

An unexpected record of the Green Jararaca, *Bothrops bilineatus* (Wied-Neuwied, 1821) in Ceará State, northeastern Brazil

Thabata Cavalcante^{1,3,*}, Robério Freire-Filho², John A. Andrade-Oliveira¹, Lidia S. de Lima³, Daniel Cassiano-Lima^{4,5}, Hugo Fernandes-Ferreira^{1,3}, and Rodrigo C. Gonzalez^{5,6}

The genus *Bothrops* Wagler, 1824 currently comprises 48 species, 30 of which occur in Brazil (Barbo et al., 2022a, b; Costa et al., 2022; Uetz et al., 2022). These snakes can be found from open areas to dense forests, including highly disturbed habitats (Campbell and Lamar, 2004). One of the most iconic *Bothrops* species is the Green Jararaca, *B. bilineatus* (Wied-Neuwied, 1821), which can be distinguished from all the other congeners by its emerald-green skin (Cunha, 1967; Campbell and Lamar, 2004).

In general, *B. bilineatus* is a nocturnal species that predominantly hunts in the vegetation for a wide variety of small vertebrates (Dixon and Soini, 1986; Cunha and Nascimento, 1993; Martins et al., 2001; Argôlo et al., 2004; Bernarde and Abe, 2006). Although it has been seen hunting in the early hours of the day (da Fonseca et al., 2021), this species usually rests in the daytime, apparently in the same spot where it hunts at night (Martins, 1993; Turci et al., 2009; Bernarde et al.,

2021). Bernarde et al. (2021) pointed out that although *B. bilineatus* can be relatively common in some specific areas, it can be less frequent or even absent in locations where they are expected to occur. This is usually an elusive species due to its arboreal habits, cryptic colouration, and low population density, which can make them hard to find in nature (Jorge-da-Silva, 1993; Campbell and Lamar, 2004; Bernarde and Abe, 2006; Dias et al., 2008; Turci et al., 2009).

The Green Jararaca has been documented in eight different countries in cis-Andean South America: Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, and Venezuela (Dal Vechio et al., 2018; Nogueira et al., 2019; Costa et al., 2022; Uetz et al., 2022). Most of its distribution is in Brazilian territory, where it is disjunct since it occurs both in the Amazon and in the Atlantic Forest (Doan and Arriaga, 2002; Argôlo et al., 2004; Campbell and Lamar, 2004; Turci et al., 2009; Nogueira et al., 2019) (Fig. 1). *Bothrops bilineatus* is widespread in the Amazon, while Atlantic Forest populations are concentrated in the southeastern regions between the states of Rio de Janeiro and Bahia, except for some additional northern records in the Pernambuco Endemism Centre (França et al., 2020). Here we report the first documented and vouchered record of *Bothrops bilineatus* for Ceará State, specifically in the Baturité Mountain Range, an Atlantic Forest remnant in the Caatinga morphoclimatic domain.

On 7 June 2022 at 11:00 h, a local farmer was pruning a banana tree in Guaramiranga Municipality, Ceará State, Brazil (municipality centroid at 4.2618°E; 38.9331°W, WSG 84; elevation ca. 792 m), when he accidentally hit a Green Jararaca that was resting at a height of about 2.0 m, coiled on a banana tree leaf amongst coffee tree branches. The animal immediately fell to the ground and died a few minutes later due to the wound. Thanks to the Projeto Malha de Fogo [Bushmaster Project], a study that is being carried out in the area and uses citizen science as a tool for research and conservation of *Lachesis muta* (Linnaeus, 1766), the local farmer was able to reach the first author, who immediately came to collect the animal.

¹ Departamento de Biologia, Centro de Ciências, Avenida Mister Hull s/n, Fortaleza, Ceará 60455-760, Brazil.

² Laboratório de Ecologia, Comportamento e Conservação, Departamento de Zoologia, Universidade Federal de Pernambuco, Avenida Professor Moraes Rego 1235, Cidade Universitária, Recife, Pernambuco 50670-901, Brazil.

³ Laboratório de Conservação de Vertebrados Terrestres, Universidade Estadual do Ceará, Rua José de Queiroz Pessoa 2554, Quixadá, Ceará 63902-098 Brazil.

⁴ Centro de Ciências da Saúde, Universidade Estadual do Ceará, Avenida Doutor Silas Munguba 1700, Campus Itaperi, Fortaleza, Ceará 60714-903, Brazil;

⁵ Museu de História Natural do Ceará Professor Dias da Rocha, Universidade Estadual do Ceará, Centro de Ciências da Saúde, Rua Divino Salvador 225, Centro, Pacoti, Ceará 62770-000, Brazil.

⁶ Departamento de Vertebrados, Museu Nacional, Universidade Federal do Rio de Janeiro, Quinta da Boa Vista s/n, Rio de Janeiro 20940-040, Brazil.

* Corresponding author. E-mail: thabcaval@gmail.com

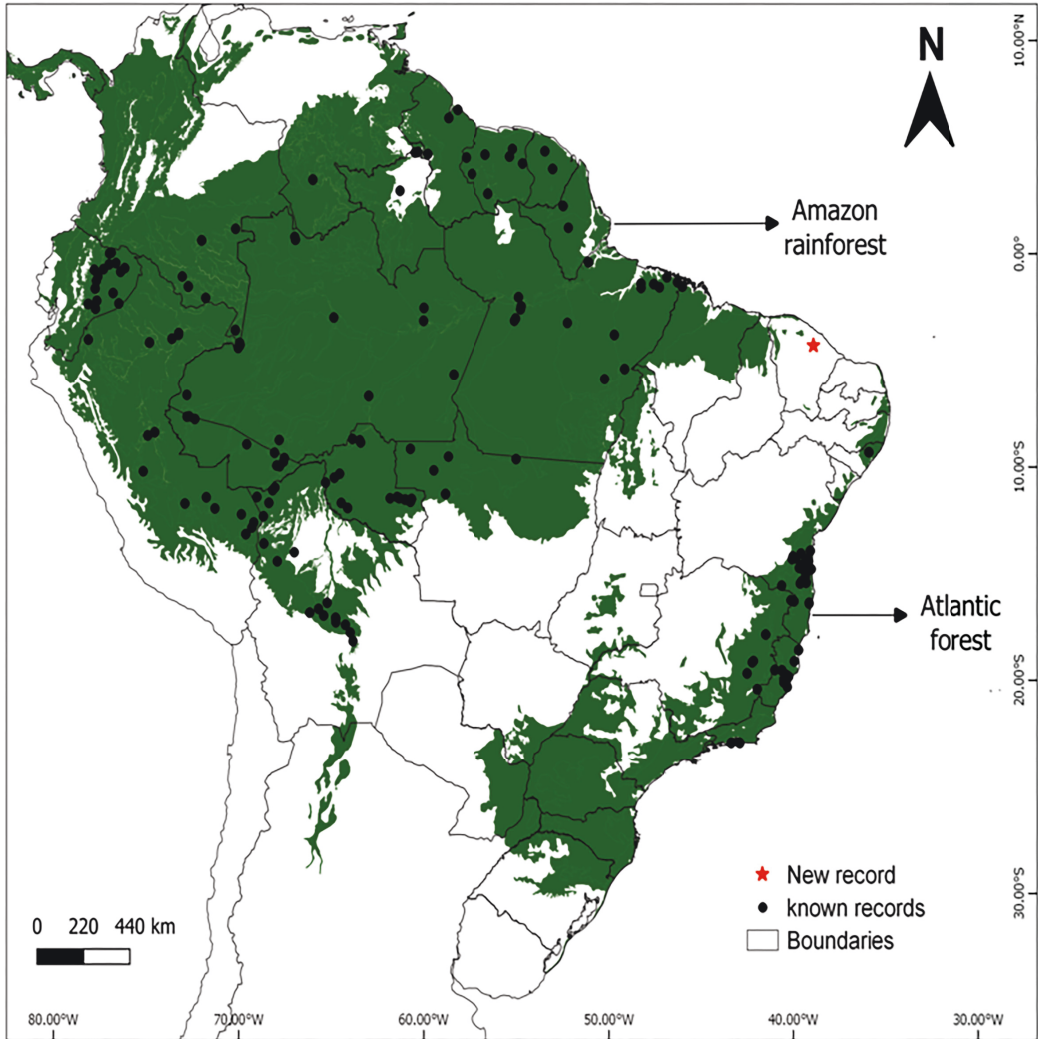


Figure 1. Geographic records of *Bothrops bilineatus* in South America. Literature records are indicated by black circles and the red star identifies the new record in the Baturité Mountain Range, Ceará State, Brazil.

The snake was an adult female (snout–vent length 674 mm, tail length 116 mm; Fig. 2), and the specimen is now housed in the Herpetological Collection of the Museu de História Natural do Ceará Prof. Dias da Rocha (MHNCE) under accession number MHNCE-R517. Because some species of *Bothrops* are highly targeted for illegal wildlife trafficking (Alves et al., 2019; La Laina et al., 2021), we do not disclose the exact locality of this finding, but only the municipality centroid instead.

The discovery of this snake was unexpected and remarkable because of three factors: the discovery of this species outside of its known distribution, the specific circumstances of how it was made, and the general rarity of these findings.

General geographic locality. This record extends the distribution of *B. bilineatus* 845 km eastward from the easternmost point of its range so far, in Domingues Municipality, Maranhão State, Brazil, and 645 km northwestward from its nearest known southeastern locality, in Murici Municipality, Alagoas State, Brazil (Dal Vechio et al., 2018; Nogueira et al., 2019) (Fig. 1). Additionally, this is the first report of the Green Jararaca in a morphoclimatic domain different from the original contiguous areas of the Amazon or the Atlantic Forest, which were classified by Olson et al. (2001) as Tropical and Subtropical Moist Broadleaf Forests.

Specific ecosystem locality. The Baturité Mountain Range, though different from the surrounding area, is inserted in the Caatinga domain: a semi-arid region, that is endemic to Brazil and covers almost the whole northeastern region of the country (Moro et al., 2015). In turn, the Caatinga was classified as part of the Deserts and Xeric Shrublands Ecoregion by Olson et al. (2001). The Baturité Mountain Range is one of the *brejos de altitude* [high wetlands] at elevations from 800–1115 m, which consists of humid and forested areas within the Caatinga (Bétard et al., 2008; Moro et al., 2015). The higher elevation of this region and the concomitant retention of the coastal humid winds and orographic rainfalls favour the establishment of a milder and wetter climate (Andrade-Lima, 1982; Bétard et al., 2008) that, in turn, allows the maintenance of a dense, humid, and isolated forest in the middle of a large dryland extension (Moro et al., 2015).

Therefore, the forest in the Baturité Mountain Range is considered a remnant of a past connection between the Amazon and the Atlantic Forest (a refuge), especially because it presents elements that are common to both domains, but different from the ones in the drier surrounding region (Borges-Nojosa et al., 2006; Moro

et al., 2015; Castro et al., 2019). In fact, several species of reptiles found in this area can also be found in the Amazon (e.g., *Oxyrhopus melanogenys*), in the Atlantic Forest (e.g., *Chironius bicarinatus*), or both (e.g., *Lachesis muta*) (Borges-Nojosa and Lima-Verde, 1999; Martins et al., 2008; Loebmann and Haddad, 2010; Nogueira et al., 2019). Nevertheless, this mountain range also possesses endemic species, such as *Atractus ronnie* and *Apostolepis thalesdelemai*, which probably evolved due to their isolation (Borges-Nojosa and Lima-Verde, 1999; Passos et al., 2007; Loebmann et al., 2009; Borges-Nojosa et al., 2017).

Serendipitous surveying. Finally, the presence of *B. bilineatus* documented here is also surprising because it was never found in the area before despite the efforts of several researchers for over 30 years (Nascimento and Lima-Verde, 1989; Borges, 1991; Borges-Nojosa et al., 2006; Ribeiro et al., 2012; Roberto and Loebmann, 2016; Borges-Nojosa et al., 2019). Even ethnozoological studies did not identify local people's recognition of this species (Fernandes-Ferreira et al., 2013). Dias et al. (2008) pointed out that knowledge about *B. bilineatus* would only be gained if studies of canopy communities were added to the herpetofaunal collection methods. Indeed, this kind of research has not yet been performed in the area, but the scientific background to this discovery leads us to assume that *B. bilineatus* is very rare and elusive in Ceará.

It is urgent to provide subsidies for further investigation of its occurrence because the whole mountain range is highly impacted by habitat loss, caused mainly by agriculture, livestock, and real estate speculation (Oliveira et al., 2007). Moreover, as with other snakes, the Green Jararaca could be locally threatened by indiscriminate killing. For these reasons, it is plausible that this species is endangered at a state level, and we draw special attention to it since it is rare in other areas of occurrence (Cunha and Nascimento, 1993; Bernarde and Abe, 2006; Dias et al., 2008; Bernarde et al., 2021), and even listed as probably extinct in others (e.g., Rio de Janeiro State; Oliveira et al., 2020).

Our finding also reinforces the role of Baturité and other *brejos de altitude* as refuges for the northeastern Brazilian fauna and its importance for their conservation (Carvalho-e-Silva et al., 2015; Roberto and Loebmann, 2016; Freitas et al., 2019). It is also worth mentioning that our record adds a new pitviper to the list of medically important snakes of Ceará (*Bothrops* aff. *atrox*, *B.* aff. *leucurus*, *B. erythromelas*, *B. lutzi*, *Crotalus durissus*, *Lachesis muta*) (Borges-Nojosa et al., 2021). This



Figure 2. *Bothrops bilineatus* from the Baturité Mountain Range, Ceará State, Brazil. (MHNCE-R517) in (A) dorsal and (B) ventral views. Scale = 1 cm. Photos by Gabriel Rios.

report also strongly reinforces the importance of citizen science-based studies. The Projeto Malha de Fogo, for example, is focused not only on ecological methods to investigate the Bushmaster's (*Lachesis muta*) natural history, but also involves local people as fundamental actors in the conservation of species. There is a sister project in Ceará called Cascavéis do Sertão, which uses a similar methodology to study the rattlesnakes (*Crotalus durissus* Linnaeus, 1758). This approach should be reproduced in other areas of Brazil to optimize scientific data and financial resources, valuing local knowledge.

Acknowledgements. We thank Antônio José de Sousa for collaborating in the fieldwork and for reporting the specimen to us, Cristiano Nogueira for providing the data for the map composition, and Gabriel V. Rios for the photographs. We also thank the Rufford Foundation (#37317-1) and Doppel Store for financial support of the Projeto Malha de Fogo, and the Rattlesnake Conservancy for supporting Cascavéis do Sertão (#FY21 Venomous Reptile Research Grant Cycle). The senior author thanks the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (#23067.047970/2021-32) for a scholarship in the post-graduate program in Systematics, Use and Conservation of Biodiversity at Federal University of Ceará. RFF has been supported by the Rufford Foundation (#196461) and the Fundação de Amparo à Ciência e Tecnologia de Pernambuco (# IBPG-1236-2.05/16). We are grateful to Fundação Cearense de Apoio ao Desenvolvimento Científico e Tecnológico for providing research grants to RCG (#06319627/2021), DCL (##03109640/2022), and HF-F (#03109640/2022).

References

- Alves, R.R.N., de Araújo, B.M.C., da Silva Policarpo, I., Pereira, H.M., Borges, A.K.M., Vieira, W.L.S., Vasconcellos, A. (2019): Keeping reptiles as pets in Brazil: ethnozoological and conservation aspects. *Journal for Nature Conservation* **49**: 9–21.
- Andrade-Lima, D. (1982): Present-day forest refuges in northeastern Brazil. In: *Biological Diversification in the Tropics*, p. 245–251. Prance, G.T., Ed., New York, USA, Columbia University Press.
- Argôlo, A.J.S. (2004): *As Serpentes dos Cacaueis do Sudeste da Bahia*. Ilhéus, Bahia, Brazil, Editus Press.
- Barbo, F.E., Booker, W.W., Duarte, M.R., Chaluppe, B., Portes-Junior, J.A., Franco, F.L., Grazziotin, F.G. (2022a): Speciation process on Brazilian continental islands, with the description of a new insular lancehead of the genus *Bothrops* (Serpentes, Viperidae). *Systematics and Biodiversity* **20**(1): 1–25.
- Barbo, F.E., Grazziotin, F.G., Pereira-Filho, G.A., Freitas, M.A., Abrantes, S.H., Kokubum, M.N.D.C. (2022b): Isolated by dry lands: integrative analyses unveil the existence of a new species and a previously unknown evolutionary lineage of Brazilian Lanceheads (Serpentes: Viperidae: *Bothrops*) from a Caatinga moist-forest enclave. *Canadian Journal of Zoology* **100**(2): 147–159.
- Bernarde, P.S., Abe, A.S. (2006): A snake community at Espigão do Oeste, Rondônia, southwestern Amazon, Brazil. *South American Journal of Herpetology* **1**(2): 102–113.
- Bernarde, P.S., Pucca, M.B., Mota-da-Silva, A., da Fonseca W.L., de Almeida, M.R.N., de Oliveira I.S., et al. (2021): *Bothrops bilineatus*: an arboreal pitviper in the Amazon and Atlantic Forest. *Frontiers in Immunology* **12**(1): 1–16.
- Bétard, F., Peulvast, J., Claudino-Sales, V. (2008): Caracterização morfoepedológica de uma serra úmida no semi-árido do nordeste brasileiro: o caso do maciço de Baturité-CE [Morphopedological characterization of a humid mountain in the Brazilian semi-arid northeast]. *Mercator* **6**(12): 107–126.
- Borges, D.M. (1991): Herpetofauna do Maciço de Baturité, Estado do Ceará: composição, ecologia e considerações zoogeográficas. Unpublished MSc thesis, Universidade Federal da Paraíba, João Pessoa, Brazil.
- Borges-Nojosa, D.M., Lima-Verde, J.S. (1999): Geographic distribution. *Lachesis muta rhombeata*. *Herpetological Review* **30**(4): 235.
- Borges-Nojosa, M.D., Loebmann, D., Lima, C.D., Melo, J.C.L., Mai, A.C.G. (2006): Reptilia, Colubridae, *Pseustes sulphureus*: distribution extension, new state record. *Check List* **2**(3): 1–3.
- Borges-Nojosa, D.M., Daniel, C.L., Castiele, H.B., James, H.D. (2017): Two new species of *Apostolepis* Cope, 1862 (Serpentes: Elapomorhini) from *brejos de altitude* in northeastern Brazil. *Revista Nordestina de Zoologia* **10**(2): 74–94.
- Borges-Nojosa, D.M., Lima, D.C., Borges-Leite, M.J., Castro, D.P., Lima, A.V.P. (2019): Mata Atlântica do Ceará: herpetofauna ameaçada e estratégias de conservação. In: *ICMBio: Plano de Ação Nacional para a Conservação da Herpetofauna Ameaçada da Mata Atlântica Nordestina*, p. 144–161. ICMBio, Brasília, Brazil, Instituto Chico Mendes de Conservação da Biodiversidade Press.
- Borges-Nojosa, D.M., Ávila, R.W., Cassiano-Lima, D. (2021): Lista de Répteis do Ceará. Available at: <https://www.sema.ce.gov.br/fauna-do-ceara/repteis/>. Accessed on 15 June 2022.
- Campbell, J.A., Lamar, W.W. (2004): *The Venomous Reptiles of the Western Hemisphere*. Volume 2. Second Edition. Ithaca, New York, USA, Cornell University Press.
- Carvalho-e-Silva, S.P., Carvalho-e-Silva, A.M.P.T., Luna-Dias, C. (2015): Anfíbios (Lissamphibia) da Reserva Biológica de Pedra Talhada. *Boissiera* **68**: 333–355.
- Castro, D.P., Rodrigues, J.F.M., Borges-Leite, M.J., Lima, D. C., Borges-Nojosa, D.M. (2019): Anuran diversity indicates that Caatinga relictual neotropical forests are more related to the Atlantic Forest than to the Amazon. *PeerJ* **6**: e6208.
- Costa, H.C., Guedes, T.B., Bérnils, R.S. (2022): Lista de répteis do Brasil: padrões e tendências. *Herpetologia Brasileira* **10**(3): 110–279.
- Cunha, O.R. (1967): Ofídios da Amazônia. I. A ocorrência de *Bothrops bilineatus bilineatus* (Wied) nas matas dos arredores de Belém, Pará (Ophidia, Crotalidae). *Boletim do Museu Paraense Emilio Goeldi* **1**(66): 1–12.
- Cunha, O.R., Nascimento, F.P. (1993): Ofídios da Amazônia: as cobras da região Leste do Pará. *Boletim do Museu Paraense Emilio Goeldi* **9**(1): 1–191.
- da Fonseca, W.L., Correa, R.R., Oliveira, A.S., de Oliveira I.S., Bernarde, P.S. (2021): Habitat use and activity of *Bothrops bilineatus smaragdinus* Hoge, 1966 in the western Brazilian Amazon (Serpentes: Viperidae). *Herpetology Notes* **14**: 567–80.

- Dal Vechio, F., Prates, I., Grazziotin, F.G., Zaher, H., Rodrigues, M.T. (2018): Phylogeography and historical demography of the arboreal pit viper *Bothrops bilineatus* (Serpentes, Crotalinae) reveal multiple connections between Amazonian and Atlantic rain forests. *Journal of Biogeography* **45**(10): 2415–26.
- da Silva, N.J., Jr (1993): The snakes from Samuel hydroelectric power plant and vicinity, Rondônia, Brazil. *Herpetological Natural History* **1**(1): 37–86.
- Dias, G., Feio, R.N., Santos, P.S. (2008): New record of *Bothriopsis bilineata* (Wied, 1825) (Serpentes, Viperidae) in the Atlantic Forest of Minas Gerais, with a discussion on its conservation. *Lundiana* **9**(1): 75–76.
- Dixon, J.R., Soini, P. (1986): The reptiles of the Upper Amazon Basin, Iquitos Region, Peru. II. Crocodylians, turtles and snakes. Milwaukee, Wisconsin, USA, Milwaukee Public Museum Press.
- Doan, T.M., Arriaga, W.A. (2002): Microgeographic variation in species composition of the herpetofaunal communities of Tambopata Region, Peru. *Biotropica* **34**(1): 101–117.
- Fernandes-Ferreira, H., Mendonça, S.V., Cruz, L.R., Borges-Nojosa, D.M., Alves, R. (2013): Hunting of herpetofauna in montane, coastal and dryland areas of northeastern Brazil. *Herpetological Conservation and Biology* **8**(3): 652–666.
- França, R.C., Morais, M., França, F.G.R., Rödder, D., Solé, M. (2020): Snakes of the Pernambuco Endemism Center, Brazil: diversity, natural history and conservation. *ZooKeys* **1002**: 115–158.
- Freitas, M.A., Abegg, A.D., Silva-Araújo, D., Almeida-Coelho, H.E., Santos-Azevedo, W., Chaves, M.F., Moura, G.J.B. (2019): Herpetofauna of five “Brejos de Altitude” of the interior of the state of Pernambuco, northeastern Brazil. *Herpetology Notes* **12**(1): 591–602.
- La Laina, D.Z., Nekaris, K.A.I., Nijman, V., Morcatty, T.Q. (2021): Illegal online pet trade in venomous snakes and the occurrence of snakebites in Brazil. *Toxicon* **193**(2021): 48–54.
- Loebmann, D., Haddad, C.F.B. (2010): Amphibians and reptiles from a highly diverse area of the Caatinga domain: composition and conservation implications. *Biota Neotropica* **10**(3): 227–256.
- Loebmann, D., Ribeiro, S.C., Sales, D.L., Almeida, W.O. (2009): New records of *Atractus ronnie* (Serpentes, Colubridae) in relictual forests from the state of Ceará, Brazil, and comments on meristic and morphometric data. *Biotemas* **22**(1): 169–173.
- Martins, M. (1993): Why do snakes sleep on the vegetation in Central Amazonia? *Herpetological Review* **24**(1): 83–84.
- Martins, M., Araujo, M.S., Sawaya, R.J., Nunes, R. (2001): Diversity and evolution of macrohabitat use, body size and morphology in a monophyletic group of neotropical pitvipers (*Bothrops*). *Journal of Zoology* **254**(4): 529–538.
- Martins, M., Marques, O.A.V., Sazima, I. (2008): How to be arboreal and diurnal and still stay alive: microhabitat use, time of activity, and defense in neotropical forest snakes. *South American Journal of Herpetology* **3**(1): 58–67.
- Moro, M.F., Macedo, M.B., Moura-Fé, M.M., Castro, A.S.F., Costa, R.C. (2015): Vegetação, unidades fitoecológicas e diversidade paisagística do estado do Ceará. *Rodriguésia* **66**(3): 717–743.
- Nascimento, F.P., Lima-Verde, J.S. (1989): Ocorrência de ofídios de ambientes florestais em enclaves de matas úmidas do Ceará (Ophidia: Colubridae). *Boletim do Museu Paraense Emílio Goeldi* **5**(1): 95–100.
- Nogueira, C.C., Argôlo, A.J., Arzamendia, V., Azevedo, J.A., Barbo, F.E., Bérnils, R.S., et al. (2019): Atlas of Brazilian snakes: verified point-locality maps to mitigate the Wallacean shortfall in a megadiverse snake fauna. *South American Journal of Herpetology* **14**(Supplement 1): 1–274.
- Oliveira, J.C.F., Gonzalez, R.C., Passos, P., Vrcibradic, D., Rocha, C.F.D. (2020): Non-avian reptiles of the state of Rio de Janeiro, Brazil: status of knowledge and commented list. *Papéis Avulsos de Zoologia* **60**: e20206024.
- Oliveira, T.S., Figueiredo, M.A., Nogueira, R.S., Sousa S.C., Souza, S.S.G., Romero, R.R. (2007): Histórico dos impactos antrópicos e aspectos geoambientais da Serra de Baturité, Ceará. In: Biodiversidade e Conservação da Biota na Serra de Baturité, Ceará, p. 17–72. Oliveira, T.S., Araújo, F.S., Eds., Fortaleza, Ceará, Brasil, Edições UFC Press.
- Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V., Underwood, E.C., Kassem, K.R. (2001): Terrestrial ecoregions of the world: a new map of life on Earth: a new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *BioScience* **51**(11): 933–938.
- Passos, P., Fernandes, D.S., Borges-Nojosa, D.M. (2007): A new species of *Atractus* (Serpentes: Dipsadinae) from a relictual forest in northeastern Brazil. *Copeia* **2007**(4): 788–797.
- Ribeiro, S.C., Roberto, I.J., Sales, D.L., Ávila, R.W., Almeida, W.O. (2012): Amphibians and reptiles from the Araripe Bioregion, northeastern Brazil. *Salamandra* **48**(3): 133–146.
- Roberto, I.J., Loebmann, D. (2016): Composition, distribution patterns, and conservation priority areas for the herpetofauna of the state of Ceará, northeastern Brazil. *Salamandra* **52**(2): 134–152.
- Turci, L.C.B., Albuquerque, S., Bernarde, P.S., Miranda, D.B. (2009): Uso do habitat, atividade e comportamento de *Bothriopsis bilineatus* e de *Bothrops atrox* (Serpentes: viperidae) na floresta do rio moa, acre, brasil. *Biota Neotropica* **9**(3): 197–206.
- Uetz, P., Freed, P., Aguilar, R., Hošek, J., Eds. (2022): The Reptile Database. Available at: <http://www.reptile-database.org>. Accessed on 11 June 2022.