



FROM PARTICIPATION TO IMPACT: REVIEWING THE TRANSFORMATIVE POTENTIAL OF CITIZEN SCIENCE IN BRAZILIAN PROTECTED AREAS

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ABSTRACT

Citizen science holds considerable potential as a strategic approach for public engagement in protected areas, yet its implementation varies substantially across conservation contexts. This paper analyses the integration of citizen science in Brazilian protected areas, focusing on its main characteristics and the variations in its use across different conservation types. Based on a systematic review of 59 publications from 2011 to 2023, the study identifies 24 good practices grouped into four analytical dimensions: volunteering, research, governance and operational. The review highlights 20 recurring challenges and compiles 35 recommendations to address methodological, institutional and participatory barriers. The findings reveal variation between conservation types: national parks tend to favour scientific and educational approaches with limited community engagement, while extractive reserves and sustainable development reserves demonstrate stronger community integration and territorial participation. This study presents a comparative mapping by protected area type, relating the characteristics of citizen science to conservation objectives. The full realisation of the transformative potential of citizen science will depend on its deeper integration into decision-making processes and governance structures, consolidating it as a strategic tool for more democratic and effective conservation.

Key words: participatory monitoring, environmental governance, biodiversity conservation, volunteer engagement, sustainable resource management

INTRODUCTION

Citizen science has gained increasing relevance in environmental conservation and natural resource management, as it values local knowledge and the observational skills of individuals and communities closely connected to their ecosystems (Conrad & Hilchey, 2011; McKinley et al., 2017). In a megadiverse country such as Brazil, with its extensive and varied network of protected areas, citizen science emerges as a promising strategy to strengthen monitoring and management of natural territories. When integrated into biodiversity research, citizen science can help transform conservation strategies by promoting more inclusive and participatory approaches that embrace diverse governance models and socio-environmental demands (Laxmi et al., 2025; Mamede et al., 2017; Nunes et al., 2023; Riesch & Potter, 2014; Vidal et al., 2025).

Although the term ‘citizen science’ is relatively recent in Brazilian environmental policy discourse, similar practices such as participatory monitoring have been adopted for some time (Nunes et al., 2023). The growing potential of citizen science in Brazil is reflected in the rise of initiatives registered as ‘citizen science’ in the Brazilian Biodiversity Information System (SiBBR), currently around 59 projects. Furthermore, more than 50 initiatives are conducted by research institutions and government bodies through the Brazilian Citizen Science Network (RBCC). The Chico Mendes Institute for Biodiversity Conservation (ICMBio) reports over 35,000 volunteers registered for environmental actions across the country (ICMBio, 2026).

Brazil’s protected areas cover around 32.5 per cent of its territory (FUNAI, 2024; ICMBio, 2024), representing a unique opportunity to enhance biodiversity conservation through local and Indigenous knowledge. Despite robust



Participants during an environmental education activity at Cachoeira da Marta Municipal Park, São Paulo, Brazil © Gabrielle Abreu Nunes

public policies, the country faces structural challenges such as weak enforcement, limited sustainable financing and underuse of traditional knowledge (Joly et al., 2019). Citizen science can contribute to overcoming these challenges by promoting public engagement, environmental education and equitable resource management (Dickinson et al., 2012).

As defined by RBCC (2025), citizen science should be understood as collaborative partnerships between scientists and interested citizens that integrate diverse forms of knowledge. This model strengthens public involvement in scientific processes, promotes scientific and technological literacy and facilitates co-development of public policies on complex socio-environmental issues.

While international studies highlight the benefits of citizen science for conservation, few integrative analyses have examined its role in Brazilian protected areas. Nunes (2021) and Nunes et al. (2023) conducted a systematic review of citizen science publications in protected areas globally between 2009 and 2019, but found no cases representing Brazil. Pegler and Ranieri (2024) provided valuable insights by identifying six studies with good practices for project design and implementation in Brazilian protected areas. However, their scope was limited to studies up to 2020, with a focus on operational guidelines rather than the social, scientific and institutional impacts of citizen science or differences across categories of conservation.

This article aims to address this gap by conducting a systematic review of citizen science publications relating to Brazilian protected areas. The study seeks to (a) identify the scope of these initiatives; (b) map good practices and challenges concerning governance, operational, scientific and volunteer engagement; (c) assess variations in citizen science application across different categories of protected areas; and (d) identify recommendations in the reviewed studies to overcome challenges and strengthen the effectiveness and sustainability of future initiatives.

METHODS

Systematic review criteria

The first stage of this study consisted of a systematic literature review to identify and analyse studies on public participation in scientific research in Brazilian protected areas. To ensure methodological rigour and transparency in the selection process, PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) were followed (Figure 1).

The search equation combined three main blocks of terms, structured using Boolean operators, to maximise scope while maintaining specificity:

- (“protected areas” OR “park” OR “forest*”): this first block of keywords was designed to capture studies carried out in different types of protected and conserved natural areas. The use of the

asterisk (*) allowed inclusion of variations of these terms (e.g. “parks”, “forests”).

AND

- (“citizen science” OR “participatory monitoring”): this block aimed to cover both the consolidated term “citizen science” and related expressions representing similar practices, particularly in applied or community contexts. For example, “participatory monitoring” is widely used in projects involving traditional and Indigenous populations.

AND

- (“Brazil” OR “Brazilian”): the third block ensured the geographical focus, retrieving only studies directly related to the Brazilian context, whether through author affiliation, case study location, or study focus.

The search was conducted in the Web of Science (Clarivate Analytics) and Scopus databases, including publications indexed up to 2023. Exclusion criteria were: (1) studies not written in English, Portuguese or Spanish; (2) duplicates between platforms; (3) lack of full access via the University of São Paulo or CAPES portal; and (4) irrelevance to the study objectives based on the title, abstract and, when necessary, full text.

Despite the methodological rigour applied following PRISMA guidelines, some limitations inherent to the review process should be considered. Because the search equation prioritised terms such as “citizen science” and “participatory monitoring”, it may not have captured studies using alternative or informal terminology, such as “community monitoring”, “participatory research” or “participatory environmental education”, particularly in initiatives led by civil society organisations or

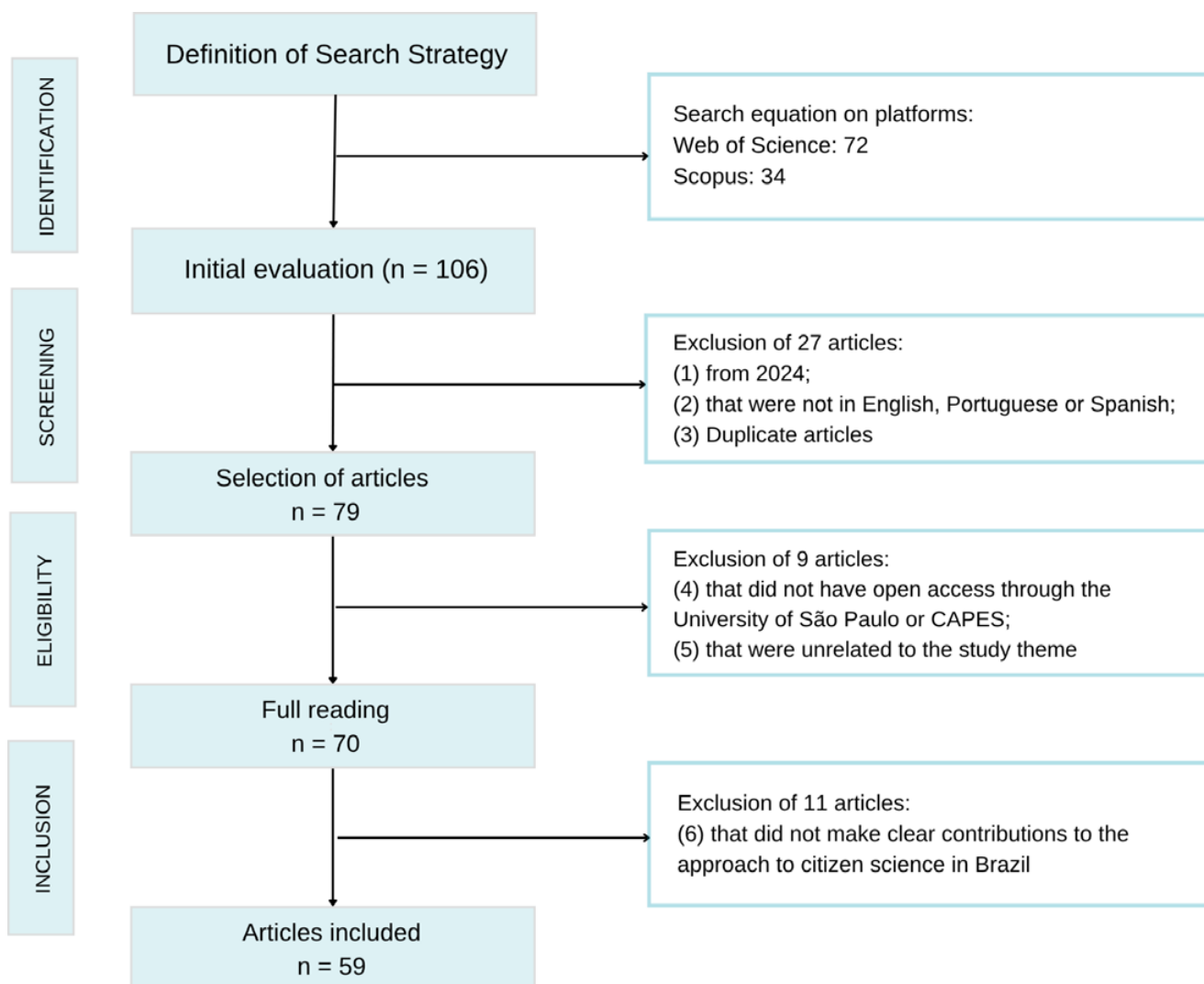


Figure 1. Systematic review steps followed in this article according to the PRISMA method.

Source: Authors

grassroots groups. This limitation may have reduced the representation of projects outside the academic sphere.

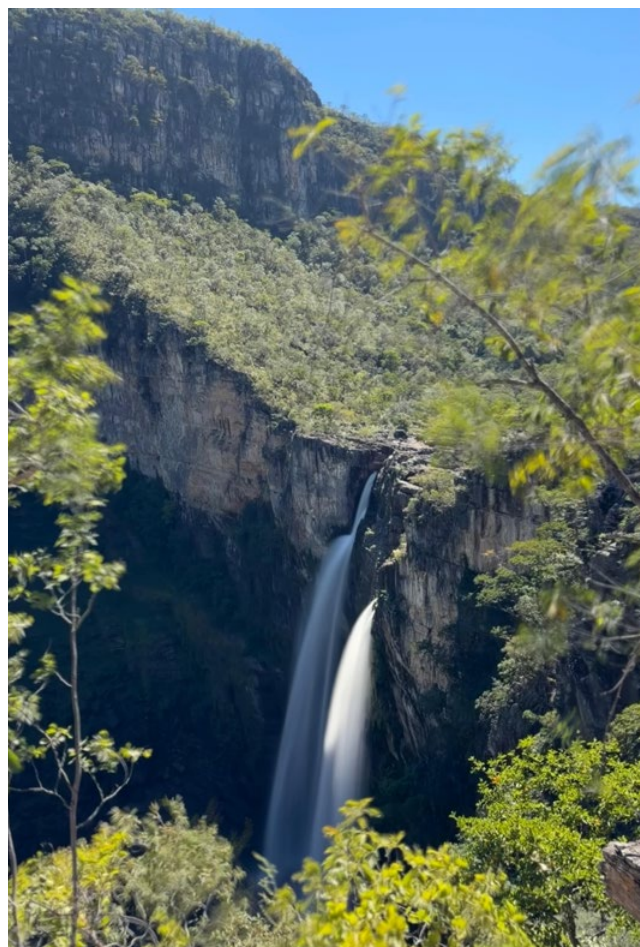
Furthermore, restricting the search to Web of Science and Scopus may have excluded relevant material from grey literature, such as technical reports, NGO documents, dissertations and theses, which often present applied results. Finally, the language criterion (English, Portuguese and Spanish) was chosen to ensure critical understanding of the material by the research team, but may have omitted publications in other languages. Nevertheless, this study offers a unique and systematic overview of the state of citizen science in Brazilian protected areas, advancing research and improving more participatory and locally adapted approaches.

DATA ANALYSIS

For the purpose of this analysis, protected areas were classified according to Brazil's National System of Nature Conservation Units (SNUC; Law No. 9.985/2000, Brasil, 2000), which organises conservation units into two main groups: Strict Protection and Sustainable Use. Strict Protection units, such as ecological stations and biological reserves, prioritise the indirect use of natural resources and restrict public access, permitting primarily scientific research and environmental education. Sustainable Use units, including environmental protection areas, national forests and extractive reserves, allow human activities compatible with conservation, often involving resident communities. In this study, the term 'protected area' refers to conservation units recognised under SNUC, excluding other territorial categories such as Indigenous lands.

Specific indicators were extracted from the selected studies to address the research objectives. For objective (a), the analysis identified the main characteristics and focus areas of citizen science initiatives, including their stated objectives, the themes addressed (e.g. biodiversity, climate change, natural resource management), alignment with the Sustainable Development Goals (SDGs) as classified by the search platforms, and their geographical distribution across Brazil, with attention to different types of protected areas.

To ensure consistency in thematic classification, studies were grouped according to their primary focus as described in titles, abstracts and keywords. Broad biodiversity studies were distinguished from ecology and environmental sciences based on their analytical scope. Studies classified as ecology explicitly addressed ecological processes such as species interactions, population dynamics or ecosystem functioning, whereas environmental sciences referred to broader and often



Waterfall and native vegetation in Chapada dos Veadeiros National Park, Goiás, Brazil © Gabrielle Abreu Nunes

interdisciplinary topics, including deforestation, ecosystem services and environmental quality.

SDG alignment was derived from metadata provided by the Web of Science and Scopus databases. These classifications reflect thematic indexing by the platforms and do not necessarily indicate that the SDGs were explicitly mentioned or analysed within each publication.

For objective (b), the analysis focused on identifying good practices, challenges and gaps using four core dimensions of citizen science in protected area contexts (Nunes et al., 2023).

The term 'volunteering' is used in this study as an analytical category to refer to participant engagement in citizen science initiatives, following previous classification frameworks. However, it is recognised that this term may not fully capture the diversity and complexity of participation in citizen science, which can include co-production of knowledge, recognition of local and Indigenous knowledge systems, and different forms of social and political engagement. In some cases, participation may also involve incentives, compensation or institutional arrangements.

- i. Volunteering: covering participant profiles, recruitment strategies, training, types of activities, and perceived benefits;
- ii. Research: addressing efficiency in the use of human and infrastructural resources, and complementarity with conventional scientific research (e.g. data collection, monitoring, analysis);
- iii. Governance: including social participation practices, collaborative mechanisms, decision-making processes, and transparency;
- iv. Operational: involving administrative and logistical elements such as funding, resource management, infrastructure, and institutional sustainability.

A qualitative content analysis was conducted to assign each study to one or more of these dimensions. This classification was based on project characteristics, outcomes and processes reported in each article. When multiple dimensions were present, all relevant categories were recorded.

For objective (c), which aimed to assess variations in the use of citizen science across different categories of protected areas, data were organised into a comparative matrix to identify which dimensions are more frequent or better integrated within each conservation unit type.

Finally, for objective (d), recommendations were compiled according to their relevance for overcoming identified challenges and strengthening project effectiveness and sustainability. These recommendations included methodological improvements, strengthened participatory governance, integration with public policies and increased long-term social engagement.

Co-occurrence analysis

A co-occurrence analysis of keywords was conducted based on article abstracts using VOSviewer software (version 1.6.20). This enabled visualisation of the relationships and clusters among the most frequently used terms, highlighting the main focus areas of citizen science within the context of Brazilian protected areas. Additionally, the temporal evolution of publications was examined, revealing possible shifts in research interest over time.

Heatmap analysis

To assess how citizen science subcategories vary across different types of Brazilian protected areas, a comparative analysis was carried out using a heatmap. This visual tool illustrates the degree of presence and integration of the four analytical dimensions examined (volunteering, research, governance and operational) across the two categories of protected areas (Table 1). For each category, an intensity score was assigned according to how frequently and deeply each citizen

Table 1. Types of Protected Areas categories in the National System of Conservation Units. *Source: Authors, based on Brazilian law no. 9.985/2000; CNUC, 2020.*

Strict Protection		
Type of UC	IUCN Category	Focus/Short Objective
Ecological Station (EE)	Ia	Strict nature protection and scientific research
Biological Reserve (Rebio)	Ia	Integral biodiversity protection with minimal human interference
National Park (Parna)	II	Conservation of ecosystems, environmental education, and controlled visitation
Natural Monument (Monat)	III	Protection of outstanding natural features with ecological or cultural value
Wildlife Refuge (RVS)	III	Maintenance of habitats critical for species conservation
Sustainable Use		
Type of UC	IUCN Category	Focus/Short Objective
Environmental Protection Area (APA)	V	Sustainable resource use, balancing conservation with local livelihoods
Area of Relevant Ecological Interest (ARIE)	IV	Protection of smaller areas with high ecological importance
National Forest (Flona)	VI	Sustainable forestry, research, and resource management
Extractivist Reserve (Resex)	VI	Sustainable use of renewable natural resources by traditional communities
Fauna Reserve (Reserva de Fauna, REF)	VI	Maintenance of viable wildlife populations with regulated resource use
Sustainable Development Reserve (RDS)	VI	Conservation of biodiversity integrated with sustainable livelihood strategies
Private Natural Heritage Reserve (RPPN)	IV	Voluntary private conservation, managed by the landowner

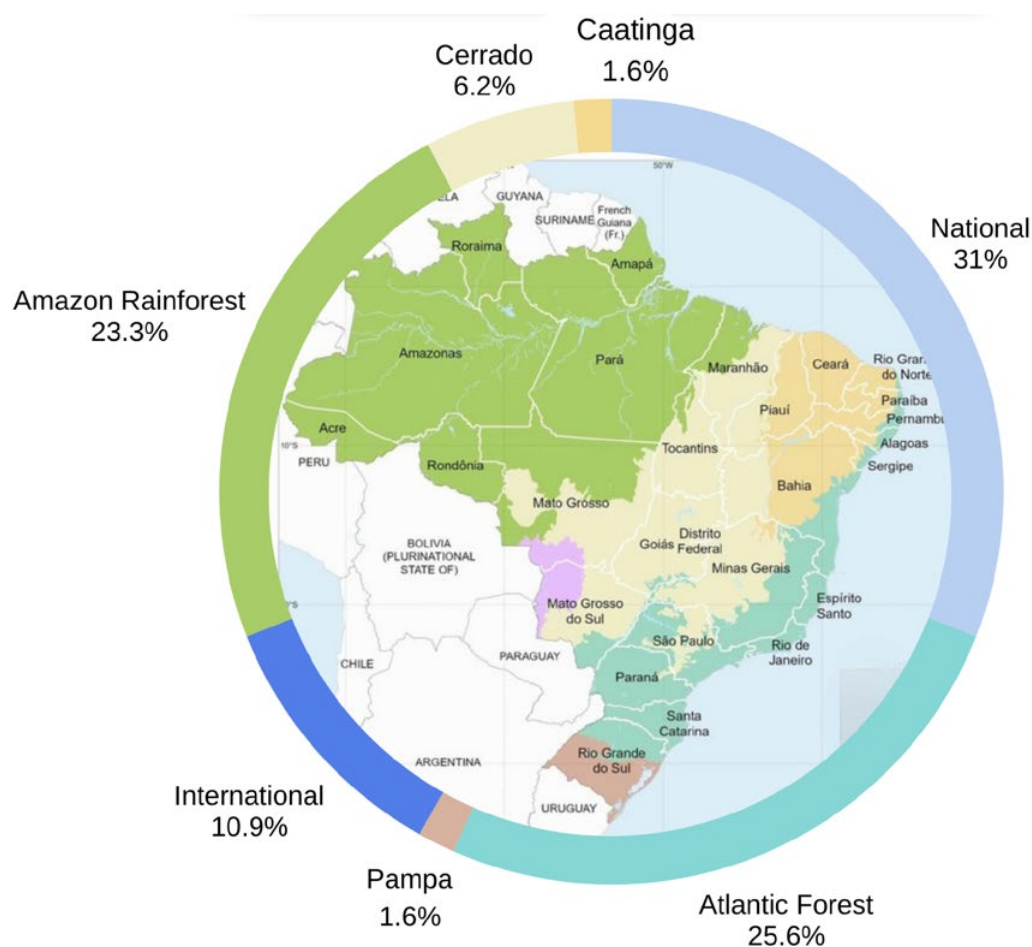


Figure 2. Geographic coverage reported in the Brazilian citizen science papers in protected areas by biome. National indicates it occurs in more than one biome. *Source: Authors adapted map from Dockendorf et al., 2022.*

science dimension was addressed in the 59 articles analysed: 0 – no mention or negligible alignment; 1 – occasional mention with low integration; 2 – moderate presence with some practical application; 3 – strong integration and frequent mention. The scores were organised into a matrix, with rows representing the citizen science dimensions and columns representing the different categories of protected areas with values converted into a colour code: white (0), light yellow (1), dark yellow (2) and dark green (3).

RESULTS

Web of Science and Scopus databases identified 79 articles, of which 59 met the inclusion criteria and provided clear contributions to at least one of the four dimensions examined: governance, operational, research and volunteering, in the context of citizen science in Brazil.

Among the themes addressed, biodiversity conservation was predominant, with 29 publications highlighting a strong focus on preserving biological diversity through citizen science initiatives. The main clusters of publications related to general biodiversity studies (9 articles), research on aquatic animals (9), and

birdwatching initiatives (8). Other studies focused on mammals, plants and insects, albeit less frequently. Ecology was another significant area, with 22 articles reflecting growing interest in how citizen participation contributes to understanding ecological processes. The environmental sciences, represented by 11 publications, emphasised the relevance of citizen science in broader environmental research, including deforestation, ecosystem services and environmental quality.

The geographical scope of the studies ranged from local and regional scales to national coverage (Figure 2), with 20 articles explicitly referring to national analyses and 7 with an international scope. The most cited biomes were the Amazon (15 articles) and the Atlantic Forest (9), followed by coastal regions (6), Cerrado (4), Caatinga (1) and Pampa (1).

The regional distribution of studies was linked to the presence of human populations in protected areas and the availability of funding for research and conservation. Many of these areas, such as extractive reserves in the Amazon, are priority territories for biodiversity studies due to their ecological importance and the existence of

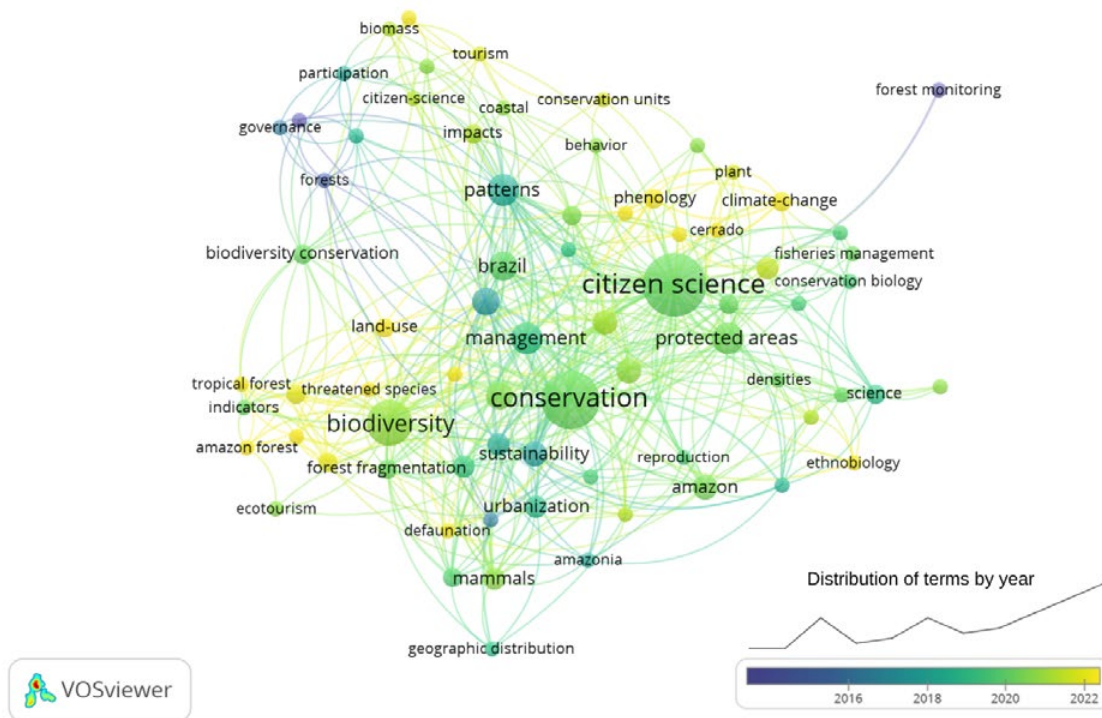


Figure 3. Correlation of keywords in Brazilian citizen science articles over time, their trends and distribution of papers published over the years in VOSviewer software 1.6.20. *Source: Authors*

communities directly dependent on natural resources for their livelihoods. Funding directed to these regions facilitates long-term research, allowing deeper understanding and improved ecosystem management.

The most represented SDG was Goal 15 – Life on Land, with 59 publications addressing the protection, restoration and sustainable use of terrestrial ecosystems, including deforestation, habitat conservation, biodiversity and land-use management. SDG 13 – Climate Action was also significant, with 37 articles discussing climate change mitigation and adaptation, including emissions reduction and policy measures. SDG 14 – Life Below Water appeared in 18 studies, focusing on marine conservation, pollution control and sustainable fishing. Other SDGs identified included SDG 1 – No Poverty (9 articles), SDG 3 – Good Health and Well-being, and SDG 11 – Sustainable Cities and Communities, each with 3 articles, addressing health access, disease prevention, urban planning and community resilience. SDG 6 – Clean Water and Sanitation was mentioned in only 1 article, highlighting the critical need for safe drinking water and sanitation in vulnerable areas. It is important to note that a single article may align with multiple SDGs, reflecting the cross-cutting nature of the challenges addressed by citizen science.

A co-occurrence map of keywords generated using VOSviewer (version 1.6.20; Figure 3) shows the central

role of citizen science, which is frequently linked with terms such as conservation, biodiversity, protected areas, management and sustainability, underscoring its broad application in Brazilian environmental research. Emerging terms like “climate change” and “phenology” appear in yellow, suggesting that these areas are gaining prominence, and that citizen science is increasingly employed to gather data and engage the public on critical environmental issues. Recent trends, highlighted by terms such as “land use” and “defaunation”, emphasise how anthropogenic factors, including agriculture and deforestation, are altering ecosystems.

The annual distribution of publications showed a marked increase over time, particularly following the COVID-19 pandemic (Figure 3). Four articles were published between 2011 and 2014, followed by steady growth between 2015 and 2020, averaging around five publications per year, then a notable acceleration from 2021, with 8 publications in 2021, 11 in 2022 and 14 in 2023.

Categorisation of good practices in citizen science publications in Brazil

This study identified 24 good practices resulting from the impacts of citizen science, distributed across four main categories: volunteering, which concentrated the majority of mapped practices, followed by research, governance and, lastly, operational. The categorisation results confirm aspects of the international review by Nunes et

Table 2. “Volunteers” classification of Brazilian citizen science papers compared to the international categorisation by Nunes et al., 2023, and the total number of articles that were cited for each subcategory. Source: Authors

Volunteers	Papers	Research	Papers
	Total		Total
Promotes local empowerment	33	Promotes time optimisation	38
Increases community interest in the topic	47	Complements traditional research	50
Promotes personal satisfaction; community appreciation	22	Increases reliability	44
Encourages education; increases community knowledge	51	Encourages future research	52
Promotes economic benefits	18	New subcategory	
New subcategories		Increase biodiversity conservation	11
Promote social interactions	6		
Cultural preservation	5	Governance	Papers
Ecological awareness	4		Total
Promotes environmental sustainability	4	Encourages communication and learning	53
Environmental justice	2	Affects public policies	8
Improves physical and mental well-being	1	New subcategories	
		Enhances decision-making	4
		Promotes better land-use planning	3
		Operational	Papers
			Total
		Promotes financial optimisation	39
		Promotes transparency	28
		Improves community and management relations	46
		Optimises time and resources	44

al. (2023) and introduce nine new subcategories that reflect the evolving nature of citizen science in relation to Brazil’s social and territorial diversity (Table 2).

Citizen science initiatives demonstrated significant impacts on volunteer participants. The subcategory “Encourages education; increases community knowledge” was the most frequent, with 51 articles describing how these projects foster learning and enhance community knowledge. Similarly, “Increases community interest” was found in 47 studies, highlighting the capacity of citizen science to spark environmental curiosity and strengthen social engagement. The subcategory “Promotes local empowerment”, cited in 33 articles, showed how direct community involvement can enhance autonomy and capacity for action.

Beyond categories identified in the international review, this study identified six new subcategories emphasising the evolving character of citizen science in Brazil and its strong connection to traditional and local communities. The subcategory “Promotes social interactions” highlights social benefits and stronger community bonds (Alexandrino et al., 2022; Martins et al., 2020; Purchase et al., 2024; Schmiedel et al., 2016). “Cultural

preservation”, noted in five articles (Begossi et al., 2019; De Melo et al., 2021; Morcatty et al., 2020; Ponce-Martins et al., 2022; Rumenos & Spazziani, 2020), stresses the importance of safeguarding cultural heritage and traditional knowledge as integral to natural history and local identity.

Another emerging subcategory is “Promotes environmental sustainability”, cited in four articles, which discuss how community-led monitoring contributes to sustainable resource use (De Melo et al., 2021; Delfino et al., 2023; González & Kröger, 2022; Marioni et al., 2013). “Ecological awareness”, also present in four studies (De Angelo et al., 2011; Freitas & Macedo, 2023; Loss et al., 2023; Mangelli et al., 2020), highlights the educational role of citizen science in raising environmental consciousness. The findings of this study align in part with Pegler and Ranieri (2024), who also conducted a systematic review of good practices in citizen science in Brazilian protected areas. However, their focus was on project design and implementation. They proposed seven main categories – financial aspects, governance, project design, methodological aspects, engagement, result dissemination and evaluation – which overlap in part with the analytical dimensions used

in this study (volunteering, research, governance and operational), though with different approaches and aims.

Although less frequent, “Improves physical and mental well-being” was cited in one article (De Melo et al., 2021), suggesting possible health benefits of participation. This perspective is reinforced by recent findings from Nunes et al. (2024) and Nunes et al. (2025), who emphasise the synergistic effects between citizen science activities and direct engagement with natural environments in promoting psychological well-being and reducing stress. These studies suggest that such initiatives contribute not only to data collection and environmental monitoring but also serve as practical strategies for fostering individual health and community resilience.

Within the “Research” article category, citizen science contributed to scientific production, with “Encourages future research” identified as the top subcategory in 52 articles. This categorization emphasizes the role of citizen science in catalyzing further investigation. “Complements traditional research”, identified in 50 articles, demonstrates synergy between volunteer-generated data and traditional methods. “Increases reliability”, cited in 44 articles, points to enhanced accuracy and robustness of information obtained. “Promotes time optimisation”, noted in 38 articles, reflects efficiency gains that allow scientists to focus on strategic tasks. A new subcategory,

“Increases biodiversity conservation”, appeared in 11 publications, highlighting the expanded impact of citizen participation on biodiversity protection.

Operational benefits were also evident: “Improves community–management relations” was cited in 46 articles, while “Optimises time and resources” appeared in 44, both indicating efficiency gains in project delivery. In governance, “Promotes communication and learning” was widely cited (45 articles), demonstrating that citizen science can act as a tool for dialogue among stakeholders. In contrast, “Affects public policy” appeared in 8 articles, suggesting that, while there is potential, direct impact on policymaking, it remains under-documented.

Two new subcategories with transformative potential emerged: “Enhanced decision-making”, mentioned in four articles, points to more informed and inclusive conservation management (Freitas & Macedo, 2023); and “Promotes better land-use planning”, identified in three articles, highlights the role of citizen science in supporting land-use strategies through fostering community cooperation and encouraging more sustainable practices (Delfino et al., 2023; Loss et al., 2023).

Heatmap analysis of citizen science across protected area types

The heatmap analysis reveals significant variation in volunteer engagement depending on the conservation objectives and accessibility of each unit type (Figure 4). Strict Protection units such as ecological stations (EE) and biological reserves (Rebio) show low integration with volunteer-related subcategories, due to restrictions on public use and the focus on preserving minimally disturbed ecosystems. National parks (Parna), natural monuments (Monat) and wildlife refuges (RVS) display moderate to high alignment with subcategories such as cultural preservation and ecological awareness, owing to environmental education activities and controlled volunteer initiatives. However, even in these contexts, direct engagement with marginalised communities remains limited, reflected in low alignment with the subcategory “environmental justice”. Where outreach or education activities do exist, they tend to focus on environmental awareness and tourism management rather than addressing structural social inequalities.

Sustainable Use units such as environmental protection areas (APA), national forests (Flona), extractive reserves (Resex) and sustainable development reserves (RDS) show a different pattern. The presence of resident or closely connected local communities facilitates continuous biodiversity monitoring, contributing to stronger alignment with socio-environmental objectives.



Gabrielle Nunes during fieldwork at Chapada dos Veadeiros National Park, Goiás, Brazil © Gabrielle Abreu Nunes

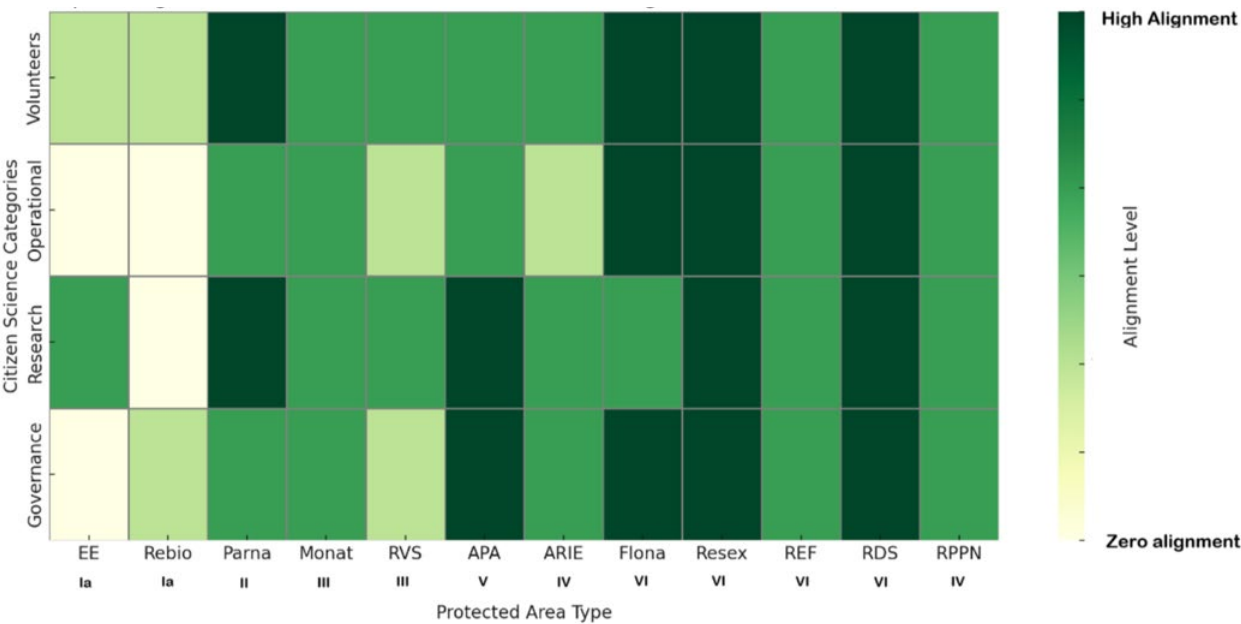


Figure 4. Heatmap in table format highlighting the alignment of citizen science characteristics within the “Volunteers, Research, Operational and Governance” scope compared to the categories of Brazilian protected areas. *Source: Authors.*

These areas show higher scores in subcategories such as local empowerment, economic benefits and participatory decision-making, although the effectiveness of these initiatives depends on the existence of clear management plans and their implementation.

In terms of research, national parks show the strongest alignment, reflecting their historical focus on scientific investigation. In contrast, operational aspects exhibit low or no integration in the most restrictive Strict Protection units, where limited access constrains opportunities for resource optimisation, community engagement and transparency. Governance remains moderate in these units, as the emphasis on ecological integrity restricts broader participatory mechanisms. While these units perform well in research-oriented citizen science, expanding opportunities for community participation could strengthen both operational and governance dimensions.

Sustainable Use units show moderate to high alignment in research subcategories, particularly where traditional knowledge and local practices are integrated. The flexibility of access and the familiarity of resident populations with their territories support more continuous and embedded initiatives. These units also show stronger alignment in operational and governance dimensions, including participatory financial management, shared decision-making and integrated land-use planning. Among these, extractive reserves and sustainable development reserves stand out as contexts where sustained community engagement enables a more consistent integration of social and ecological objectives.

These findings indicate that the effectiveness and scope of citizen science are closely shaped by the institutional and social context of each protected area category. In settings where participation is embedded within management structures, citizen science can extend beyond data collection to support decision-making processes and adaptive management. Conversely, in more restrictive contexts, its role remains more limited and primarily research-oriented, highlighting opportunities for more inclusive approaches where appropriate.

Challenges and recommendations for future projects

Volunteer engagement emerged as a primary challenge. Fourteen studies noted that participants often lack the necessary expertise, underscoring the need for enhanced training and capacity-building. Communication difficulties (4 studies) and trust issues (3 studies) further impede effective collaboration and data collection. To mitigate these challenges, recommendations include increasing volunteer participation (10 studies), tailoring engagement strategies to community profiles (8 studies), providing non-economic incentives (4 studies) and implementing comprehensive education programmes (9 studies).

Methodological challenges in research were prominent. Sixteen studies highlighted deficiencies in the design and implementation of citizen science methodologies, while 13 studies pointed to issues with data reliability and 11 studies raised concerns about overall project viability. Recommendations to address these issues include improving communication between researchers and volunteers (12 studies), leveraging technological tools (9



Participants engaging in a nature-based educational activity at Cachoeira da Marta Municipal Park, São Paulo, Brazil
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studies), refining research methods (21 studies) and ensuring consistent project monitoring (13 studies).

Operational challenges involve limited management openness to community input (3 studies), underutilisation of data for decision-making (2 studies) and funding shortages (4 studies). Suggested solutions are increasing management transparency (4 studies), adopting best practices (8 studies), identifying diverse funding sources (5 studies) and optimising resource allocation (5 studies).

Governance challenges, such as ineffective stakeholder communication (7 studies), data ownership issues (2 studies) and conflicts of interest (4 studies), further complicate project success. Recommendations for governance include exploring alternative institutional arrangements (7 studies), enhancing stakeholder communication (10 studies), and aligning projects with public policies from the outset (8 studies).

DISCUSSION

The results highlight that citizen science in Brazilian protected areas is not applied uniformly, but rather shaped by institutional arrangements, levels of access and the presence of local communities. This variation suggests that the effectiveness of citizen science depends less on the methodology itself and more on how it is embedded within governance structures and management practices. In particular, the stronger

performance observed in Sustainable Use units indicates that long-term engagement and locally grounded participation are critical for achieving broader conservation outcomes beyond data collection.

These findings reinforce the idea that citizen science can contribute not only to knowledge production but also to governance processes. In contexts where communities are directly involved in resource use and management, citizen science appears to facilitate more continuous monitoring, stronger local ownership and greater alignment with socio-environmental objectives. Conversely, in more restrictive contexts, its role remains limited to supporting scientific research, with fewer opportunities to influence decision-making or promote inclusive governance.

An example of an integrated and participatory approach is the Monitora Participatory Biodiversity Monitoring Programme in the Amazon (Tófoli et al., 2019). By combining traditional knowledge with scientific methods, the programme has strengthened data collection and decision-making processes. Shared research priorities have contributed to sustained community engagement and long-term commitment to conservation, resulting in more context-specific and effective biodiversity management strategies. This example illustrates how citizen science can move beyond contributory models towards more collaborative and co-produced forms of knowledge.

The identification of 24 good practices, particularly those related to education, community engagement and research complementarity, further supports the role of citizen science as a bridge between scientific and social dimensions of conservation. However, the limited presence of practices associated with policy influence and decision-making highlights an important gap. This suggests that, despite its potential, citizen science remains underutilised as a governance tool in many protected area contexts.

From a management perspective, these results indicate that aligning citizen science initiatives with the specific objectives, governance models and socio-territorial contexts of protected areas is essential to enhance their effectiveness. Initiatives that are designed with local realities in mind, and that actively involve communities in both data generation and decision-making processes, are more likely to produce lasting outcomes. This also implies that standardised approaches may be less effective than context-sensitive strategies.

More broadly, these findings offer valuable insights for conservation strategies both within and beyond Brazil. The Brazilian case reflects a combination of high

biodiversity, social inequality and complex institutional arrangements that are common across many countries in the Global South. In this context, citizen science emerges as a flexible approach that can be adapted to different governance settings, helping to address ecological and social challenges. Mapping where citizen science is well integrated, and where limitations persist, can support the development of more inclusive and effective conservation strategies.

The challenges identified across volunteering, research, operational and governance dimensions point to the need for more integrated approaches. Strengthening citizen science requires coordinated efforts that combine capacity-building, methodological refinement, institutional openness and long-term engagement strategies. When these elements are addressed together, citizen science has the potential to evolve from a data collection tool into a mechanism that supports adaptive management, social inclusion and more equitable conservation outcomes.

CONCLUSION

This article evaluated the potential of citizen science as a strategic tool for protected area management in Brazil. Based on a systematic review of 59 studies, the findings show that citizen science is expanding, but remains unevenly distributed across biomes and protected area categories. While it is strongly associated with biodiversity research, its integration into governance and decision-making processes is still limited.

The study identified 24 good practices across volunteering, research, governance and operational dimensions, highlighting the central role of public engagement and the growing relevance of social and territorial aspects such as cultural preservation and environmental justice. Significant variation was observed between Strict Protection and Sustainable Use units, with the latter showing greater potential for integrating citizen science into management and governance processes.

By providing a comparative analysis across protected area types, this study offers practical insights for managers, practitioners and policymakers seeking to strengthen participatory and context-sensitive conservation strategies. Given Brazil's ecological diversity and socio-institutional complexity, the findings also contribute to broader debates on conservation in the Global South. The analytical framework and lessons identified here are transferable to other contexts facing similar challenges, supporting the development of more inclusive, adaptive and effective approaches to protected area management.



Freshwater ecosystem and surrounding native vegetation in Chapada dos Veadeiros National Park, Goiás, Brazil
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REFERENCES

- Alexandrino, E. R., Camboim, T. A., Chaves, F. G., Bovo, A. A. A., da Silva, M. A. G., da Silva, D. A. M., Moss, M., Souza, T. P., de Oliveira Santos, C., de Mattos Brito, C. B., et al. (2022). Which birds are Brazilians seeing on urban and non-urban feeders? An analysis based on a collective online birding. *Ornithology Research*, 30(2), 104–117.
- Begossi, A., et al. (2019). Fishers and groupers (*Epinephelus marginatus* and *E. morio*) on the coast of Brazil: integrating information for conservation. *Journal of Ethnobiology and Ethnomedicine*, 15, 1–26.
- Brasil (2000). Lei nº 9.985, de 18 de julho de 2000. Regulamenta o art. 225, §1º, incisos I, II, III e VII da Constituição Federal, institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências. *Diário Oficial da República Federativa do Brasil*, Brasília, DF, 18 jul. 2000.
- Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment*, 176, 273–291. <https://doi.org/10.1007/s10661-010-1582-5>
- Delfino, H. C., et al. (2023). Multisource data reveals relevant trends in a Chilean Flamingo (*Phoenicopterus chilensis*) population at an important coastal wetland of southern Brazil: implications for conservation and planning. *Journal of Coastal Conservation*, 27, 33.
- De Melo, E. P. C. et al. (2021). Exotic species are perceived more than native ones in a megadiverse country such as Brazil. *Anais da Academia Brasileira de Ciências*, 93, e20191462.
- Dickinson, J. L., et al. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, 10, 291–297.
- Dockendorff, C., Fuss, S., Agra, R., Guye, V., Herrera, D., & Kraxner, F. (2022). Committed to restoring tropical forests: An overview of Brazil's and Indonesia's restoration targets and policies. *Environmental Research Letters*, 17(9), 093002.
- Freitas, E. M. O., & Macedo, H. S. (2023). Perspectivas e limitações do monitoramento participativo de cetáceos: utilização de plataforma de oportunidades pelo setor turístico na APA do Anhatomirim. *Desenvolvimento Regional e Meio Ambiente*, 13, 56–90.
- FUNAI (2024). *Brasil indígena*. Retrieved from http://mapas2.funai.gov.br/portal_mapas/pdf/brasil_indigena.pdf
- González, N. C., & Kröger, M. (2022). The adoption of earth-observation technologies for deforestation monitoring by Indigenous people: evidence from the Amazon. *Globalizations*, 20, 415–431.
- ICMBio - O Instituto Chico Mendes de Conservação da Biodiversidade (2026). Volunteer Program Dashboard [Painel do Programa de Voluntariado]. Retrieved from <https://app.powerbi.com/>
- ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade (2020). *Manual de aplicação do Sistema de Análise e Monitoramento de Gestão*. Brasília: ICMBio.
- ICMBio - O Instituto Chico Mendes de Conservação da Biodiversidade (2026). Dashboard of Brazilian natural conservation units [Painel unidades de conservação Brasileiras]. Retrieved from <https://app.powerbi.com/view?r=eyJrIjoiaMDNmZTA5Y2ltNmFkMy00Njk2LWl4YjYtZDZJNzFkOGM5NWQ4IiwidCI6IjJiMjY2ZmE5LTNmOTMtNGJiMS05ODMwLTZyNDY3NTJmMDNlNCIsImMiOiJF9>
- Joly, C. A., et al. (2019). Brazilian assessment on biodiversity and ecosystem services: summary for policy makers. *Biota Neotropica*, 19(4).
- Laxmi, K. R., Reddy, M. N., Reddy, P. A., Sandeepa, P., & Hemanth, L. (2025). Bio-eye: an advanced wildlife detection framework. *International Journal of Engineering Research and Science & Technology*, 21(1), 28–39.
- Loss, S. R., et al. (2023). Citizen science to address the global issue of bird–window collisions. *Frontiers in Ecology and the Environment*, 21, 418–427.
- Mamede, S., Benites, M., & Alho, C. J. R. (2017). Ciência cidadã e sua contribuição na proteção e conservação da biodiversidade na Reserva da Biosfera do Pantanal. *Revista Brasileira de Educação Ambiental (RevBEA)*, 12(4), 153–164.
- Mangelli, T. S., et al. (2020). Voluntary scuba diving as a method for monitoring invasive exotic marine species. *Ethnobiology and Conservation*, 10.
- Martins, G. de M., et al. (2020). Territorial behaviour and breeding in the Southern Antpitt Corythopis delalandi (Aves: Rhynchocyclidae) in southeastern Brazil. *Journal of Natural History*, 54, 1827–1844.
- Marioni, B., Botero-Arias, R., & Fonseca Junior, S. (2013). Local Community Involvement as a Basis for Sustainable Crocodilian Management in Protected Areas of Central Amazonia: Problem or Solution? *Tropical Conservation Science*, 6(4), 555–569.
- McKinley, D. C., et al. (2017). Citizen science can improve conservation science, policy, and practice. *Conservation Biology*, 31, 282–283.
- Morcatty, T. Q., et al. (2020). Adapting a traditional hunting technique to improve capture rates for the endangered yellow-footed tortoise (*Chelonoidis denticulatus*) during ecological surveys in Amazonia. *Journal of Ethnobiology*, 40, 252–267.
- Nunes, G. A., & Lindenkamp, T. C. M. (2021). Citizen science and sustainability: potentials of public participation in tourism in conservation units. *Revista Eletrônica Uso Público em Unidades de Conservação*, 9(14), 79–99.
- Nunes, G. A., Pegler, G. F., & Ranieri, V. E. L. (2023). Public engagement in scientific research in protected areas: from research to management *Revista Brasileira de Ecoturismo*, 16, 4. <https://doi.org/10.34024/rbecotur.2023.v16.14314>
- Nunes, G., Duarte, D. M., & Magro, T. C. (2024, junho). *Citizen science as a tool to promote mental well-being and connection with nature in a Brazilian park*. Conference, FORESTS & SOCIETY TOWARDS 2050 IUFRO 2024, Stockholm, Sweden. https://www.researchgate.net/publication/390838715_Citizen_Science_as_a_tool_to_promote_mental_well-being_and_connection_with_nature_in_a_Brazilian_Park
- Nunes, G., Soldado, E. B. R., Buijs, A., & Magro, T. C. L. (2025). *Impacts of citizen science on well-being among older adults: Insights from a small-scale study* [Paper presentation]. 4th World Conference on Forests and Parks for Public Health, Luxembourg. https://www.researchgate.net/publication/396311819_Impacts_of_citizen_science_on_well-being_among_older_adults_Insights_from_a_small-scale_study
- Nunes, G. A., Soldado, E. B. R., Magro, T. C. L. (2025). Can observing nature improve human well-being? Opportunities for Ecotourism. *Revista Brasileira de Ecoturismo*, 18, 83–98. <https://doi.org/10.34024/rbecotur.2025.v18.19293>
- Nunes, G. A. & Ranieri, V. E. L. (2025). Citizen science as a promising approach for cave monitoring in protected areas. *Ambiente & Sociedade*, 28, e00184. <https://doi.org/10.1590/1809-4422asoc01841vu28L4OA>
- Pegler, G. F., & Ranieri, V. E. L. (2024). Citizen Science in protected areas: best practices for project formulation and implementation. *Ambiente & Sociedade*, 27, e00152. <https://doi.org/10.1590/1809-4422asoc01521vu27L4OA>
- Ponce-Martins, M., et al. (2022). Assessing the contribution of local experts in monitoring Neotropical vertebrates with camera traps, linear transects and track and sign surveys in the Amazon. *Perspectives in Ecology and Conservation*, 20, 303–313.
- Purchase, C., et al. (2024). Reintroduction of the extinct-in-the-wild Spix's Macaw (*Cyanopsitta spixii*) in the Caatinga Forest Domain of Brazil. *Diversity*, 16, 80.

- RBCC - Rede Brasileira de Ciência Cidadã. (2025). *Documento orientador do sistema de Governança da RBCC* (3rd ed.). RBCC
- Riesch, H., & Potter, C. (2014). Citizen science as seen by scientists: methodological, epistemological and ethical dimensions. *Public Understanding of Science*, 23(1), 107–120.
- Rumenos, N. N., & Spazziani, M. D. L. (2020). Citizen science and environmental education: training courses and encouragement in a national park. *Remea – Revista Eletrônica do Mestrado em Educação Ambiental*, 127–144.
- Schmiedel, U., et al. (2016). Contributions of paraecologists and parataxonomists to research, conservation, and social development. *Conservation Biology*, 30, 506–519. <https://doi.org/10.1111/cobi.12661>
- Tófoli, C. F., et al. (2019). *Monitoramento participativo da biodiversidade: aprendizados em evolução* (Vol. 2). São Paulo: Instituto de Pesquisas Ecológicas/MEMNON.
- Vidal, D. G., Lopes, H. S., & Maia, R. L. (2025). Exploring the multifaceted relationship between human health and urban nature in times of crises. *Frontiers in Ecology and Evolution*, 13, 1562049. <https://doi.org/10.3389/fevo.2025.1562049>

RÉSUMÉ

La science citoyenne recèle un potentiel considérable en tant qu'approche stratégique pour l'engagement du public dans les aires protégées, mais sa mise en œuvre varie considérablement selon les contextes de conservation. Cet article analyse l'intégration de la science citoyenne dans les aires protégées brésiliennes, en mettant l'accent sur ses principales caractéristiques et les variations dans son utilisation selon les différents types de conservation. S'appuyant sur une revue systématique de 59 publications parues entre 2011 et 2023, l'étude identifie 24 bonnes pratiques regroupées en quatre dimensions analytiques: le bénévolat, la recherche, la gouvernance et les aspects opérationnels. Cette revue met en évidence 20 défis récurrents et compile 35 recommandations visant à surmonter les obstacles méthodologiques, institutionnels et participatifs. Les résultats révèlent des disparités entre les différents types de zones de conservation : les parcs nationaux ont tendance à privilégier des approches scientifiques et éducatives avec une implication communautaire limitée, tandis que les réserves extractives et les réserves de développement durable font preuve d'une intégration communautaire et d'une participation territoriale plus fortes. Cette étude présente une cartographie comparative par type de zone protégée, mettant en relation les caractéristiques de la science citoyenne avec les objectifs de conservation. La pleine réalisation du potentiel transformateur de la science citoyenne dépendra de son intégration plus profonde dans les processus décisionnels et les structures de gouvernance, ce qui permettra de la consolider en tant qu'outil stratégique pour une conservation plus démocratique et plus efficace.

RESUMEN

La ciencia ciudadana encierra un potencial considerable como enfoque estratégico para la participación ciudadana en las áreas protegidas; sin embargo, su aplicación varía sustancialmente según los distintos contextos de conservación. Este artículo analiza la integración de la ciencia ciudadana en las áreas protegidas brasileñas, centrándose en sus principales características y en las variaciones en su uso según los distintos tipos de conservación. A partir de una revisión sistemática de 59 publicaciones entre 2011 y 2023, el estudio identifica 24 buenas prácticas agrupadas en cuatro dimensiones analíticas: voluntariado, investigación, gobernanza y aspectos operativos. La revisión destaca 20 retos recurrentes y recopila 35 recomendaciones para abordar las barreras metodológicas, institucionales y participativas. Los resultados revelan diferencias entre los distintos tipos de conservación: los parques nacionales tienden a favorecer enfoques científicos y educativos con una participación comunitaria limitada, mientras que las reservas extractivas y las reservas de desarrollo sostenible muestran una mayor integración comunitaria y participación territorial. Este estudio presenta un mapeo comparativo por tipo de área protegida, relacionando las características de la ciencia ciudadana con los objetivos de conservación. La plena realización del potencial transformador de la ciencia ciudadana dependerá de su mayor integración en los procesos de toma de decisiones y en las estructuras de gobernanza, consolidándola como una herramienta estratégica para una conservación más democrática y eficaz.

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