Visual census versus citizen science: which is the best method for surveying an elusive and threatened snake?

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Abstract Visual methods of surveying snakes are subject to observer bias and their accuracy is often questioned. Data collection by non-specialists offers an alternative way to record sightings. We present citizen science as a valuable tool for surveying the viperid snake *Lachesis rhombeata*, yielding more data than a traditional visual census in a remnant of the Atlantic Forest in north-east Brazil. From visits to local museum/university collections and a literature search, we obtained only 10 georeferenced historical records for this species in the study area dating from 1990 to 2020. In 218 h of visual field surveys during 2022 and 2023, covering 15,000 m², we did not locate any *L. rhombeata* individuals, probably because their low population density and cryptic habits made their detection difficult. However, during the same period we acquired 110 georeferenced records through citizen science. The high number of records from citizen science underscores the value of this approach when working with an elusive and threatened snake. *Lachesis rhombeata* is often implicated in human–wildlife conflict but engaging local people in the project led to positive behavioural changes. Through citizen science we were able to examine live individuals, map the species' current distribution, investigate threats to its survival and contribute data for studies on taxonomy, diet, home range, diseases and ethno-herpetology.

Keywords Atlantic Forest, citizen science, conservation, herpetological surveys, *Lachesis rhombeata*, South American bushmaster, Viperidae

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The combination of camouflage colouration, slow movement, solitary habits and cryptic behaviour makes some species of snakes difficult to detect (Rocha & Silva, 2015). In addition, study areas are often extensive, trained observers are few, and survey time, effort and resources are limited. In combination, these factors contribute to a low detection rate of individuals and lack of data to assess their populations (Steen, 2010).

These difficulties also apply in the case of two species of the genus *Lachesis*, which are commonly referred to as bushmasters (Wied-Neuwied, 1824). These are the largest neotropical venomous snakes, reaching up to 3 m in length (Zamudio & Greene, 1997; Hamdan et al., 2024). They are terrestrial, nocturnal, oviparous vipers living at low population densities, employing ambush hunting strategies and using burrows as shelters (Campbell & Lamar, 2004). Until 2024 they were considered to be two subspecies of *Lachesis muta*: *L. muta muta* and *L. muta rhombeata* (Zamudio & Greene, 1997). However, a recent taxonomic review indicated they are actually two distinct species, with *L. muta* concentrated in the Amazon and *L. rhombeata* endemic to the Brazilian Atlantic Forest (Hamdan et al., 2024). *Lachesis muta* is categorized as Least Concern on the IUCN Red List (Gutiérrez-Cárdenas et al. 2021) but since being recognized as a separate species, *L. rhombeata* has not yet been assessed according to the criteria of the Brazilian and the IUCN Red Lists. However, when this taxon was considered a subspecies, the IUCN Red List (Martins & Marques, 2000) and regional Red Lists in Brazil (for the states of Ceará, Rio de Janeiro, Minas Gerais, Espírito Santo, Bahia and Pernambuco) categorized it as Vulnerable (Martins & Molina, 2008; Navega-Gonçalves & Porto, 2016; SEMA, 2022). Therefore, following its designation as a separate species, a reassessment of its conservation status is necessary.

Conducting systematic visual surveys for snakes involves considerable effort, requiring numerous hours in the field and/or large teams of researchers (Steen, 2010). An alternative way to gather information is through citizen science, using observations made by non-specialists (Silva et al., 2019a,b; Wangyal et al., 2020). Here, we present citizen science as a valuable tool to improve *L. rhombeata* surveys compared to traditional visual censuses.

We conducted fieldwork in the Baturité Massif, in the north-eastern Brazilian state of Ceará, during 2021–2023. This area is an Atlantic Forest remnant with Amazonian influence within the semi-arid Caatinga Domain, at an elevation of 800–1,115 m (Silveira et al., 2020). It is

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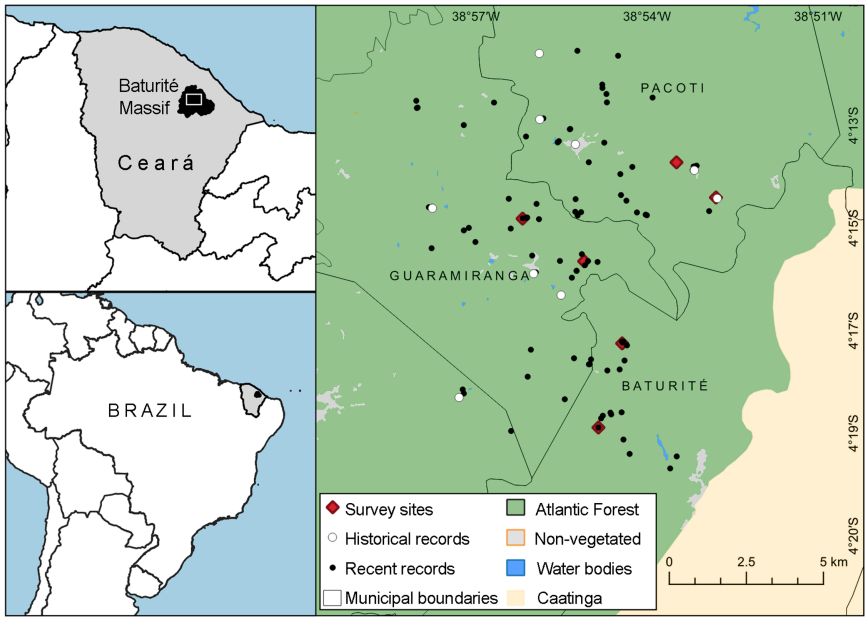


FIG. 1 Location of the six survey sites and occurrence records of bushmasters *Lachesis rhombeata* in the Baturité Massif, Ceará, Brazil. Two of the historical records (Records 1 and 2; see Supplementary Table 1) are not distinguishable on the map because they are too close together and so overlap. (Readers of the printed journal are referred to the online article for a colour version of this figure.)

characterized by mild conditions, with temperatures ranging from 13 °C to 27 °C throughout the year and > 1,200 mm of annual rainfall (Junior & Caracristi, 2022).

We compiled data on *L. rhombeata* from the literature and online databases, and from specimens preserved at the Museu de História Natural do Ceará Prof. Dias da Rocha (MHNCE) and the Herpetological Collection of the Federal University of Ceará (CH-UFC). During May 2021–December 2023, we conducted searches using Google Scholar (Google, 2021), PubMed (NIH, 2021) and Web of Science (Clarivate, USA), without a time filter and using the following keywords: *Lachesis*, *Lachesis muta*, *Lachesis muta rhombeata*, north-eastern Brazil, and Ceará.

We conducted field studies during July–September 2022 and in February 2023. We selected these months because they cover the peak activity period of *L. rhombeata*, based on its reproductive cycle and the local environmental conditions, notably lower temperatures and increased humidity (Alves et al., 2014; Souza & Almeida-Santos, 2022). The species is an ambush predator that typically exhibits low movement rates but becomes more active during the breeding season as it searches for mates, increasing the probability of encounters (Campbell & Lamar, 2004).

We surveyed four randomly selected plots at each of six sites (25 × 25 m; marked with coloured tape), totalling 24 plots and covering an area of 15,000 m² (Fig. 1). Surveys were conducted by a team of four observers (TC, RFF, JAA, and LSL), who simultaneously scanned every possible microhabitat using herpetological hooks and torches. Vegetation was carefully parted, fallen logs were turned over, and cavities were inspected. During 8 days, two surveys were carried out per day in each plot: one in the morning, between 06.00 and 12.00, and another at night, between 18.00 and 00.00, with the four observers starting from the same side of the plot and returning while searching all possible microhabitats for individuals. The fieldwork was carried out over a period of 24 days, with a total sampling effort of 218 hours, including 62 hours of survey time per plot and 54 hours per observer. No evidence of *Lachesis rhombeata* was found during any of the surveys.

From October 2021 to February 2023, we engaged with local people by distributing posters featuring our research objectives, photographs of the snake and contact details (Fig. 2). We posted this material via social media channels (Instagram, 2021; WhatsApp, 2021). We also distributed posters in the four municipalities of Baturité Massif (Baturité, Mulungu, Pacoti, Guaramiranga) during May 2021–August 2023. We encouraged local community members to send us photographs and location details of any bushmaster snakes they encountered. Using this information, we recorded the geographical coordinates of the snakes and safely captured them for measurement.

Our search of the literature and museum/university collections yielded 10 records of *L. rhombeata* dating from 1990–2020. We obtained 110 georeferenced records (photographs and videos) provided by 61 local people and we captured or collected 28 specimens (15 alive, 13 dead), including 15 adult males, 11 adult females and two juvenile females. WhatsApp was the most frequently used communication channel (n = 95), followed by Instagram (n = 8), phone calls and personal communications (n = 7; Supplementary Table 1). The live individuals were transported to the MHNCE laboratory, where they were measured, sexed, photographed and sampled for biological material. Each snake was individually marked with a small

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FIG. 2 Poster distributed to the communities of the Baturité Massif, Ceará, Brazil, regarding bushmasters *Lachesis rhombeata*: (a) original poster in Portuguese; (b) poster translated into English.

cut on the ventral scales just above the cloacal scale to allow identification in case of recapture. After processing, the animals were released into the State Environmental Protection Area of the Baturité Massif, within the same municipalities where they had been captured. For each individual, we recorded snout–vent length, tail length, sex and body mass (kg) to assess the biological profile of the population, and collected tissue samples for genetic analysis. Specimens found dead were deposited in the MHNCE collection. The main causes of death were injuries inflicted by agricultural tools (e.g. knives, machetes and hoes) and vehicular collisions (cars or motorcycles).

We organized photo and video records of *L. rhombeata* individuals by location and date/time of sighting, counting multiple observations of the same individual on the same day as a single record. However, in some instances where a snake had been recorded by a citizen scientist but had not been captured for individual marking, we were unable to determine whether records from different dates and in different locations were of the same individual animal or distinct individuals.

Although the visual survey effort was adequate, the lack of sightings is unsurprising. *Lachesis* species are characterized by cryptic colouration, low mobility, low population density and a dispersed distribution, making them difficult to detect (Campbell & Lamar, 2004). Few individuals have been documented since the first record of the species (Borges-Nojosa & Lima-Verde, 1999), despite decades of research (Roberto & Loebmann, 2016). However, citizen science is a promising new source of data, yielding more records of this rare snake in its natural habitat as well as in anthropogenic environments, such as streets and avenues (Supplementary Plate 1), compared to historical records from the last 25 years (Roberto & Loebmann, 2016). Although the species is large and easily observable in open areas, we did not consider visual acuity to be a limiting factor in our field searches. Instead, we regarded the considerable movement of people and animals in and out of the forest fragments as the principal factor influencing the communities' encounters with the animals, with a larger number of people increasing the chances of an encounter with the snakes.

Our findings underline the value of citizen science for gathering data on rare and elusive animals. The involvement of local communities enhanced our survey efforts through the largely increased number of observers operating in the study area on a daily basis (Goiran & Shine, 2019; Wangyal et al., 2020). We were unable to locate any bushmasters using traditional ecological survey methods because of their sparse distribution and use of underground burrows (Barrio-Ámoros et al., 2020). In contrast, snake encounters by local people carrying out agricultural activities are commonly reported across Brazil (Silva et al., 2020). We were able to record such encounters by engaging directly with local communities, combined with the use of social media, resulting in a high number of records and captures of *L. rhombeata*. Furthermore, our citizen science approach also led to the first record of another viper species for Ceará state, the green jararaca *Bothrops bilineatus* (Cavalcante et al., 2022).

This included visits to locations where bushmasters had been sighted, the publication of regular sighting reports shared on the project's Instagram page (Projeto Malha de Fogo, 2022), as well as quarterly reports on the website of The Rufford Foundation (Cavalcante, 2022), along with conversations with the local population to keep them informed and to respond to any questions. These included, for example, which procedures would be carried out with

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captured specimens, biological information (e.g. size, weight and sex) and issues related to envenomations. We also carried out environmental education activities using actions and educational materials focused on information about venomous snakes. These activities were conducted in both formal and non-formal spaces, such as schools, public squares and at tourism events (Supplementary Plate 2).

Through the involvement of local communities, we gained a clearer understanding of the distribution of *L. rhombeata* and the threats it faces, such as indiscriminate killing by locals. In the Baturité Massif, conflicts involving this species have been documented because of the risk it poses to humans and domestic animals (Fernandes-Ferreira et al., 2013). The use of *L. rhombeata* for food and ornamental purposes has also been reported, but only rarely (Fernandes-Ferreira et al., 2013). Moreover, the species is affected by roadkill as well as habitat loss and fragmentation as a result of ongoing deforestation. These factors contributed to the categorization of the species as Critically Endangered in the state of Ceará in 2022 (SEMA, 2022). We also used the collected data to improve the taxonomic knowledge of the population. In addition, the individuals collected during our work were used in other studies, such as a taxonomic review of the Brazilian populations of *Lachesis* (Hamdan et al., 2024), which recognized them as two different species by analysing molecular and morphological data. Citizen science also played a crucial role in the rediscovery of the Endangered tree boa *Corallus cropanii* in Brazil, which had not been sighted for 64 years (Silva et al., 2019b). Importantly, community involvement in conservation projects has driven significant behavioural changes (Lewandowski & Oberhauser, 2017). In this study, local communities adopted an alert system for animal rescues and the sharing of information. In this way citizen science can serve as an important bridge between conservationists and communities, raising awareness amongst local people about species often perceived as repulsive and improving our understanding of the challenges of human–wildlife coexistence.

Author contributions Study design, data analysis, writing: TC, RCG, HF-F; data collection: TC, RF-F, JAA-O, LSL; revision: all authors.

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Conflicts of interest None.

Ethical standards Fieldwork activities, procedures with animals and interviews with people were conducted with permission from Instituto Chico Mendes de Conservação da Biodiversidade (#79537), Secretaria do Meio Ambiente do Estado do Ceará (#11235460/2021), Comitê de Ética de Experimentação Animal (#7361210922) and Comitê de Ética em Pesquisa da Universidade Federal do Ceará (#5801754). As such, our research abided by the *Oryx* guidelines on ethical standards.

Data availability The data supporting our findings are available in the Supplementary Material.

References

Alves, F.Q., Argolo, A.J.S. & Carvalho, G.C. (2014) Reproductive biology of the Bushmaster *Lachesis muta* (Serpentes: Viperidae) in the Brazilian Atlantic Forest. *Phyllomedusa*, 13, 99–109.

Barrio-Ámoros, C.L., Corrales, G., Rodríguez, S., Culebras, J., Dwyer, Q. & Flores, D.A. (2020) The bushmasters (Lachesis spp.): Queens of the rainforest. An overview of the taxonomy, distribution, natural history, lore, and conservation of the largest vipers in the world. *Reptiles & Amphibians*, 27, 358–382.

Borges-Nojosa, D.M. & Lima-Verde, J.S. (1999) *Lachesis muta rhombeata* – geographical distribution. *Herpetological Review*, 30, 235–235.

Campbell, J.A. & Lamar, W.W. (2004) *The Venomous Reptiles of the Western Hemisphere*. Cornell University Press, Ithaca, USA.

Cavalcante, T. (2022) *Conservation Strategies for Vulnerable Bushmaster Snakes (*Lachesis muta rhombeata*) in Forest Remnants, Northeastern Brazil*. Project updates and reports. rufford.org/projects/thabata-cavalcante-dos-santos/conservation-strategies-vulnerable-bushmaster-snakes-lachesis-muta-rhombeata-forest-remnants-northeastern-brazil [accessed August 2025].

Cavalcante, T., Freire-Filho, R., Andrade-Oliveira, J.A., Lima, L.S., Cassiano-Lima, D., Fernandes-Ferreira, H. & Gonzalez, R.C. (2022) An unexpected record of the green jararaca *Bothrops bilineatus* (Wied-Neuwied, 1821) in the state of Ceará, northeastern Brazil. *Herpetology Notes*, 15, 867–871.

Fernandes-Ferreira, H., Mendonça, S.V, Cruz, R.L., Borges-Nojosa, D.M. & Alves, R.R.N. (2013) Hunting of herpetofauna in montane, dryland, and coastal areas of northeastern Brazil. *Herpetology Conservation and Biology*, 8, 652–666.

Goiran, C. & Shine, R. (2019) Grandmothers and deadly snakes: an unusual project in 'citizen science'. *Ecosphere*, 10, e02877.

Google (2021) *Google Scholar*. Google, Menlo Park, USA. scholar.google.com [accessed July 2025].

Gutiérrez-Cárdenas, P., Rivas, G., Caicedo, J.R., Ouboter, P., Hoogmoed, M.S. & Murphy, J. (2021) *Lachesis muta*. In *The IUCN Red List of Threatened Species* 2021. dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T62254A44946798.en.

Hamdan, B., Sandro, L., Bonatto, S.L., Rödder, D., Seixas, V.C., Santos, R.M.F., Santana, D.J. et al. (2024) When a name changes everything: taxonomy and conservation of the Atlantic bushmaster (*Lachesis* Daudin, 1803) (Serpentes: Viperidae: Crotalinae). *Systematics and Biodiversity*, 22, e2366215.

Instagram (2021) *Instagram*. Meta Platforms, Menlo Park, USA. instagram.com [accessed July 2025].

Junior, R.R.S. & Caracristi, I. (2022) Análise Climática do Maciço de Baturité (CE): Subsídio ao Planejamento e Gestão Ambiental. *Ciência Geográfica*, 16, 2227–2258.

Lewandowski, E. & Oberhauser, K. (2017) Butterfly citizen scientists in the United States increase their engagement in conservation. *Biological Conservation*, 208, 106–112.

https://doi.org/10.1017/S0030605324001571 Published online by Cambridge University Press

Liberatore, A., Bowkett, E., Macleod, C., Spurr, E. & Longnecker, N. (2018) Social media as a platform for a citizen science community of practice. *Citizen Science: Theory and Practice*, 3, 1–14.

Martins, M. & Marques, O.A.V. (2000) *Lachesis muta* ssp. *rhombeata*. In *The IUCN Red List of Threatened Species* 2000. dx.doi.org/10.2305/IUCN.UK.2000.RLTS.T39903A10281034.en.

Martins, M. & Molina, F.B. (2008) Panorama geral dos répteis ameaçados do Brasil. In *Livro Vermelho da Fauna Brasileira Ameaçada de Extinção* (eds A.B.M. Machado, G.M. Drummond & A.P. Paglia), pp. 327–334. Biodiversitas, Brasília, Brazil.

Navega-Gonçalves, M.E.C. & Porto, T. (2016) Snake conservation in Brazilian biomes. *Bioikos*, 30, 55–76.

NIH (National Institutes of Health) (2021) *PubMed*. United States National Library of Medicine, National Institutes of Health, Bethesda, USA. pubmed.ncbi.nlm.nih.gov [accessed July 2025].

Projeto Malha de Fogo (2022) *Projeto Malha de Fogo, Instagram*. instagram.com/projetomalhadefogo/?hl = en [accessed August 2025.]

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, 134–152.

Rocha, W.A. & Silva, M.B. (2015) Serpentes do Brasil: introdução aos estudos em história natural. In *Métodos em Ecologia e Comportamento Animal* (eds M.S.C. Moura, L.S. Carvalho & F. Prezoto), pp. 235–279. Edufpi, Teresina, Brazil.

Rose, F., Simpson, T., Ott, J., Manning, R. & Martin, J. (2010) Survival of western cottonmouths (*Agkistrodon piscivorus leucostoma*) in a pulsing environment. *The Southwestern Naturalist*, 55, 11–15.

SEMA (2022) *Portaria N 146/2022. Lista Vermelha dos Anfíbios e Répteis Continentais Ameaçados de Extinção do Ceará*. Secretaria do Meio Ambiente, Fortaleza, Ceará, Brazil.

Silva, A.M., Colombini, M., Moura-Da-Silva, A.M., Souza, R.M., Monteiro, W.M. & Bernarde, P.S. (2019a) Ethno-knowledge and attitudes regarding snakebites in the Alto Juruá region, western Brazilian Amazonia. *Toxicon*, 171, 66–77.

Silva, B.R., Corrêa, L.M., Gennari, D., Dias, R.A., Abrahão, C., Landroz, E.M.J. et al. (2019b) Projeto de conservação Jiboia do Ribeira, *Corallus cropanii* (Hoge, 1953). Galoá. proceedings.science/cbh-2019/trabalhos/projeto-de-conservacao-jiboia-do-ribeira-corallus-cropanii-hoge-1953?lang = pt-br [accessed 4 October 2024].

Silva, J.L., Fonseca, W.L., Silva, A.M., Amaral, G.L.G., Ortega, G.P., Oliveira, A.S. et al. (2020) Venomous snakes and people in a floodplain forest in the western Brazilian Amazon: potential risks for snakebites. *Toxicon*, 187, 2–244.

Silveira, A.P., Loiola, M.I.B., Gomes, V.S., Lima-Ver, L.W., Oliveira, T.S., Silva, E.F. et al. (2020) Flora of Baturité, Ceará: a wet island in the Brazilian semiarid. *Floresta e Ambiente*, 27, e20180320.

Souza, E. & Almeida-Santos, S.M. (2022) Reproduction in the bushmaster (*Lachesis muta*): uterine muscular coiling and female sperm storage. *Acta Zoologica*, 103, 244–255.

Steen, D. (2010) Snakes in the grass: secretive natural histories defy both conventional and progressive statistics. *Herpetological Conservation and Biology*, 5, 183–188.

Wangyal, J.T., Bower, E., Tshewang, S., Wangi, D., Rinchen, K., Phutsho, S. & Tashi, C. (2020) New herpetofaunal records from the Kingdom of Bhutan obtained through citizen science. *Herpetological Review*, 51, 790–798.

WhatsApp (2021) *WhatsApp*. Meta Platforms, Menlo Park, USA. whatsapp.com [accessed July 2025].

Zamudio, K.R. & Greene, H.W. (1997) Phylogeography of the bushmaster (*Lachesis muta*: Viperidae). *Biological Journal of the Linnean Society*, 62, 421–442.

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