SHORT COMMUNICATION

Geographic distribution model for *Mabuya agmosticha* (Squamata: Scincidae) in northeastern Brazil

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ABSTRACT. The Neotropical lizard *Mabuya agmosticha* Rodrigues, 2000 is a habitat-specialist of thorny bromeliads in rocky outcrops of northeastern Brazil. Its distribution in the Caatinga Domain is most likely relictual. In recent years, new surveys conducted in northeastern Brazil have revealed new records of the species in the Caatinga and also in the Atlantic Forest Domain. In this study, we add four new records for *M. agmosticha*, extending its known geographic range in the states of Rio Grande do Norte and Paraíba. In addition, we investigated the potential geographical distribution of the species using ecological niche modeling (ENM), which combines the available occurrence records with environmental variables. Our model revealed a continuous range of areas with suitable climatic conditions for the species, from the state of Rio Grande do Norte to the northeast portion of the state of Bahia, plus some relictual distribution spots, mainly in the states of Bahia, Pernambuco, Ceará and western Rio Grande do Norte. Based on the model, we suggest that the distribution of *M. agmosticha* is continuous on a large geographic scale. On a smaller spatial scale, however, it is clear that its distribution is clumped, reflecting its specialist habits associated with rupicolous bromeliads.

KEY WORDS. Biogeography; Caatinga; lizards; skinks; species distribution models.

The semiarid Caatinga is a mosaic of thorny shrubs and seasonally dry, xerophytic and deciduous forests that occupy most of northeastern Brazil. It is bound by the Atlantic Forest to the east, by the Amazon Forest to the west and by the Cerrado to the south (Leal et al. 2005). As the result of centuries of inappropriate and unsustainable exploitation of its natural resources, the Caatinga is now seriously threatened (Velloso et al. 2002). The biodiversity of the Caatinga has remained relatively overlooked despite recent survey efforts (Albuquerque et al. 2012). More specifically, notwithstanding recent efforts to expand the geographical coverage of the sampled areas (Freire et al. 2009, 2012, 2013, Moura et al. 2011, Garda et al. 2013, Cavalcanti et al. 2014), the herpetofauna of the Caatinga has remained unsatisfactory known (Rodrigues 2003).

The lizard *Mabuya agmosticha* Rodrigues, 2000 was described from two sites in the Caatinga (Xingó-AL and Cabaceiras-PB; Fig. 1 – points 1 and 2). It is a habitat-specialist that is intimately associated with clumps of rupicolous bromeliads (*Encholirium spectabile* Martius ex Schultes f.) popularly known as "macambiras" (Rodrigues 2000). For this reason, Rodrigues (2003) suggested that its distribution is likely to remain relictual in the Caatinga even after intensive surveys.

As predicted by Rodrigues (2003), *M. agmosticha* has been subsequently found in other Caatinga areas (Fig. 1) in the states of Paraíba (Arzabe et al. 2005, Freire et al. 2009, Magalhães Júnior et al. 2014), Pernambuco (Moura et al. 2011, Magalhães Júnior et al. 2014), Sergipe (S.M. Rocha unpubl. data), Rio Grande do Norte (Jorge & Freire 2010) and Ceará (Ribeiro et al. 2012, Magalhães Júnior et al. 2014). In addition, more recent records have extended the distribution of this species to the Atlantic Forest Domain: Dias & Rocha (2013) recorded it in restinga in the state of Bahia, and (F.R. Delfim unpubl. data), after examination of specimens deposited in seven herpetological collections in Brazil, provided new records from various localities in the state of Sergipe.

In this study, we add four new locations for *M. agmosticha* in the Caatinga, three in the state of Rio Grande do Norte and one in the state of Paraíba. We identified the specimens by comparing them with the diagnostic characters provided by Rodrigues (2000). All specimens are deposited in the Herpetological Collection of the Federal University of Rio Grande do Norte (CHBEZ). Additionally, we investigated the potential geographical distribution of *M. agmosticha* using ecological niche modeling (ENM), which combines the available occur-

rence records with environmental variables. The potential application of ENM techniques in biogeography is promising, especially with respect to species that are scarce, have cryptic habits, are restricted in distribution or have been poorly sampled (PEARSON et al. 2007). Through modeling, and considering the hypothesis of RODRIGUES (2003), we investigated the influence of abiotic factors on the distribution pattern of *M. agmosticha*. We expected the model to predict a relictual pattern of areas that offer suitable environmental conditions for the species.

The four new records (Table I, Fig. 1) were obtained from 2012 to 2014 in the states of Rio Grande do Norte (RN) and Paraíba (PB). The first record, on December 16, 2012,was obtained at Serra de João do Vale, municipality of Jucurutu-RN, during a short-term survey in the area; three of us (RFDS, MFK and MMR) collected one specimen of *M. agmosticha* (CHBEZ 3981) within a clump of *E. spectabile* on a rocky outcrop. The second record is from April 26, 2013 at Serra da Barriguda, municipality of Alexandria-RN; MJMA collected one adult specimen of *M. agmosticha* (CHBEZ 3975) within a clump of *E. spectabile* on a rocky outcrop. The third record was obtained during a field expedition of the Research Program on Biodiversity (PPBio Semiárido/CNPq) to the Chapada do Apodi, municipality of Felipe Guerra-RN; we collected one specimen of *M. agmosticha* (CHBEZ 4085) within a clump of *E. spectabile* on an extensive limestone rocky outcrop. The fourth record is from Parque Estadual da Pedra da Boca, municipality of Araruna-PB. On a visit to this protected area, JSJ observed and photographed several individuals of *M. agmosticha* in clumps of *E. spectabile* (Fig. 2).

The distribution model was generated using MAXENT 3.3.3k (PHILLIPS et al. 2006), a well-established algorithm (ELITH et al. 2006) that works well for small samples (PEARSON et al. 2007). MAXENT uses a probability distribution of maximum entropy to predict approximate species distributions from presence data. Environmental variables were obtained from the WorldClim database (www.worldclim.org, HIJMANS et al. 2005) as generic grids with 30 arc-seconds resolution (~1 km). We used Bioclim climate variables for current conditions (~1950-2000). The bioclimatic layers were cropped to span from latitudes from 0°30' to 17°00'S and longitudes from 44°30' to 34°30'W; this includes the Caatinga Domain and the northern part of the Atlantic Forest. Eleven of the 19 original climate variables were removed due to high correlations ($r > 0.8$), to minimize multicollinearity among the layers. The variables used were Bio1 (annual mean temperature), Bio3 (isothermality), Bio4 (temperature seasonality), Bio7 (temperature annual range), Bio12 (annual precipitation), Bio17 (precipitation of driest quarter), Bio18 (precipitation of warmest quarter), Bio19 (precipitation of coolest quarter), and altitude. We performed 20 bootstrap replications, with 25% of random test points to evaluate the model. The model was generated with the dismo package under the R software (HIJMANS et al. 2013).
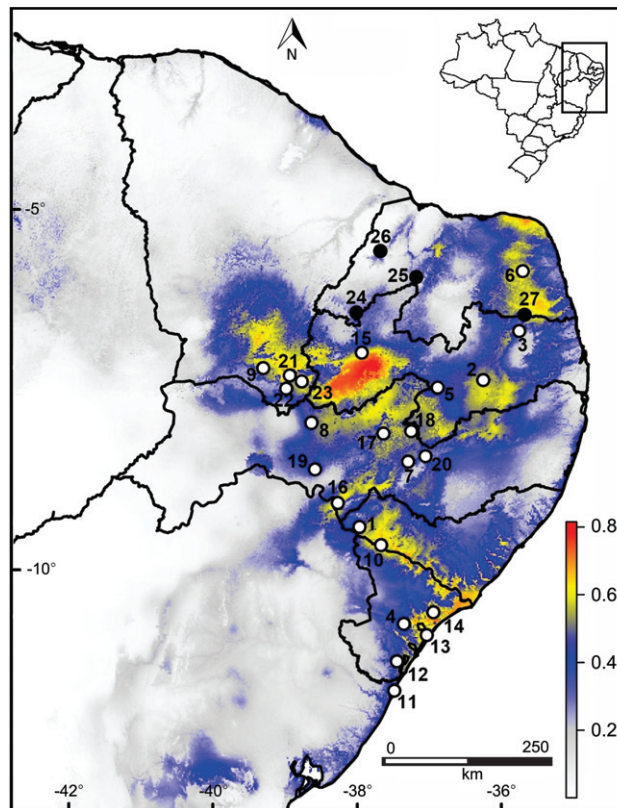

Figure 1. Known records (circles) and distribution model (colored area) of *Mabuya agmosticha* in northeastern Brazil. White circles represent literature records, and black circles are the new records. Colors indicate the environmental suitability predicted by the model, which ranges from 0 (white) to 1 (red). See Table I for locality names and geographic coordinates.

The distribution model for *M. agmosticha* is shown in Fig. 1. The area under the curve (Test AUC) was 0.884 ± 0.041, indicating that the model performed well. The environmental suitability was explained primarily by precipitation of coolest quarter (26.0%), temperature seasonality (22.3%), and precipitation of driest quarter (12.2%). The optimal niche occupied by the species (environmental suitability area more than 0.5) is defined by precipitation of coolest quarter between 45 and 745 mm, temperature seasonality above 11.4°C, and precipitation of driest quarter between 4 and 177 mm.

Our results extend the known geographical distribution of *M. agmosticha* 220 km to the west and 160 km to the north of the nearest known localities (Santa Maria-RN and Coremas-PB, respectively). *Mabuya agmosticha* is difficult to collect in the habitat where it occurs (rupicolous thorny bromeliads). Pitfall traps (one of the main methods used in herpetofauna surveys) are ineffective for sampling in rocky outcrops, the only habitat where the species is regularly found. Moreover, it is

Figure 2. Live specimen of *Mabuya agmosticha* on a leaf of "macambira" (*Encholirium spectabile*) in Parque Estadual da Pedra da Boca, Paraíba state, Brazil. In the lower right corner, an individual of *E. spectabile* (diameter: ~60 cm).

difficult to find and to collect *M. agmosticha* using active visual search because individuals often hide within bromeliad clumps (pers. obs.). This is perhaps one of the main reasons for the low representation of *M. agmosticha* in herpetological collections, together with insufficient sampling efforts. The distribution model (Fig. 1), however, suggests that the potential distribution of the species is much broader than it is currently documented. It encompasses most of the states of Paraíba, Alagoas and Sergipe, as well as considerable portions of the states of Rio Grande do Norte, Pernambuco and Ceará. It is also possible that the species occurs in inland portions of the state of Bahia.

Besides the Caatinga, the model predicts the occurrence of *M. agmosticha* in the Atlantic Forest in the states of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and northeastern portion of Bahia. However, the occurrence of the species in the Atlantic Forest may be limited by biotic factors, such as the availability of suitable microhabitats (bromeliads).

The geographic distribution of *E. spectabile*, the main bromeliad used by *M. agmosticha* (MAGALHÃES JUNIOR et al. 2014), encompasses the entire distribution range of *M. agmosticha* predicted by the model, except for coastal areas of the Atlantic Forest Domain, where this bromeliad does not occur (FORZZA 2005). Another limiting biotic factor is the presence of competitors, such as *Mabuya macrorhyncha* Hoge, 1946, sister taxon of *M. agmosticha* (MIRALLES & CARRANZA 2010), which has similar ecological attributes, including bromelicolous habit (FREIRE 1996). Recent research (DIAS & ROCHA 2013), however, reported the presence of *M. agmosticha* in an Atlantic Forest restinga in Bahia, associated with tank bromeliads (*Aechmea* sp.) in sympatry and sintopy with *M. macrorhyncha*, a record that requires further investigation. Furthermore, according to DIAS & ROCHA (2013), *M. agmosticha* inhabits terrestrial tank-bromeliads besides rupicolous bromeliads ("macambiras").

The distribution model indicates a continuous range of areas that have favorable climatic conditions for t *M. agmosticha*

Table I. Localities and coordinates (in decimals) used in the distribution model for *Mabuya agmosticha*, including the new records. States: (AL) Alagoas, (BA) Bahia, (CE) Ceará, (PB) Paraíba, (PE) Pernambuco, (RN) Rio Grande do Norte, (SE) Sergipe. Biomes: (CA) Caatinga, (AF) Atlantic Forest.

Locality	Biome	Coordinates (lat, long)	Reference
Xingó (AL)	CA	-9.4000, -37.9667	RODRIGUES (2000)
Fazenda Bravo, Cabaceiras (PB)	CA	-7.3667, -36.2500	RODRIGUES (2000)
Fazenda Cachoeira da Capivara, Cacimba de Dentro (PB)	CA	-6.6833, -35.7497	ARZABE et al. (2005)
Serra de Itabaiana, Itabaiana (SE)	AF	-10.7453, -37.3506	CARVALHO et al. (2005)
Fazenda Almas, São José dos Cordeiros (PB)	CA	-7.4708, -36.8808	FREIRE et al. (2009)
Fazenda Tanques, Santa Maria (RN)	CA	-5.8540, -35.7010	JORGE & FREIRE (2010)
Parque Nacional Serra do Catimbau, Buíque (PE)	CA	-8.4932, -37.2918	MOURA et al. (2011)
Fazenda Saco, Serra Talhada (PE)	CA	-7.9561, -38.6333	MOURA et al. (2011)
Araripe bioregion (CE)	CA	-7.2000, -39.3000	RIBEIRO et al. (2012)
Monumento Natural Grota do Angico, Poço Redondo (SE)	CA	-9.6500, -37.6667	S.M. Rocha (unpubl. data)
Restinga de Costa Azul, Jandaíra (BA)	AF	-11.6744, -37.4842	DIAS & ROCHA (2013)
Estância (SE)	AF	-11.2664, -37.4486	F.R. Delfim (unpubl. data)
Barra dos Coqueiros (SE)	AF	-10.9000, -37.0328	F.R. Delfim (unpubl. data)
Japaratuba (SE)	AF	-10.5853, -36.9419	F.R. Delfim (unpubl. data)
Coremas (PB)	CA	-6.9833, -37.9333	MAGALHÃES JUNIOR et al. (2014)
Petrolândia (PE)	CA	-9.0667, -38.2667	MAGALHÃES JUNIOR et al. (2014)
Custódia (PE)	CA	-8.1000, -37.6333	MAGALHÃES JUNIOR et al. (2014)
Sertânia (PE)	CA	-8.0667, -37.2500	MAGALHÃES JUNIOR et al. (2014)
Floresta (PE)	CA	-8.6000, -38.5833	MAGALHÃES JUNIOR et al. (2014)
Arcoverde (PE)	CA	-8.4167, -37.0500	MAGALHÃES JUNIOR et al. (2014)
Mauriti (CE)	CA	-7.3833, -38.7667	MAGALHÃES JUNIOR et al. (2014)
Brejo Santo (CE)	CA	-7.4833, -38.9833	MAGALHÃES JUNIOR et al. (2014)
Milagres (CE)	CA	-7.3000, -38.9333	MAGALHÃES JUNIOR et al. (2014)
Serra da Barriguda, Alexandria (RN)	CA	-6.4272, -38.0100	This study
Serra de João do Vale, Jucurutu (RN)	CA	-5.9333, -37.1767	This study
Chapada do Apodi, Felipe Guerra (RN)	CA	-5.5750, -37.6794	This study
Parque Estadual da Pedra da Boca, Araruna (PB)	CA	-6.4567, -35.6753	This study

(environmental suitability > 0.4), extending from the state of Rio Grande do Norte to the northeast portion of the state of Bahia (Fig. 1). The model also predicts some relictual spots of distribution, mainly in the states of Bahia, Pernambuco, Ceará and western Rio Grande do Norte (Fig. 1). The occurrence of the species in Chapada do Apodi – RN (Fig. 1, point 26), for instance, is in a relictual spot according to the model.

In conclusion, based on the model, we suggest that the distribution of *M. agmosticha* is continuous on a large geographic scale. On a smaller spatial scale, however, it is clear that its distribution is clumped and is strictly associated with its microhabitat (rupicolous bromeliads). The absence of *M. agmosticha* from some occurrence areas as predicted by the model may be the result of biotic (competitors, availability of microhabitats) and historic factors (low dispersal capacity of the species, which is a habitat-specialist). For instance, the suit-

ability of the northeastern coast of the state of Bahia is intermediate (blue color in Fig. 1), but the Restinga de Costa Azul (Fig. 1, point 11) seems to be the southern limit of the species' range, at least on the coast, since it was not found in the southernmost restingas of Bahia surveyed by DIAS & ROCHA (2014). Certainly, a greater number of herpetological surveys will help to better understand the pattern of distribution of this species, and also of other lizard species of the Caatinga.

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