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Ichthyofauna of the Brazilian semiarid region reservoirs: a scientometric analysis of publications from the last 50 years

Ictiofauna dos açudes da região semiárida brasileira: uma análise cienciométrica de publicações dos últimos 50 anos

Ana Luisa Eufrasio Pinto[1], Juan Alves Pereira[2] and Bianca de Freitas Terra[1,2*]

[1]Centro de Ciências Agrárias e Biológicas, Universidade Estadual Vale do Acaraú – UVA, Av. Padre Francisco Sadoc de Araújo, 850, Campus da Betânia, CEP 62040-370, Sobral, CE, Brasil

[2]Programa de Pós-Graduação em Ecologia e Conservação, Universidade Estadual da Paraíba – UEPB, Av. das Braúnas, 351, Bairro Universitário, CEP 58429-500, Campina Grande, PB, Brasil

*e-mail: bianca_freitas@uvanet.br

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Abstract: Aim: The construction of reservoirs in the Brazilian semiarid region is a predominant practice aimed mainly at water supply. Introducing fish in these ecosystems has generated environmental and social consequences. We analyzed articles on the ichthyofauna found in reservoirs from this region over the past 50 years. **Methods:** This qualitative-quantitative scientometric analysis considered the scientific impact of the articles, the origin of the species studied, the main topics covered, and women´s participation in the authorship. The articles were collected from the leading research databases: Google Scholar, SciELO (Scientific Electronic Library Online), and Web of Science. **Results:** We found 60 scientific papers on the subject. Most had low impact and visibility, and the state that contributed the most was Rio Grande do Norte (RN). The three most studied reservoirs made up almost half of the articles found (28). Research has only advanced considerably in the last decade, and the most discussed topics are related to the cultivation of commercial fish species, emphasizing pisciculture, reproductive biology, and fish nutrition. **Conclusions:** Despite the significant number of women participating, their visibility in the scientific community remains limited, which affects the community as a whole. Besides, it is crucial to continue promoting research on fish taxonomy, phylogenetics, and functional ecology in the reservoirs of the Brazilian semiarid region.

Keywords: dams; semiarid; scientific publication; scientific impact.

Resumo: Objetivo: A construção de reservatórios na região semiárida brasileira é uma prática predominante destinada principalmente ao abastecimento de água e, com a introdução de peixes como atividade amplamente praticada, gera consequências ambientais e sociais. O estudo analisou artigos sobre a ictiofauna encontrada em reservatórios dessa região nos últimos 50 anos. **Métodos:** A análise cienciométrica qualitativa-quantitativa considerou o impacto científico dessas publicações, a origem das espécies estudadas, os principais temas abordados e a participação de mulheres na autoria desses trabalhos. Os artigos foram coletados nos principais bancos de dados de pesquisa: Google Scholar, SciELO (Scientific Electronic Library Online) e Web of Science. **Resultados:** Foram encontradas 60 publicações sobre ictiofauna, a maioria delas de baixo impacto e pouca visibilidade, e o estado que mais contribuiu com publicações foi o Rio Grande do Norte (RN), com três reservatórios compreendendo quase metade dos artigos encontrados (28). Houve um avanço considerável nas pesquisas somente na última década e os temas mais discutidos estão relacionados ao cultivo de espécies comerciais de

peixes, com destaque para os seguintes assuntos: piscicultura, biologia reprodutiva e nutrição de peixes. **Conclusões:** Apesar do número significativo de mulheres participantes, sua visibilidade na comunidade científica ainda é limitada, o que afeta a comunidade como um todo. Além disso, é fundamental continuar promovendo pesquisas sobre taxonomia, filogenética e ecologia funcional de peixes em reservatórios do semiárido brasileiro.

Palavras-chave: barragens; semiárido; publicação científica; impacto científico.

1. Introduction

The semiarid region of Brazil is characterized by dry forests and naturally intermittent rivers and streams. Historic droughts that severely impacted this area led to the construction of numerous river dams. The first large government-subsidized reservoir in this region was the Cedro Dam in Ceará, built during the timeframe of the Brazilian Empire (1822-1889) (Monteiro, 2020). Alongside the dam projects, a fishing initiative was introduced, which often involved the introduction of non-native fish species into the reservoirs to provide animal protein to the population (Brasil, 2022). This practice popularized artisanal fishing, which has significant economic and ethnobiological importance for local communities and is a primary activity in these systems (Oliveira et al., 2016).

The construction of reservoirs and fish stocking are essential practices for meeting the water and nutritional needs of riverside populations (Kerezsy et al., 2017). However, these practices can lead to significant environmental changes and negatively impact biodiversity (Carneiro & Campos, 2006; Grill et al., 2019; Barbarossa et al., 2020; Carvalho, 2020). River damming alters water flow and chemical composition and is one of the greatest threats to freshwater biodiversity. It causes habitat fragmentation, blocks migration routes, and reduces river connectivity, limiting fish access to nursery areas and feeding sites (Agostinho et al., 2016; Pelicice et al., 2017). Additionally, introducing non-native species is the second leading cause of biodiversity loss, following habitat destruction (Reid et al., 2019; Barbarossa et al., 2020).

The native fish fauna in this region's river basin is quite diverse. According to Rosa et al. (2003), 240 fish species have been recorded in the area, with an endemism rate of 57%. Lima et al. (2017) identified 386 species and reported an endemism rate of 52%. However, research on fish biodiversity in the semiarid region has historically lacked sufficient investment, resulting in gaps in the database and knowledge (Nicola et al., 2016). During the ten years from 2006 to 2016, only 18 studies were conducted on fish from the semiarid region, half of which focused on describing new species. These studies are unevenly distributed across the region, with states such as Alagoas, Sergipe, and Minas Gerais lacking any research on fish within their borders. At the same time, other states also have fewer published works. Research on the ichthyofauna of reservoirs in these areas is minimal, with most reservoirs having only one publication (e.g., Orós in Ceará and Jaramataia in Alagoas). Addressing these gaps and reducing disparities in research is highly urgent, particularly in light of global and regional needs for biodiversity conservation and environmental management.

Scientometrics has become a powerful tool for science policy, influencing the direction of projects and institutional funding by analyzing priorities, perspectives, trends, and gaps in current knowledge (Ivancheva, 2008; Razera, 2016). This study aimed to examine the research on reservoir ichthyofauna in the semiarid region of Brazil over the past 50 years. It includes an analysis of the impact of publications, the spatial and temporal distribution of studies, the species studied, the main subjects covered, and the involvement of women's researchers in this field. We hope this study identifies potential areas for future research, contributes to the long-term preservation of biological diversity, and supports enhanced fisheries management and species conservation programs.

2. Material and Methods

This study is a scientometric analysis with both qualitative and quantitative aspects (Gerhardt & Silveira, 2009). It examines articles published in scientific journals over the past 50 years. We gathered articles from Google Scholar, SciELO (Scientific Electronic Library Online), and Web of Science. When using Google Scholar, we applied the following filters: "period (1973 to 2023)" and "include citations". The filter on the SciELO website was set to "Coleções (Brasil)". It was left open without specific markings. The keywords used in the searches included "açude", "reservatório", "peixe", "ictiofauna", "nordeste", "semiárido", "reservoir", "fish", "ichthyofauna", "northeast", "semiarid", with different combinations. These general keywords allowed us to select articles from various fields such

as zoology, ecology, veterinary, and aquaculture to understand how the fish in these environments are being studied.

After saving the articles, we downloaded them into the JabRef program in the "BibTeX" format (JabRef, 2022). We grouped them by year of publication and manually reviewed them to avoid repetition or publications that deviated from the topic (e.g., reviews or studies conducted outside of the reservoir limits). We then exported the data as an Excel spreadsheet. After that, we reviewed the spreadsheet again to remove duplications and add information not obtained in JabRef (e.g., number of citations and gender of the first author). Next, we created different spreadsheets with the analyzed metrics, which included the impact factor of the journals, evaluation within the Qualis-Periódicos system, spatial (states) and temporal (year) distribution of the studies, number of citations, the subjects covered, the origin of the target species of the survey (native or non-native), and identification of the author's gender to calculate woman participation in research.

The Qualis evaluation system assesses the impact of publications based on the journals in which they are published. According to CAPES's most recent classification (2017-2020), journals are grouped into nine strata and receive a single general classification rather than one per subject area. The strata are A1 to A4 (high impact), B1 to B4 (medium impact), and C or unclassified (low impact). The impact factor (IF), which reflects the yearly mean number of citations of articles published in the last two years in a given journal (Brasil, 2018), was accessed through the website JCR Clarivate (2022). The citations received by each publication were obtained from the Google Scholar database (data collected in November 2023) and were used to assess the significance of the work as a reference.

Each article was carefully analyzed and categorized into subjects based on their research themes, using the Tagcrowd platform (tagcrowd.com) (Steinbock, 2006) to create a word cloud. This approach highlighted the most frequently cited topics and provided a sample of the diverse research areas studied over the years, focusing on studying ichthyofauna. The main subjects identified in the research were determined by examining the titles and abstracts. These subjects were closely related to the nature of the research and its primary objectives, such as reproductive biology, nutrition, and species composition. The word cloud calculated the prominence of each category based on its frequency in the publications, with topics that were more frequently covered appearing more prominently in the cloud.

We gathered information on whether the species discussed in each article were native or non-native from their methodology and results sections. We categorized the articles into three groups: 1) publications about native species, 2) publications about introduced species, and 3) publications that covered both groups. Additionally, we identified three publications for which we could not determine the origin of the species due to insufficient information. To investigate women's contribution to these works, we determined the gender of the authors of each publication as either woman or man. We determined author genders by analyzing names and, when necessary, photos available on ResearchGate, Google Scholar, and/or institutions' websites. We acknowledge that the binary gender system limits this approach, but we believe it can help initiate discussions about gender imbalances. Furthermore, we used the geographic information system software Quantum GIS (QGIS) (http://qgis.osgeo.org, 2021) to map out the states and research institutions contributing to the analyzed studies and the partnerships and collaborative research groups among different institutions.

3. Results

A total of 63 scientific articles were found on the search platforms. After reviewing and excluding two articles that did not meet the selection criteria and one duplicate, 60 publications remained for analysis. These articles were published in 40 journals covering Biodiversity, Zootechnics, Fishing resources, Veterinary Medicine, Agricultural Sciences, Geography, Fisheries, and Aquaculture (Table 1).

Of the 40 journals we examined, 17 had no Impact Factor. This means that 23 journals had an Impact Factor ranging from 0.1 to 8.2, and half (12) had an Impact Factor of 1.0 or less. These journals were categorized across all Qualis CAPES strata. The number of journals classified as Qualis CAPES A and B was 16 and 17, respectively; five did not have a Qualis classification, and two were classified in stratum C. Only one scientific article (published in 2003) received over 100 citations. Additionally, 33 articles received less than ten citations (published between 2004 and 2023), 21 received between ten and 40 citations (between 2003 and 2020), two received between 40 and

Table 1. List of journals containing scientific articles being analyzed, along with their Impact Factors (IF) and Qualis CAPES ratings. Of the 40 journals, 17 did not have an Impact Factor, and five were not classified according to Qualis. "Nº" denotes the number of articles from each journal in this research.

Journal	IF	Qualis CAPES	Nº
Acta Ichthyologica et Piscatoria	0.8	B3	1
Acta Limnologica Brasiliensia	1.6	B2	6
Acta of Fisheries and Aquatic Resources			1
Acta Scientiarum. Biological sciences	0.6	B2	1
Aquaculture	3.9	A1	1
Aquaculture Reports	3.1	A2	2
Aquaculture Research	1.9	A1	1
Arquivo Brasileiro de Medicina Veterinária e Zootecnia	0.4	B1	1
Biota Amazônia		B4	7
Biota Neotropica	1.0	B1	3
Boletim do Instituto de Pesca	0.5	A4	2
Brazilian Journal of Biology	1.6	A3	2
Check list journal of species lists and distribution			1
Documentos Técnico Científicos			1
Ecological Indicators	7.0	A1	1
Ecology of Freshwater Fish	1.6	A2	1
Entorno Geográfico	0.1	A3	1
Environmental Science and Pollution Research	0.9	A2	1
Freshwater Biology	2.8	A1	1
Hydrobiologia	2.2	A2	2
Iheringia Serie Zoologia	0.5		3
Journal of Animal Behaviour and Biometeorology	1.8	B2	1
Journal of Applied Ichthyology	0.7	B2	1
Revista Biotemas	0.7	B2	1
Revista Brasileira de Ciências Veterinária		B3	1
Revista Brasileira de Ciências Agrárias	0.3	B2	1
Revista Brasileira de Geografia Física		A2	1
Revista Brasileira de Higiene e Sanidade Animal		B4	1
Revista Brasileira de Zoociências		B4	1
Revista de Biologia e Ciências da Terra		B1	1
Revista de Biologia Tropical	0.8	B1	2
Revista Ceres		B1	1
Revista de Economia e Sociologia Rural		A1	1
Revista de Política Agrícola		B1	1
Revista GeoSaberes			1
Revista Nordestina de Biologia		C	1
Revista Nordestina de Zoologia		C	1
Scientia Plena		A4	1
Science of the Total Environmental	8.2	A1	1
Scientific World Journal		A3	1

80 citations (between 2016 and 2018), and three articles were not cited at all (in 2016, 2017, and 2020) (Figure 1).

Only one article was published in some years, while the maximum number of articles published in a single year reached seven. The average number of articles published per year was one. Although there has been an increase in publications since 2010, very few studies have focused on fish species from reservoirs in the Brazilian semiarid region, with fewer than ten articles published yearly (Figure 2).

Twenty-one subjects were identified, some more prominent than others, as illustrated in the word cloud (Figure 3). The most common publications addressed native and non-native species, accounting for 22 articles. This was followed by 19 articles that focused exclusively on native species and 16 articles dedicated solely to non-native species.

In 24 articles, the first authors were equally identified as men or women. However, articles written by male authors (8) outnumbered those written solely by women authors (4). Additionally,

out of 277 authors, 162 were men, and 115 were women. The state contributing the most publications was Rio Grande do Norte (RN), accounting for 48% of the published articles. This was followed by the states of Ceará (15%), Paraíba (8%), Maranhão (8%), São Paulo (5%), Pernambuco (4%), and Rio de Janeiro (2%) (Figure 4). Each of the remaining states contributed less than 1%. The institutions with the most publications were from Rio Grande do Nort state. Specifically, the Federal University of Rio Grande do Norte (UFRN) and the Federal Rural University of Semi-Árido (UFERSA) together produced 28 publications, accounting for 47% of the total articles published (Figure 4). Among the most studied reservoirs are the Santa Cruz, Eurico Gaspar Dutra, and Umari reservoirs in Rio Grande do Norte (Figure 5).

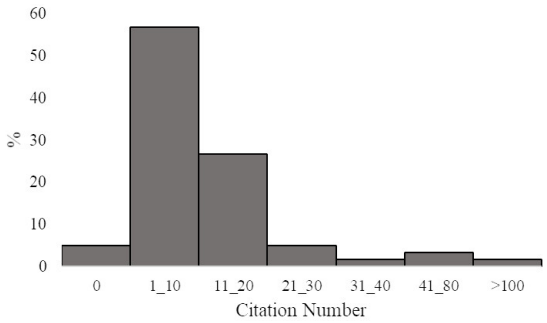


Figure 1. Distribution of citation numbers according to *Google Scholar* (total number of papers: 60).

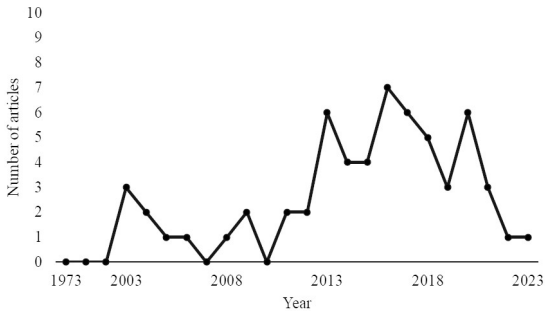


Figure 2. Number of articles published per year. No article was found between 1973 and 2002. The first published article dates from 2003, with a slight increase in publications over the last decade.

4. Discussion

Most articles that explore the fish species in reservoirs within the Brazilian semiarid region have been published in small, lesser-known journals. Only a few articles have been published in high-impact journals, with the most cited ones appearing in journals classified between A2 and A1, having an impact factor ranging from 2.2 to 7.0. The most cited article, with 150 citations, is "*Do fish regulate phytoplankton in shallow eutrophic Northeast Brazilian reservoirs?*" by Lazzaro et al. (2003), which was published in Freshwater Biology (IF = 2.8 and Qualis CAPES = A1). According to Padial et al. (2010), there is generally less bias in citations within ecology, and the number of articles cited in this field is usually high, potentially explaining the observed pattern. However, studies focusing on the fish species in reservoirs within the Brazilian semiarid region typically have limited relevance. This trend

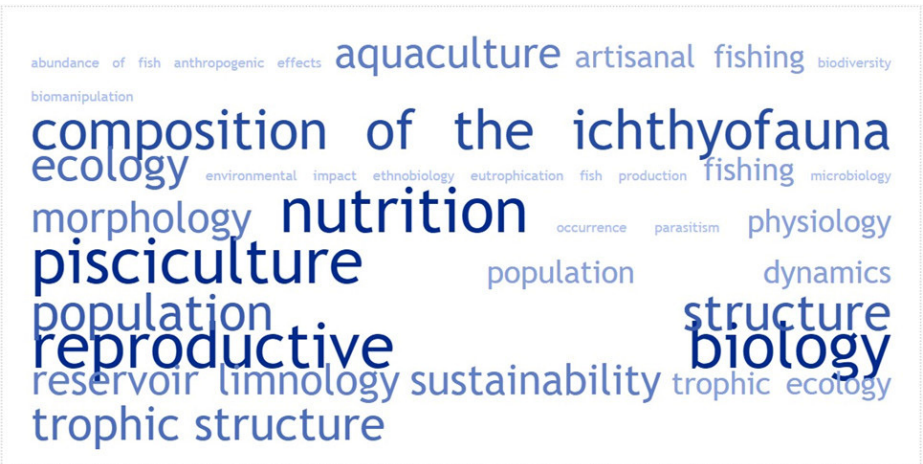
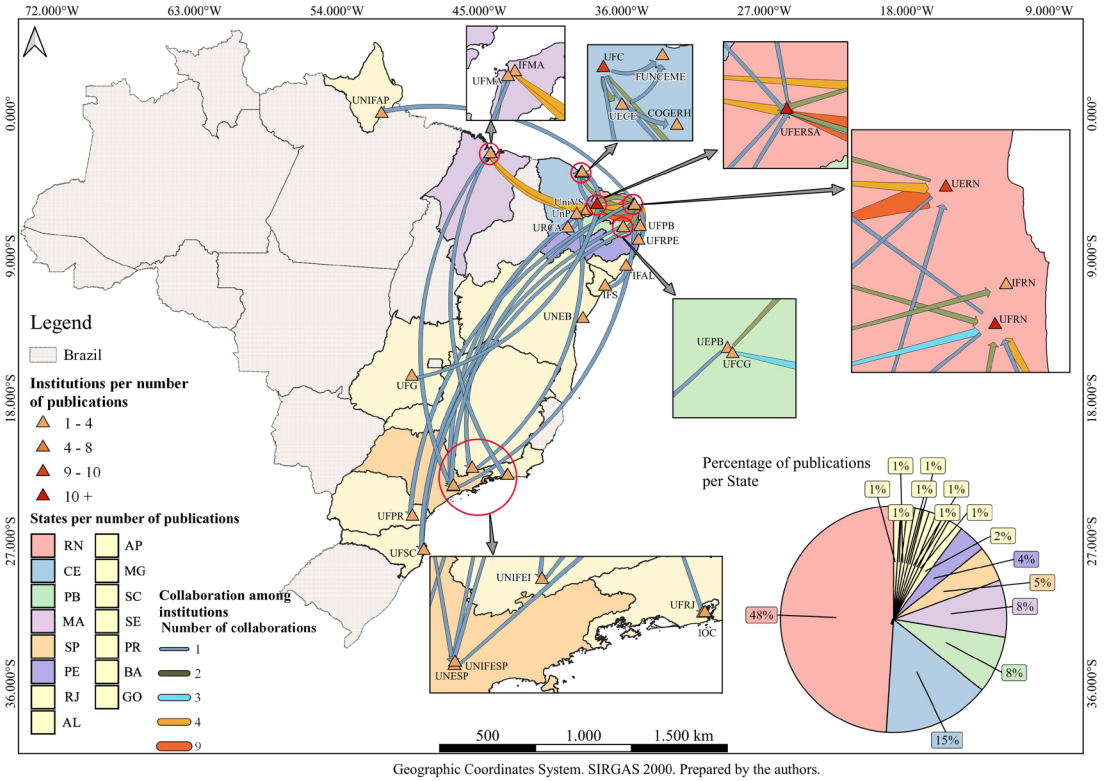


Figure 3. Word cloud with the subjects covered in the publications. The most discussed topics stand out in dark blue and larger letters; in light blue and small letters, the least published topics in the area are highlighted. The most frequently published topics in this area were nutrition, pisciculture, and reproductive biology.



Geographic Coordinates System. SIRGAS 2000. Prepared by the authors.

Figure 4. Map showing the institutions, the collaboration level among them, and states in Brazil that published studies on reservoir ichthyofauna from the Brazilian semiarid region (1973-2023). RN - Rio Grande do Norte; CE - Ceará; PB - Paraíba; MA - Maranhão; PE - Pernambuco; AL - Alagoas; AP - Amapá; MG - Minas Gerais; RJ – Rio de Janeiro; SC – Santa Catarina; SP - São Paulo; SE - Sergipe; PR - Paraná.

may be attributed to the nature of the research being conducted, reflected in the low and concentrated citation numbers. The year of publication may also affect an article's citation count, but further investigation is necessary to understand why more than half of the articles have received low citation numbers.

Although we focused on analyzing the last 50 years, we noticed a significant increase in articles published from 2010 onwards. Only in the last decade has a considerable advancement in research into the ichthyofauna of reservoirs in the Brazilian semiarid region. This growth is connected to the rise in scientific publications across different fields of study and may be linked to increased research funding during that time (Dudziak, 2018). Furthermore, implementing public policies to attract and retain researchers in this region has contributed to this development. However, particular areas require further exploration. For instance, only two articles on evaluating sustainability programs in reservoirs have been published. The first study assessing the sustainability of a fish-breeding program was published in 2013 and has only received one citation. The second one, published in 2016, received 77 citations. Additionally, a decline in the number of publications has been observed from 2020 onwards. However, this recent decrease cannot be explained at this time.

The most frequently cited article discusses ecology, but other vital topics need better coverage. According to the word cloud, topics like biodiversity, anthropogenic effects, environmental impacts, and ethnobiology were not given enough attention. On the other hand, nutrition, reproductive biology, and pisciculture were the subjects most discussed, with 27 published articles. These subjects relate to a critical activity in reservoirs, particularly in the Brazilian semiarid region: the production of animal protein for consumption. This economic and socially significant activity has ecological consequences for the native fish species, leading to changes in their composition and a significant reduction in their abundance and richness (Brito et al., 2020; Agostinho et al., 2016). Impoundments contribute to the homogenization of aquatic life, leading to more remarkable similarities among different groups of organisms. Additionally, introducing and

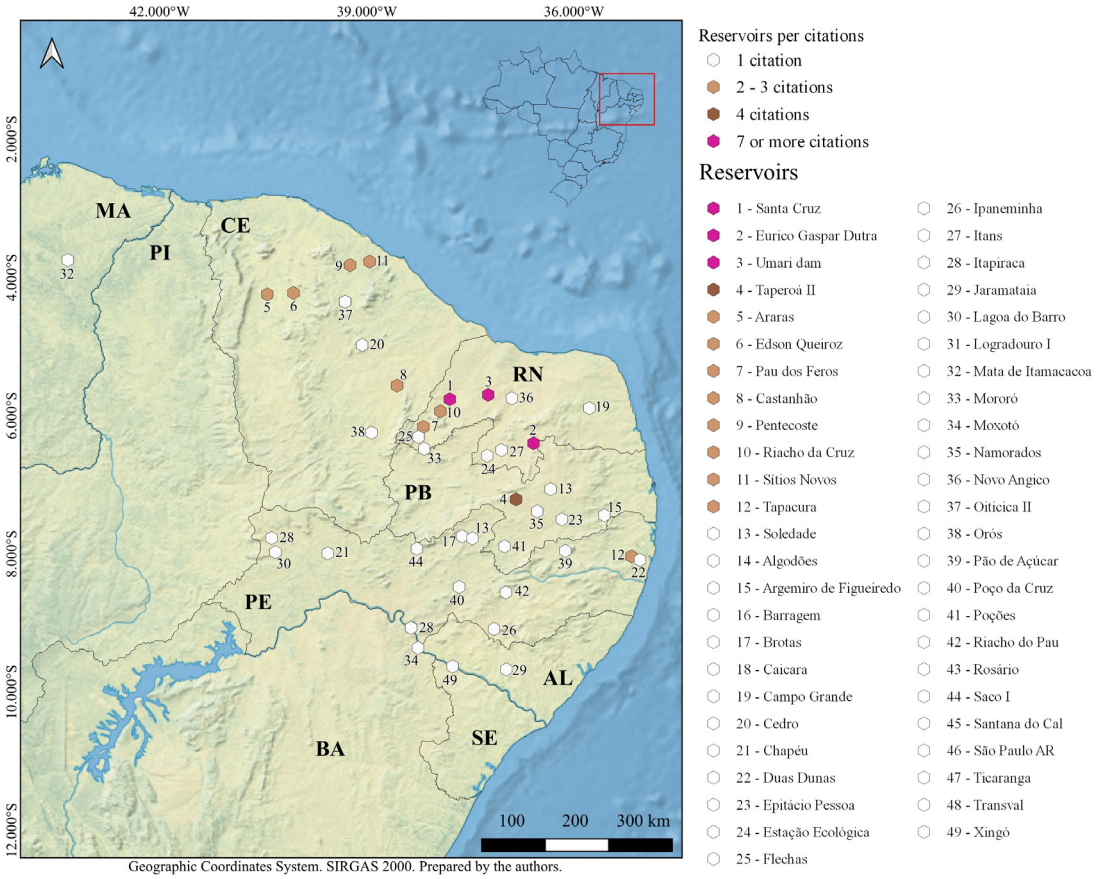


Figure 5. Map showing the reservoirs and the number of articles published. RN - Rio Grande do Norte; CE - Ceará; PB - Paraíba; MA - Maranhão; PE - Pernambuco.

stocking non-native fish species is the second largest cause of biodiversity loss (Barbarossa et al., 2020; Reid et al., 2019; Bezerra et al., 2018).

Despite the large number of articles that presented studies on native species, there was also a high number of studies on non-native species or a combination of both classifications. This reflects the significance of introduced species, primarily driven by fish stocking programs. Some species can become invasive and strong competitors, which can affect the existence of native species, change the habitat, and jeopardize the biodiversity of these areas. Without natural ecological controls, these animals may undergo irreversible modifications, leading to observable consequences (Vitule, 2009). Despite the challenges and issues in the analyzed studies, only one dealt with this specific subject, titled "*The impact of a biomanipulation experiment on the ichthyofauna diet from a neotropical reservoir in the Brazilian semiarid*", published in Acta Limnologica Brasiliensia. In this article, Moura et al. (2018) conducted a biomanipulation experiment. They analyzed its impact on feeding fish species from a semiarid reservoir before removing an invasive non-native species, the Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758). Three out of the five species studied showed a change in diet composition.

The publications analyzed revealed some interesting findings. In this study, 53% of the first authors were men, and 47% were women, indicating a relatively balanced representation. However, when considering the most impactful articles, only one had a woman as the first author, and men authored the article with the highest number of citations. This trend is indicative of a broader pattern in the field of Science. It is important to note that during the COVID-19 pandemic, women female researchers with children experienced a productivity drop of over 10% compared to male researchers with children (Ashaia, 2022). This gender discrepancy continues to impact article publication and scientific productivity.

The scenario mentioned is linked to the postgraduate programs (PPG), mainly in RN, such as PPG-PSICOB (Postgraduate Program in Psychobiology at UFRN), PPGBEA (Postgraduate

Program in Bioecology at UFRN), and the PPGCA (Postgraduate Program in Animal Science at UFERSA). These programs have been evaluated by CAPES (Coordination for the Improvement of Higher Education Personnel) as programs of academic excellence, demonstrating significant advancements in the number of articles published and the expansion of collaboration networks with other institutions. Consequently, the most studied reservoirs are located in RN, and the three most studied reservoirs comprise almost half of the scientific articles (28) included in this study.

The results of PPG evaluations shape public and private policies for the postgraduate sector and determine the size and distribution of development initiatives such as scholarships, grants, and support. These evaluations also help identify regional disparities in the National Postgraduate System (SNPG), guiding efforts to establish and expand new Programs (Dorsa, 2020). Some authors, such as Schwartzman (2002) and Souza et al. (2020), emphasize that evaluation processes typically arise from two primary needs. First, there is the need for the State to guide funding and manage the pressures resulting from the increasing expansion of access to higher education and collaboration with the productive sector. Second, there are the needs of universities, which require government incentives and funding to preserve their research autonomy, essential for maintaining their critical and innovative nature.

In addition to various universities across the country, there were contributions from other public institutions, the Ceará Water Resources Management Company, the Secretariat of Rural Production and Agrarian Reform of Pernambuco, and the São Francisco Hydroelectric Company (Chesf). Collaborations with institutions from other countries also highlighted international partnerships (six papers presented an international collaboration with one or more institutions from six different countries: France (1), Portugal (1), Senegal (1), Spain (3), South Africa (2), and United States of America (1)). Two of the most cited articles featured international collaborations, such as the Institut de Ciències del Mar (ICM-CSIC), Lazzaro et al. (2003), and Laboratoire d'Ecologie de Paris, Bezerra et al. (2018). Furthermore, the article with the highest impact and visibility had an international collaboration with the Institute of Aquatic Ecology, Spain, Rocha et al. (2021). Research conducted in cooperation with other authors and institutions generally has a better chance of acceptance and higher citation rates, mainly when collaboration occurs between different institutions compared to works published individually (Vanz & Stumpf, 2010; Adefila et al., 2023). The link between collaboration and productivity is now widely recognized, indicating that the more authors/affiliated institutions involved, the greater the reach and potential for citations (Adefila et al., 2023). Sharing of materials and equipment, exchange of scientific knowledge, greater specialization, and in-depth research are all advantages of such collaborations (Zanotto et al., 2016).

Hence, it is essential to continue promoting research on fish taxonomy, phylogenetics, and functional ecology in the reservoirs of the Brazilian semiarid region. Additionally, there are opportunities to advance studies in other areas, such as reproductive biology and fish farming. Studying reservoirs is essential and can be aligned with sustainable development by assessing species conservation and mitigating potential threats. However, there is a need for increased scientific investment and collaborative efforts that involve society. This will give researchers more incentives to work together and enhance the visibility of their studies.

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Data availability

The entire dataset supporting the results of this study has been published in the article itself.

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