



A review of the knowledge on ichthyofauna of a tropical bay: Todos os Santos Bay, Brazil

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Abstract: A combination of a bibliometric and descriptive analysis was used to explore the scientific production information on the ichthyofauna of the Todos os Santos bay (TSB), Bahia, Brazil. For this, articles published in the databases of peer-reviewed journals, such as Scopus, Web of Science (WoS), Scientific Electronic Online (SciELO) and Google Scholar, were utilized. Additionally, a consultation was also carried out in the curriculum lattes of researchers who develop studies in the region. A total of 119 articles were selected for the period from 1973 to 2022, published in 58 journals and 2 books. The production of articles varied over time, with the highest number of publications in 2001. 43 institutions were identified, with the State University of Feira de Santana standing out. Trophic ecology (28 studies) was the most discussed topic. Among the studied environments, sandy beaches (24 studies) and muddy beaches (23 studies) predominated. A total of 289 species of fish were cited in the documented studies. It is recommended to expand there search to other geographic regions and ecosystems in the TSB. Furthermore, it is expected that this study may be useful for a better allocation of resources for research on the ichthyofauna of the TSB.

Key words: fish, literature review, coastal habitats, South America.

Uma revisão do conhecimento sobre a ictiofauna de uma baía tropical: Baía de Todos os Santos, Brasil. Resumo: Uma combinação de análise bibliométrica e descritiva foi utilizada para explorar as informações da produção científica sobre a ictiofauna da Baía de Todos os Santos (BTS), Bahia, Brasil. Para isso, foram utilizados artigos publicados nas bases de dados de periódicos revisados por pares, como Scopus, Web of Science (WoS), Scientific Electronic Online (SciELO) e Google Scholar. Também foi realizada consulta aos currículos lattes de pesquisadores que desenvolvem estudos na região. Foram selecionados 119 artigos para o período de 1973 a 2022, publicados em 58 periódicos e 2 livros. A produção de artigos variou ao longo do tempo, com maior número de publicações em 2001. Foram identificadas 43 instituições, com destaque para a Universidade Estadual de Feira de Santana. A ecologia trófica (28 estudos) foi o tema mais discutido. Entre os ambientes estudados predominaram praias arenosas (24 estudos) e lamosas (23 estudos). Um total de 289 espécies de peixes foram citadas nos estudos documentados. Recomenda-se expandir a pesquisa para outras regiões geográficas e ecossistemas da BTS. Além disso, espera-se que este estudo possa ser útil para uma melhor alocação de recursos para pesquisas sobre a ictiofauna da BTS.

Palavras-chave: peixe, revisão da literatura, habitats costeiros, América do Sul.

Introduction

Coastal bays are large bodies of water that play a critical role in the survival of marine organisms, serving as important breeding, feeding and nursery areas, especially for fish and invertebrates (Franco & Santos 2018; Pinto *et al.* 2022). They are home to a great diversity of species that sustain most of the goods and services of their extremely heterogeneous habitats and interconnected compartments, such as mangroves, sandbanks, mudflats and seagrass meadows that increase habitat diversity and biological productivity (Andrade-Tubino *et al.* 2020). Estuaries provide food, regulate water quality, protect coastal damage and flooding caused by storms, provide recreational opportunities and aesthetic and spiritual value (Needles *et al.* 2015). These systems have also become progressively vulnerable to human impacts related to unplanned urbanization and population growth, which entail in declines in marine biodiversity and disruptions in ecosystem functioning (Franco & Santos 2018).

Bibliometry is a scientific method used to uncover emerging trends in the performance of articles and journals, patterns of collaborations, research components, and to explore the intellectual structure of a specific domain of existing literature (Donthu *et al.* 2021). Bibliometric research involves the application of quantitative and statistical techniques (e.g., descriptive statistical analysis or performance analysis and cluster analysis or scientific mapping) to bibliographic data (e.g., publications and citations) (Mukherjee *et al.* 2022). Bibliometric analyses are essential for researchers to identify research focus areas, access important articles, collaborate with other countries, and explore future research directions (Olisah & Adams 2021). The dynamics of changes in the subjects and focuses of research can be clearly shown through bibliometrics (Xie *et al.* 2023). Bibliometric studies allow, through an overview, to identify gaps in knowledge and methodologies that can be used in future studies.

Literature reviews have been developed in Brazil in recent years, addressing several topics related to fish and fishing, among which are: the analysis of the scientific production on freshwater ichthyofauna (Azevedo *et al.* 2010); ichthyofauna of estuarine environments (Blaber 2013; Blaber & Barletta 2016; Gerhardinger *et al.* 2020);

Scientometric analysis for Western Atlantic *Cynoscion* species; fishery production of *Paralichthys* (Santos & Vianna 2017, 2018); climate change and fisheries in the Southwest of the South Atlantic (Franco *et al.* 2020); eating and reproductive habits (Nascimento *et al.* 2021) and in reef environments (Rocha & Sampaio 2022). As stated by Blaber (2013), Brazil was one of the countries that most published in the period between 2002 and 2012 on tropical estuarine fish, contributing to 7% of the publications in this period. Literature reviews on ichthyofauna are non-existent in the TSB.

Understanding how studies on the ichthyofauna in the Todos os Santos Bay (TSB), Bahia, Brazil are being developed is relevant to identify patterns and trends in the literature, identifying main methodologies used, themes, research centers and authors, in addition to recognizing knowledge gaps that can guide the implementation of future studies and support the management of coastal areas.

Based on the dataset and studies on the TSB ichthyofauna, this research aims at making a qualitative and quantitative approach to scientific production, as to answer the following questions: What is the production of literature in the sampled period? Who are the main authors, institutions, and number of partnerships? What are the most influential journals? Furthermore, the locations, types of studies, environments studied, fishing gear used, and most studied species are reported. To answer the proposed questions in our study, we built a unified methodological approach using bibliometric analysis, combined with qualitative descriptors.

Material and Methods

Study area: The TSB (12°61'–13°13'S/–38°45'–38°82'W), is a complex ecosystem with brackish and marine waters, small inland bays, many islands, reefs, estuaries, mangroves, and rainforest. Since June 5, 1999 (as per State Law, No. 7595), it constitutes an area of environmental protection (Soares *et al.* 2011). With an area of 1,233 km² and maximum N-S (E-W) length of approximately 50 km (45 km), it has a very defined seasonality, with a dry season between September and March and a rainy season between April and June (Mariani *et al.* 2022) (Fig. 1). It is located in the coastal zone of the

state of Bahia, belonging to the Eastern Brazil Marine Ecoregion, according to the classification proposed by Spalding *et al.* 2007.

The TBS is a typical coastal plain estuarine system that receives flow from the three main hydrographic basins of the Paraguaçu, Subaé and Jaguaripe rivers. It has an average depth of 9.8 m, and approximately 94% of its area is less than 25 m, with wind regimes determined by the seasonal trade winds (Aguar *et al.* 2019). It is an environment protected from wave action, with circulation dominated by the seas and salinity varying between 28 and 36 (Silva *et al.* 2024). The tides are semi-diurnal, ranging from 0.11 on the shelf to 0.06 inside the bay (Fonseca *et al.* 2024). The inflow of freshwater into the estuary has been on a long-term downward trend, and a peculiar hypersaline condition has been recorded in the region (Mariani *et al.* 2022).

The climate at the entrance to the bay is tropical humid, with an average air temperature of

25.2°C and average precipitation and evaporation of 2100 mm and 1002 mm, respectively. Average monthly air temperatures vary between 30°C in summer and 21.3°C in winter and sea surface temperatures from the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua show that the average maximum and minimum (2003-12) within the bay occur in February (30.5°C) and August (20.5°C - 26.5°C), respectively, due to variations in solar radiation. (Santana *et al.* 2022).

According to Dantas *et al.* 2012, since the beginning of its occupation in the 16th century, multiple uses of natural resources have been implemented. Industrial growth began in the 1930s, when oil was discovered and explored in the TSB waters, in the Reconcavo's sedimentary basin. The main industrial activities developed are chemical, petrochemical, metallurgical, food products and fertilizers (Rocha *et al.* 2012).

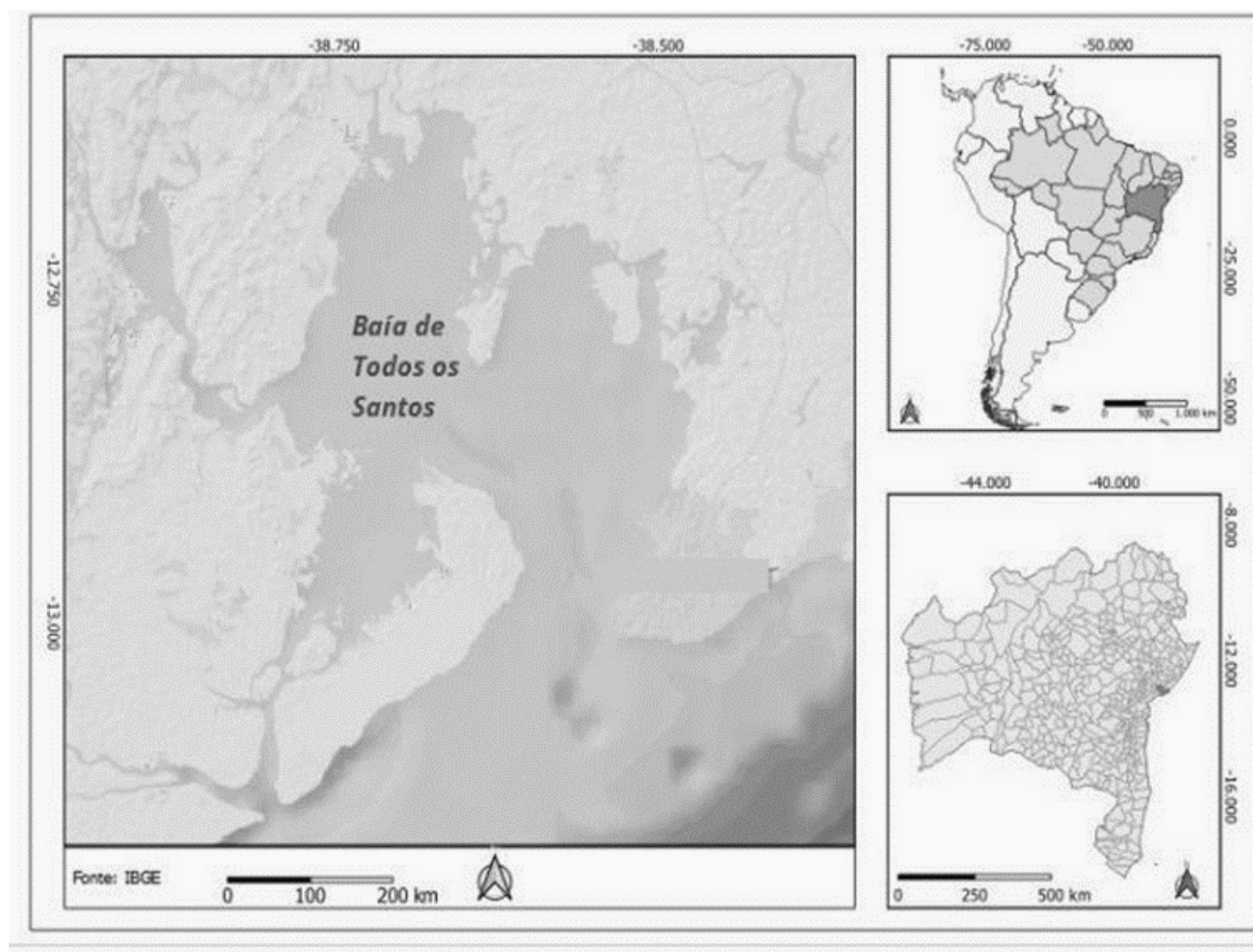


Figure 1. Study área: the Todos os Santos Bay, Bahia, Brazil

Inclusion criteria: The methodological approach was divided into two main steps: the first step included the choice of databases, identification of terms and filters in the research. The search was limited to publications in journals to avoid duplicity bias. Review articles, reviews, conference proceedings, incomplete studies, and studies in press were excluded from this research. Studies were selected in all languages and throughout the analyzed period, from 1973 to 2022. For the selection of articles, a manual screening was performed based on the established criteria, then a reading of the found studies was performed for their titles and/or the abstract, as to identify and exclude studies that did not fit to the objectives of this research. In the subsequent step, all selected scientific articles were used for bibliometric analysis and to answer the qualitative questions proposed in this study. The investigation included scientific articles on DNA, morphometry, distribution and recruitment, feeding, behavior, fishing, use of fish as a bioindicator, new occurrences, description of new species, taxonomic inventories, community studies, breeding, achromatic anomaly, pollution affecting the ichthyofauna. Due to the scarcity of studies on *Pristis* sp., a study on ethnobiology that deals with this species was included.

Database: To answer the proposed questions in this research, we performed a search in the literature between March and November of 2022 in the databases of Scopus, Web of Science (WoS), Scientific Electronic Online (SciELO), and Google Scholar. A consultation was also carried out in the curriculum lattes of the main researchers who develop studies in the TSB to ensure the inclusion of all studies. The taxonomic classification and spelling of species names followed Fricke *et al.* (2023). The list of valid species recorded is presented in systematic order of families as following Van der Laan *et al.* (2023). Genera and species are presented alphabetically by family.

Search and Sorting strategy: The search terms “Todos os Santos Bay” AND fish* were used aiming at the return of a wider body of literature. For ecological studies we combine the words “Todos os Santos Bay” AND “reproductive biology” OR reproduction AND fish* and “Todos os Santos Bay” AND diet OR “trophic ecology” AND fish*.

Data analysis: The growth of scientific production was analyzed through the annual survey of publications and the comparison of studies distribution regarding the average value and the values for standard deviation and means.

Furthermore, we analyzed the research fronts (institutions, partnerships, and authors) aiming to identify centers knowledge production and the cooperation between them.

Authorship was analyzed by surveying the number of articles per author. Multiple authorship studies, as well as the participating institutions received the same value (1), that is, without fractional attribution. The studies were analyzed according to their authorship, date of publication, title, institution, number of partnerships, journal, habitat, fishing gear (sampling device) and cited species.

Results

According to the survey carried out, after screening, we found 119 scientific articles published in the period from 1973 to 2022, with an annual average of 2.38 (Standard Deviation 2.6) (Fig. 2), being the first study performed in 1973 in the region of Monte Serrat (Salvador) in tide pools, was carried out by Almeida, V.G. during 1970 to 1971. In the decades from 1972 to 1979 and 1980 to 1990, only 01 study was found, respectively. Between 1991 and 2001 there were 28 studies, from 2002 to 2012, 45, and from 2013 to 2022, 44. The books were published in 2016 and 2018, edited by EDUNEB (University of the State of Bahia) and EDUFBA (Federal University of Bahia), respectively.

The highest numbers of publications were observed in 2001 (10 studies; 8.4%) followed by 2007 (8 studies; 6.7%) and 1999 and 2002 (with 7 studies; 5.8, each) of the total publications. The distribution of the accumulated number of publications in the historical series showed constant growth from 1998 onwards (with a peak in 2001) and a slow evolution in previous periods (Fig. 2).

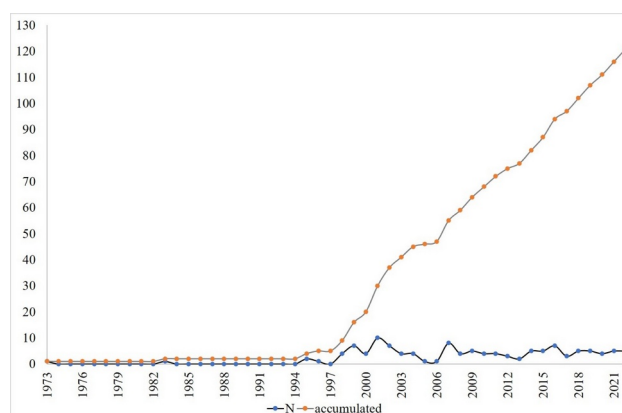


Figure 2. Annual and accumulated production of studies on ichthyofauna published between the period 1973 and 2022 (number of publications) in Todos os Santos Bay.

Regarding the number of publications per author, we found 171 authors, an average of 1.4 authors per study. Only 2 studies were single authored. The 10 main authors can be seen in Fig. 3, with emphasis on Lopes, P.R.D., with 56 documents with publications from 1995, he is also affiliated to the State University of Feira de Santana (UEFS), with his research focused on taxonomic inventories and trophic ecology of TSB fish species.

A total of 43 institutions participating in research on the TSB ichthyofauna were identified, of which 10 are international and 20 are public higher education institutions. The State University of Feira de Santana (BA) (UEFS, 66 documents) and the Federal University of Bahia (UFBA, 45) stood out. UFBA had the highest number of partnerships in the development of studies (with 28, 8 of which were international) followed by UEFS with 12 (1 of which was international) (Table I). In addition, the number of articles from a single institution, that is, the authors' addresses that were from the same institution (n= 61) was greater than that of collaborative articles.

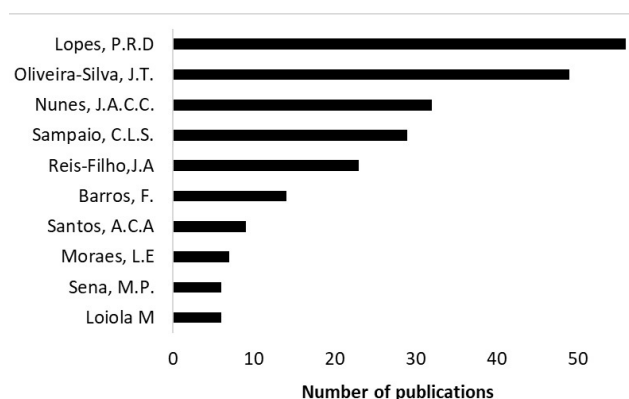


Figure 3. The ten most productive authors who published studies carried out in Todos os Santos Bay between 1973 and 2022

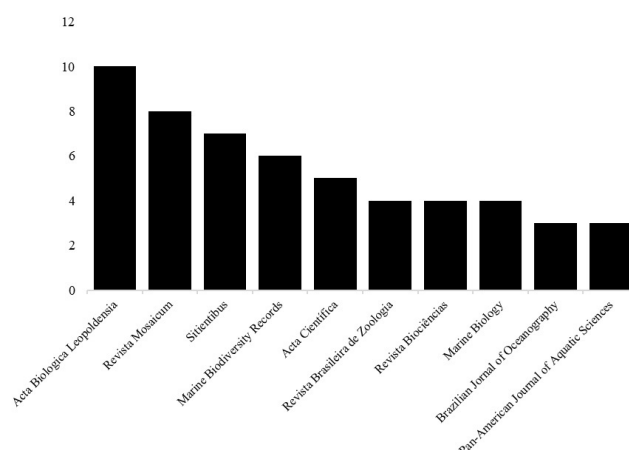


Figure 4 (on left column). Main journals that published studies on the ichthyofauna of Todos os Santos Bay during the period from 1973 to 2022.

We identified 58 journals, among which 32 are international. From these journals, 36 had only one study and 8 had two studies. Acta Biologica Leopoldensia (with 10 studies, 8.4%), Mosaicum (9 studies, 7.5%) and Sitientibus (7 studies, 5.8%) were responsible for 21.8% of the total number of studies selected in this research (Fig. 4). Sixty (50.4%) were written in Portuguese and fifty-nine studies (49.5%) in English.

Among the 119 studies published on the TSB ichthyofauna between 1973 and 2022, only 56 reference the study location. Most of these studies were carried out on the beach of Ponta da Ilha, Ilha de Itaparica, (Vera Cruz municipality) (18), followed by the beaches of Itapema, (Santo Amaro) and, Cabuçú, (Saubara) (12 each) and in the estuary of the Paraguaçu river (11). Twenty-two studies do not specify the location, indicating only TSB study area (Fig. 5). Between 1970 and 1971, the first published researches took place in the city of Salvador (Barra and Monte Serrat locations). From 1991, studies began in Cacha Pregos, Ilha de Itaparica (Vera Cruz), and in 1995 they expanded to the western part of the TSB (Santo Amaro and Saubara municipalities). In general, the studies are punctual and developed in periods of less than 2 years, restricting themselves to the western part of the bay. Seventeen articles (14.2%) did not specify the period sampled ([Supplementary Table I](#)).

The main studies published based on the criteria established in this study on the ichthyofauna of the TSB included the following topics or themes of investigation: trophic ecology (28 studies; 23.5%), new records (26; 21.8%), behavior (14; 11.7%), taxonomic inventories and community structure (11; 9.2% each) and fishing (5; 4.2%) (Fig. 6). The first studies published with trophic ecology started in 1995 with 2 species: *Hypanus guttatus* (Bloch & Schneider 1801) (Carqueija *et al.* 1995) and *Ogcocephalus vespertilio* (Linnaeus 1758) (Lopes & Miranda 1995). Taxonomic inventories were pioneering research in the region, and studies related to fish ecology began in 1997.

Sandy beaches (24 articles; 20.1%), muddy beaches (23; 19.3%), reefs (20; 16.8%) and estuaries (14; 11.7%) were the most studied coastal environments or ecosystems. In twelve studies (10.1%) there was no identification of the environment (Fig. 7).

Table I. Institutions and participations in studies on the TBS ichthyofauna from 1973 to 2022.

Institution	N
State University of Feira de Santana	66
Federal University of Bahia	45
Federal University of Alagoas	20
Federal University of Paraíba	13
ECUS	7
Federal University of Sul da Bahia	7
Federal University of Pará	5
Federal University of Espírito Santo	5
ICHTUS	4
Federal University of Rio Grande do Norte	4
Salvador Catholic University	4
State University of Rio de Janeiro	3
University of São Paulo	3
Cambridge University	2
Federal University of Santa Catarina	2
Aquatic biota	2
Federal University of Fluminense	2
Santa Úrsula University	2
Paulista State University	2
State University of Sudoeste da Bahia	2
State University of Bahia	2
Federal University of Rio de Janeiro	3
University of Copenhagen	1
National Museum of Marine Biology (Taiwan)	1
Fish Bizz Ltda	1
University of the Ryukyus, Japan	1
State University of Paraíba	1
University of Adelaide	1
Curtin University	1
Federal University of Rio Grande do Sul	1
Federal Rural University of the Semi-Árido	1
National Marine Science Centre, Southern Cross University	1
Vila Velha University	1
ECOIA	1
Reef Conservation Project (PCR)	1
Reef Ecology Group	1
INCT IN-TREE ¹	1
University of California	1
Federal University of Pernambuco	1
Porto of University	1
ONG V.I.V.A	1
University St Andrew	1

¹ INCT IN-TREE: National Institute of Science and Technology in Interdisciplinary and Transdisciplinary Studies in Ecology and Evolution

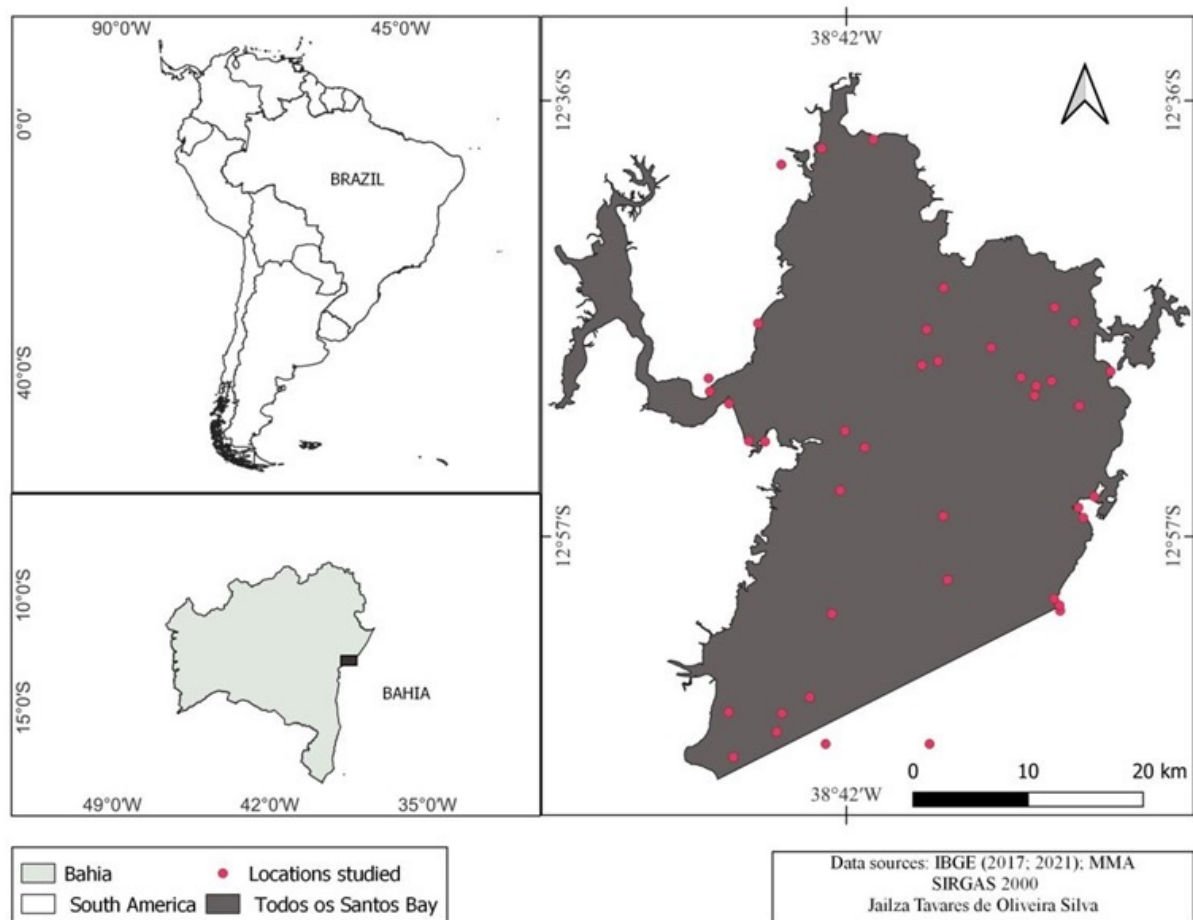


Figure 5. Locations of published studies on ichthyofauna at Todos os Santos Bay, in the Eastern Brazil Marine Ecoregion, from 1973 to 2022.

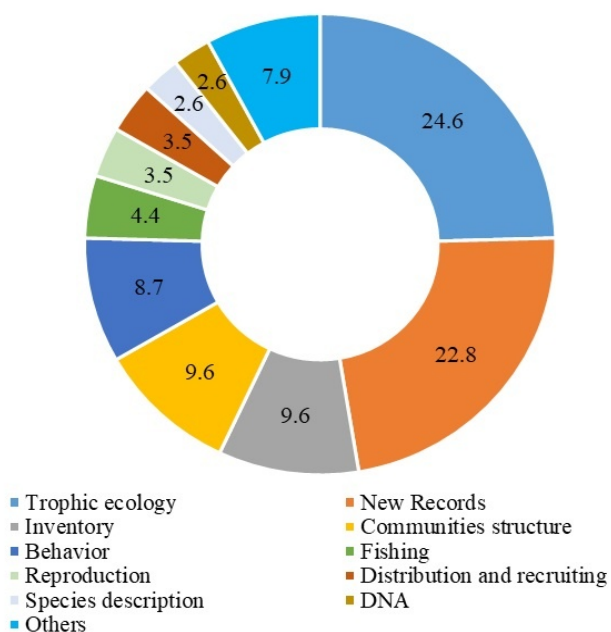


Figure 6. Main themes studied in the period from 1973 to 2022 on the Todos os Santos Bay ichthyofauna..

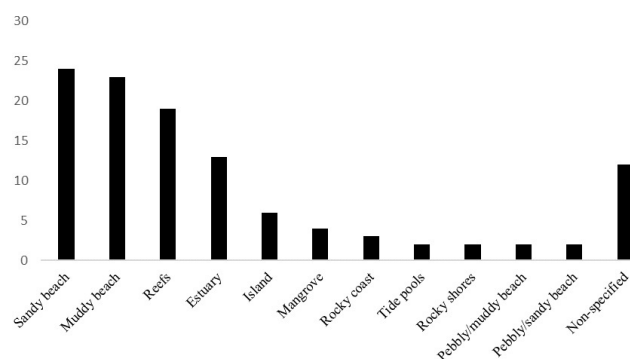


Figure 7. Ecosystems or environments targeted by the ichthyofauna studies at the Todos os Santos Bay, published between 1973 to and 2022.

Eighteen fishing gears were used in the development of the research. Hand trawling predominated (48 studies), followed by visual census/snorkeling (27). There was no specification of fishing gear in 21 studies (Fig. 8). Between 1970 and 1971, the samplings applied were the use of chemical substances (rotenone), for studies of fish in tide pools in Salvador, according to studies by Almeida,

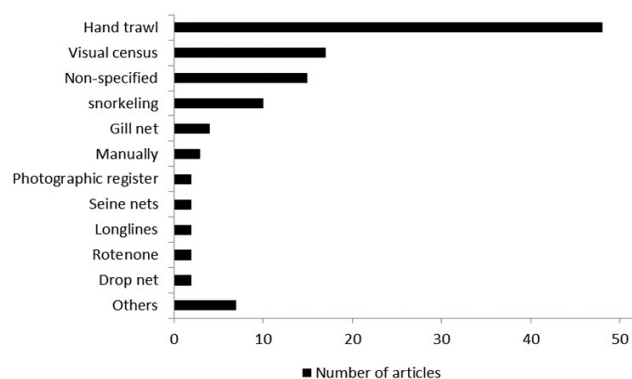


Figure 8. Sampling methods used in studies on the ichthyofauna of Todos os Santos Bay from 1973 to 2022.

1973; 1983. The use of a hand trawl net started in 1988. Only 6 studies used more than one fishing gear. The methodology used to capture fish is chosen according to the conditions of the studied ecosystem.

According to published data, the TSB ichthyofauna is composed of 289 species, distributed in 87 families and 34 orders ([Supplementary table II](#)). The orders with the highest number of families are Carangiformes and Acanthuriformes (11 families, 12.6% each), Perciformes (7 families; 8.0%), and Tetraodontiformes (5; 5.7%) (Fig. 9a). Carangidae (19 species; 6.5%), Sciaenidae (18; 6.2%), Labridae, and Haemulidae (14; 4.8%) were the most representative families (Fig. 9b). The most cited species include *Caranx latus* Agassiz, 1831 (Carangidae) and *Sphoeroides greeleyi* Gilbert 1900 (Tetraodontidae), with 13 studies each. While *Haemulon steindachneri* (Jordan & Gilbert 1882) (Haemulidae), *Sphoeroides testudineus* (Linnaeus 1758) (Tetraodontidae), and *Albula vulpes* (Linnaeus 1758) (Albulidae) were cited in 12 studies each (Fig. 10). Among the registered species, it is worth mentioning the presence of the invasive species *Omobranchus sewalli* (Fowler 1931) (Blenniidae) and *Butis koilomatodon* (Bleeker, 1849) (Eleotridae) mentioned by Barros *et al.* 2018 and Reis-Filho *et al.* 2019a, respectively.

The number of species cited in the selected research varied during the sampled period, with the highest peaks in 2011 (n= 199), 2015 (n= 162), 2019 (n= 139) e 2010 (n= 128). During this period, studies focused on fishing areas and community structure, bringing lists of species found in the localities, thus accounting for a greater number of species (Fig. 11).

Discussion

Over the years, it was observed an increase in the frequency and number of publications of studies

on the ichthyofauna of the Todos os Santos Bay (TSB), mainly from 1997 onwards, with a peak in 2001 and a drop in 2007 (n=8), and from this year on, there was almost a stability in the number of studies, up to the present date. According to Azevedo *et al.* 2010, Brazil contributed with 0.83% of world scientific production in 1995, and 1.44% in 2001. Blaber 2013 cites an increase in the number of publications for the period of 2002 to 2012 on tropical estuarine fish. Rocha & Sampaio 2022 point Brazil at the top of productivity in the southwest Atlantic, with the most cited articles focusing mainly on the areas of ecology, conservation and fisheries research. Barbosa & Lanari, 2022, report an upward trend in scientific production for Patos Lagoon (Rio Grande do Sul, southern Brazil), consistent with the increase in world scientific production. According to Liao & Huang 2014, the data from scientific productions and citations demonstrate that research in aquatic ecosystems has increasingly attracted the attention of scientific communities, becoming an important field of research. The trend in increasing publications observed here for TSB follows what has been happening worldwide regarding the ichthyofauna of estuarine ecosystems.

In Bahia, the State University of Feira de Santana and the Federal University of Bahia lead the ranking of published studies on the ichthyofauna of the TSB, probably due to their proximity to this ecosystem. Another possible explanation is that both institutions have post-graduate programs where students contribute to Brazilian scientific production. As stated by Azevedo *et al.* 2010, science in Brazil is strongly based on the public sector, which was verified in our research as well as by Junqueira *et al.* 2020, in studies with fish from Brazilian streams. In this study, it was also observed that the most productive authors were affiliated with public sector institutions. Barbosa & Lanari 2022 also found for Patos Lagoon the prominence of the Foundation University of Rio Grande (FURG), in published studies and in the affiliation of the most productive authors. Carvalho & Tejerina-Garro 2019, analyzing temporal and spatial trends in the research of freshwater fish in the state of Goiás, found that the contribution of local institutions is spatially concentrated. Dias *et al.* 2016, state that post-graduate programs and students are drivers of Brazilian scientific production on biodiversity. Olisah & Adams 2021, analyzing scientific production in South African estuaries observed that the most prolific institutions are in coastal areas or

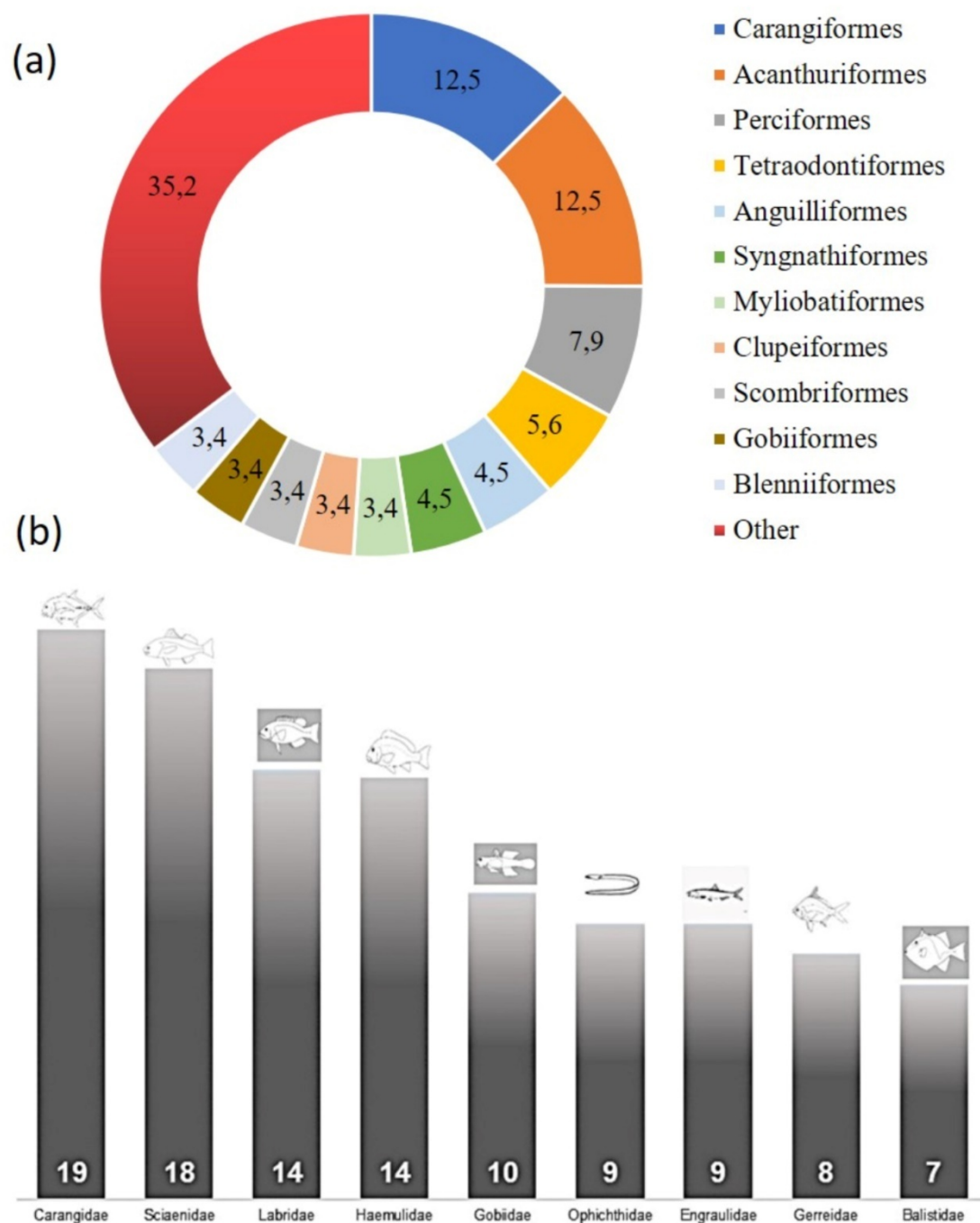


Figure 9. Orders (a) and families (b) of most representative fish recorded in the studies analyzed for the Todos os Santos Bay in the period from 1973 to 2022.

close to them. Based on what has been observed, both for the TSB and in regions of Brazil, public institutions and postgraduate programs play a significantly relevant role in the development of scientific research and dissemination of academic production in Brazil and worldwide. Seeking additional sources of funding from private institutions and expanding the international

collaborative network would contribute to broadening the distribution of studies in the region with new approaches.

The high number of multi-authored studies from institutions on the TSB ichthyofauna demonstrates that science is increasingly becoming collaborative, showing the interest and investment shared in this theme, mainly by development

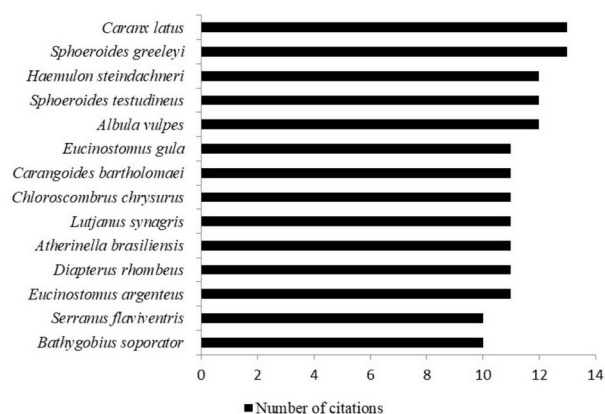


Figure 10. Most cited fish species in studies on the Todos os Santos Bay ichthyofauna from 1973 to 2022.

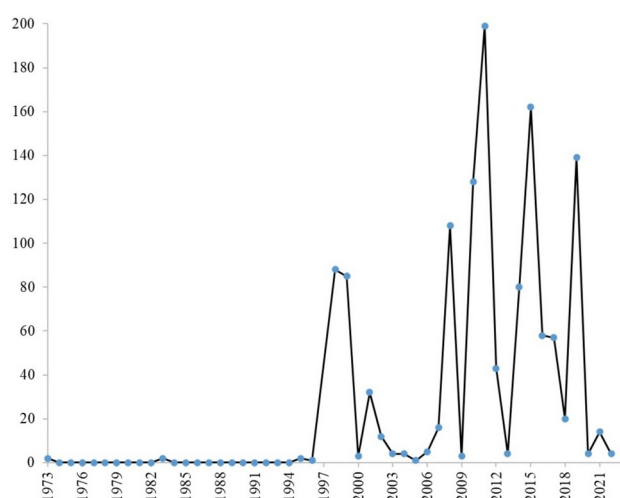


Figure 11. Number of species cited in studies on the Todos os Santos Bay ichthyofauna from 1973 to 2022.

agencies. Our results show that, as observed in Patos Lagoon (Barbosa & Lanari 2022) and in Goiás (Carvalho & Tejerina-Garro 2019), national collaborations are predominant in TSB studies. The low representativeness of studies with international cooperation in the TSB may be due to, as observed by Barbosa & Lanari 2022, the global vision of the researcher, the existence of geographical distance between countries and socioeconomic and linguistic barriers. Guia *et al.* 2019, concluded that scientific collaboration between countries is positively and statistically associated with postcolonial links, language, similar level of economic development, proximity of scientific capacity, social proximity, and international students. The increase of post-graduate programs is a factor for the growth of the national scientific production and its visibility in the world context (Almeida & Guimarães 2013).

Regarding the sources of publications, the studies in the researched period (1973 to 2022) were

concentrated in several journals from various areas of knowledge. A relevant fact is that despite the greater number of publications from international journals, of the top 10 journals in which the researchers published, 6 are Brazilian, some without QUALIS classification and with little visibility. Macmanus *et al.*, 2020, mention that when studies by Brazilian researchers are published in Brazil, they tend to be in lower quality journals, but this does not occur when they are published abroad. Based on the studies performed, we found that the western part of the TSB is the most studied when comparing to other locations. Most of these studies were developed by the State University of Feira de Santana and one of the possible explanations is accessibility and geographic proximity, since it is closer to these locations, while the Federal University of Bahia is closer to the eastern region and, however, has developed a smaller number of studies in this area. In general, in most locations, specific studies prevail, with short-term time series (less than three years), without replication or standardization in the samples.

According to Junqueira *et al.* 2020, studies with these characteristics may be associated with a lack of logistics, resources, and the very nature of the study. Beyond that, these authors point out that restricted temporal scales can lead to the estimation of diversity, compromising the results and, consequently, the conclusions of the study. The observed results indicate that long-term research on the ichthyofauna of the TSB is non-existent, even in the face of the numerous anthropic threats that plague the TSB since its occupation. Restricting surveys to small spatial and temporal scales reduces the ability to draw general ecological conclusions and hampers regional conservation actions (Dias *et al.* 2016). The lack of long-term spatial and temporal studies makes it impossible to obtain ecological conclusions as well as the implementation of conservation measures in the region.

Among the research analyzed in our study, we found a variety of topics addressed ($n=15$), however, studies related to trophic ecology and new records were more investigated. A similar trend was observed for the ichthyofauna of other ecosystems, for example, in freshwater ichthyology studies from 1986 to 2005 (Azevedo *et al.* 2010), in Brazilian streams (Dias *et al.* 2016), and in Goiás, ecology and systematics/taxonomy are the main fields of research (Carvalho & Tejerina-Garro 2019). The large number of studies carried out on fish taxonomy in the TSB mainly reflects the training and research

area of the researchers affiliated with the two main public universities. A more comprehensive approach to studying the ichthyofauna of the TSB is necessary in order to understand and conserve the biodiversity of this ecosystem.

Our dataset shows that fish from sandy and muddy beaches have been studied more than fish from other TSB environments. This can be explained by the development of studies in locations where these ecosystems predominated, such as the beaches of Ponta da Ilha (Itaparica Island, Vera Cruz), Cabuçú (Saubara) and Itapema (Santo Amaro). Cabuçú beach is cited for presenting high turbidity due to the muddy substrate, in addition to the entrainment of organic substances from the urbanization process of its coast (Oliveira-Silva *et al.*, 2008). The TSB, whose dominant coastal vegetal formation are the mangroves, act as an important area of natural refuge for several species of fish (in addition to molluscs and crustaceans), including those of commercial value that spend the initial stages of their life cycle there (Lopes *et al.* 1998), while sandy beaches represent physically dynamic environments, providing habitats for a diverse and abundant fauna, as well as being an essential ecosystem for maintaining water filtration, nutrient cycling, wildlife support, and fish and shellfish nurseries (Pinto *et al.* 2022). The concentration of studies in these environments can be explained by their predominance in TSB. However, it is essential that studies cover a wide variety of environments.

Among the fishing gear used in the studies considered, the hand trawl predominated. Nonetheless, Silva *et al.*, 2020 comment that the beach trawl net has little representation in the studies analyzed to characterize the fishing nets of the north and northeast coast of Brazil, being present in 4% of the studies. In addition, they mention that the size of the mesh (0.5 cm) characterizes a gear of low selectivity, being able to capture juvenile animals, which was observed in research carried out by the Fish Division of the Museum of Zoology at UEFS in the TSB locations (Lopes, pers. comm.) Gerhardinger *et al.* 2020, identified that most studies in Babitonga Bay (Paraná, southern Brazil) used bottom trawling with gates as the main method of collecting ichthyofauna. For a more accurate assessment of the ichthyofauna in this region, it is necessary to expand the use of fishing gear and collection methods.

Castelnau & Jordan, for instance, contributed to the knowledge of marine fish in Bahia through the list of collected species, according to Almeida 1983.

The documented ichthyofauna of the TSB represents 21.9% of the marine fish species with documented or highly probable occurrence on the Brazilian coast, according to the survey done by Menezes *et al.* 2003. At the same time, it is likely that this percentage is outdated, as new species described and occurring in the TSB have been recorded in recent years, such as, for example, Bauer *et al.* 2021 and Chao *et al.* 2022. The discovery of new species in the region indicates the importance of continuous research to update and expand knowledge of the local and Brazilian ichthyofauna. A similar species richness (287) was recorded by Gerhardinger *et al.* 2020 in the 62 studies on the fish fauna of Babitonga Bay.

The most cited fish species in studies *Caranx latus* Agassiz 1831, found both in coastal and offshore environments, highly appreciated as food and widely distributed in the Atlantic Ocean (Gonzalez *et al.* 2021) and *Sphoeroides greeleyi* (Linnaeus 1758) a particularly abundant species and often among the most common species sampled in tropical mangroves along the northeast coast of Brazil (Lima *et al.* 2018).

The presence of *Omobranchus sewalli* (Fowler 1931), an exotic species in the TSB, has also been documented in other areas of Brazil (Garcia Junior *et al.* 2015; Lamas *et al.* 2016; Vilar *et al.* 2011), probably introduced by accidental transport by ballast water from foreign cargo ships. According with Frehse *et al.* 2016, the generation of knowledge about non-native and invasive species in Brazil is slow because it is limited to small and new research groups linked to few universities. At TSB, studies reporting the occurrence of exotic species are incipient, limited only to occurrence records.

The bibliometric analysis showed that there was an oscillation in the scientific production on the TSB ichthyofauna, mainly in recent years. The results presented here from the analysis of 118 articles do not represent the total of scientific research in the region, as books, book chapters and gray literature were not included. Nonetheless, this is the first evaluation of scientific production using bibliometrics for the TSB. The results show that the Acta Biológica Leopoldensia was the predominant journal in publications and the State University of Feira de Santana (UEFS) was the most productive institution in number of published studies. Furthermore, differences were observed in the studies on the TSB ichthyofauna in relation to different regions and ecosystems. The western region of the TSB is the most studied, with emphasis

on the sandy beaches and, in particular, Ponta da Ilha location of the Itaparica Island, Vera Cruz municipality. Despite the large number of fishing gear and sampling techniques used in different studies, the hand trawl net stood out in different environments, as well as studies with trophic ecology. *Caranx latus* and *Sphoeroides greeleyi* were the most cited fish species in the studies reviewed.

Some gaps need to be filled, such as a greater number of national and international collaborative publications, to add more value to scientific production. In addition, it is recommended to expand studies to other geographic regions and ecosystems in the TSB, such as the northern and eastern regions; to reef environments and islands; a greater number of studies that address ecology (with new ecological frameworks), distribution and biology of species using different collection methods and with basic information about sampling protocols so that other researchers can replicate. Other identified knowledge gaps include the need for studies investigating the connectivity between fish populations across the different habitats that form the TSB; of studies that try to explain the influence of climate change on the ichthyofauna; as well as of the human use and occupation of the bay's territory on the occurrence, distribution and abundance of fish, threatened and exotic species in Todos os Santos Bay.

Implementation of projects with greater spatial, temporal (long-term) and ecological comprehensiveness would enable a better understanding of the functioning of the TSB ecosystem, serving as a basis for guiding public policies aimed at the conservation and sustainable use of the ecosystem and natural resources of the bay. Furthermore, it is expected that this study may be useful for a better allocation of resources in the research of the TSB ichthyofauna.

Ethical statement

The present investigation did not involve regulated animals and did not require approval by an Ethical Committee.

Acknowledgment

We thank MSc. Jociara Costa for preparing the location map and the coordination of the Post-graduate Program in Modeling in Earth and Environmental Sciences for paying for funding the translation of the manuscript.

Supplementary material

Supplementary Table I:

https://docs.google.com/spreadsheets/d/18s1IUbjawXyJw-d-RNLHEWpl1VB8f4at/edit?usp=drive_link&ouid=115596650392331380719&rt=pof=true&sd=true

Supplementary Table II:

https://docs.google.com/spreadsheets/d/168QhYbID9sdexcVFxWEPLdjwDYZKbJ97/edit?usp=drive_link&ouid=115596650392331380719&rt=pof=true&sd=true

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Received: November 2023

Accepted: August 2024

Published: May 2025