail length = 68 mm) swimming along the margin of an artificial reservoir at the Agroreservas do Brasil farm in Unaí, Minas Gerais, Brazil (-15.898472, -46.623083; elev. 900 m asl). This constitutes the first record of *M. rutilus* from the northwestern region of Minas Gerais (Fig. 1). The nearest previously documented records are 150 km and 210 km away in the Distrito Federal and in Bonito de Minas, Minas Gerais, respectively. This individual exhibited several defensive behaviors, including body elevation, assumption of an S-shaped posture, false strikes, biting, erratic escape movements, and gaping (Fig. 2). The snake was captured by hand, photographed, euthanized with a 20% lidocaine injection into the coelom, fixed in 10% formalin for one week, preserved in 70% ethanol, and deposited in the Laboratório de Fauna e Unidades de Conservação at the University of Brasília (RAB03285). The identity of the species was confirmed by Dr. Cristiano Nogueira.

We used 19 bioclimatic variables from the WorldClim database (Fick and Hijmans 2017) to build a species-distribution model (SDM) for *Mesotes rutilus*, and ranked environmental covariates based on their percent contribution to the model (Phillips et al. 2006). We assessed collinearity among predictors using the variance inflation factor (VIF) (Marquardt 1970). The VIF is calculated from the R^2 of a regression in which each predictor is modeled as a function of all other predictors, indicating how much a given predictor is explained by the remaining variables (Naimi and Araújo 2016). A VIF above 10 suggests problematic multicollinearity, which leads to the removal of the variable with the highest VIF to reduce redundance (Chatterjee and Hadi 2006).

We used the maximum entropy (Maxent) algorithm to model the potential distribution of *Mesotes rutilus*, using bioclimatic variables as predictors (Phillips et al. 2006; Phillips and Dudik 2008). Modeling was conducted using R packages, including "sdm" (Naimi and Araújo 2016), "rJava" (Urbanek 2019), "dismo" (Hijmans et al. 2011), "ggspatial" (Dunnington 2023), "usdm" (Naimi 2015), and "terra" (Hijmans 2023). We ran the model 1,000 times using 10 subsamples, with 75% of the data used for training and 25% for testing. Model performance was evaluated using the area-under-the-curve (AUC) criterion, with values above 0.70 considered informative (Baldwin 2009). We evaluated accuracy using the true-skill statistic (TSS) and Pearson's correlation coefficient, comparing predicted occurrence probabilities with observed presence-absence test data (Elith et al. 2006; Shabani et al. 2018). We also identified the most influential bioclimatic variables in the Maxent predictions.

The distribution model for *Mesotes rutilus* (Fig. 3) showed high predictive accuracy (AUC = 0.91, COR = 0.69, TSS = 0.77, deviation = 0.76). The most influential explanatory variables were BIO2 (mean diurnal temperature range: the mean of the monthly differences between maximum and minimum temperatures), BIO6 (minimum temperature of the coldest month), BIO12 (annual precipitation), BIO13 (precipitation of the driest month), and BIO18 (precipitation of the warmest quarter). Of these, BIO6 was the most important, accounting for 67.2% of the model's explanatory power, followed by BIO12 (7.8%), BIO18 (2.4%), BIO2 (2%), and BIO13 (0.9%).

The species-distribution model indicated that the most suitable areas for the species, which have the highest suitability values, are in southwestern Brazil. Suitable areas also were found in southern Brazil and in parts of the inland northeastern region (Fig. 3). Although a distribution gap exists at

Figure 2. Defensive postures observed in a female Prado's Coastal House Snake (*Mesotes rutilus*): gaping (left) and anterior body raised in an S-shaped posture (right). Photographs by Afonso Santiago de Oliveira Meneses (left) and Luis Felipe Lima (right).

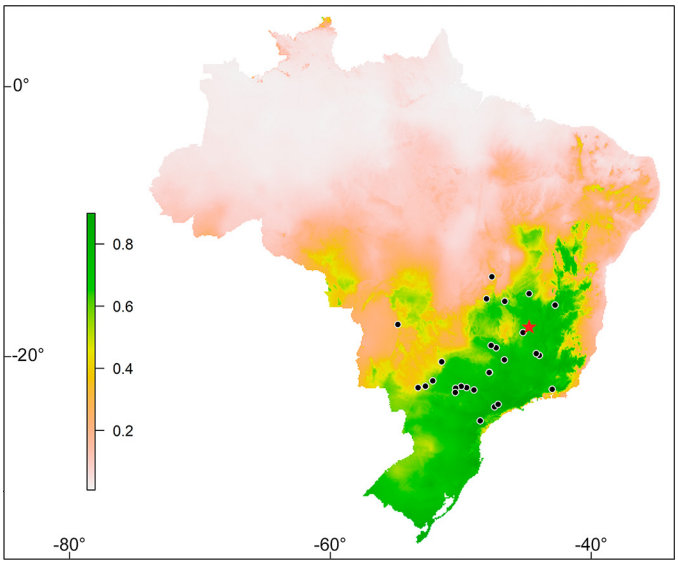

Figure 3. Predicted distribution of Prado's Coastal House Snake (*Mesotes rutilus*) based on SDM analysis. Warmer colors indicate higher probabilities of occurrence. Black dots mark records from the literature and the red star marks the new record.

the junction of Minas Gerais, São Paulo, and Rio de Janeiro, high detectability in this region suggests that new records could be found there. Despite the few records in western Brazil (Fig. 1), the model indicated that additional occurrences also could be found in this region, which includes some highly suitable areas.

The lack of records of *Mesotes rutilus* in certain climatically suitable areas may be driven by factors other than climate. The species appears highly reliant on humid habitats such as forests, veredas, and wetlands (França and Araújo 2006; França et al. 2008), which are vulnerable to deforestation and climate change (Salmona et al. 2023). Much of southeastern Brazil has faced significant deforestation due to agriculture and urbanization (Martinelli et al. 2010), leading to reductions in suitable habitats for *M. rutilus* and emphasizing the need for increased fieldwork in these regions to better understand the species' distribution in order to guide conservation actions for this rare and potentially endangered species.

Mesotes rutilus has a well-documented range of defensive behaviors (Magalhães-Guedes et al. 2017). However, our observation is the first recorded instance of gaping in the genus. Gaping has been observed in other tachymenine snakes, including the *Tomodon dorsatus* Duméril, Bibron, and Duméril 1854, *Dryophylax dixoni* (Bailey and Thomas 2007), *Calamodontophis* spp., and *Gomesophis brasiliensis* (Gomes 1918) (Franco et al. 2006; Menezes et al. 2017; Rojas-Morales et al. 2020), suggesting that this behavior could be a common anti-predator strategy in the clade.

Gaping is sometimes accompanied by a dark oral mucosa, which might amplify the warning signal of the display (Marques and Sazima 2022). However, *Mesotes rutilus* has a white mucosa, similar to *Gomesophis brasiliensis* and *Dryophylax dixoni*, whereas *Tomodon dorsatus* and *Calamodontophis* spp. exhibit dark mucosae. (Trevine et al. 2022), the presence of dark mucosae could have evolved independently of gaping behavior, as previously suggested by Marques and Sazima (2022). Despite lacking dark oral mucosae, *M. rutilus* has a red dot on its lip, which could enhance the threatening appearance of gaping and function as a warning signal. Such visual signals observed in a number of small animals resemble eye-like spots, which are associated with reduced attack rates by avian and piscine predators (Hossie and Sherratt 2013; Kjernsmo and Merilaita 2013).

Defensive behavior in snakes can be influenced by physiological and environmental factors, including body temperature, energetic costs, and stress (Passek and Gillingham 1997). Gaping often accompanies S-shaped behavior (Marques and Sazima 2022), although we did not observe that combination in *Mesotes rutilus*. This low-energy behavior could enhance defensive strategies or serve as an alternative when energetically demanding displays are impractical (Passek and Gillingham 1997).

The tribe Tachymenini consists of snakes that exploit different strata of the landscape. However, most species in the clade exhibit habits associated with humid environments, as they feed mainly on anurans and annelids (França et al. 2008; França and Braz 2013; Trevine et al. 2022). Remnants of Cerrado in protected areas serve as refuges for species dependent on specific habitats (Françoso et al. 2015); consequently, the loss and degradation of such environments pose significant threats to habitat specialists such as *Mesotes rutilus*.

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