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GEOGRAPHICAL DISTRIBUTION OF *Ninia hudsoni* (SERPENTES: DIPSADIDAE) WITH NEW OCCURRENCE RECORDS

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The Neotropical snake genus *Ninia* (Dipsadidae, Dipsadinae, Dipsadini) currently comprises ten species: *Ninia atrata* (Hallowell, 1845), *Ninia celata* McCranie & Wilson, 1995, *Ninia espinali* McCranie & Wilson, 1995, *Ninia diademata* Baird & Girard, 1853, *Ninia franciscoi* Angarita-Sierra 2014, *Ninia hudsoni* Parker, 1940, *Ninia maculata* (Peters, 1861), *Ninia pavimentata* (Bocourt 1883), *Ninia psephota* (Cope 1875), and *Ninia sebae* (Duméril, Bibron & Duméril, 1854). These semifossorial snakes are typically Mesoamerican with few species (*N. atrata*, *N. hudsoni* and *N. franciscoi*) occurring in northwestern South America (Angarita-Sierra 2014; van Wallach *et al*. 2014). They live in the forest litter or under logs and rocks and are rarely seem on the surface (Burger & Werler 1954). Despite some species are considered important components of the leaf-litter herpetofauna (Savage & Lahanas 1991) most of them lacks basic biological data.

Ninia hudsoni is a small snake with dorsal scales keeled, dark gray dorsum and creamy white nuchal band and venter (Duellman 1978). Its known distribution range is based on scattered literature records from Brazil, Ecuador, Guyana and Peru. Here we present an updated distribution map of *N. hudsoni* with two new records from southern Amazon and six unpublished records found in herpetological collections. We also implemented an ecological niche modeling (ENM) to predict climatically suitable areas for the occurrence of *N. hudsoni* in northern South America.

In order to compile data on the known distribution of *Ninia hudsoni* we searched occurrence records on the literature (papers, books and theses) and accessed some herpetological collections databases by contacting curators or through institutional websites (*e.g.* Torres-Carvajal *et al.* 2015; *species*Link 2016). When not available in original sources geographical coordinates were estimated with higher accuracy as possible based on spatial references and descriptions of the area mentioned by the authors.

We have used all 26 localities gathered in this study (Table 1) to generate an ecological niche modeling (ENM). This analysis estimates the predicted geographic distribution of *N. hudsoni* based on the climatically suitable regions for the species. We downloaded 19 climatic variables from the WorldClim database (see http://www.worldclim.org/ for variable descriptions) interpolated to 2.5 arc-min resolution (Hijmans *et al.* 2005) and elevation data from NASA website (www2.jpl.nasa.gov/srtm/). To avoid over-prediction and low specificity, we cropped the bioclimatic layers to span from latitude 13 to -20 and longitude -83 to -43 (values in decimal degrees). This background encompasses the Amazonian biome and adjacent areas. To avoid model overparameterization, we removed strongly correlated variables ($r > 0.80$)

based on their biological relevance for *N. hudsoni*. We built our model using nine out of 20 original environmental variables (Bio3, Bio4, Bio7, Bio11, Bio12, Bio15, Bio17, Bio18, and Bio19). We assessed the importance of each variable to the model through values of permutation importance (i.e. the loss of model predictive power when each variable is excluded). We implemented ENM in R platform vs. 3.2.3 (R Core Team, 2016) using the maximum entropy algorithm (Phillips & Dudik 2008) and 'dismo' package (Hijmans *et al.* 2013). First, we trained the model based on 75% of randomly selected presence records and used the remaining 25% to test the model in 20 bootstrap repetitions. We evaluated the model performance using the area under the curve (AUC) for the test data. AUC statistics assess the sensitivity (absence of omission error) and the specificity (absence of commission error) of a model (Fielding & Bell 1997). AUC value of 0.50 indicates model performance compared to null expectations (random prediction), while higher AUC values indicate better models, with maximum prediction being 1 (Hanley & Mcneil 1982).

Our first new record was made on May 30th, 2011, in the municipality of Aripuanã, state of Mato Grosso, Brazil. An adult specimen of *N. hudsoni* (Figure 1a) was found and photographed by a biologist (Christopher Fernandes) working for the Dardanelos Hydroelectric Power Plant. The specimen was in an area of abandoned pasture (-10.1628°, -59.4831°) 180 meters straight from the closest lowland forest fragment and was released after being photographed. It was found during the day after the passage of a bulldozer that unearthed it from a depth of 20-30 cm. This unusual record suggests that *N. hudsoni* can inhabits altered habitats and exhibits authentic fossorial behavior.

Our second record is from the municipality of Assis Brasil, in the state of Acre, Brazil. An adult specimen (Figure 1b) was found on February 10th, 2016 during a herpetological survey in the Rio Acre Ecological Station. The snake was active at 8 pm above the leaf litter in an area of floodplain forest (-11.0239°, -70.2178°). This specimen was collected (license: ICMBio #48448-2) and deposited in the herpetological collection of the Universidade Federal Rural de Pernambuco (voucher number: CHPUFRPE 4425).

Figure 1. Live specimens of *Ninia hudsoni* from (a) Aripuanã, Mato Grosso, Brazil and (b) Assis Brasil, Acre, Brazil. Photos by C. Fernandes and M. A. Freitas, respectively.

Silva *et al.* (2010) mentioned *N. hudsoni* as previously recorded in the state of Acre but they do not attribute a specific citation for this record. In her doctoral thesis about the snakes from Acre, Silva (2006) listed *N. hudsoni* citing the study of Peters & Orejas-Miranda (1970) as reference. However, the distribution of *N. hudsoni* in the work of Peters & Orejas-Miranda (1970) is referred solely as 'British Guiana; Amazonian Ecuador'. Vanzolini (1986) also refers to the occurrence of *N. hudsoni* in the state of Acre without referring to a voucher specimen. Moreover, after contacting some curators and check online databases we found no specimens from Acre deposited in the main herpetological collections in Brazil. Thus, the specimen that we found in Assis Brasil is the first confirmed record of *N. hudsoni* from the state of Acre.

Current records suggest that *N. hudsoni* is restricted to the north, south and west edges of the Amazon. A similar distribution pattern is known for some species of birds (Remsen *et al.* 1991) but, to our knowledge, is not a common pattern among the herpetofauna. This unusual distribution was corroborated by ENM, which did not predict the occurrence of *N. hudsoni* in core areas of Amazon (Figure 2). The average training AUC for the replicate runs was 0.954 (SD = 0.022; n = 20 replicate model runs), indicating a high performance model (Fielding & Bell 1997). Most part of the model was explained by only four variables, based on their permutation importance values: temperature seasonality (Bio4, 31.3%), mean temperature of coldest quarter (Bio11, 29.4%), annual precipitation (Bio12, 11.9%) and precipitation of driest quarter (Bio17, 10.5%). Despite many records of *N. hudsoni* close to the Andes, elevation does not seem to be a decisive factor to its occurrence. In fact, *N. hudsoni* occurs in a wide elevational range (from 84 to 2,294 m above sea level; see Table 1). Andean slopes do seem to harbor most of the climatically suitable regions for *N. hudsoni*, but adequate conditions also occurs in lower elevations.

The major climatically suitable regions that lack occurrence records of *N. hudsoni* are located in southern Venezuela and Andean slopes in northwestern Colombia. All known records of *N. hudsoni* are east of the Andes, which may indicate that this mountain range acts as a barrier to its dispersion, as for many other herpetofauna species (Duellman 1979). Thus, it is likely that *N. hudsoni* does not occur west of Andes, despite the suitable conditions predicted in western Colombia (Figure 2). However, we believe the lack of records in southern Venezuela is due to a sampling gap, since this is the least studied area for reptiles in the country (Rivas *et al.* 2012). Moreover, no evident barrier seems to prevent the occurrence of *N. hudsoni* in that region.

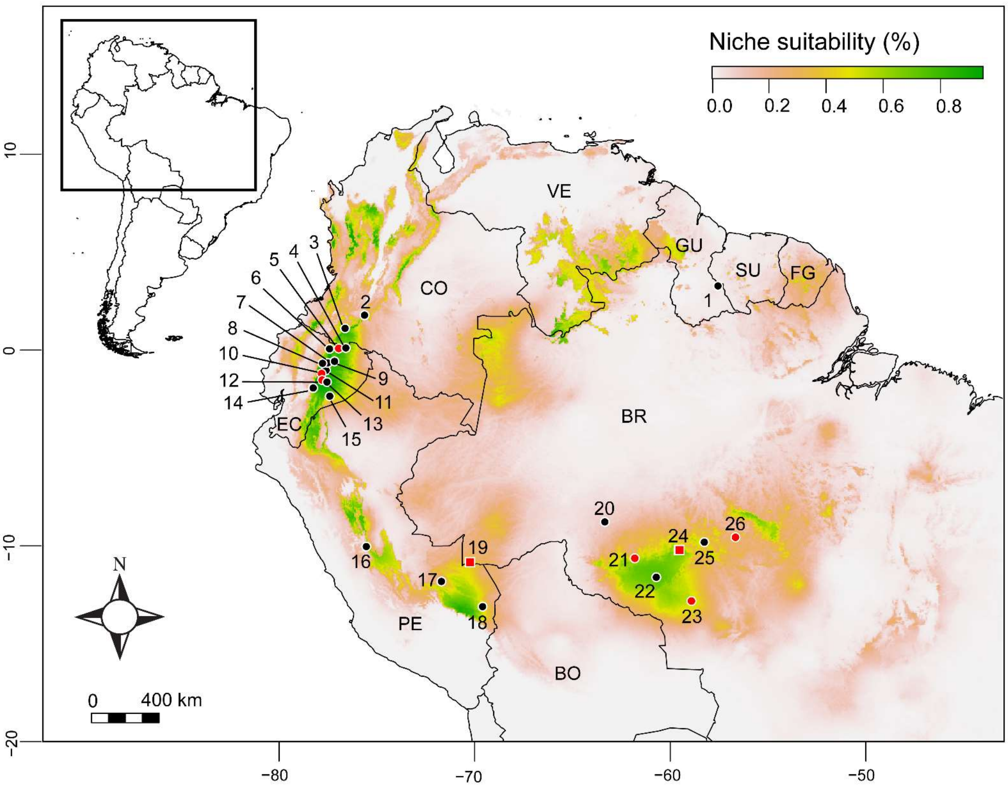

Figure 2. Predicted distribution of *Ninia hudsoni* based on climatic niche suitability. Occurrence localities are related to literature data (black circles), unpublished collection records (red circles) and new records for Brazilian Amazon (red squares). A list with all numbered localities can be found in Table 1.

Table 1. Locality records of *Ninia hudsoni*. Elev. – elevation in meters; Long. – longitude; Lat. – latitude.

Map	Country	**State/Department**	**Locality/Municipality**	**Elev. (m)**	**Long.**	**Lat.**	**Source**
1	Guyana	East Berbice-Corentyne	New River (type-locality)	197	-57.5793	3.2444	Parker 1940
2	Colombia	Caquetá	Florencia	728	-75.6486	1.7497	Angarita-Sierra 2014
3	Colombia	Putumayo	Centro Experimental Amazónico, Mocoa	596	-76.6422	1.0783	Betancourth-Cundar & Gutiérrez 2010
4	Ecuador	Sucumbíos	Puerto Libre, Rio Aguarico	297	-76.7528	0.0756	Duellman 1978
5	Ecuador	Sucumbíos	Santa Cecília	321	-76.9667	0.0500	Fundación Puerto Rastrojo (speciesLink)
6	Ecuador	Sucumbíos	Estación Cayagama	753	-77.4389	0.0300	Valencia & Garzon 2011
7	Ecuador	Napo	Wildsumaco Wildlife Sanctuary	1,323	-77.6008	-0.6875	Camper 2015
8	Ecuador	Napo	Rio Hollín	1,195	-77.7126	-0.7088	Torres-Carvajal *et al.* 2015
9	Ecuador	Orellana	Ávila Viejo	807	-77.4281	-0.6105	Torres-Carvajal *et al.* 2015
10	Ecuador	Pastaza	Arajuno	544	-77.7000	-1.2333	MZUSP[1]
11	Ecuador	Napo	Estación Biológica Jatun Sacha	398	-77.6167	-1.0667	Vigle 2008
12	Ecuador	Pastaza	Alto Rio Curaray	717	-77.6666	-1.4167	MZUSP[1]
13	Ecuador	Pastaza	Rio Siquino, Rio Villano	583	-77.5509	-1.5017	Angarita-Sierra 2014
14	Ecuador	Pastaza	Cantón Pastaza, Barrilio Bella Vista	2,294	-78.2725	-1.9686	Angarita-Sierra 2014
15	Ecuador	Morona-Santiago	Cantón Taisha	319	-77.4257	-2.3855	Valencia *et al.* 2009
16	Peru	Pasco	Pozuzo	1,143	-75.5563	-10.0681	Lehr & Lara 2002
17	Peru	Cusco	Parque Nacional del Manu	413	-71.7167	-11.8500	Catenazzi *et al.* 2013
18	Peru	Madre de Dios	Tambopata Research Center	236	-69.6128	-13.1381	Duellman 2005
19	Brazil	Acre	Estação Ecológica Rio Acre, Assis Brasil	331	-70.2178	-11.0239	this study
20	Brazil	Rondônia	Usina Hidrelétrica de Samuel	84	-63.3622	-8.8097	Silva Jr 1993
21	Brazil	Rondônia	Ribeirão Riachuelo, Ji-Paraná	158	-61.8333	-10.6667	Instituto Butantã (speciesLink)
22	Brazil	Rondônia	Fazenda Jaburi, Espigão do Oeste	332	-60.7308	-11.6339	Bernarde & Abe 2006
23	Brazil	Mato Grosso	Juruena	333	-58.9333	-12.8500	MZUSP[1]
24	Brazil	Mato Grosso	Fazenda Maracatiá, Aripuanã	212	-59.4831	-10.1628	this study
25	Brazil	Mato Grosso	Fazenda São Nicolau, Cotriguaçu	230	-58.2758	-9.8450	Kawashita-Ribeiro *et al.* 2011
26	Brazil	Mato Grosso	Paranaíta	247	-56.6821	-9.5944	MZUSP[1]; UFMT[2] (speciesLink)

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Although some Mesoamerican species of *Ninia* are considered locally abundant (Savage & Lahanas 1991), *N. hudsoni* seems to be naturally rare all over its distribution. Most of its local records are based on a single or very few specimens (*e.g.* Duellman 1978; Silva-Jr 1993; Bernarde & Abe 2006; this study). Even mid to long-term inventories using complementary sampling methods recorded only one individual of *N. hudsoni* (*e.g.* Bernarde & Abe 2006; our record from Aripuanã-MT). The same studies suggest that pitfall traps, despite being considered effective on sampling semifossorial snakes (Enge 2001; Ribeiro-Júnior *et al.* 2011), may do not succeed in capturing *N. hudsoni*, which is most often found in occasional encounters (*e.g.* Camper 2015; this study). Therefore, it is likely that there are still gaps in the distribution of *N. hudsoni*, which might be due to its cryptic habits and natural low abundance.

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