Check List 10(2): 388–391, 2014

ISSN 1809-127X (available at *www.checklist.org.br*)

Check List
Journal of species lists and distribution

NOTES ON GEOGRAPHIC DISTRIBUTION

A preliminary geographic distribution map of *Elachistocleis muiraquitan* Nunes de Almeida & Toledo, 2012 (Amphibia: Anura: Microhylidae)

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ABSTRACT: *Elachistocleis muiraquitan* was recently described from fifteen specimens found at two sites in Acre state, northwestern Brazil. Prior to the description of *E. muiraquitan*, individuals fitting the description of this species found in southeastern Peru and northwestern Bolivia were identified as *Elachistocleis bicolor*, a species associated with markedly different habitat and environmental conditions. Here, we re-identified these specimens and also propose the first map of *E. muiraquitan*'s potential distribution, based on known localities along with climatic and environmental parameters.

Elachistocleis Parker, 1927 is a frog genus that has undergone much taxonomic revision in recent years. There are currently sixteen recognised species (De Sá *et al.* 2012; Pereyra *et al.* 2013), where half of which have been described within the last three years. Prior to the description of five new species by Caramaschi (2010) any *Elachistocleis* presenting an immaculate venter was designated as *Elachistocleis bicolor* Guérin-Meneville, 1838 (Duellman and Thomas 1996) or *Elachistocleis ovalis* Schneider, 1799. It has been argued that *E. ovalis* should be considered a *nomen dubium* (Caramaschi 2010), although De Sá *et al.* (2012) include *E. ovalis* as a valid species in their work. The records that we reviewed were identified as *E. bicolor* from southeastern Peru and northwestern Bolivia. We also evaluate two recordings identified as *E. ovalis* that also come from the same locality in Peru (southeastern). According to Caramaschi (2010), *E. bicolor* is distributed across southeastern South America, but not in southeastern Peru and northwestern Bolivia. In the light of recent taxonomic evidence, there are several instances of populations previously identified as *E. bicolor* being re-classified (Giaretta *et al.* 2012). The most recent example is the description of a new Argentinian *Elachistocleis* species (*E. haroi*; Pereyra *et al*. 2013).

Nunes *et al.* (2012) recently described *Elachistocleis muiraquitan,* which has an immaculate venter and is distinguished from others in the genus by a light and merged mid-dorsal stripe running from the post cephalic fold to the vent. It also has a longer head than any of the other species that lack ventral patterning. This species was described from fifteen specimens found at two sites in Acre state, Brazil and to date there is no other published information on this species. Here we present new records of the species and propose the first map of its potential distribution.

The nearest part of the recognised range of *E. bicolor* is more than 900km away from the area where *E. muiraquitan* has been found, with major differences in climate and vegetation between the two regions (IUCN 2012). The range of *E. bicolor* covers an area of hot arid steppe and warm temperate climates, while *E. muiraquitan* is found in an equatorial monsoon climate, with high temperatures and rainfall (Kottek *et al.* 2006; World Meteorological Organisation 2013). Our recent inspection of museum specimens of *E. bicolor* and review reports by other researchers (Moravec and Aparicio 2000; 2004; Nunes de Almeida and Toledo 2012; von May *et al.* 2008) suggest that previous records of *E. bicolor* from southeastern Peru and northwestern Bolivia represent *E. muiraquitan*. We revised specimens collected by John Cadle and Theodore Papenfuss in the Tambopata Province, Madre de Dios Department, Peru and deposited at the Museum of Vertebrate Zoology (MVZ) at the University of California, Berkeley, USA (MVZ 173704, MVZ 173706, MVZ 103707, MVZ 199477 and MVZ 199478 (Figure 1d); and specimens collected by RvM (Permit numbers 008-2002-INRENA-J-DGFFS-DCB and 012-2003-INRENA-IFFSDCB, issued to RvM for collection in Madre de Dios, Peru) at the Los Amigos Biological Station, Manu Province, Madre de Dios Department, Peru and deposited in the Museo de Historia Natural Universidad Nacional Mayor de San Marcos, Peru (MUSM-24224, MUSM-24278, MUSM-24329). Measurements of the specimens deposited at the MVZ match the head to body length ratios described for *E. muiraquitan.* In terms of morphology and coloration all of these specimens, along with those from MUSM, have characteristics that fit the description of *E. muiraquitan*. Photos of a specimen taken at the Los Amigos Biological Station and published under the name *E. bicolor* (photos 181 and 182 in von May *et al.* 2010) represent *E. muiraquitan.* An individual found at Romero Lodge, Madre de Dios, Peru, in 2012, was also identified as *E. muiraquitan* and is shown in Figures 1a, 1b

and 1c. Where we were unable to examine specimens from some localities directly, we consulted other herpetologists working in the respective occurrence areas to confirm specimens' identification. Additionally, the similarity of the calls of *E. muiraquitan* (Nunes de Almeida and Toledo 2012) and *E. bicolor* recorded in 'Frogs of Tambopata' (Cocroft 2001) and *E. ovalis* in 'Ranas de Bolivia' (Marquéz *et al.* 2002) suggests that these are all recorded individuals of the same species. These three calls have a frequency of approximately 4 kHz, with duration of 3 to 4 seconds (*E. muiraquitan*), whereas *E. bicolor* has a frequency of 5 kHz, and call duration of around 2.5 seconds (De la Riva *et al*. 1996).

The map shown in Figure 2 was created using localities where we confirmed that *Elachistocleis* species matched the description of *E. muiraquitan*. Environmental factors were taken from WorldClim (version 1.4; http://www.worldclim.org/; Hijmans *et al.* 2005) and the U.S. Geological Service (USGS), Global Forest Resource Assessment (FRA 2000; http://edc2.usgs.gov/glcc/fao/index.php) and added to the modelling program MaxEnt (version 3.3.3e; http://www.cs.princeton.edu/~schapire/maxent/; Phillips *et al.* 2004, 2006). MaxEnt has been shown to perform well at low sample sizes (Hernandez *et al.* 2006, Raxworthy *et al.* 2007), such as the sample size for *E. muiraquitan*.

Five pilot models were constructed using the WorldClim data, each focussing on a different environmental variable (e.g. precipitation). Variables with the highest per cent contribution to each pilot model were used to construct a further model (Appendix 1) (Baldwin and Bender 2008). This model was jackknifed to assess variable importance and to point out highly correlated variables (Baldwin 2009). The final model was bootstrapped (100 replicates) to create a continuous logistic output of probability distribution. The average training area under curve (AUC) value for the replicate runs in the receiver operator characteristic (ROC) output was 0.991, showing a very good model fit.

To create a binary presence / absence map the output was processed in ArcGIS 10 using the maximum training sensitivity plus specificity logistic threshold (Cao *et al.* 2013). There is evidence of some overprediction and it should be noted the map shows potential distribution and not realized distribution (Phillips *et al.* 2006). Further work is required in both sampling effort and identification of potentially uninhabited areas.

Table 1. Details of records of *Elachistocleis* specimens used to create the predicted range map shown in Figure 2. Abbreviations used for specimen numbers refer to the following collections: ZUEC = Museo de Zoologia 'Prof. Adão José Cardoso' Universidade Estadual de Campinas, Brazil; MUSM = ; CBF = Colecion Boliviana de Fauna, Instituto de Ecologia, Museo de la Historia Natural, La Paz, Bolivia; USNM = Smithsonian Institution, National Museum of Natural History; MVZ = Museum of Vertebrate Zoology at Berkeley, University of California; MCZ = Museum of Comparative Zoology, Harvard University; RMMU = Redpath Museum, McGill University. * Indicates records which have been confirmed as E. muiraquitan; the other specimens should be examined for further confirmation.

ORIGINAL NAME	SPECIMEN NUMBER	LOCATION	RECORD SOURCE
*Elachistocleis muiraquitan**	ZUEC 5666	Acre, Xapuri, Brazil	Nunes *et al.* 2012
*Elachistocleis muiraquitan**		Rio Branco, Brazil	Nunes *et al.* 2012
*Elachistocleis bicolor**	MUSM 24224, 24278, 24329	Los Amigos Biological Station, Peru	von May *et al*. 2009
*Elachistocleis bicolor**		Las Piedras Biodiversity Station, Peru	von May *et al*. 2009
*Elachistocleis bicolor**		Cusco Amazónico, Peru	von May *et al*. 2009
*Elachistocleis bicolor**		Cocha Cashu, Peru	von May *et al.* 2009
*Elachistocleis bicolor**		Centro Sachavacayoc, Peru	von May *et al.* 2009
*Elachistocleis bicolor**		Eco Amazonia, Peru	von May *et al.* 2009
*Elachistocleis bicolor**		Explorer's Inn, Peru	von May *et al.* 2009
*Elachistocleis bicolor**		Tambopata Center, Peru	von May *et al.* 2009
*Elachistocleis bicolor**		Romero Rainforest Lodge, Peru	Andrew Whitworth, 6th October 2012
*Elachistocleis bicolor**		Riberalta, Bolivia	Dahl *et al.* 2009
*Elachistocleis bicolor**	CBF (1)	6km NE of Riberalta, Bolivia	Moravec and Aparicio, 2000
*Elachistocleis bicolor**	CBF (1)	Nacebe, Bolivia	Moravec and Aparicio, 2004
*Elachistocleis bicolor**		Sacrificio, Bolivia	Dahl *et al.* 2009
*Elachistocleis bicolor**		Palmira, Bolivia	Dahl *et al.* 2009
*Elachistocleis bicolor**		Cobija, Bolivia	Dahl *et al.* 2009
Elachistocleis bicolor		Balta, Peru	Duellman and Thomas, 1996
Elachistocleis bicolor	USNM 247434	Explorer's Inn, Peru	Smithsonian Museum Database
Elachistocleis bicolor	USNM 247660	Explorer's Inn, Peru	Smithsonian Museum Database
Elachistocleis bicolor	USNM 343270	Explorer's Inn	Smithsonian Museum Database
Elachistocleis bicolor	USNM 343271	Explorer's Inn	Smithsonian Museum Database
Elachistocleis bicolor	USNM 343272	Explorer's Inn	Smithsonian Museum Database
Elachistocleis bicolor	USNM 343273	Explorer's Inn	Smithsonian Museum Database
*Elachistocleis bicolor**	MVZ 173704	Cusco Amazónico Albergue Lodge	John E. Cadle
*Elachistocleis bicolor**	MVZ 173706	Cusco Amazónico Albergue Lodge	John E. Cadle
*Elachistocleis bicolor**	MVZ 173707	Cusco Amazónico Albergue Lodge	John E. Cadle
*Elachistocleis bicolor**	MVZ 199477	Cusco Amazónico Albergue Lodge	Theodore J Papenfuss
*Elachistocleis bicolor**	MVZ 199478	Cusco Amazónico Albergue Lodge	Theodore J Papenfuss
Elachistocleis bicolor	MCZ A-88302	Cocha Cashu	Dr Alan Ross Kiester
Elachistocleis ovalis	RMMU 1071	Cusco Amazónico	Mark Chandler
Elachistocleis ovalis	RMMU 1072	Cusco Amazónico	Mark Chandler

Figure 1. a) to **c)** In-life photos of *Elachistocleis muiraquitan* found at Romero Rainforest Lodge (-12°13′23.5914″ S, 70°58′50.505″ W), Madre de Dios, Peru on 6 October 2012 (photos by A. Whitworth). **d)** Specimens collected by John Cadle and Theodore Papenfuss deposited in the Museum of Vertebrate Zoology at the University of California, Berkeley (from left to right: MVZ 173704, MVZ 173706, MVZ 103707, MVZ 199477 and MVZ 199478).

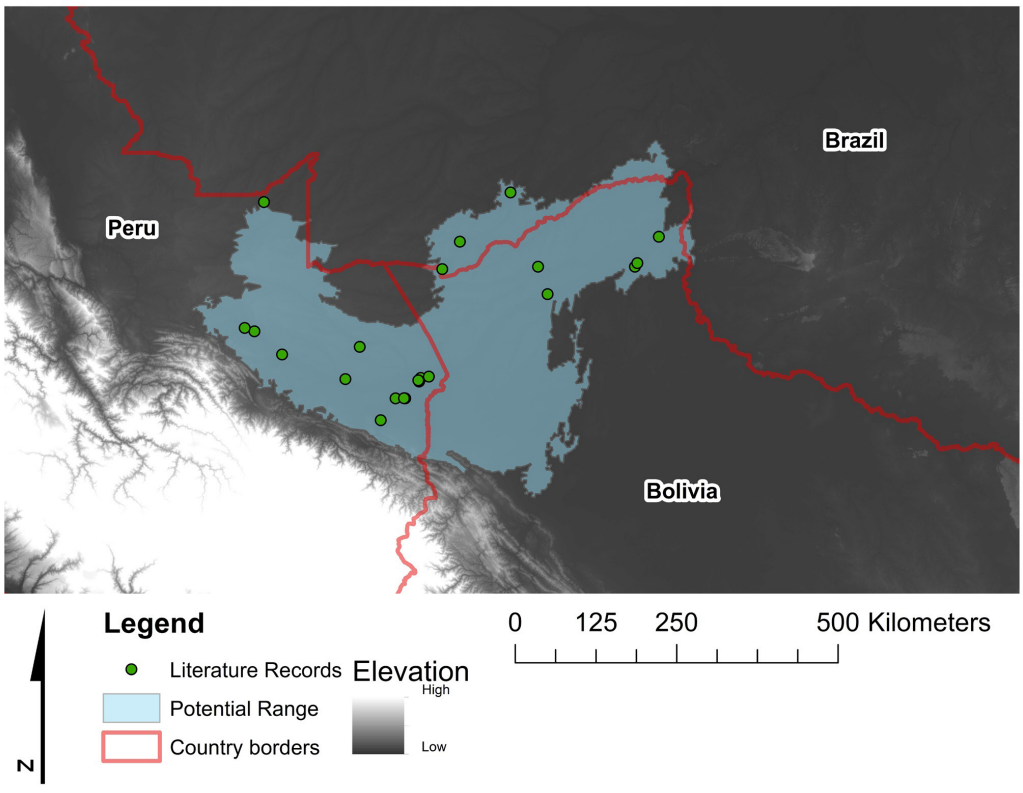

Figure 2. Map showing locality records of *Elachistocleis muiraquitan* (as given in Table 1) and a potential predicted range using MaxEnt. The contribution of the different environmental factors is detailed in Appendix 1.

Acknowledgments: We first of all thank The Crees Foundation and its director Quinn Meyer for supporting the herpetological research as part of their conservation and biodiversity monitoring programme. Also the University of Glasgow, especially Dr Ross MacLeod and Prof. Roger Downie, for supporting fieldwork conducted in Peru. Thanks also to the Universidad Nacional Mayor de San Marcos and the Museum of Vertebrate Zoology at Berkeley for providing a base to deposit valuable specimens and also to the Ministerio de Agricultura of Peru for providing the permit to conduct research in Peru. We also thank Chicago Herpetological Society, the Louise Hiom Fund and Glasgow Natural History Society for financial support with project and field equipment. We thank Jiří Moravec (National Museum, Prague, Czech Republic) for providing information on Bolivian specimens. RvM thanks Margarita Medina-Müller and Nemesio Carrillo for field assistance, the Amazon Conservation Association for providing a research grant to work at Los Amigos Biological Station, and the National Science Foundation Postdoctoral Research Fellowship Program in Biology (DBI-1103087).

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Received: October 2013
Accepted: February 2014
Published online: May 2014
Editorial Responsibility: Natan Medeiros Maciel

Appendix 1. A description of variable layers used by MaxEnt to develop the predicted potential range in Figure 2 and the contribution and permutation importance of each layer.

VARIABLE	PERCENT CONTRIBUTION	PERMUTATION IMPORTANCE
Temperature seasonality (standard deviation *100)	40.1	27.5
Average precipitation for April	14.2	4.3
Average precipitation for November	8.4	9.9
Precipitation of driest month	7.2	1.5
Global forest resources assessment (FRA 2000)	6.9	0.7
Average maximum temperature for May	6	6.2
Average minimum temperature for December	4.6	3.1
Slope	4.3	19.3
Minimum temperature of coldest month	3.4	11.2
Average precipitation for May	2.9	15.7
Mean temperature of warmest quarter	1.9	0.6