Citizen science expanding knowledge: a new record of the lizard *Heterodactylus imbricatus* (Squamata, Gymnophthalmidae) in south-eastern Brazil

Cássio Zocca[‡,§], André Felipe Barreto-Lima[‡], Dulce Barbosa Daleprane[§], Natalia P. Ghilardi-Lopes[|,‡]

‡ National Institute of the Atlantic Forest, Santa Teresa, Brazil
§ Projeto Bromélias, Postgraduate Program in Animal Biology, Federal University of Espírito Santo, Vitória, Brazil
| Federal University of ABC, São Bernardo do Campo, Brazil

Corresponding author: Cássio Zocca (zoccabio@hotmail.com)

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Abstract

Background

Through citizen science projects, like Projeto Bromélias, community members contribute valuable data on species diversity, notably those with low detectability like the *Heterodactylus imbricatus* lizard. A recent observation in the State of Espírito Santo (south-eastern Brazil), amidst coffee and eucalyptus crops, highlights the utility of widespread technology use in tracking and documenting wildlife. Such initiatives are especially beneficial for mapping the distribution of rare, endemic or endangered reptiles. Therefore, we advocate for more citizen science initiatives near protected areas, involving local communities.

New information

We provide a new record for the species *Heterodactylus imbricatus*, a microteiid lizard of low detectability from the Atlantic Forest of south-eastern Brazil. *Heterodactylus imbricatus* (Rio de Janeiro Teiid) was recorded near the protected area "Reserva Biológica Augusto Ruschi" by a citizen volunteer who contributes herpetofauna records to the Bromelias Project (https://www.inaturalist.org/projects/projeto-bromelias). *Heterodactylus imbricatus* is a very poorly-known species in the localities where it occurs, probably due to its fossorial habit, genera's restricted occurrence range, habitat specificity and the absence of proper survey methods fitted to fossorial species, such as the utilisation of pitfall traps. By publishing the records of volunteer citizens, we hope that

more people will contribute to increase the knowledge of biodiversity in the mountainous region of Espírito Santo State and expand our collective knowledge.

Keywords

community engagement, conservation, geographic distribution, local communities, volunteer citizens

Introduction

Citizen science projects can provide valuable scientific data through community participation in scientific research (Bonney et al. 2009a, Bonney et al. 2009b, Miller-Rushing et al. 2012, Burgess et al. 2017, Niemiller et al. 2021), which is essential for conservation (Cooper et al. 2007, Theobald et al. 2015, Parker et al. 2018, Aristeidou et al. 2021) and natural resource management (Charnley et al. 2008). For example, through citizen science, it is possible to assess species diversity and distribution (Elith and Leathwick 2009, Gómez-Hoyos et al. 2018,Phillips 2016), and evaluate their biological responses to environmental change (Lepetz et al. 2009).

Such an approach can be advantageous for gathering occurrence data of species with low detectability, such as lizards of the genus *Heterodactylus* (Rodrigues et al. 2007, Rodrigues et al. 2009a). This genus includes three species of limb-reduced fossorial lizards with very elongate bodies and tails, whose range is restricted to Brazil, in the States of Bahia (*Heterodactylus septentrionalis* Rodrigues, Freitas and Silva, 2009), Minas Gerais, Rio de Janeiro, São Paulo, and Espírito Santo (*Heterodactylus imbricatus* Spix, 1825 and *Heterodactylus lundii* Reinhardt and Lutken, 1862). As these species rely on protected areas, local changes in the environment, even at small scales, can lead to their local extinctions (Román-Cuesta and Martínez-Vilalta 2006).

Heterodactylus imbricatus is a rare cryptozoic lizard with low detectability due to its fossorial habit, spending most of the time under the leaf litter. This species occur at high altitudes in the Atlantic Rainforest and gallery forests in the Brazilian Cerrado (Von Hering 1898, Rocha et al. 2004, Sendas and Araújo 2004, Dixo and Verdade 2006, Dixo and Metzger 2009, Rodrigues et al. 2007, Rodrigues et al. 2009a, Rodrigues et al. 2009b , Marques et al. 2009, Novelli et al. 2011, Oliveira et al. 2020). In the present article, we report a new occurrence record of the lizard *H. imbricatus* in the State of Espírito Santo, identified by a participant of Projeto Bromélias citizen science project.

The Projeto Bromélias (Bromelias Project - https://www.inaturalist.org/projects/projeto-bromelias) has been developing community engagement in science around the protected area "Reserva Biológica Augusto Ruschi", in the Municipality of Santa Teresa, State of Espírito Santo, since 2012. This is done through visits to residents, distribution of educational materials (brochures, cards and stickers), itinerant events, and photo exhibitions that highlight the importance of wilderness, raise awareness and encourage

people to change their attitudes towards nature. In addition, the dissemination of the project and popularisation of science was also carried out through social media on the internet, to engage the community to register, through geolocated photographs, the amphibian species in their surroundings, using smartphone devices.

Materials and methods

On the morning of 30 August 2019, at 10:20 am, a specimen of *H. imbricatus* was photographed with a smartphone by a local volunteer near the protected area "Reserva Biológica Augusto Ruschi", Municipality of Santa Teresa, State of Espírito Santo, south-eastern Brazil (19°52'54.4"S, 40°34'27.7"W; 790 m alt.; Fig. 1). The adult specimen of *H. imbricatus* was observed in exposed soil, near the volunteer's residence, located in an anthropized area, surrounded by agricultural crops, such as coffee and eucalyptus cultivations. The photograph and geolocation of the specimen (Fig. 2) was sent via WhatsApp by the volunteer to the Bromelias Project coordinator.

Heterodactylus imbricatus was previously recorded in five municipalities in the State of Espírito Santo: Santa Leopoldina (ZUEC-REP 1455; collected by J. L Helmer & C. Zamprogno in 1982), Venda Nova do Imigrante (MZUSP 88147; Rodrigues et al. 2009a), Cariacica (Tonini et al. 2010), Mimoso do Sul (Oliveira et al. 2020) and Domingos Martins (CEPEMAR 2004). The volunteer's record represents a new locality for *H. imbricatus*, being the sixth for the State of Espírito Santo, extending its distribution by 25 km to the north of the State, in a new municipality (Santa Teresa), representing an advance in the understanding of the geographic distribution of the species. It is noteworthy that this is the first record of this species for the State of Espírito Santo, based on citizen science data. The Municipality of Santa Teresa is the target of several works in different fields of biology and one of the most frequently sampled areas in the State. It comprises a high diversity of taxa such as amphibians, birds, butterflies, plants and small mammals (Thomaz and Monteiro 1997, Brown and Freitas 2000, Passamani 2000, Simon 2000, Ferreira et al. 2019). Despite this, there are few studies focused on inventorying reptile species, leaving large gaps in knowledge about the geographic distribution of species.

Data resources

The data underpinning the analysis reported in this paper are deposited at GBIF, the Global Biodiversity Information Facility, https://ipt.pensoft.net/resource?r=citizen_science_heterodactylus.

Taxon treatment

Heterodactylus imbricatus Spix, 1825

Material

a. locationID: Reserva Biológica Augusto Ruschi; higherGeographyID: **TGN: 9158266**; higherGeography: South America, Brazil, Espírito Santo; continent: South America; country: Brazil; countryCode: Brazil/BRA; stateProvince: Espírito Santo; municipality: Santa Teresa; verbatimElevation: 790 m; locationAccordingTo: Getty Thesaurus of Geographic Names", "GADM"; verbatimCoordinates: 19 52 54.4S 40 34 27.7W; verbatimLatitude: 19 52 54.4S; verbatimLongitude: 40 34 27.7W; verbatimCoordinateSystem: degrees minutes seconds; verbatimSRS: unknown; georeferencedBy: Cássio Zocca (CZ); georeferenceVerificationStatus: verified by curator; type: StillImage; occurrenceID: 3F14EFEE-48EB-55EC-9A51-25EE0D9F01BF

Description

An adult specimen of *Heterodactylus imbricatus* (Fig. 2)

Taxon discussion

Heterodactylus imbricatus Spix, 1825 is a species of the order Squamata, of the family Gymnopthalimidae Fitzinger, 1826, inserted in the tribe Heterodactylini (Goicoechea et al. 2016).

H*eterodactylus imbricatus* is restricted to areas with a cold climate associated with high elevations and mountainous areas of south-eastern Brazil and is usually found in leaf litter (Dixo and Verdade 2006, Rodrigues et al. 2009a). Initially, the known distribution of this species was restricted to areas of the Atlantic Forest, but Novelli et al. (2011) recorded its occurrence in the domain of the Cerrado biome.

Discussion

The record of *Heterodactylus imbricatus* by a citizen scientist shown in the present study evidences how easy it can be for those people with access to internet to explore the wildlife around them and contribute to expanding our knowledge about biodiversity. This result is in accordance with other published works, which demonstrated citizen science can contribute to a rapid accumulation of knowledge about the distribution of reptile species, including rare, endemic and/or endangered species (Price and Dorcas 2011, Theobald et al. 2015, Phillips 2016, Gómez-Hoyos et al. 2018).

Heterodactylus imbricatus is a very poorly-known species due to its fossorial habit. By publishing the records of volunteer citizens, we hope that more people will contribute to

increase the knowledge of biodiversity in the mountainous region of Espírito Santo and expand our collective knowledge (Costello et al. 2013).

We believe it is vital for local communities near protected areas, as well as for policy-makers and managers, to comprehend the significance of these initiatives and taxonomic groups in conserving habitats, biodiversity and ecosystem services (Alves 2012). We advocate for the initiation of citizen science projects in areas neighbouring protected zones, actively involving the local communities, following the example of Projeto Bromelias.

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References

- Alves RR (2012) Relationships between fauna and people and the role of ethnozoology in animal conservation. Ethnobiology Conservation 1: 1-69. URL: https://ethnobioconservation.com/index.php/ebc/article/view/20
- Aristeidou M, Herodotou C, Ballard H, Higgins L, Johnson R, Miller A, Young A, Robinson L (2021) How Do Young Community and Citizen Science Volunteers Support Scientific Research on Biodiversity? The Case of iNaturalist. Diversity 13 (7): 318. https://doi.org/10.3390/d13070318
- Bonney R, Ballard HL, Jordan R, McCallie E, Phillips T, Shirk J, Wilderman CC (2009a) Public participation in scientific research: defining the field and assessing its potential for informal science education. Center for Advancement of Informal Science Education (CAISE). A CAISE Inquiry Group Report. URL: https://files.eric.ed.gov/fulltext/ED519688.pdf
- Bonney R, Cooper C, Dickinson J, Kelling S, Phillips T, Rosenberg K, Shirk J (2009b) Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience 59 (11): 977-984. https://doi.org/10.1525/bio.2009.59.11.9
- Brown J,K, Freitas AV (2000) Diversidade de Lepidoptera em Santa Teresa, Espírito Santo. Boletim do Museu de Biologia Mello Leitão 11 (12): 71-118. URL: http://boletim.sambio.org.br/pdf/11_05.pdf
- Burgess HK, DeBey LB, Froehlich HE, Schmidt N, Theobald EJ, Ettinger AK, HilleRisLambers J, Tewksbury J, Parrish JK (2017) The science of citizen science: exploring barriers to use as a primary research tool. Biological Conservation 208: 113-120. https://doi.org/10.1016/j.biocon.2016.05.014

- CEPEMAR (2004) Plano de Manejo do Parque Estadual de Pedra Azul. CEPEMAR - Serviços e Consultoria em Meio Ambiente Ltda.. URL: https://iema.es.gov.br/Media/iema/Unidades%20de%20Conserva%C3%A7%C3%A3o/Plano_Manejo%20Pedra%20Azul-compactado.pdf
- CERN (2018) Ampliação Mina Volta Grande - Relatório de Impacto Ambiental (RIMA). CERN (Consultoria e Empreendimentos de Recursos Naturais Ltda.). URL: https://amg-files.s3.sa-east-1.amazonaws.com/SSMAQ/RIMA.pdf
- Charnley S, Fischer AP, Jones E (2008) Traditional and local ecological knowledge about forest biodiversity in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR 751: 1-52. https://doi.org/10.2737/pnw-gtr-751
- Cooper CB, Dickinson J, Phillips T, Bonney R (2007) Citizen Science as a tool for conservation in residential ecosystems. Ecology and Society 12 (2). URL: http://www.jstor.org/stable/26267884
- Costello M, May R, Stork N (2013) Can we name Earth's species before they go extinct? Science 339 (6118): 413-416. https://doi.org/10.1126/science.1230318
- Dixo M, Verdade VK (2006) Herpetofauna de serrapilheira da Reserva Florestal de Morro Grande, Cotia (SP). Biota Neotropica 6 (2). https://doi.org/10.1590/s1676-06032006000200009
- Dixo M, Metzger JP (2009) Are corridors, fragment size and forest structure important for the conservation of leaf-litter lizards in a fragmented landscape? Oryx 43 (03): 435-442. https://doi.org/10.1017/s0030605309431508
- Elith J, Leathwick J (2009) Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology, Evolution, and Systematics 40 (1): 677-697. https://doi.org/10.1146/annurev.ecolsys.110308.120159
- FAI UFSCar (2021) Plano de Manejo do Parque Natural Municipal Olésio do Santos. Secretaria do Meio Ambiente - Prefeitura Municipal de Salto de Pirapora. URL: https://www.saltodepirapora.sp.gov.br/instarenv/assets/uploads/file/1v3btva7.pdf
- Ferreira RB, Mônico AT, da Silva ET, Lirio FCF, Zocca C, Mageski MM, Tonini JFR, Beard K, Duca C, Silva-Soares T (2019) Amphibians of Santa Teresa, Brazil: the hotspot further evaluated. ZooKeys 857: 139-162. https://doi.org/10.3897/zookeys.857.30302
- Goicoechea N, Frost D, De la Riva I, Pellegrino KM, Sites J, Rodrigues M, Padial J (2016) Molecular systematics of teioid lizards (Teioidea/Gymnophthalmoidea: Squamata) based on the analysis of 48 loci under tree-alignment and similarity-alignment. Cladistics 32 (6): 624-671. https://doi.org/10.1111/cla.12150
- Gómez-Hoyos D, Méndez-Arrieta R, Méndez-Arrieta A, Seisdedos-de-Vergara R, Abarca J, Barrio-Amorós C, González-Maya J (2018) Anuran inventory in a locality of the buffer area of La Amistad International Park, Costa Rica: pilot study for citizen science application. Anales de Biología 40: 57-64. https://doi.org/10.6018/analesbio.40.07
- ICMBio - MMA (2012) Plano de ação nacional para conservação dos répteis e anfíbios ameaçados de extinção na Serra do Espinhaço. Ministério do Meio Ambiente (MMA). URL: https://www.gov.br/icmbio/pt-br/assuntos/biodiversidade/pan/pan-herpetofauna-do-espinhaco/1-ciclo/pan-herpetofauna-do-espinhaco-sumario.pdf
- Lepetz V, Massot M, Schmeller D, Clobert J (2009) Biodiversity monitoring: some proposals to adequately study species' responses to climate change. Biodiversity and Conservation 18 (12): 3185-3203. https://doi.org/10.1007/s10531-009-9636-0

- Lumiar Consultoria e ou Assessoria (2019) Plano de manejo - Área de Proteção Ambiental Boqueirão da Mira. ICMBio. URL: http://www.srjacutinga.mg.gov.br/documentos/PLANO_APA_BM_FINAL_II.pdf
- Marques OAV, Pereira DN, Barbo FE, Germano VJ, Sawaya RJ (2009) Os répteis do município de São Paulo: diversidade e ecologia da fauna pretérita e atual. Biota Neotropica 9 (2): 139-150. https://doi.org/10.1590/s1676-06032009000200014
- Miller-Rushing A, Primack R, Bonney R (2012) The history of public participation in ecological research. Frontiers in Ecology and the Environment 10 (6): 285-290. https://doi.org/10.1890/110278
- Mol RM, França ATRC, Tunes PH, Costa CG, Clemente CA, et al. (2021) Reptiles of the Iron Quadrangle: a species richness survey in one of the most human exploited biodiversity hotspots of the world. Cuadernos de Herpetología 35 (2): 283-302. https://doi.org/10.31017/CdH.2021.
- Niemiller KDK, Davis M, Niemiller M (2021) Addressing 'biodiversity naivety' through project-based learning using iNaturalist. Journal for Nature Conservation 64: 126070. https://doi.org/10.1016/j.jnc.2021.126070
- Novelli IA, Lucasa PDS, Santos RC (2011) Reptilia, Squamata, Gymnophthalmidae, *Heterodactylus imbricatus* Spix, 1825: Filling gaps in the state of Minas Gerais. Check List 7 (1): 30-31. https://doi.org/10.15560/7.1.30
- Oliveira JF, Santos Rd, Lopes-Silva ML, Barros LdPV, Risse-Quaioto B, Militão CM, Fatorelli P, Belmoch FL, Castro TMd, Rocha CFD (2020) Reptiles of the Serra das Torres Natural Monument: using the Rapid Assessment method to fill a knowledge gap in the Atlantic Forest of southeastern Brazil. Biota Neotropica 20 (2): e20190726. https://doi.org/10.1590/1676-0611-bn-2019-0726
- Parker S, Pauly G, Moore J, Fraga N, Knapp J, Principe Z, Brown B, Randall J, Cohen B, Wake T (2018) Adapting the bioblitz to meet conservation needs. Conservation Biology 32 (5): 1007-1019. https://doi.org/10.1111/cobi.13103
- Passamani M (2000) Análise da comunidade de marsupiais em Mata Atlântica de Santa Teresa, Espírito Santo. Boletim do Museu de Biologia Mello Leitão 11 (12): 215-228.
- Phillips J (2016) Updated geographic distributions of Michigan herpetofauna: a synthesis of old and new sources. Journal of North American Herpetology 1: 45-69. https://doi.org/10.17161/jnah.vi1.11925
- Price SJ, Dorcas ME (2011) The Carolina Herp Atlas: an online, citizen-science approach to document amphibian and reptile occurrences. Herpetological Conservation & Biology 6: 287-296.
- Rocha CF, Bergallo HG, Pombal JP, Geise L, Van Sluys M, Fernandes R, Caramaschi U (2004) Lista de anfíbios, répteis e mamíferos do Estado do Rio de Janeiro, Sudeste do Brasil. Publicações Avulsas do Museu Nacional 104: 1-24. URL: http://www.herpetologiamuseunacional.com.br/Pombal/pdf/04_spp_Rio.pdf
- Rodrigues MT, Machado Pellegrino KC, Dixo M, Verdade VK, Pavan D, Suzart Argolo AJ, Sites JW (2007) A new genus of microteiid lizard from the atlantic forests of state of Bahia, Brazil, with a new generic name for *Colobosaura mentalis*, and a discussion of relationships among the Heterodactylini (Squamata, Gymnophthalmidae). American Museum Novitates 3565 (1): 1-27. https://doi.org/10.1206/0003-0082(2007)496[1:angoml]2.0.co;2
- Rodrigues MT, De Freitas MA, Silva TFS (2009a) New species of earless lizard genus *Heterodactylus* (Squamata: Gymnophthalmidae) from the highlands of Chapada

Diamantina, state of Bahia, Brazil. Journal of Herpetology 43 (4): 605-611. https://doi.org/10.1670/08-133.1
- Rodrigues MT, Cassimiro J, Pavan D, Curcio FF, Verdade VK, Pellegrino KCM (2009b) A new genus of microteiid lizard from the Caparaó Mountains, Southeastern Brazil, with a discussion of relationships among Gymnophthalminae (Squamata). American Museum Novitates 3673: 1-27. https://doi.org/10.1206/622.1
- Román-Cuesta MR, Martínez-Vilalta J (2006) Effectiveness of protected areas in mitigating fire within their boundaries: case study of Chiapas, Mexico. Conservation biology: the journal of the Society for Conservation Biology 20 (4): 1074-1086. https://doi.org/10.1111/j.1523-1739.2006.00478.x
- Sendas FA, Araújo AF (2004) Inventário preliminar dos répteis do Parque Nacional do Itatiaia (PNI), Rio de Janeiro. Revista Universidade Rural 24 (2): 151-157.
- Simon JE (2000) Composição da avifauna da Estação Biológica de Santa Lúcia, Santa Teresa-ES. Boletim do Museu de Biologia Mello Leitão 11 (12): 149-170.
- Stroppa GM (2012) Composição da Fauna de Lagartos e Anfisbenídeos (Squamata) em um fragmento de Mata Atlântica na Zona da Mata de Minas Gerais, Brasil. Universidade Federal de Juiz de Fora, Juiz de Fora, 50 pp.
- Theobald EJ, Ettinger AK, Burgess HK, DeBey LB, Schmidt NR, Froehlich HE, Wagner C, HilleRisLambers J, Tewksbury J, Harsch MA, Parrish JK (2015) Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. Biological Conservation 181: 236-244. https://doi.org/10.1016/j.biocon.2014.10.021
- Thomaz LD, Monteiro R (1997) Composição florística da mata atlântica de encosta da Estação Biológica de Santa Lúcia, município de Santa Teresa-ES. Boletim do Museu de Biologia Mello Leitão 7: 3-48.
- Tonini JFR, Carão LdM, Pinto Id, Gasparini JL, Leite YLR, Costa LP (2010) Non-volant tetrapods from Reserva Biológica de Duas Bocas, state of Espírito Santo, Southeastern Brazil. Biota Neotropica 10 (3): 339-351. https://doi.org/10.1590/s1676-06032010000300032
- Von Hering H (1898) Contributions to the herpetology of Sao Paulo, Brazil: I. Proceedings of the Academy of Natural Science of Philadelphia 50: 101-109.

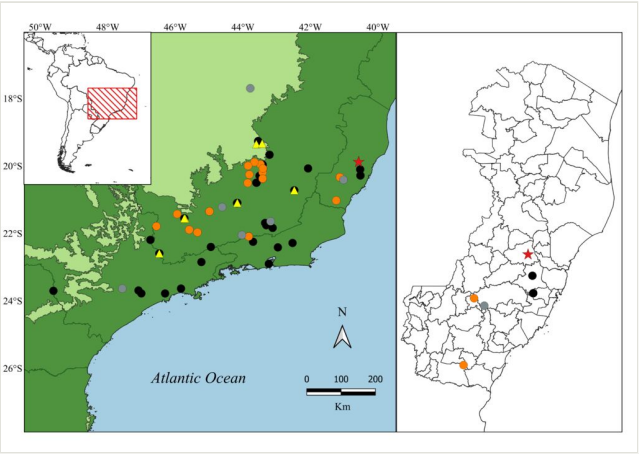

Figure 1.

On the upper left corner - map of South America, highlighting the geographic distribution of *Heterodactylus imbricatus* in Brazil (red rectangle). In the centre - occurrence points of *H. imbricatus* in Brazil. On the right - map of State of Espírito Santo showing the cities in which *H. imbricatus* occur. Black circles = GBIF and SiBBr data; Orange circles = data from scientific literature (Tonini et al. 2010, Novelli et al. 2011, Mol et al. 2021); Grey circles = data from grey literature (Management Plans and Thesis - CEPEMAR 2004, ICMBio - MMA 2012, Stroppa 2012, CERN 2018, Lumiar Consultoria e ou Assessoria 2019,FAI UFSCar 2021); Yellow triangles = iNaturalist Research grade data; Red star = new occurrence point for the Municipality of Santa Teresa (present study). GBIF = Global Biodiversity Information Facility (www.gbif.org) and SiBBr = Sistema de Informação sobre a Biodiversidade Brasileira (www.sibbr.gov.br)

Figure 2.

Adult of *Heterodactylus imbricatus* (dorsal view) recorded by a volunteer citizen at her residence, near the protected area “Reserva Biológica Augusto Ruschi”, Municipality of Santa Teresa, State of Espírito Santo, Brazil.