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Current knowledge of Holothuriida (Holothuroidea: Echinodermata) from Brazil

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Sea cucumbers are the second most diverse class among echinoderms. They are characterized by an elongated body and dermal ossicles in the body wall. Among the included groups in that class, the order Holothuriida encompasses many species of commercial interest. Faced with the threats of biodiversity loss resulting from the climate crisis and the advancement of cities, this study provides an overview of recent research involving the Holothuriida of the Brazilian Coast. Searches were carried out in the main periodical databases, using appropriate keywords, targeting publications on the subject in the period between 2000 and 2023. In total, 69 publications were found, most of them corresponding to scientific articles in international journals. Most of the studies come from the Northeast region in Brazil (56.52%). Regarding lines of research, those involving taxonomy and molecular analysis were the most prevalent. Over these 20 years, seven species constituted new occurrences. Of note are the studies focused on *Holothuria (Halodeima) grisea*, which makes up 39.13% of papers. Despite progress, little is known about morphological variations, genetic distance between populations, population densities, and on reproductive biology of species. Brazil has a vast, heterogeneous coastal area, with unique characteristics to which the species are adapted. The findings reinforce the importance to expand studies aiming on knowing the biodiversity, reproductive biology, and population densities of species. Such data are essential for the creation of public policies aimed at the conservation of species of Holothuriida and their habitats.

KEYWORDS

Sea cucumber, Holothuroidea, Holothuriidae, *Holothuria*, Brazilian coast, *Holothuria grisea*

1 Introduction

Class Holothuroidea is represented by the taxonomic orders Apodida, Elaspodida, Holothuriida, Dendrochirotida, Persiculida, Molpadida, and Synallactida (Miller et al., 2017), that together include 29 families, 246 genera and about 1700 species (WoRMS, 2023). About 50 species of this class are known for the Brazilian coast; of these, 14 belong to

the order Holothuriida, including species of Mesothuriidae (Ancona Lopez, 1958, 1962; Brito, 1960, 1962; Tommasi, 1969, 1971, 1972; Mondin, 1973; Tommasi and Aron, 1988; Freire and Grohmann, 1989; Moura et al., 2010, 2016; Martins et al., 2012, 2017; Prata et al., 2014a; Prata et al., 2014b, Prata and Christoffersen, 2017). Holothuriida is one of the most diverse orders of the class Holothuroidea. Its main synapomorphy is the presence of the gonad on only one side of the dorsal mesentery; nowadays it comprises the families Holothuriidae and Mesothuriidae (Miller et al., 2017).

Species of Holothuriida usually display medium to large size, peltate tentacles, and body classified according to arrangement of the ambulacral podia as bivium (dorsal) and trivium (ventral) (Pawson et al., 2010). Its diversity is high in shallow tropical environments (O'Loughlin et al., 2007), living in coral reefs and on soft or hard substrates, usually hidden in crevices, under rocks, on the sediment or gravel, and buried in the sediment (Prata et al., 2014b). Sea cucumbers is an important component of the marine fauna and can comprise up to 95% of the benthic community in some areas (Heezen and Hollister, 1971). Several species ingest and rework large amounts of sediment, being bioturbators of soft-bottom habitats (Miller and Pawson, 1990).

Some species are important fishery resources, considered as healthy food in several Asian countries (Conand, 1989, 2004). With the great demand for this delicacy, the price per kilo became exorbitant (Purcell et al., 2012) and fishing has expanded to other locations where its consumption is not common, such as the Western Atlantic (Conand, 2018). Because of disordered fishing globally, now about 16 species integrate the red list of threatened species of the Union for Conservation of Nature (IUCN) (Purcell et al., 2023). In Brazil, sea cucumber fishing is not regulated. Their capture and/or sale is considered illegal in accordance with federal laws 9,605/1998 and 11,959/2009. These regulate environmental crimes and fishing activities in the country, respectively.

However, fishing of *Holothuria* (*Halodeima*) *grisea* has already been reported for some states, as São Paulo and Ceará (Hadel et al., 1999; Lima et al., 2001; Souza Junior et al., 2017). Fishing appears to be more pronounced in the State of Ceará, where captures are carried out in an artisanal way through the manual picking of sea cucumbers in tide pools (Souza Junior et al., 2017; Ponte and Feitosa, 2019). According to Ponte and Feitosa (2019) the intense fishing pressure on reefs located at Xavier beach (Ceará State) caused a local collapse of the population of sea cucumbers. This led to the development of fishing on submerged reefs, where snorkeling is required. These authors report that sea cucumber fishing in these locations represents an important source of income for fishermen, and it is necessary that government agencies regulate this activity in order to avoid overexploitation of this resource.

Before the 2000s, few studies had been carried out covering the Holothuroidea fauna from Brazil. Examples are Verrill (1868); Rathbun (1879); Ludwig (1881; 1882); Sluiter (1910); Oliveira (1949); Ancona Lopez and Sawaya (1955); Ancona Lopez (1958; 1962); Tommasi (1957; 1969; 1971; 1972; 1974; 1999); Brito (1960; 1962); Deichmann (1963); Lima-Verde (1969); Freitas et al. (1973); Mondin (1973); Tommasi and Aron (1988); and Freire and Grohmann (1989). In general, these studies present species lists

and taxonomic inventories from a determined locality, with little information on ecology and biology of the species.

Studies on Holothuroidea from the Brazilian coast is still insufficient to estimate its current diversity and, especially, their population stocks. Considering the ecological importance of the Holothuriida species and that they are more common in tropical waters, as well as that this group is the target of predatory fishing, this work presents a review of the current knowledge of the order from the Brazilian coast, from the 2000s to the present day.

2 Materials and methods

The bibliographic research on Holothuriida from Brazil was conducted between April and October 2023. Studies were selected according to type: scientific articles, books, book chapters, monographs, dissertations, and thesis. The preparation of the research was done locating scientific documents in bibliographic bases. Search was made in Scopus, Web of Science, Scielo, Google Scholar, and Biblioteca Digital Brasileira de Teses e Dissertações (BDTD [Brazilian Digital Library of Theses and Dissertations]), using the keywords: Holothuroidea, Aspidochirotida, Holothuriida, *Actinopyga*, *Holothuria*, *Mesothuria*, and *Zygothuria*, always in association with the word 'Brazil' or 'Brasil'. Those keywords could be present in the title, in the keywords and/or in the abstract of the documents, in order to increase search results. Regarding time, the searches were limited to studies published between 2000 and 2023, published in any language.

The processes of analysis of quantitative data followed Gil (2002), through the steps: establishment of categories, tabulation, and statistical analysis of data. Categories followed these descriptors: a) type of production; b) temporal distribution; c) geographical distribution; d) institutions originating publications; e) link with postgraduate programs; g) thematic focus. A list of species from Brazil is provided, indicating the recent papers found with species descriptions (from 2000 to 2023). Tabulation, analysis, and graphs of data were done in the software Excel, with each information listed below the respective descriptors, following the established categorization. The complete data can be accessed in the [Supplementary Material](#).

3 Results

In this research 69 academic studies were found, among monographs, dissertations, thesis, book chapters and scientific papers published in periodicals.

3.1 List of the species

The current work reports 14 species of the order Holothuriida from the Brazilian coast, including oceanic islands (Table 1). Most species came from shallow waters, with six from the deep sea (Moura, 2016), of which *Holothuria* (*Cystipus*) *pseudofossor*

TABLE 1 Synthesis of species belonging to Holothuriida with records for the Brazilian coast, including oceanic islands.

Order	Family	Genera	Species	Recent bibliography
Holothuriida	Holothuriidae	<i>Actinopyga</i> Bronn, 1860	<i>Actinopyga agassizii</i> (Selenka, 1867)	Prata et al. (2014b), Martins et al. (2017)
		<i>Holothuria</i> Linnaeus, 1767	<i>Holothuria (Cystipus) pseudofossor</i> Deichmann, 1930	Prata et al. (2014b), Moura (2016); Martins et al. (2017)
			<i>Holothuria (Semperothuria) surinamensis</i> Ludwig, 1875	Prata and Christoffersen (2012), Prata et al. (2014b), Martins et al. (2017)
			<i>Holothuria (Holothuria) dakarensis</i> Panning, 1939	Prata et al. (2014a, 2014b)
			<i>Holothuria (Theelothuria) princeps</i> Selenka, 1867	Martins et al. (2012), Prata et al. (2014b)
			<i>Holothuria (Platyperona) parvula</i> (Selenka, 1867)	Prata et al. (2014b)
			<i>Holothuria (Halodeima) grisea</i> Selenka, 1867	Prata et al. (2014b), Martins et al. (2017)
			<i>Holothuria (Vaneyothuria) lentiginosa brasiliensis</i> Tommasi & Oliveira, 1976	Moura (2016)
			<i>Holothuria (Halodeima) manningi</i> Pawson, 1978	Martins et al. (2017)
			<i>Holothuria (Thymiosycia) arenicola</i> Semper, 1868	Prata et al. (2014b), Martins et al. (2017)
	Mesothuriidae	<i>Mesothuria</i> Ludwig, 1894	<i>Mesothuria gargantua</i> Deichmann, 1930	Moura (2016)
			<i>Mesothuria maroccana</i> Perrier R., 1898	Moura (2016)
			<i>Mesothuria verilli</i> (Théel, 1886)	Campos et al. (2010); Moura (2016)
		<i>Zygothuria</i> R. Perrier, 1898	<i>Zygothuria</i> sp.	Moura (2016)

The bibliography indicated corresponds to taxonomic studies between 2000 and 2023 that provide descriptions of the species.

Deichmann, 1930 was also found in shallow waters (Prata et al., 2014b; Martins et al., 2017).

Except for *Holothuria (Halodeima) grisea* Selenka, 1867 and *Holothuria (Thymiosycia) arenicola* Semper, 1868, the species reported from Brazil have limited distributions along the coast. There are only specific taxonomic studies carried out for them, and few specimens were deposited in scientific collections or observed with Remotely Operated Vehicles (ROVs).

3.2 Types of production

The most frequent academic papers analyzed were scientific articles, representing 75.36% of the total (n = 52), followed by master dissertations (17.39%, n = 12), doctoral thesis (2.90%, n = 2), and book chapters (4.35%, n = 3). Most of the analyzed articles were published in international journals and in English. 28 (40.57%) were studies published in Brazilian journals and 27 (39.13%) in Portuguese. Only one study was published in French.

3.3 Temporal distribution

The focus of this research were the works produced in the present Millenium. The findings show that the quantity of studies increased between 2012 and 2019, reaching a peak in 2013 and 2014 with 7 studies published (Figure 1). From the early 2000s to 2010, the number of studies was low, reaching a maximum of two papers

per year. A decrease in production was also observed between 2020 and 2021, increasing again in 2022.

This increase observed between 2012 and 2019 is related to the development of the 'Programa de Reestruturação e Expansão das Universidades Federais' (REUNI [Program to Support Restructuring and Expansion Plans of Federal Universities]). The REUNI started in 2007 and resulted in a considerable expansion of public universities and in opportunities for higher education throughout the country, with a view to its internalizing (Bizerril, 2020). The reduction in studies between 2020 and 2021 is related to the public emergency caused by COVID-19, a time when people had to confine themselves to their homes.

3.4 Geographical distribution of publications

The analyzed papers were performed in 11 federal units in Brazil. Three regions were represented, with 56.52% of the total located in Northeast Brazil (n = 39), followed by the Southeast Region (36.23%, n = 25), and then the Southern Region (7.25%, n = 5) (Figure 2). No related studies were observed for the Northern Region.

Northeast Brazil evidences a promising scientific production, particularly concerning Science Teaching in Biological Sciences. Promising scientific production concentrates most of the work on the Holothuriida. Lack of studies along the Amazon littoral, bathing the Sates of Amapá and Pará, point to a conspicuous a knowledge gap.

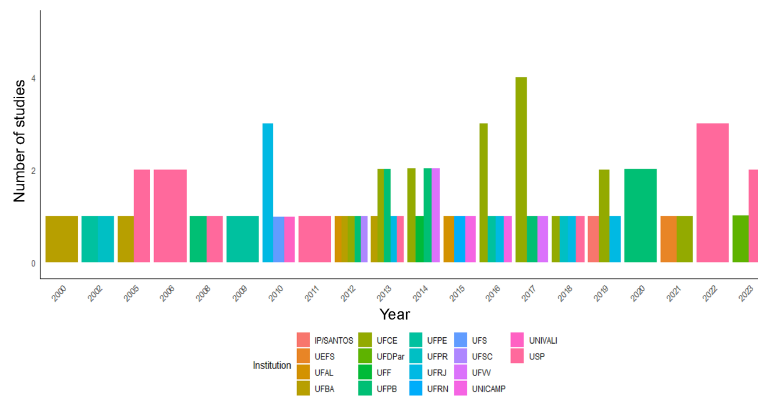


FIGURE 1

Number of studies by year and institution. UFCE, Federal University of Ceará; USP, University of São Paulo; UFPB, Federal University of Paraíba; UFRJ, Federal University of Rio de Janeiro; UFBA, Federal University of Bahia; UFPE, Federal University of Pernambuco; UFAL, Federal University of Alagoas; UFV, Federal University of Vila Velha; UNICAMP, University of Campinas; UFPR, Federal University of Paraná; UFRN, Federal University of Rio Grande do Norte; UFS, Federal University of Sergipe; UEFS, State University of Feira de Santana; UFDFar, Federal University of Delta do Parnaíba; UFF, Federal University Fluminense; UFSC, Federal University of Santa Catarina; UNIVALI, University of Vale do Itajaí; IP/Santos, Advanced Marine Fish Research Center of Santos/São Paulo.

3.5 Origin of publications

Most publications came from Public Institutions of Higher Education (97.10%) or government agencies (1.45%), and only one from private institution (1.45%). Some papers share authors belonging to different universities in a same paper. In these cases, however, we considered the origin of the paper as that of the first author. The most productive institutions were Federal University of Ceará, with 26.08% ($n = 18$) of the scientific productions, followed by University of São Paulo, with 17.39% ($n = 12$), Federal University of Paraíba, with 13.04% ($n = 9$), and Federal University of Rio de Janeiro, with 10.14% ($n = 7$) (Figure 1). Other institutions published between three to one study. Of these publications, 46.37% came from postgraduate programs.

3.6 Thematic focus of publications

Most of studies analyzed correspond to Taxonomic papers (40%), molecular studies (29%), and studies in ecology (17.40%). Other studies considered reproductive biology (6%), fishery (6%), and reviews (1.6%) (Figure 3).

In the taxonomic category, works are more numerous, and can be divided into lists of echinoderm species for a given area; lists of species/taxonomic studies of Holothuroidea for a given locality or region; and new occurrence studies. Four studies focus exclusively on the Order Holothuriida. Most studies focusing on the Class Holothuroidea involve descriptions with detailed images and add data such as re-descriptions of species, ecological notes, and geographical and bathymetric distribution; some also include the morphometry of the dermal ossicles.

Among the 14 species belonging to the order Holothuriida along the Brazilian coast, the most common in the studies were *H. (H.) grisea* and *Holothuria (Thymiosycia) arenicola*. The studies cover the Northeast, Southeast and South regions. However, there is a lack of information about the fauna of Holothuriida from the North region, as well as for the States of Maranhão, Piauí, Sergipe (Northeast region), Espírito Santo (Southeast region), Paraná and Rio Grande do Sul (South region). In relation to deep-sea species, only four studies were found. All of them reporting species from Campos Basin, Southwest Atlantic (Campos et al., 2010; Moura et al., 2010).

Ecological studies show the spatio-temporal distribution of holothurian species, most focused on the species *Holothuria (Halodeima) grisea*; other studies cover behavioral aspects, diet, sediment and habitat analysis, and survival of species exposed to different variables. Two studies mentioned behavioral aspects of *H. (H.) grisea*. One of them evaluated the selectivity and food preference of juveniles of *H. (H.) grisea* subjected to different diets and the feeding behavior of the animals, in relation to two different photoperiods. The species had a nocturnal feeding habit

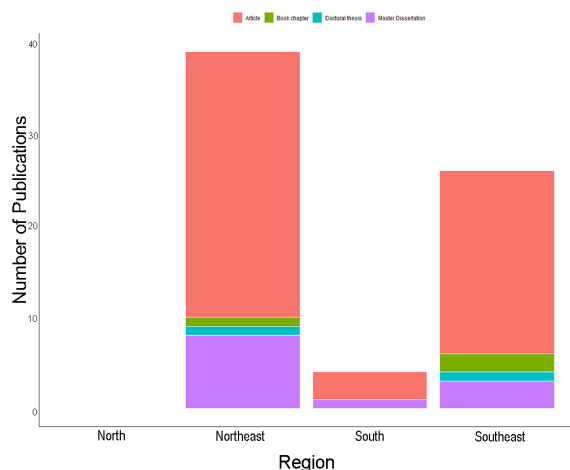
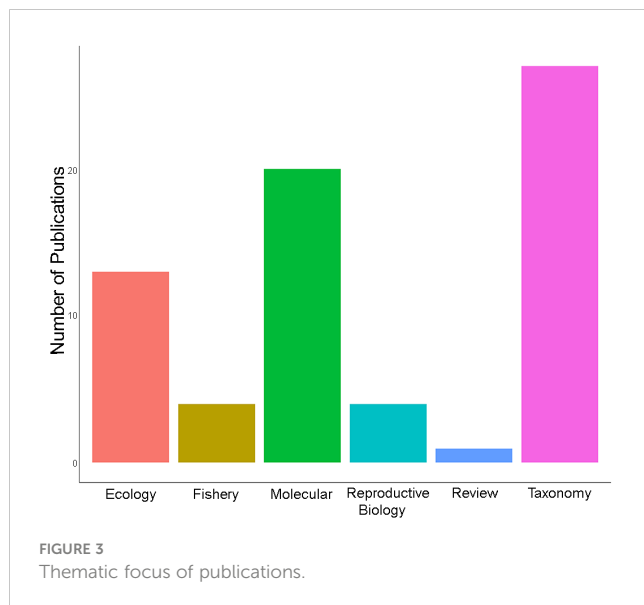


FIGURE 2

Number of papers by type and for region.



and did not demonstrate selectivity or preference for the tested diets. The second study adds that knowing the behavior of holothurians can provide information about the basic learning mechanisms in Echinodermata.

Regarding spatial distribution patterns and populations, only three studies were found. Furthermore, the works deal with only one species, *H. (H.) grisea*, a species that has been studied by different lines of research. According with those studies, *H. (H.) grisea* was found more densely in the subtidal stratum, occurring in smaller quantities in autumn. Studies addressed the recycling of organic matter, correlating the survival of *H. (H.) grisea* with organic matter at different population densities, showing that the higher the density, the lower the chances of juvenile survival in controlled environments.

Another study related the content of organic matter to the presence of *H. (H.) grisea* in the environment and showed that there was a greater amount of calcium carbonate in samples collected in places where the species is found. There was one work reporting the parasite eulimid *Melanella eburnean* in *H. (H.) grisea*. Eulimids are gastropods that parasitize the external body wall of some species of Holothuroidea. Some studies have also analyzed the stomach contents in *H. (H.) grisea* to indicate if their diet is selective or not. These studies show that, in general, the diet of *H. (H.) grisea* is not selective. There was even a study on the nutritional value and yield of *H. (H.) grisea*.

Studies in the molecular category were diverse ($n = 20$). About 50% refer to studies on immune system cells, molecular markers, and analysis of body wall compounds. Some studies cover the microbiome of the body wall or the digestive tract; others focus on genetic diversity, primer design, and use of microchips, among other aspects. Some works characterized and described the effects of lectin in *H. (H.) grisea* (HGL). Among these studies, there was also a description of the HGL-2 (Melo et al., 2014). The lectin has been isolated and tested for its anti-inflammatory and hemolytic activities. Other compounds tested was fucosylated chondroitin sulfates type II, which were studied for their anticoagulant action and calcium affinities.

Researches on the ecotoxicological aspects of the species of the order Holothuriida have also been conducted, particularly with *H. (H.) grisea*. These studies demonstrated its potential environmental bioindicator and capacity to maintain water in tissues during hyperosmotic conditions. They also observed that when exposed to air *H. (H.) grisea* could reduce the osmotic permeability of their body wall, preventing loss of water into the air or water entry/salt exit during rain.

Molecular studies also addressed characteristics of the microbiota of the digestive tract in comparison to the sediment and diet. An analysis showed different microbiota in larger and smaller individuals. Furthermore, it was observed in Holothuriida that bacteria selectively enriched in their guts were spread on ambient sediments via feces, maintaining the ecological role of the host and promoting the mineralization of organic matter. Studies characterizing microsatellite loci, drawing of primers, and structural studies of genetics were also carried out with *H. (H.) grisea*, further improving knowledge about the species. Another study with *H. (H.) grisea* described the morphology and function of cells in the organic matrix of the ossicles, involved in the calcification and developing appropriate protocols for maintaining cells in culture. Studies on the healing process in *H. (H.) grisea* showed a rapid wound closure action through the synthesis of new collagen fibers. Those fibroblasts and two spherulocyte populations are involved in this process.

Regarding fisheries, the studies reported and characterized such activities for certain beaches on the coast of Ceará (Northeast region), showing the process from fishing to selling. The results indicated an annual catch of 12,341 kg per year in some localities, which are totally commercialized, since sea cucumber is not consumed in Brazil (Souza Junior et al., 2017). According to the authors, Brazilian environmental agencies need to act regarding *H. (H.) grisea* fishing, since there is no information on population stocks, nor supervision or management in Brazil. Another issue highlighted in these studies was the need to improve the infrastructure of sea cucumber processing sites and to encourage the adoption of hygienic-sanitary practices by fishermen.

The studies that deal with reproductive biology address the gonadal cycle and larval development of *Holothuria (Halodeima) grisea*. Four studies involved those aspects, detailing the gonadal cycle of this species in two localities of Northeast and Southern Brazil, respectively. According to the findings, the gonads of *H. (H.) grisea* increase between October and February in the Southern coast, while in the northeast coast, gonad growth occurs from December to February. There are mature individuals along the year and the sexual activity increased in summer. The maturation period and variations in body components do not present notable differences between the sexes.

Fewer studies dealing with review ($n = 1$) were found. The review presented the historical development of echinoderm studies and current research in Brazil and cited some species of the order Holothuriida. New methods and protocols were addressed in four studies. One of the proposals suggests the use of a proteolytic enzyme to dissolve holothurian tissues, resulting in ossicles with a more preserved surface. This suggestion has not been widely used, because the method of dissolving the tissue with commercial bleach

solution is more accessible. Another study proposes the identification of holothurian taxa from disarticulated ossicles.

In the molecular area, a study suggests an integrative approach to study coelomocytes. For this approach, the authors used live and stained cells, scanning electron microscopy and morphometric analyses. They were able to separate seven cell types from the immune system of *Holothuria*. Considering sea cucumber fishing and the need to understand the populations of *H. (H.) grisea* in Brazil, a master dissertation proposes the application of microchips to these animals. The microchip was implanted in *H. (H.) grisea* using eugenol as an anesthetic. The author concluded that would be a way to monitor individuals and an efficient approach for short-term research.

In general, the majority of studies with Holothuriida as their main object deal with the species *Holothuria (Holodeima) grisea*, from ecological to molecular aspects, totaling around 39.13% of the documents. Studies considering the family Holothuriida, in general, represent approximately 20.28%, in which are addressed the analysis of enzymatic compounds, tissue regeneration mechanisms, characterization of coelomocytes, among others. Those who address the Class Holothuroidea (17.39%) include taxonomic studies, such as species inventories, ecological aspects, and molecular studies. Studies that focus on echinoderms and mention species of Holothuriida represent 23.20% and constitute taxonomic studies or reviews.

4 Discussion

The revision of Brazilian Holothuriida reports 14 species, most from shallow waters (e.g.: *Holothuria (Theelothuria) princeps*, *Holothuria (Holothuria) dakarensis*, *Holothuria (Platyperona) parvula*, *Holothuria (Cystipus) pseudofossor*). Except for *Holothuria (Thymiosycia) arenicola* and *Holothuria (Halodeima) grisea*, the species reported from Brazil have restricted distributions, as a result of taxonomic studies performed, mainly, with material held in collections. These materials may include specimens collected decades ago (e.g. Prata et al. (2014b), includes specimens collected in 1981, but which were analyzed and identified only recently). The populations of several species of marine invertebrates have been decreasing with the exposure to various environmental impacts (Sigwart et al., 2023). If we consider the changes that coastal environments have undergone in recent decades, such as the expansion of cities, waste disposal, loss of habitat, and climate change, it is not possible to say whether these species still occur in those locations sampled decades ago. Therefore, inventorying biodiversity remains an urgent task.

Along the period from 2000 and 2023, the publication of studies on Holothuriida began to increase in 2012, with a small drop in 2020, during the Covid-19 pandemic. From 2022, the number of studies increased again. With the emergence of effective vaccines against the virus, life gradually returned to normal, which consequently made it possible for research to resume. The increase in the number of publications from 2012 matches with the academic training of the first researchers to obtain master and doctorate levels after the REUNI Program. Furthermore, research

mostly comes from public institutions. This shows the importance of public universities and academic programs for advancing science in Brazil.

The analyses indicates that most research is published in international journals and in English, in order to ensure a broad audience. In general, the studies are the result of master and doctoral researchers. This indicates that researchers tend to continue their research activities after completing graduate studies. On the other hand, it is noticed that researchers focused on different research lines rarely work together (see [Supplementary Material](#)). The studies came from 11 of the 27 federative units of Brazil, being concentrated in the Northeast and Southeast regions. This finding is particularly interesting, given that before the 2000s research was more linked to institutions in the Southeast and South regions of the country. These data also show that little is still known about the echinoderm fauna of the Northern region. This represents a problem, since the reefs at the mouth of the Amazon River, despite having recently been discovered (Moura et al., 2016), already faces enormous dangers of exploitation by oil extraction (Francini-Filho et al., 2018).

The survey showed studies focused on aspects of taxonomy, molecular analysis, ecology, fishery, and reproductive biology. In less quantity on reviews and some studies propose new methodologies or protocols. Rarely two or more themes are combined, about 7.24% (n=5). Studies are usually descriptive; they describe characteristics and do not involve experimental testing or extracting components. Experimental studies, about 36.23%, are related to ecological and molecular research. Molecular studies have focused on testing or isolating compounds from the genus *Holothuria*, mainly *H. (H.) grisea* (Moura et al., 2013, 2015) and in analyzing its microbiome (Yamazaki et al., 2019). These subjects have special importance for ecology, aquaculture, and pharmacology.

For most species, information is limited to taxonomic and distribution aspects. Highlighted are a large gap in knowledge about their areas of occurrence, population size, and biology, among others. Being a continental and unequal country, efforts are necessary to expand the geographic and bathymetric distribution of species. Taxonomic and systematic research is still extremely important to know biodiversity (Prata et al., 2014a; Moura et al., 2016; Martins et al., 2017). Brazilian researchers need to be encouraged to expand their research to understand ecological and reproductive biology aspects of Holothuriida (Bueno et al., 2015). Without these data, it is not possible to propose effective measures for the conservation of species and of their habitats.

Regarding fishery, the consumption of sea cucumbers is not part of the Brazilian diet, despite small records of consumption and fishing of *H. (H.) grisea* in some locations still in the 90s (Hadel et al., 1999). Seizures of the Federal police and recent studies show that fishing for these animals has increased in Brazil. Souza Junior et al. (2017) and Ponte and Feitosa (2019) show unregulated fishing of *Holothuria (Halodeima) grisea* in coastal areas of the state of Ceará. These areas are far from large urban centers and fishing is not monitored. The fishing occurs on a small scale and in an artisanal way. Ponte and Feitosa (2019) described the fishing cycle

in two locations on that coast. They estimated that more than 12,3 tons of *H. (H.) grisea* per year in 2015–2016, corresponding to 380 thousand individuals. This fishing occurs at spring tides through active search and snorkeling. These authors emphasize that there are other communities along the coast of Ceará that also capture these animals for commercialization. The fishing supplies the international illegal market, with China being the largest buyer (Ponte and Feitosa, 2019; Valenti et al., 2021).

Purcell (2010) finds that the price per kilo varies from species to species, with those better known as *Apostichopus japonicus* being more expensive compared to other sea cucumbers that are less known and small, such as *H. (H.) grisea*. Furthermore, poorly processed animals, from places where there is no sanitary control, also have a value below the market. Souza Junior et al. (2017) and Pontes and Feitosa (2019) observed that fishing carried out on the coast of Ceará is carried out improvised by fishermen, which reduces the added value. Freire et al. (2021) built a database on fishing in Brazil and mentions sea cucumbers for the first time. These authors reinforce the need to evaluate the impact of fishing and environmental factors on population stocks.

Holothuria (Halodeima) grisea is distributed across practically the entire Brazilian coast, including ocean islands (Tommasi, 1969; Prata et al., 2014b; Martins et al., 2017). According to the International Union for Conservation of Nature (IUCN) red list and list of Brazilian threatened species, *H. (H.) grisea* is considered of less concern. However, the near absence of studies on the species and its populations may be masking the impact it has been suffering over the last decades. A decline in population has already been observed in some locations (Souza Junior et al., 2017). Controlling sea cucumber fishing is a challenge, first because these animals are not recognized as fishing resources in Brazil, and there is still no legislation to regulate this fishing (Brasil, 1998; 2009); secondly because there is not enough knowledge to estimate population stocks, as well as their reproduction. Furthermore, if fishing is regulated, another demand that arises is the breeding and maintenance of these animals outside of their natural environment.

Population and genetic data are particularly important, as there are increasingly more studies emphasizing the economic and pharmaceutical potential of sea cucumbers, which could be explored through their cultivation under controlled conditions (Valenti et al., 2021). However, growing sea cucumbers is still a challenge and has not been enough to control fishing in most consumer countries. Valenti et al. (2021) points out that there is research underway to cultivate *H. (H.) grisea* to obtain commercial quantities of heparin in Brazil.

Other studies emphasized the bioturbation role played by sea cucumbers and recommended considering it in coastal environment monitoring programs. However, there is still a lot to know about the relationship between the substrate and sea cucumbers. *H. (H.) grisea* is sensitive to heavy metals such as lead and tin (Pereira et al., 2014). Studies on osmosis and ionic gradients in the body wall of *H. (H.) grisea* showed that this species has a greater capacity to maintain water in tissues during hyperosmotic conditions. These studies recommend considering this species in coastal environment monitoring programs.

In relation to studies involving a species as a focus, only papers on *Holothuria (Halodeima) grisea* were found. Despite that, there is scarce information about its population density, preferences, areas where the largest populations are concentrated, and even about its reproduction and life cycle along the coast. The Brazilian coast is extensive and heterogeneous, presenting diverse environmental characteristics (Ventura et al., 2013), to which species of Holothuriida can adapt. Furthermore, many of these areas can be subject to environmental impacts, whether due to the increase of cities or to climatic crisis. Given the little knowledge about the species, studies combining one or more aspects are of special interest for conservation. Studies with an emphasis on the analysis of compounds for pharmaceutical purposes also need to find a sustainable solution for obtaining these compounds just in case a large-scale quantity is needed. Solutions for fishing species of commercial interest must be found in order to avoid their extinction in the environment (Purcell et al., 2023).

Although it is difficult for Brazilian authorities to control sea cucumber fishing in the country, fishing cannot be regulated without first having an accurate assessment of stocks and knowing the distribution of populations along the coast. Environmental managers need advice to build an action plan for commercial species. The first step is to improve knowledge about the species along the coast with the development of genetic, ecological, reproductive biology and cultivation studies, among others. Brazil has specialized professionals, in different areas, that could cover the gaps of knowledge, able to form a research group on sea cucumbers and articulate management strategies with public authorities in order to prevent overexploitation of this resource and to recover populations. Creating a research group on sea cucumbers with these researchers to propose an action plan that directs the necessary research and coordinating management strategies with public authorities could be a decisive step towards avoiding over-exploitation of this resource and recovering the populations.

This review provides a better understanding on actual knowledge of the Holothuriida for Brazilian waters. Researchers of Holothuriida cover few areas of knowledge, being concentrated in taxonomic and molecular studies. The data collected emphasizes that investigations about Holothuroidea in Brazil were carried out by few researchers, which could explain the gaps of knowledge. Certainly, the interaction between these researchers should be encouraged, to fill the gaps, and to provide measures for the conservation of the Holothuriida and to promote their sustainable development.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

JP: Data curation, Formal analysis, Writing – original draft. MC: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2024.1333253/full#supplementary-material>

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