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Bromeliad-Dwelling Frogs Revealed by Citizen Scientists

Cássio Zocca [1,2,*], Natalia Pirani Ghilardi-Lopes [2,3] and Rodrigo Barbosa Ferreira [1,4]

[1] Projeto Bromélias, Programa de Pós-Graduação em Biologia Animal, Universidade Federal do Espírito Santo, Vitória 29075-910, ES, Brazil; rodrigoecologia@yahoo.com.br
[2] Instituto Nacional da Mata Atlântica (INMA), Av. José Ruschi, Santa Teresa 29650-000, ES, Brazil; natalia.lopes@ufabc.edu.br
[3] Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, São Bernardo do Campo 09606-045, SP, Brazil
[4] Instituto de Ciências Biológicas, Universidade de Brasília, Brasília 70910-900, DF, Brazil
* Correspondence: zoccabio@hotmail.com

Abstract: Understanding species composition across temporal and spatial scales through participatory monitoring has contributed to the development of several studies focused on biodiversity in Neotropical ecosystems. Habitat loss and the illegal collection of bromeliads pose significant threats to bromeligenous frogs, which depend on the rainwater collected between bromeliad leaves for egg and tadpole development. In this study, we compiled a comprehensive dataset of bromeligenous frogs using data from "Projeto Bromélias" on the iNaturalist citizen science platform. Our dataset includes records of 85 species of bromeligenous frogs, representing 52% of the 164 known species that reproduce in bromeliads. These species belong to 33 genera and 10 families and are reported from 18 countries. Twenty-eight species are listed in threatened categories on a global scale. Our findings extended the known geographic distribution of four species. Notably, the green and black poison dart Frog, *Dendrobates auratus*, was recorded as a non-native species in Hawaii, USA. Regarding the temporal data, the number of bromeligenous records increased substantially after 2009. This study highlights the value of citizen science platforms as important tools for monitoring bromeliad inhabitants and contributing to management and conservation initiatives.

Keywords: Anura; bromeliad frogs; citizen science; conservation status; crowdsourcing; open databases; public participation

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1. Introduction

Estimating and monitoring biodiversity is crucial for understanding species composition across time and space, which in turn facilitates effective management and conservation strategies [1–3]. However, spatial and temporal sampling gaps in biodiversity estimates are common throughout the Neotropical region due to limited research funding, a small number of scientists, and the region's exceptionally high biodiversity [4–6].

Citizen science online platforms offer a promising solution to these sampling gaps by compiling broad-scale biodiversity data from the public, who upload geo-located photographs of observed wildlife [7–9]. Indeed, citizen science data have already contributed to a wide range of studies on birds [10], corals [11], sharks [12], bees [13], and frogs [14,15].

Citizen science projects that focus on frogs have generated substantial data at local, state, national, and global scales (e.g., [14,16]). Frogs are relatively easy for citizen scientists to record due to their slow locomotion, distinct colors, species-specific vocalizations, and frequent presence in human-altered areas. Gathering global occurrence data is an urgent priority [17,18], especially for highly threatened taxa such as bromeliad-dwelling frogs (hereafter bromeligenous), which are among the most imperiled animal groups on the planet [19]. Indeed, many of the 164 known species of frogs specialized in rearing their tadpoles in the rainwater accumulated between the leaves of bromeliads [20,21] face extinction due to rising air temperatures, habitat loss, and the harvesting of bromeliads from natural habitats for ornamental purposes [22,23].

The family Bromeliaceae comprises 3780 species primarily found in South America, Central America, the Caribbean Islands, and southern North America, with a single species in Africa [24]. Due to their ornamental value, bromeliads are often cultivated in backyards, gardens, and indoors [25] and have been introduced to various regions worldwide [26]. This introduction can potentially extend the range of associated frog species beyond their native habitats [27,28]. However, the trade of bromeliads poses a threat to wild species due to predatory and illegal harvesting practices. In Brazil, several ornamental species are threatened [29] due to overharvesting, which also endangers their associated frog species [23]. Citizen scientists can contribute to the conservation of bromeligenous frogs by providing data on their distribution across both native and novel habitats over time.

"Projeto Bromélias" conducts field research and outreach activities aimed at conserving organisms associated with bromeliads, including bromeligenous frogs [30]. In this study, we present an exploratory analysis of bromeligenous frog records from the "Projeto Bromélias" database on the iNaturalist platform, offering insights into their richness, geographic distribution, and conservation status. We discuss our findings within the context of the citizen science framework and its potential for monitoring bromeligenous frogs.

2. Materials and Methods

We established "Projeto Bromélias" on iNaturalist (www.inaturalist.org/projects/projeto-bromelias) to collect and analyze records of bromeligenous frogs worldwide. On the iNaturalist platform, a record is classified as "Needs ID" when the species identification is not agreed upon by the iNaturalist community (mainly professionals in biological sciences) but meets specific technical criteria, such as having a date, geographic coordinates, photos or sounds, and not representing a captive or cultivated organism. Records that do not meet these criteria are classified as "Casual". For this study, we only considered the 6159 records classified as "Research grade". indicating a consensus on species identification within the iNaturalist community.

From the iNaturalist database, we filtered 164 species of bromeligenous frogs, with 140 species based on [21] and the remaining 24 species sourced from secondary literature. Our final dataset comprised obligate and facultative bromeligenous species. We obtained the records from iNaturalist in December 2021 and considered the following metadata for analysis: date, user login, quality grade, latitude and longitude coordinates, locality, and species identification. Taxonomic classification followed Amphibian Species of the World: An Online Reference [31].

We initially selected bromeligenous frogs from their native ranges across Neotropical countries, followed by records from other countries, to investigate introductions into novel areas. Notably, some Neotropical countries, such as Argentina, the Bahamas, Chile, El Salvador, Paraguay, and Uruguay, do not harbor bromeligenous frogs. To identify possible range expansions within Neotropical countries for the recorded species, we analyzed their spatial distribution following the Amphibian Species of the World online database [31].

As an exploratory analysis of the dataset, we examined the absolute and relative numbers of families, genera, and species. Additionally, we assessed potential biases and gaps in the representation of bromeligenous frogs by analyzing the number of records over time (from the first record in 1981 until 31 December 2021), the geographical distribution of the records, the most frequently recorded species (N > 50 records), and the conservation status of each recorded species (based on [19]).

We created a heat map using a kernel density estimation (i.e., a density map) from the location data of the bromeligenous frogs with the heatmap plugin in QGIS version 3.22.4 [32]. To ensure smoother color attenuation, we applied a logarithmic function with a base of 10 for the color scale.

3. Results

Among families, Dendrobatidae had the highest number of records and species (4880 records; 86%; 36 species; 42%), followed by Hylidae (360 records; 6%; 26 species; 31%). Notably, only the family Centrolenidae, which comprises one species of bromeligenous frog (*Cochranella riveroi*), had not been recorded by the iNaturalist community.

Within genera, *Oophaga* (2340 records; 41%) and *Dendrobates* (1780 records; 31%) had the highest number of records, while *Ranitomeya* (11 species; 13%) and *Andinobates* (10 species; 12%) had the highest number of species. Eight genera (*Allobates*, *Ameerega*, *Cochranella*, *Ctenophryne*, *Minyobates*, *Myersiohyla*, *Nyctimantis*, and *Tepuihyla*; 24%) had no records in the iNaturalist community.

Among species, *Oophaga pumilio* (1992 records; 35%; Figure 1A) and *Dendrobates auratus* (1672 records; 29%; Figure 1B) had the highest number of records, followed by *Diasporus diastema* (247 records; 4%; Figure 1C). Forty-four species (52%) had fewer than 10 records (Table 1), and 63 species had not been recorded by the iNaturalist community.

Table 1. Bromeligenous frog species recorded in the Neotropical region by citizen scientists from the Projeto Bromélias on iNaturalist. N = number of records submitted to iNaturalist; N% = percentage in relation to the total number of records. Conservation status according to IUCN (2022): CR (Critically Endangered), EN (Endangered), VU (Vulnerable), NT (Near Threatened), LC (Least Concern), DD (Data Deficient), and NE (Not Evaluated).

Species (Organized by Families)	Common Names	N (N%)	Conservation Status
Aromobatidae			
Anomaloglossus beebei (Noble, 1923)	Golden Rocket Frog	24 (<1%)	EN
Brachycephalidae			
Ischnocnema nasuta (Lutz, 1925)	Pointy-Nosed Robber Frog	3 (<1%)	LC
Ischnocnema venancioi (Lutz, 1958)	Venancio's Robber Frog	2 (<1%)	LC
Bufonidae			
Dendrophryniscus berthalutzae Izecksohn, 1994	NA	3 (<1%)	LC
Dendrophryniscus brevipollicatus Jiménez de la Espada, 1870	Coastal Tree Toad	14 (<1%)	LC
Frostius pernambucensis (Bokermann, 1962)	Frost's Toad	1 (<1%)	LC
Melanophryniscus alipioi Langone, Segalla, Bornschein and de Sá, 2008	NA	3 (<1%)	DD
Melanophryniscus milanoi Baldo, Bornschein, Pie, Firkowski, Ribeiro and Belmonte-Lopes, 2015	NA	1 (<1%)	NE
Dendrobatidae			
Adelphobates quinquevittatus (Steindachner, 1864)	Rio Madeira Poison Frog	10 (<1%)	LC
Andinobates bombetes (Myers and Daly, 1980)	Cauca Poison Frog	55 (1%)	VU
Andinobates daleswansoni (Rueda-Almonacid, Rada, Sánchez-Pacheco, Velásquez-Álvarez and Quevedo-Gil, 2006)	NA	3 (<1%)	EN
Andinobates dorisswansonae (Rueda-Almonacid, Rada, Sánchez-Pacheco, Velásquez-Álvarez and Quevedo-Gil, 2006)	NA	6 (<1%)	VU
Andinobates fulguritus (Silverstone, 1975)	Yellowbelly Poison Frog	27 (<1%)	LC
Andinobates minutus (Shreve, 1935)	Bluebelly Poison Frog	27 (<1%)	LC
Andinobates opisthomelas (Boulenger, 1899)	Andean Poison Frog	56 (1%)	VU
Andinobates tolimensis (Bernal-Bautista, Luna-Mora, Gallego and Quevedo-Gil, 2007)	NA	1 (<1%)	VU
Andinobates victimatus Márquez, Mejía-Vargas, Palacios-Rodríguez, Ramírez-Castañeda and Amézquita, 2017	NA	11 (<1%)	EN

Table 1. *Cont.*

Species (Organized by Families)	Common Names	N (N%)	Conservation Status
Andinobates virolinensis (Ruiz-Carranza and Ramírez-Pinilla, 1992)	Santander Poison Frog	7 (<1%)	VU
Colostethus ruthveni Kaplan, 1997	NA	14 (<1%)	NT
Dendrobates auratus (Girard, 1855)	Green and Black Poison Frog	1672 (29%)	LC
Dendrobates leucomelas Steindachner, 1864	Yellow-headed Poison Frog	27 (<1%)	LC
Dendrobates tinctorius (Cuvier, 1797)	Dyeing Poison Frog	81 (1%)	LC
Excidobates condor Almendáriz, Ron and Brito M., 2012	NA	1 (<1%)	EN
Excidobates mysteriosus (Myers, 1982)	Maranon Poison Frog	2 (<1%)	EN
Oophaga granulifera (Taylor, 1958)	Granular Poison Frog	171 (3%)	VU
Oophaga histrionica (Berthold, 1845)	Harlequin Poison Frog	44 (<1%)	CR
Oophaga lehmanni (Myers and Daly, 1976)	Lehmann's Poison Frog	9 (<1%)	CR
Oophaga pumilio (Schmidt, 1857)	Strawberry Poison Frog	1992 (35%)	LC
Oophaga sylvatica (Funkhouser, 1956)	NA	116 (2%)	NT
Oophaga vicentei (Jungfer, Weygoldt and Juraske, 1996)	NA	8 (<1%)	EN
Phyllobates lugubris (Schmidt, 1857)	Lovely Poison Frog	56 (1%)	LC
Phyllobates vittatus (Cope, 1893)	Golfodulcean Poison Frog	197 (3%)	VU
Ranitomeya amazonica (Schulte, 1999)	NA	29 (<1%)	DD
Ranitomeya benedicta Brown, Twomey, Pepper and Sanchez-Rodriguez, 2008	NA	1 (<1%)	VU
Ranitomeya fantastica (Boulenger, 1884)	Red-headed Poison Frog	21 (<1%)	VU
Ranitomeya flavovittata (Schulte, 1999)	NA	7 (<1%)	LC
Ranitomeya reticulata (Boulenger, 1884)	Redback Poison Frog	55 (1%)	LC
Ranitomeya toraro Brown, Caldwell, Twomey, Melo-Sampaio and Souza, 2011	NA	8 (<1%)	NE
Ranitomeya uakarii (Brown, Schulte and Summers, 2006)	NA	14 (<1%)	LC
Ranitomeya vanzolinii (Myers, 1982)	Brazilian Poison Frog	5 (<1%)	LC
Ranitomeya variabilis (Zimmermann and Zimmermann, 1988)	Zimmermann's Poison Frog	100 (2%)	DD
Ranitomeya ventrimaculata (Shreve, 1935)	Amazonian Poison Frog	44 (<1%)	LC
Ranitomeya yavaricola Pérez-Peña, Chávez, Twomey and Brown, 2010	NA	2 (<1%)	DD
Eleutherodactylidae			
Adelophryne maranguapensis Hoogmoed, Borges and Cascon, 1994	NA	3 (<1%)	EN
Diasporus diastema (Cope, 1875)	Caretta Robber Frog	247 (4%)	LC
Diasporus vocator (Taylor, 1955)	Agua Buena Robber Frog	11 (<1%)	LC
Eleutherodactylus auriculatoides Noble, 1923	Northern Hammer Frog	3 (<1%)	EN
Eleutherodactylus flavescens Noble, 1923	Yellow Split-toed Frog	14 (<1%)	NT
Eleutherodactylus wetmorei Cochran, 1932	Tiburon Whistling Frog	4 (<1%)	VU
Hemiphractidae			
Flectonotus fitzgeraldi (Parker, 1934)	Dwarf Marsupial Frog	28 (<1%)	LC

Table 1. *Cont.*

Species (Organized by Families)	Common Names	N (N%)	Conservation Status
Flectonotus pygmaeus (Boettger, 1893)	Puerto Cabello Treefrog	4 (<1%)	LC
Fritziana goeldii (Boulenger, 1895)	Colonia Alpina Treefrog	29 (<1%)	LC
Fritziana mitus Walker, Wachlevski, Nogueira da Costa, Nogueira-Costa, Garcia and Haddad, 2018	NA	7 (<1%)	NE
Fritziana tonimi Walker, Gasparini and Haddad, 2016	NA	1 (<1%)	NE
Fritziana ulei (Miranda-Ribeiro, 1926)	NA	1 (<1%)	NE
Gastrotheca fissipes (Boulenger, 1888)	Igaracu Marsupial Frog	2 (<1%)	LC
Hylidae			
Bokermannohyla astartea (Bokermann, 1967)	Paranapiacaba Treefrog	2 (<1%)	LC
Bromeliohyla bromeliacia (Schmidt, 1933)	Bromeliad Treefrog	12 (<1%)	LC
Bromeliohyla dendroscarta (Taylor, 1940)	Greater Bromeliad Treefrog	1 (<1%)	EN
Bromeliohyla melacaena (McCranie and Castañeda, 2006)	NA	4 (<1%)	EN
Ecnomiohyla minera (Wilson, McCranie and Williams, 1985)	Guatemala Treefrog	1 (<1%)	VU
Isthmohyla picadoi (Dunn, 1937)	Volcan Barba Treefrog	3 (<1%)	LC
Ololygon alcatraz (Lutz, 1973)	Alcatraz Snouted Treefrog	1 (<1%)	CR
Ololygon arduoa (Peixoto, 2002)	NA	6 (<1%)	DD
Ololygon perpusilla (Lutz and Lutz, 1939)	Bandeirantes Snouted Treefrog	25 (<1%)	LC
Osteocephalus deridens Jungfer, Ron, Seipp and Almendáriz, 2000	NA	11 (<1%)	LC
Osteocephalus fuscifacies Jungfer, Ron, Seipp and Almendáriz, 2000	NA	16 (<1%)	LC
Osteocephalus oophagus Jungfer and Schiesari, 1995	Oophagous Slender-legged Treefrog	45 (<1%)	LC
Osteocephalus planiceps Cope, 1874	NA	108 (2%)	LC
Osteopilus crucialis (Harlan, 1826)	NA	1 (<1%)	VU
Osteopilus marianae (Dunn, 1926)	Jamaican Yellow Treefrog	1 (<1%)	EN
Osteopilus ocellatus (Linnaeus, 1758)	Jamaican Laughing Treefrog	12 (<1%)	NT
Osteopilus wilderi (Dunn, 1925)	Jamaican Green Treefrog	2 (<1%)	VU
Phyllodytes edelmoi Peixoto, Caramaschi and Freire, 2003	NA	20 (<1%)	DD
Phyllodytes gyrinaethes Peixoto, Caramaschi and Freire, 2003	NA	1 (<1%)	DD
Phyllodytes luteolus (Wied-Neuwied, 1821)	Yellow Heart-Tongued Frogs	19 (<1%)	LC
Phyllodytes melanomystax Caramaschi, Silva and Britto-Pereira, 1992	Bahia Heart-Tongued Frogs	1 (<1%)	LC
Phytotriades auratus (Boulenger, 1917)	Trinidad Golden Treefrog	1 (<1%)	EN
Triprion spinosus (Steindachner, 1864)	Coronated Treefrog	67 (1%)	NT
Leptodactylidae			
Crossodactylodes izecksohni Peixoto, 1983	Izecksohn's Bromeliad Frogs	1 (<1%)	NT
Physalaemus spiniger (Miranda-Ribeiro, 1926)	Iguape Dwarf Frog	11 (<1%)	LC
Microhylidae			
Chiasmocleis antenori (Walker, 1973)	Ecuador Silent Frog	5 (<1%)	LC

Table 1. *Cont.*

Species (Organized by Families)	Common Names	N (N%)	Conservation Status
Strabomantidae			
Pristimantis acuminatus (Shreve, 1935)	Canelos Robber Frog	24 (<1%)	LC
Pristimantis aureolineatus (Guayasamin, Ron, Cisneros-Heredia, Lamar and McCracken, 2006)	NA	4 (<1%)	LC
Pristimantis waoranii (McCracken, Forstner and Dixon, 2007)	NA	3 (<1%)	DD
Total		5692	

Figure 1. Bromeligenous frog species most recorded by the iNaturalist community (**A**–**C**) and some additional threatened species (**D**–**O**), along with their conservation status (indicated in parentheses): (**A**) *Oophaga pumilio* (LC), (**B**) *Dendrobates auratus* (LC), (**C**) *Diasporus diastema* (LC), (**D**) *Phyllobates vittatus* (VU), (**E**) *Oophaga granulifera* (VU), (**F**) *Andinobates opisthomelas* (VU), (**G**) *Andinobates bombetes* (VU), (**H**) *Oophaga histrionica* (CR), (**I**) *Anomaloglossus beebei* (EN), (**J**) *Ranitomeya fantastica* (VU), (**K**) *Andinobates victimatus* (EN), (**L**) *Adelophryne maranguapensis* (EN), (**M**) *Oophaga lehmanni* (CR), (**N**) *Ololygon alcatraz* (CR), and (**O**) *Excidobates mysteriosus* (EN). Photographs by citizen scientists Steve Bentsen (**A**), Rory Wills (**B**), Fabian A. Boetzl (**C**), Josh V. Addesi (**D**), Laurent Hesemans (**E**), Andrés M.F. Cano (**F**), David Monroy (**G**), Cristian G. Acosta (**H**), Peter G. Kaestner (**I**), Dennis Nilsson (**J**,**K**), Pedro Peloso (**L**), Andrés M.F. Cano (**M**), Diego Santana (**N**), and Danny Lawrence (**O**). CR = Critically Endangered, EN = Endangered, and VU = Vulnerable.

Regarding conservation status, 28 species (33%) were classified under threatened categories globally (Table 1). Specifically, three species (4%) were Critically Endangered (CR), 14 species (17%) were Vulnerable (VU), and 12 species (14%) were Endangered (EN). Additionally, eight species (9%) were Data Deficient (DD), and five species (6%) required assessment (NE).

Among the threatened species, the poison frog *Phyllobates vittatus* had the highest number of records (197; 4%; Figure 1D), followed by *Oophaga granulifera* (171 records; 3%; Figure 1E), *Andinobates opisthomelas* (56 records; 1%; Figure 1F), *Andinobates bombetes* (55 records; 1%; Figure 1G), *Oophaga histrionica* (44 records; <1%; Figure 1H), *Anomaloglossus beebei* (24 records; <1%; Figure 1I), *Ranitomeya fantastica* (21 records; <1%; Figure 1J), and *Andinobates victimatus* (11 records; <1%; Figure 1K). Most threatened species (20 species; 71%) had fewer than 10 records, including *Adelophryne maranguapensis* (3 records; <1%; Figure 1L), *Oophaga lehmanni* (9 records; <1%; Figure 1M), *Ololygon alcatraz* (1 record; <1%; Figure 1N), and *Excidobates mysteriosus* (2 records; <1%; Figure 1O), among others (Table 1; Figure 2).

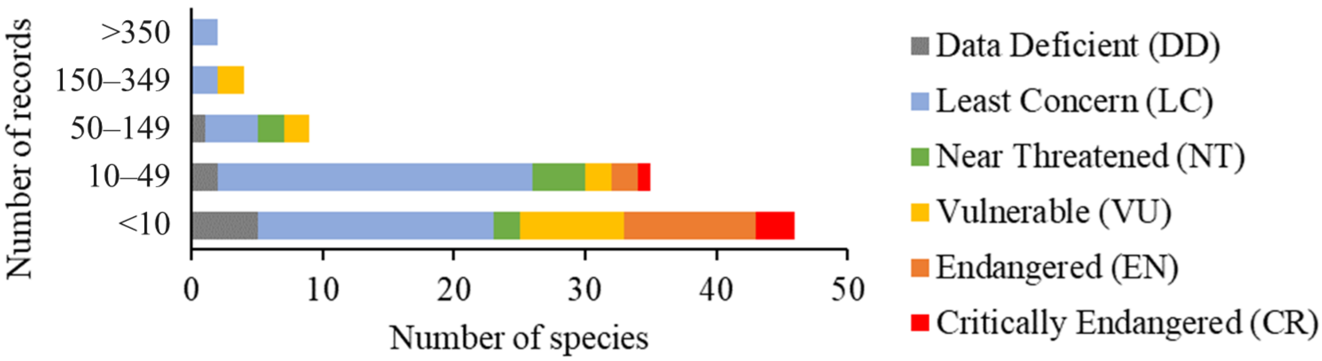

Figure 2. Number of species per number of records by their threatened status according to the IUCN Red List.

Four species exhibited new occurrence points within the Neotropical region. The new records have extended the known range of *Diasporus diastema* by approximately 65 km from Panama to the northwest of Colombia. The distribution of *Ranitomeya amazonica* expanded by 320 km from Brazil to the east of French Guiana. The distribution of *Ranitomeya yavaricola* and *Pristimantis acuminatus* extended by 165 km from Peru to the west and 470 km from Peru to northwest Brazil, respectively. Furthermore, since 2009, 56 observers have reported 65 records of *Dendrobates auratus* as a non-native in Hawaii, approximately 7800 km from its original distribution.

Our final dataset included records from 18 countries across the Neotropical region, spanning from Mexico (latitude 18°51′ N) to southern Brazil (latitude 28°09′ S) (Figure 3). Costa Rica had the highest number of records (3328; 59%), followed by Panama (999 records; 18%). Brazil recorded the highest number of species (35; 41%), followed by Colombia (22 species; 26%), Peru (12 species; 14%), and Ecuador (11 species; 13%).

Our final dataset included records from 2764 iNaturalist observers. The number of records of bromeligenous frogs has significantly increased, with a mean of 178 records (SD = 292) per year after 2009 (Figure 4). The trend in the number of records of bromeligenous frogs mirrored the increase in the number of users on iNaturalist, which rose substantially after 2013, with a mean of 107 users (SD = 183) per year.

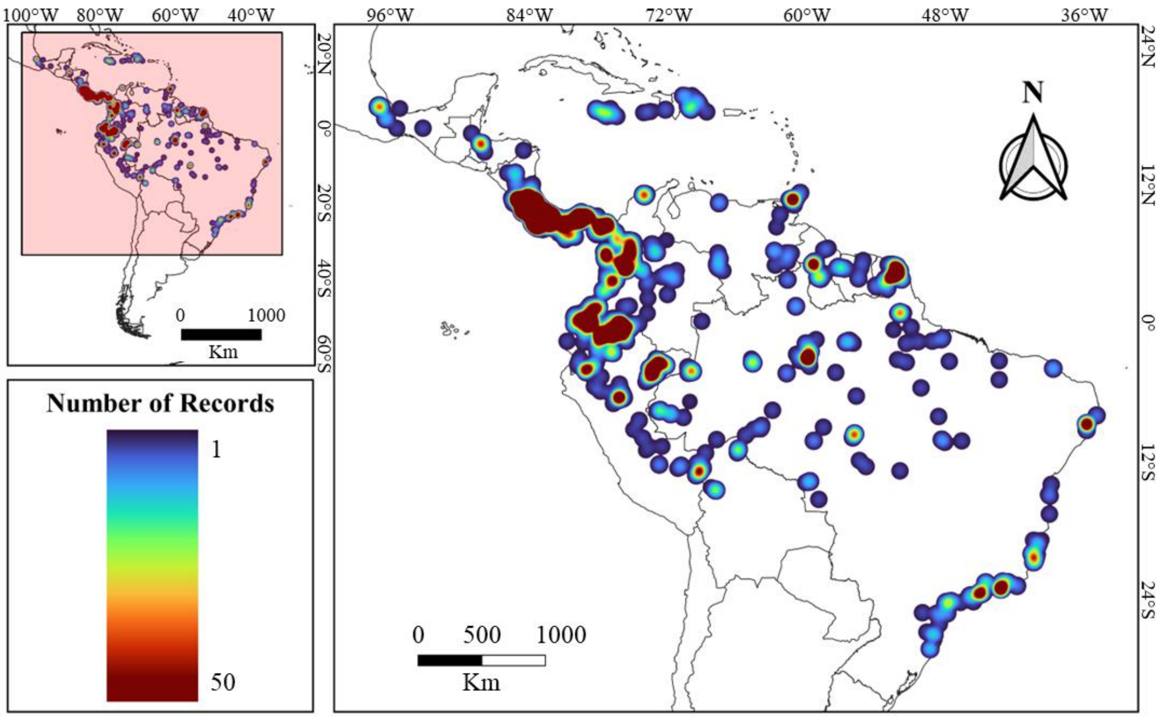

Figure 3. Heat map depicting the number of records (log 10) of bromeligenous frogs reported by citizen scientists in the Neotropical region from 1981 to 2021. The color gradient indicates the variation in the number of records: dark blue indicates a small number of records (<2) and dark red indicates a high number of records (50>).

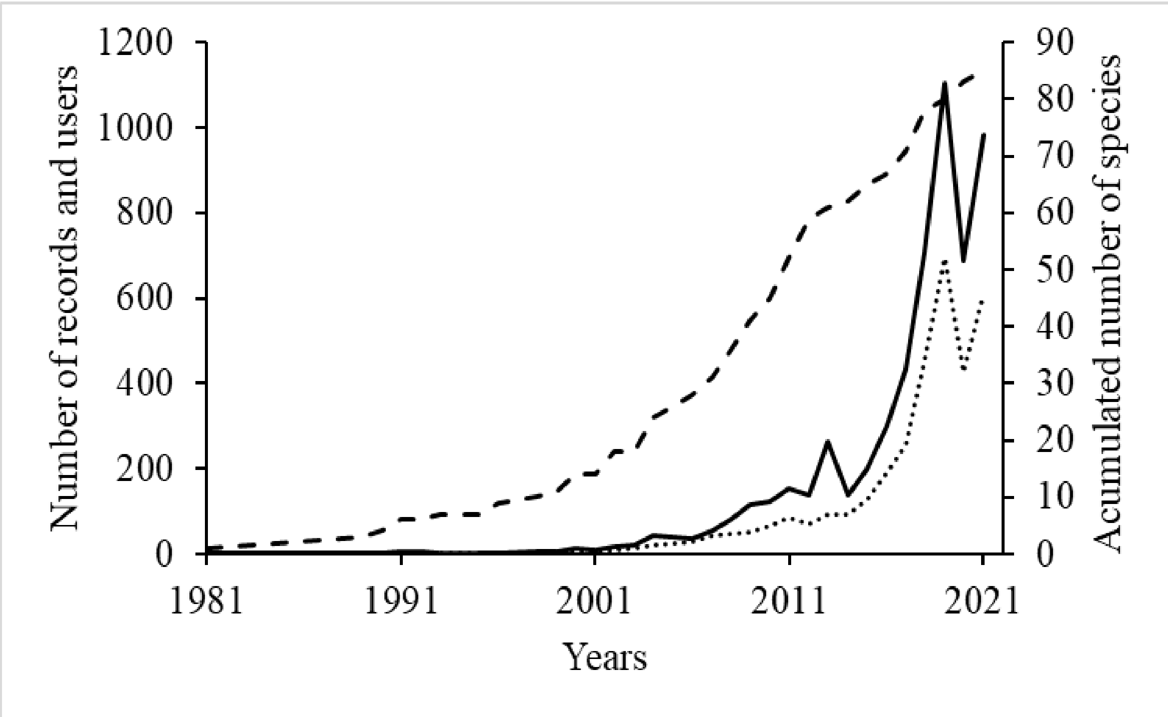

Figure 4. Accumulated number of bromeligenous frog species recorded on iNaturalist (dashed line), number of validated records submitted by citizen scientists (continuous line), and number of users that submitted records to iNaturalist (dotted line).

4. Discussion

Our study shows the important contribution of citizen scientists to understanding the composition of bromeligenous frogs across both space and time. This first inventory of bromeligenous frogs recorded by citizen scientists on a global scale comprised 52% (85 species) of the known 164 species of bromeligenous frogs. Studies have demonstrated the accuracy of citizen science data in understanding patterns of frog species richness on both small and large scales [33,34].

On the other hand, 63 species (38%) of bromeligenous frogs have yet to be recorded by the iNaturalist community. In general, bromeligenous frogs have sampling challenges, as some species exhibit microendemic distributions restricted to mountaintops, while others utilize epiphyte and canopy bromeliads. Additionally, most species have small population sizes and hide inside bromeliads [35,36]. Therefore, it is imperative for protected area managers, researchers, public agencies, and civil society to engage citizen scientists in sampling efforts within areas of potential occurrence of these unrecorded species.

The poison dart frogs *Oophaga pumilio* and *Dendrobates auratus* emerged as the most recorded species in our dataset, showcasing notable color variability [37] and inhabiting the tropical rainforests connecting South and Central America [31]. These species are members of the family Dendrobatidae, which boasted the highest number of records (n = 4880) and species (n = 36) in our dataset. Dendrobatidae encompasses 65 species of charismatic bromeligenous frogs, renowned for their striking aposematism and potent skin toxins [21,31]. Given their vibrant colors and presence in heavily touristic areas (e.g., Costa Rica, Panama, Ecuador, and Colombia), dendrobatid species are often sought after by citizen scientists, primarily tourists and professional photographers.

Among the bromeligenous frogs listed as threatened with extinction—comprising 14 Vulnerable (VU), 12 Endangered (EN), and three Critically Endangered (CR) species—20 species had fewer than 10 records. Citizen scientists have also documented some threatened species that are poorly understood and rarely documented, such as *Bromeliohyla dendroscarta* (EN), *Crossodactylodes izecksohni* (NT), *Excidobates condor* (EN), *Osteopilus marianae* (EN), *Phytotriades auratus* (EN), and *Ololygon alcatraz* (CR), each with only one record. Additionally, our findings highlighted Data Deficient (DD) and Need Assessment (NE) species, often restricted to a few localities with isolated populations (e.g., *Fritziana tonimi*, *Melanophryniscus alipioi*, *Phyllodytes gyrinaethes*, *Pristimantis waoranii*, *Ranitomeya toraro*, *R. yavaricola*, and *Ololygon arduoa*; [31]). Studies have indicated that DD and NE species are frequently overlooked in conservation and resource allocation plans [38] and may face extinction threats [39]. Establishing long-term monitoring, readily achievable through platforms like iNaturalist, is imperative to comprehend the distribution and population trends in these threatened (VU, EN, CR) and potentially threatened (DD, NE) species.

Our dataset unveiled new occurrence points for four species (*D. diastema*, *P. acuminatus*, *R. amazonica*, and *R. yavaricola*), underscoring the significant contribution of citizen science in expanding data collection opportunities [40]. Also, the poison dart frog *Dendrobates auratus* was reported as non-native in Hawaii in 2009. *Dendrobates auratus*, as well as *Rhinella marina* and *Eleutherodactylus planirostris*, pose a significant threat to the conservation of native invertebrates in Hawaii [28,41,42]. Non-native species might impact novel ecosystems through predation or poisoning of native species, competition, the introduction of pathogens and parasites, and genetic contamination [43,44]. It is noteworthy to mention that the global trade of bromeliads may amplify the introduction of bromeligenous frogs into novel areas worldwide. The potential of citizen science data for monitoring non-native species geographically and over time is arguably one of its most valuable applications, thereby facilitating more effective control and eradication efforts [45,46].

Our dataset revealed a high number of species and records in Central (Costa Rica and Panama) and South (Brazil, Colombia, Peru, and Ecuador) America, following the pattern of species richness of bromeliads in these regions [24]. Studies evaluating citizen scientists' data have indicated a bias toward areas proximate to urban and tourist areas [47,48], likely attributable to heightened sampling efforts in areas with convenient access to natural sites and a more representative occurrence of common species with wide geographic distribution [49]. Our findings corroborate this pattern, with a notable concentration of records near touristic sites renowned for citizen science bioblitzes, such as Costa Rica and Panama.

We found a substantial data gap in the central region of Brazil, likely due to the predominance of bromeliad species in this area with low or negligible rainwater storage capacity, such as those belonging to the genera *Bromelia*, *Dyckia*, and *Encholirium* [50]. Moreover, despite literature that documents the presence of bromeligenous frog species in Cuba (four species) and Guatemala (three species) (e.g., [51–55]), none of these species were recorded by the iNaturalist community.

Our data also unveiled a temporal trend characterized by an increasing number of bromeligenous records and iNaturalist users, a pattern observed in other taxonomic groups and citizen science projects as well [56,57]. Hence, it is plausible that bromeligenous frogs from Cuba and Guatemala will be documented in the future. The increased use of iNaturalist across the Neotropical region may further augment the user base and potentially lead to reports of the 63 unrecorded species.

The citizen science platform used in our study showed a reliable degree of confidence regarding taxonomic identities and provided wide-ranging data on the species. Additionally, ongoing monitoring through citizen science holds promise for the early detection of non-native species or population decline. The dataset employed in this study, sourced from citizen science initiatives, marks the first step towards comprehending bromeligenous frogs in the Neotropical region. Hence, the use of iNaturalist for inventorying and monitoring these species stands as a key tool in conservation initiatives.

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