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ECOSYSTEMS

The iNaturalist platform as a source of data to study amphibians in Brazil

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Abstract: Based on debilitating recent budget cuts for science, Brazilian researchers had to find alternative ways to continue scientific production. Here we provide a perspective for the use of citizen-science data deposited in the iNaturalist platform as an alternative source of data to support biodiversity research. Observations contributed by volunteers can be analyzed at large spatial and temporal scales and can respond to questions in behavioral and population ecology. We analyzed this potential through the example of Brazilian amphibians, a group that is less studied worldwide than birds. In fact, to our knowledge, only two studies have been published that are based on citizen-science data for Brazilian amphibians. At the time of writing, the iNaturalist platform has over 14,800 research grade observations from Brazil, representing 698 species, a number increasing daily. Compared to other species-rich countries, volunteer-collected datasets from Brazil cover a relatively high taxonomic diversity (61%), providing a plethora of valuable data. Despite this potential, there are large spatial gaps in sampling in Brazil. Here we encourage established and budding herpetologists not only to use the platform to retrieve data, but also to contribute to iNaturalist actively, with new observations, as well as by identifying species in existing records.

Key words: Brazil, budget cuts, community scientists, frogs, knowledge gaps.

INTRODUCTION

Biodiversity research conducted exclusively by professional scientists is spatially, temporally, and financially limited (Tulloch et al. 2013). This often results in restricted data collection, particularly considering the difficulties of conducting long-term and large-scale field-based research projects. On the other hand, in the long term and after an initial investment and ongoing management, crowdsourcing approaches or projects with data collected by a large number of volunteers can result in large sample sizes from extensive areas for a relatively low cost compared to data collected exclusively by professionals (Devictor et al. 2010, Newman et al. 2011). The definition *sensu lato* of citizen science is knowledge construction based on the participation of a network of people (Bonney et al. 2009b). Citizen science can be described as a research technique that relies on the public to gather scientific information (Bonney et al. 2009b, Kullenberg & Kasperowski 2016). This approach usually involves a project manager, who is often a scientist, to engage a team of volunteers to collect data (Haklay et al. 2021). In some projects, the public also collaborate with project design and analysis (Bonney et al. 2009a). However, regardless of the degree of public participation, the interaction will benefit both scientists and the general public, since the process creates a large amount of data, while citizens actively participate in knowledge production. For conservation biology and other applied research fields, both benefits are substantial (Gray et al. 2017).

In Brazil, scientific publications based on citizen-collected data mostly focus on birds (Schubert et al. 2019, Alexandrino et al. 2022, de Souza et al. 2022). Nevertheless, some articles have been published on arthropods (Mesaglio et al. 2021), marine species (Machado et al. 2021) and primates (Nery et al. 2021). While amphibians are popular subjects of citizen science in other countries (e.g., *FrogWatch* in North America (AZA 2021), *FrogID* in Australia (Australian Museum 2021), and *Frogs on the Road* in the EU (Konnad Teel 2021)), we only know of two recent studies on the topic in Brazil (Forti et al. 2022a, b) and a search of the Scopus database did not return any other publications. The participation of Brazilian volunteers in environmental research is still considered limited (Cunha et al. 2017), nevertheless, there are many ongoing national initiatives that are producing interesting results. Some of these local or national monitoring programs deserve to be highlighted, such as *Wikiaves* (for birds - https://www.wikiaves.com.br/), *DeOlhoNosCorais* (for corals – https://serrapilheira.org/projetos/deolhonoscorais/), *Sistema Urubu* (for roadkill – https://sistemaurubu.com.br) and *Guardiões da Chapada* (for insect pollinators – Viana et al. 2022). Unfortunately, some of these initiatives do not facilitate the downloading of data *en masse*, do not openly share data or lack a platform to access the database, which leads to their underutilization (Tulloch et al. 2013).

The exponential growth of non-structured biodiversity data on online citizen science platforms (i.e., web pages that connect people who share scientific observations) can open new avenues to answer scientific questions with regard to various biological groups (Tulloch et al. 2013). In tropical countries, many amphibian species are poorly known, however, most of them are relatively easy to observe and are often charismatic and popular among observers (Jimenez & Lindemann-Matthies 2015a, b). These characteristics make amphibians good subjects for new crowdsourcing projects or to be studied using data from existing generalist citizen science platforms. In addition, the latter option brings enormous benefits to scientists with restricted financial means. In particular, large amounts of data are often available, leaving researchers to focus on cleaning, organizing, analyzing and interpreting the data to answer study questions. Nevertheless, understanding and correcting for biases (either by filtering data or by applying various analytical methods) are crucial to obtain credible results (Szabo et al. 2012).

While starting a new citizen science project would imply the costs of planning the project, recruiting, training and retention of participants, developing protocols, providing training material and other online resources, selecting adequate methods for the evaluation and validation of records, the use of an already consolidated platform can directly facilitate data access at no additional cost. In this context, iNaturalist is one of the most popular citizen science platforms that makes millions of biodiversity observations openly available, virtually all around the planet (https://www.inaturalist.org). The global community of contributors who submit photos and sound recordings to iNaturalist surpasses 3,000,000. iNaturalist also has over 280,000 identifiers with different taxonomical specialties. While the collected data are available to be used in different studies with regard to ecology, biogeography and conservation biology, the availability, quality and taxonomic coverage varies temporally and spatially around the world. Low-income countries in general and those in tropical zones in particular, have fewer observations and observers than high-income nations (Hughes et al. 2021). Evidently, regions with few observations and lower taxonomic coverage have limited opportunities to support the production of knowledge on biodiversity. Therefore, in this study we focus on the following study question: "To what degree citizen science has contributed and has the potential to contribute to our knowledge on amphibians in Brazil?" Based on this question, we provide a vision for Brazil to study amphibians using data in the iNaturalist database. We describe the relevant data available through iNaturalist the number of observations, as well as spatial and species coverage, and compare the representativeness of amphibian diversity among 202 countries. We provide this inter-country comparison to demonstrate the state of citizen science in Brazil compared to other countries in the world. In addition, we discuss how metadata can be accessed and how photographs can serve as a source of data. In conclusion, we discuss the potential of citizen science data for amphibian research in Brazil.

MATERIALS AND METHODS

We filtered for research grade amphibian observations on iNaturalist on February 25, 2022. Observations are categorized as research grade when at least two people have submitted identifications to an observation and at least two-thirds of the identifiers agree on the identification of a taxon. We obtained the number of species, observations, observers and identifiers for 202 countries. We also obtained species diversity (i.e., the total number of species) for these countries using AmphibiaWeb (2021). Dividing the number of species represented in the iNaturalist database by the number of species on AmphibiaWeb, we calculated species coverage for each country. All statistical analysis were carried out in R version 4.1.0 (R Core Development Team 2020). We tested the effect of species diversity on the number of observations using a Poisson generalized linear model after checking for statistical assumptions. We also modeled species coverage in relation to the number of observations and species diversity using beta regression through the *betareg* R package (Cribari-Neto & Zeileis 2010). As we fitted distribution probability to proportional values, we divided the percentages by 100, transforming species coverage to values between 0 and 1. We substituted values of 1 (complete coverage) by 0.999 in order to run the beta regression. We elaborated graphs using the *ggplot2* package (Wickham 2016) to highlight the position of Brazil in relation to other countries based on the interaction between the above-mentioned variables. To illustrate spatial gaps, we produced a heat map based on the geographical locations of amphibian observations with exact coordinates (n = 8190) in Brazil using QGIS version 3.20 (QGiS Development Team 2021).

RESULTS

With 698 species (as of 21 September, 2022), Brazil had the highest amphibian diversity among all countries on iNaturalist, representing 61% of the described species in the country (Supplementary Material -Table SI). These species were represented by almost 14,866 observations submitted by 2906 observers and identified by 1118 collaborators. Species diversity affected the number of observations of amphibians in the platform (AIC = 556,0388, estimate = 3.024×10^{-03}, z-value = 1150, $p < 2 \times 10^{-16}$). Countries with high amphibian species diversity had more observations than species-poor countries (Figure 1a). South American countries with high species diversity, such as Brazil, Colombia, and Ecuador had a substantial contribution to the iNaturalist database (around 10,000 observations each). The beta regression

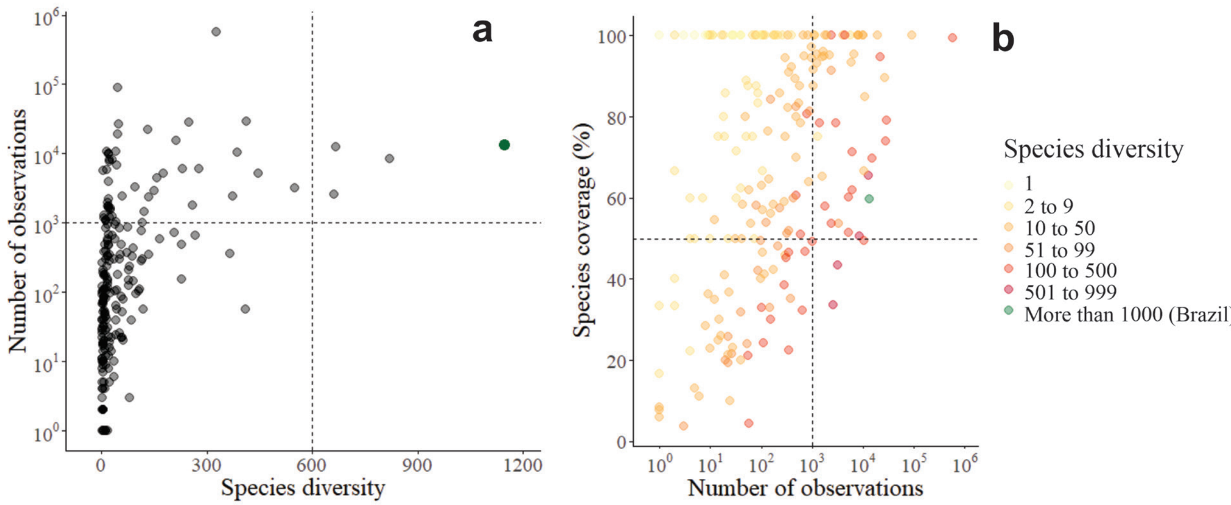

Figure 1. (a) Relation between species diversity (total number of species based on AmphibiaWeb) and the number of observations on iNaturalist. Each circle represents a country and darker circles indicate that the number of observations and species diversity among multiple countries fall to the same location. The green filled dot in the upper right quadrat represents Brazil. (b) Relation between the number of observations and species coverage on iNaturalist. The color of the circles indicates a gradient of species diversity with the green dot in the upper right quadrat indicating Brazil with over 1000 amphibian species. Note that for both graphs the axes with number of observations are on a logarithmic scale.

model predicted that the number of observations and the species diversity for each country affected the proportion of species coverage (phi coefficient = 1.9254, z-value = 11.2, $p < 2*10^{-16}$). While the number of observations positively contributed to the model (estimate = $4.361*10^{-06}$, z-value = 2.375, p = 0.0175 – Figure 1b), species diversity negatively affected species coverage (estimate = – $2.345*10^{-03}$, z-value = – 4.202, p = $2.65*10^{-05}$). Some countries (especially islands, such as Bahrain and Saint Helena) with high species coverage and few observations did not fit well to the model by also having few (often < 9) species. Many countries had a complete (100%) species coverage and the number of species was higher than predicted by the model (Figure 1b). Compared to other countries, Brazil had a high number of observations, as well as high species coverage (Table SI) in the iNaturalist database. However, most observations in Brazil come from the southeast, with large gaps in central western and northern regions, especially in Amazonia (Figure 2).

DISCUSSION

Our results suggest that megadiverse countries should increase social engagement to improve the taxonomic coverage of citizen science data and therefore increase their applicability. Evidently, a higher number of observers will increase the number of observations on the iNaturalist platform, even though a large proportion of observations are submitted by “superobservers” (Rosenblatt et al. 2022). Brazil has the highest amphibian diversity in the world and based on our model this represents a particular challenge. This challenge could be tackled by more observers in order to increase species coverage in the iNaturalist dataset. Observers should increase efforts in areas with large spatial gaps. Nevertheless, Brazil still has a relatively high taxonomic coverage on this platform compared to other species-rich countries, such as Peru and Venezuela. While species misidentifications and temporal and geographical biases are known to plague

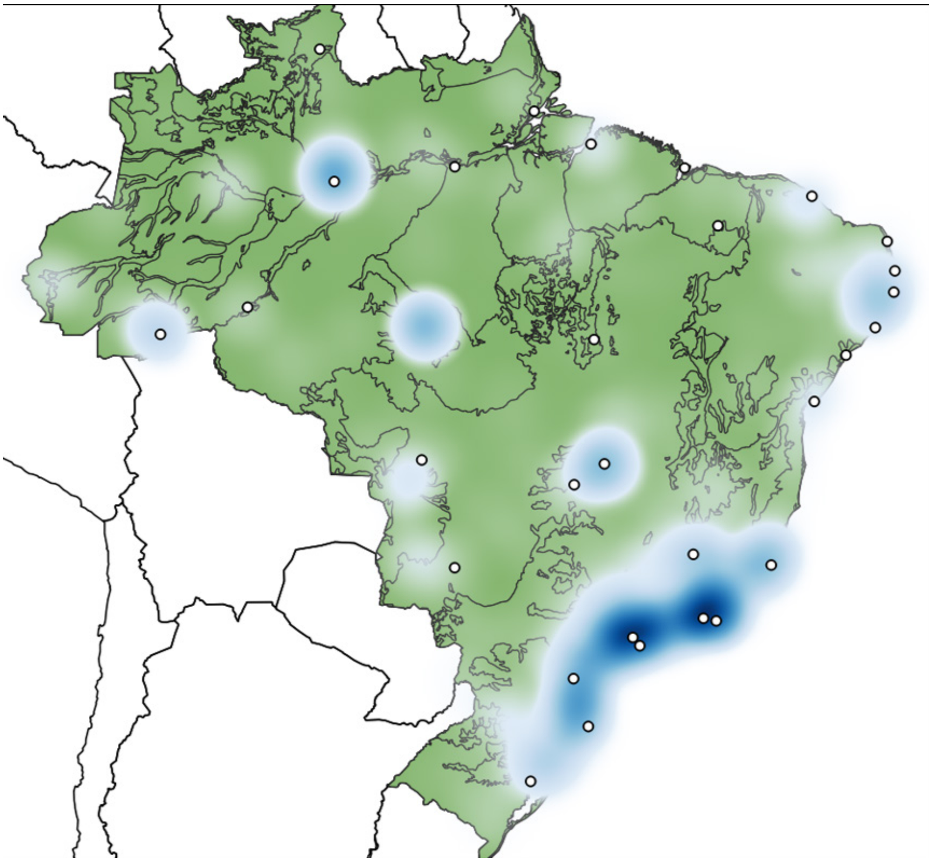

Figure 2. Heat map of anuran observations in Brazil in iNaturalist (n = 8190). Darker blue shades represent a higher density of observations concentrated around major cities.

citizen science data (Lukyanenko et al. 2016, Szabo et al. 2012), observations in the iNaturalist dataset can potentially contribute to the study of Brazilian amphibians, based on the relatively high number of observations submitted by thousands of observers and identified by other contributors. Initiatives originating from or involving community scientists can complement data from traditional sources, such as museum collections (Spear et al. 2017) and scientific expeditions (Deutsch & Agostini 2017).

Many scientists who are working with citizen-collected datasets for the first time can be intimidated by the uncertainties with regard to species misidentifications (see for instance Gorleri & Areta 2022) and the issues related to presence-only data. However, spatially and temporally unstructured or semi-structured occurrence data have been shown to provide valuable information with regard to species distributions and trends (Szabo et al. 2010). In addition, statistical tools, such as those adapted for phenological studies in the *phenesse* R package (Belitz et al. 2020), can address some of these issues. While concerns about the reliability of observations made by non-professional scientists need to be considered, observations obtained by traditional means are rarely validated by a community of experts. In a citizen science platform, such as iNaturalist, observations are available to a community of peers, many of them professional biologists, who can give scientific legitimacy to taxon identifications.

Science is presumably about ideas, theory, rigor, and sensory data (i.e., observations). The citizen-science approach has inspired scientists to produce knowledge with public involvement about a plethora of topics. Among others, citizen-collected data have been used to monitor range extension (Hidalgo-Mora et al. 2021), invasive species (Encarnação et al. 2021, Johnson & Yates 2020), and diseases (Ecoclub Amphibian Group et al. 2016). Photographs, sound recordings, and videos shared on citizen-science platforms allow to study behavior, including trophic interactions (Maritz & Maritz 2020, Callaghan et al. 2021) and habitat use (Marsh et al. 2017). With regard to conservation, citizen-collected data have been used to describe the effects of urbanization (Mitchell et al. 2020, Westgate et al. 2015), roads (Marsh et al. 2017) and bushfires (Rowley et al. 2020).

Similar approaches can be implemented at national scales, as a large amount of data are already available (e.g., 14,866 amphibian observations identified at species level in Brazil). Metadata and natural history observations can be easily extracted from photos, videos and sound recordings on the website. Secondary data extracted from images have already been used to improve our knowledge on amphibian natural history at large spatial scales (Forti et al. 2022a,b). For specific large projects that analyze phenology or distribution, metadata can be extracted using the *rinat* package (Barve & Hart 2021), which obtains data through the Application Programming Interface (API).

Data from projects using the iNaturalist platform can be suitable for analysis by undergraduate or graduate students or even senior researchers restricted by quarantine measures or federal budget cuts prohibiting field trips for data collection. Citizen science can also improve the attitudes of the general public towards amphibians and other threatened species (Reynolds et al. 2018, Steven et al. 2017). Therefore, we encourage biologists occupying senior academic positions to use the iNaturalist platform for project-based learning at their educational institutions (Forti in press 2023). This approach can nurture general values of science and nature protection (Niemiller et al. 2021). A simple project to list frog species around a university campus can be a useful initiative for students to improve their natural history knowledge and affinity for biodiversity conservation (Reynolds et al. 2018). In conclusion, we advocate that citizen science projects should be encouraged in Brazil and other countries with high amphibian diversity. Northern and central western Brazil in particular lack amphibian observations and could be targeted by visiting or local naturalists. We also showed the potential to study amphibians in Brazil using citizen science, in particular through the iNaturalist platform. Finally, we expect that once researchers understand and use this approach, they will also spread the information about the value of this tool.

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SUPPLEMENTARY MATERIAL

Table SI.

How to cite

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Both authors conceived the idea, designed the research, participated in revisions, edited the manuscript, and approved the submission. LRF produced and analysed data and wrote the manuscript draft.