Ocean and Coastal Research

Review
Special Article Collection
Di Domenico, M., Andriguetto-Filho, J.M.D. and Lopes R.M. (eds)
An ocean of science, worms, and humaneness:
a tribute to Paulo Lana
http://doi.org/10.1590/2675-2824072.22155
ISSN 2675-2824

An analysis of meiofauna knowledge generated by Latin American researchers

Bernardo Baldeija[1], Diego Lercari[1,*]

[1] UNDECIMAR - Faculty of Sciences - University of the Republic (Iguá, 4225 - Montevideo - 11400 - Uruguay).

* Corresponding author: lercari@fcien.edu.uy

Abstract

The study of benthic meiofauna has been undertaken in Latin America since the beginning of the 20th century, recently gaining attention due to its recognized role on the ecological functioning of meiofauna assemblages. Bibliometric data provide information regarding research results, explain the degree to which a subject has advanced, and identify its major strengths and weaknesses. In Latin American countries, this type of review is scarce for meiofauna communities. This study analyzes knowledge of marine meiofauna by focusing on the documents Latin American authors published from 1990 to 2021. Documents from three bibliographic databases were analyzed to obtain the most relevant bibliometric indicators. Moreover, the interrelationships between authors, countries, and concepts were analyzed using science mapping techniques. Latin American research on marine meiofauna has increased since the 1990s, producing a total of 399 documents over three decades by almost 1,000 authors. Brazil produced the majority of these documents (predominantly published by Brazilian authors and institutions). The number of documents by country was associated with five development indicators. Their main sources and keywords indicate that ecology, oceanography, and biogeography were the main addressed topics, especially on deep marine environments. Most productive authors were clustered into main research groups with varying degrees of links. We conclude that research efforts on marine meiofauna are gaining importance despite the small number of documents by a relatively low number of research groups. We found a high centralization of documents by countries and a relation with four indicators, such as country size and research spending. Greater regional collaboration could further expand the knowledge of marine meiofauna in Latin America.

Keywords: Meiobenthos; State of Art; Interstitial Fauna; Marine Ecosystem; Systematic Review

INTRODUCTION

Meiofauna refers to microscopic animals living in the sediment layer of oceans and freshwater floors (known for their phylodiversity, in which Nematoda, Tardigrada, Platyhelminthes, Annelida, Mollusca, and Crustacea constitute their dominant representatives). They play a vital ecological role, including the (re) biomineralization of organic debris, nutrient cycling, and pollutant filtration. They are also increasingly being used as tools for studying the impacts of human activity on marine and freshwater environments (Giere, 2009; Balsamo et al., 2012).

Studies on the taxonomy of animals from marine benthic interstitial environments began in the mid-19th and early 20th century, especially in Europe (Giere, 2009). The description of new major groups, such as Kinorhyncha (Dujardin, 1851) and archianellids (Giard, 1904), were important

Submitted: 22-Nov-2022
Approved: 05-Jul-2023
Editor: Rubens M. Lopes

milestones. Soon after, meiofaunal research in Latin America began thanks to the pioneering work of North American Nathan Cobb (1920), who conducted studies on the Brazilian nematofauna. Later, in the middle of the 20th century, authors Ernest Marcus and Eveline Marcus conducted taxonomic and systematic meiofaunal research in Brazil, publishing more than 200 related studies (Medeiros, 1987; Corrêa, 1991). Latin America had other pioneering studies that evaluated benthic meiofauna in marine environments during the 1970s and 1980s. For example, Clasing (1976) analyzed benthic meiofauna in Puerto Montt, Chile. Later, several papers were published in Costa Rica (de la Cruz and Vargas, 1987; Guzmán et al., 1987; Vargas, 1988). In the 1990s, studies on the ecology of Latin American benthic meiofauna began to gain importance. Several conceptual reviews on benthic meiofauna worldwide addressed their economic, socioecological, and methodological aspects (Hulings and Gray, 1971; Gee, 1989; Schratzberger and Ingels, 2018; Majdi et al., 2020).

As science advanced, the number of publications greatly increased over the years and is likely to continue growing. The incessant generation of new information means that incorporating new data into general conceptual frameworks is challenging. It may be difficult for scholars to stay informed as research updates old data (Briner and Denyer, 2012). Therefore, scientific tools designed for methodical literature reviews can facilitate the organization and understanding of specific knowledge generation. Scientific publication reviews are a crucial aspect of the research process, serving to evaluate and quantify the impact of knowledge generation within specific research communities (Rueda-Clausen et al., 2005). Bibliometrics (a subject of scientometrics) provides information on the results of the research process and volume, evolution, visibility, and structure of a research field. Bibliometric studies analyze the scientific literature, usually using bibliographic databases and statistical analyses, providing information on the productivity of authors, institutions, and countries and on the distribution and evolution of research topics (Aria and Cuccurullo, 2017), and enabling the assessment of scientific activity and its impact at different levels. Moreover, "science mapping," a recently developed technique for analyzing research, enables the identification and visualization of the patterns of knowledge generation in a particular field (Eck and Waltman, 2017).

Although bibliometric techniques have existed for decades (Costa et al., 2020), very few reviews have used them to analyze scientific progress on meiofauna (but see Guo et al., 2010; Montanara et al., 2022; Santos et al., 2022). In fact, Brazil only has one review on marine meiofaunal ecology (Maria et al., 2016). This study mainly stresses sampling strategies and the use of meiofauna as a tool to assess climate change. Beyond this antecedent for the Latin American region as a whole, this type of review is non-existent. However, bibliometrics and science mapping may provide researchers and science managers with a valuable tool for understanding the current state of the scientific field, identifying emerging trends and gaps, and facilitating collaboration and knowledge sharing. It can help researchers make more informed decisions about where to focus their research efforts and contribute to the overall advancement of the discipline.

In the case of meiofauna, the number of publications have steadily increased worldwide in recent decades, indicating a growing interest in this field. Most researches have been conducted in Europe, North America, and Asia, strongly focusing on ecology and taxonomy. The most frequently studied taxa include nematodes, copepods, and polychaetes, emphasizing their role in the marine food chain and their response to environmental changes (Guo et al., 2010; Vanreusel et al., 2010; Majdi and Traunspurger, 2015; Schratzberger and Ingels, 2018). These advances have led to a better understanding of the diversity and organization of meiofaunal assemblages and their role in marine ecosystem functioning.

Considering the lack of a broad overview of knowledge generation, this research aims to analyze the documents published on marine meiofauna in Latin American countries from 1990 to 2021. We comprehensively examined documents addressing meiofauna topics that have

been authored or co-authored by Latin American researchers, irrespective of whether the studies were conducted within Latin American territories. Thus, we assess Latin American researchers' contributions to the global understanding of meiobenthos. We aimed to determine the rate of growth of this scientific area, identify its main variables, and find the most important studies, sources, affiliations, and countries involved in the Latin American generation of knowledge on meiofauna. Moreover, we aimed to identify the multiple areas of study on this topic and the collaborative links between authors and countries to evaluate the following hypotheses (common to bibliometric analyses): a) As in most scientific fields (Szteren and Lercari, 2022), we would find a continuous growth in the number of publications on meiofauna; b) According to bibliometric theory (Egghe, 1987; Egghe and Rousseau, 2011), production would follow an asymmetric pattern, in which a small core of more or less specialized sources would publish most studies (e.g., journals); c) Similarly, we expected that few authors would produce many studies; and many authors, few studies; d) Scientific production per country would relate to certain characteristics, such as surface area, population, GDP, etc.; and e) In this context, larger countries would publish more. In addition to testing these hypotheses, this review enables us to visualize the cooperative relationships between countries and research groups. Similarly, we provided a conceptual map of the main researched themes. The analyses we conducted make a valuable scientific contribution not only to meiobenthologists but also to marine biologists as a whole. They can help enhance our understanding of the current state of the discipline and promote new research avenues and opportunities for collaboration in Latin America.

METHODS

Bibliographic data acquisition

The analyzed documents were retrieved from three bibliographic databases: Scopus and Web of Science (for research around the globe) and SciELO (for Latin America). The research output from different countries may vary significantly across bibliographic databases due to their differential coverage of subject areas, as highlighted by Singh et al. (2021). To overcome this limitation, three databases were carefully chosen based on their distinctive indexing, ensuring a more comprehensive range of documents. SciELO lacks the information necessary for a complete bibliometric analysis. Thus, its data were analyzed separately.

Studies were collected using the following search strings in the title, keywords, or abstract fields of each database: meiofauna OR meiobenthos OR meiobenthic. Only documents published from 1990 up to the first semester of 2021 by authors or co-authors from Latin American countries were considered. Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, the Dominican Republic, Uruguay, and Venezuela were included in this review. Subsequently, the documents were analyzed individually and duplicates and studies which evaluated environments other than the marine one were excluded. Finally, Scopus and the Web of Science documents were added to this corpus. To provide additional context, the same query was performed for European countries (including Russia and the United States) to compare the volume of documents produced in these regions with that in Latin America.

Finally, Scopus and WoS documents were added. PRISMA guidelines were followed to document the different phases of our bibliographic review as they map the number of found, included, and excluded records and exclusion criteria (Mengist et al., 2020). These were included as Supplementary Material (Figure S1): PRISMA Flow Diagram. The chosen bibliographic databases are accessible as Data S1 and Data S2.

Bibliometric description

Our document collection was described using conventional bibliometric indices for the analyzed period. The main assessed information included number of sources (e.g., journals, books, chapters,

etc.), total number of documents, average number of documents per year, average citations per document, and total used references. The number of each document type (e.g., reviews, books, etc.); total number of authors, authors of single-authored documents, and authors of multi-authored documents; authors' collaboration indices; documents per author; authors per document; and co-authors per document were also determined.

The occurrence frequency of countries (e.g., authors' country affiliation) and that of authors in the documents were assessed to find the most cited documents and authors in the studied period. The H index (Hirsch, 2005) was estimated to analyze the quality of authors' documents by considering the set of researchers' most cited studies and the number of citations for each of them. The main sources in which documents related to meiofauna in Latin America were published were analyzed to obtain a preliminary perspective of the different developed topics and research categories. The frequency of research subject categories in the main 15 sources (https://www.scimagojr.com/journalrank.php) was assessed. The aforementioned information was ranked to highlight the most relevant cases in our document collection. R (R CORE TEAM, 2020) was used to develop our quantitative bibliometric analysis of our collection of bibliographic references. In particular, the specialized *bibliometrix* package was employed (Aria and Cuccurullo, 2017).

Moreover, statistical analyses were performed to observe the correlations (Pearson's correlation coefficient) between several country development indicators and the total production of documents from 2010 to 2021, the decade with the largest document production. In total, nine variables were analyzed: area size (km^2), total population, gross domestic product (GDP: current US$), GDP per capita (US$), investment in education and research (% of total GDP), economic growth (annual %), marine protected areas (% of total country area), and number of researchers (per million persons). These indicators were obtained from the World Bank database (https://data.worldbank.org/) for all countries with at least one publication on meiofauna from 1990 to 2021. Analyses were performed in R (R Core Team, 2016) using the "tidyverse" and "corrplot" packages.

Bibliometric networks

Advanced techniques to visualize scientific output are increasingly needed as publication numbers grow and knowledge accumulates. Bibliometric networks consist of nodes and edges. Nodes can refer to, for instance, publications, journals, researchers, countries, institutions, or keywords. Edges indicate relations between node pairs. In total, three types of bibliometric networks were analyzed: co-authorship, country co-occurrence, and keyword co-occurrence. In bibliometric networks based on co-authorship, researchers, research institutions, or countries are linked to each other based on the number of publications jointly authored by them (Luukkonen et al., 1993).

The co-authorship network was used to delineate the properties of the community researching meiofauna in Latin America (Peters and Raan, 1991). This enabled us to describe the main research groups and their interactions (collaboration) by document co-authorship. Similarly, country co-occurrence enabled the visualization of high-level collaboration between countries.

Moreover, a network of co-occurring concepts was implemented based on keywords supplied by authors in a publication. The number of co-occurrences of two keywords is the number of publications in which both keywords occur in a keyword list (Peters and Raan, 1993). Following this rationale, a map of keyword co-occurrences in the chosen studies was implemented so we could visualize the conceptual structure of meiofauna as a research field in Latin America (Courtial and Callon, 1991; Delecroix and Epstein, 2004). For that, the keywords included in the entire database were identified and ordered based on their frequency of appearance. The words used in the bibliometric search and those related to countries, cities, and specific sites (such as "Brazil," "Montevideo" or "Havana") were disregarded as they were considered uninformative.

Mapping co-author and co-occurrence networks was performed in VOS viewer (Eck and Waltman, 2007). It constructs a map based on a co-occurrence matrix. The construction of a map is a process that consists of three steps. In the first step, a similarity matrix is calculated based on the co-occurrence matrix, using association strength (Eck

and Waltman, 2007) as a similarity measure. In the second step, a map is constructed by applying VOS mapping to a similarity matrix. Finally, in the third step, the map is translated, rotated, and reflected (Eck and Waltman, 2009) to facilitate visualization.

RESULTS

Bibliometric description

We found 396 documents related to benthic meiofauna and published from 1990 to the first half of 2021 in Latin America on Scopus, Web of Science, and SciELO. Scopus/WoS contain most documents (377). We only retrieved 19 documents from SciELO. Scopus/WoS documents were published as scientific articles, reviews, conference papers, book chapters, notes, and proceedings papers. Scientific production showed an annual growth rate of 11.49%, averaging 13.06 documents per year (Hypothesis a); 2014, 2018, and 2019 had the highest number of publications, with more than 30 publications per year, increasing from 2012 onward; the average number of citations per year remained consistently stable since 1990, without any significant increase or decrease, except for 2010, which had a higher-than-average number of citations (Figure 1). Table 1 shows other data, such as total keywords, sources, and collaboration indicators. Our complementary query found 2725 documents conducted in Europe (including Russia) and 957 in the United States.

Table 1. Bibliometric information of the published documents on benthic meiofauna by Latin America researchers from 1990 to 2021.

Description	Results	
Main Information	**Scopus/WOS**	**SciELO**
Sources (Journals, Books, etc.)	126	13
Documents	377	19
Average documents per year	13.061	0.63
Average citations per document	16.05	-
Total References	14358	-
Document Types		
Article	358	19
Book chapter	3	0
Conference paper	5	0
Note	2	0
Proceedings paper	2	0
Review	10	0
Document Contents		
Different Keywords	992	-
Total Keywords	1870	-
Authors		
All Authors	970	56
Single-authored documents	8	2
Multi-authored documents	962	54
Authors' Collaboration		
Documents per Author	0.385	-
Authors per Document	2.59	-
Co-Authors per Document	4.51	-
Collaboration Index	2.64	-
Countries		
All Countries	25	-
Latin American Countries	10	-
Other Countries	15	-

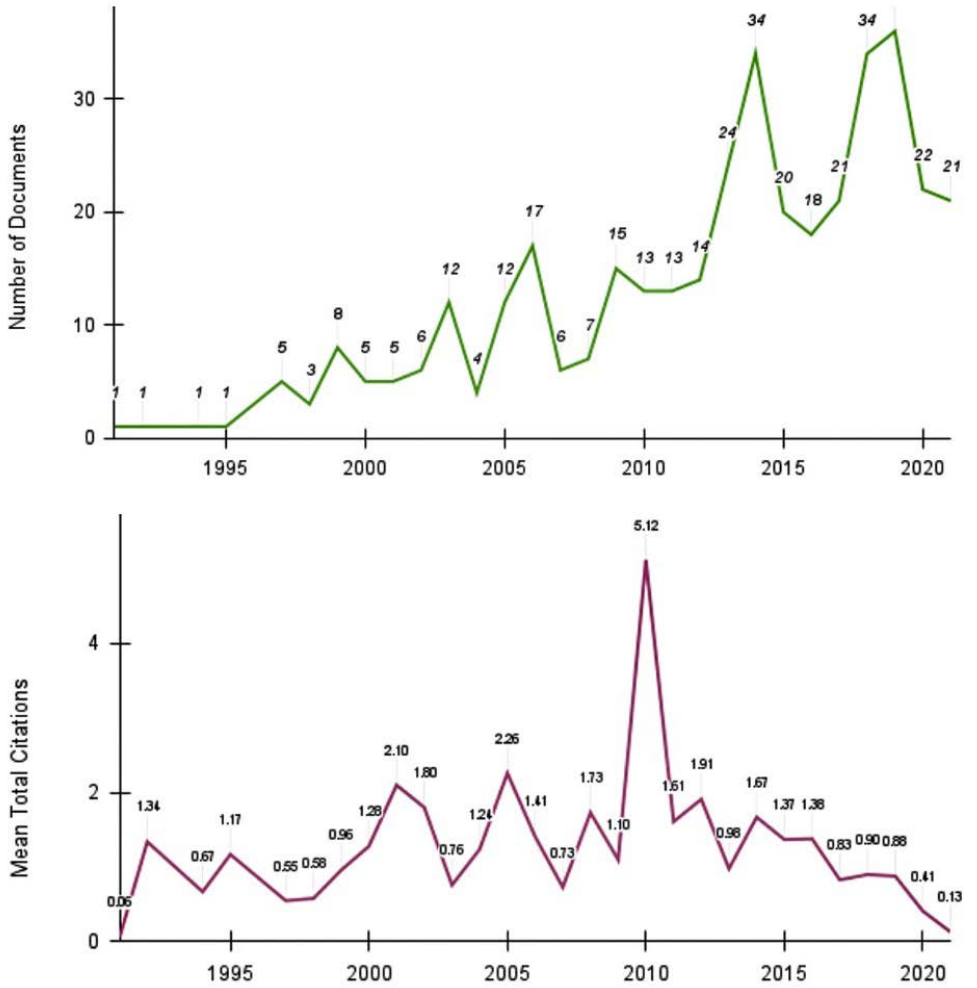

Figure 1. Annual scientific production (A) and annual mean citations (B) on marine meiofauna by Latin American researchers in the last 30 years (1990-2021).

We found 126 different sources in WoS/Scopus. The journal Marine Biodiversity showed the largest number of published documents on the benthic meiofauna in Latin America in the analyzed period. The 15 sources with the highest number of publications corresponded to approximately 45% of all documents in this study (Figure 2a), consisting of sources outside Latin America (Hypothesis b). SciELO had 13 publishing sources, all of which were journals in Latin American countries, with the Brazilian Journal of Oceanography (recently entitled Ocean and Coastal Research) being the most relevant, with four published documents (Figure 2b), and standing out for being the only source that appears in all three databases as a main source.

The 10 most cited documents on Scopus/WoS totaled 10.8% of all citations in our collection. We found two types of documents: those that treat meiofauna as a part of their investigations and those in which it constitutes their main research focus. For example, in the five most cited studies, Ramirez-Llodra et al. (2010) and Wei et al. (2010) mainly focus on the environment (e.g., benthic deep habitats), addressing the meiofauna as a component of these ecosystems. However, other

highly cited studies in our collection exclusively focused on meiofauna biotic components, such as De Ley et al. (2005), who evaluated the molecular barcoding of Nematoda, or Bik et al. (2012), who assessed the metagenomics of meiofauna communities (Table 2). The main documents (regarding citations) were published in the following journals: Biogeosciences, Plos One, Philosophical Transactions of the Royal Society B: Biological Science, Proceedings of the National Academy of Sciences, and Marine Ecology. The five studies highlighted above were the only ones that showed an individual average of citations per year closer to the total average of citations per year (comparing Table 1 and Table 2). SciELO has no data on its most cited documents.

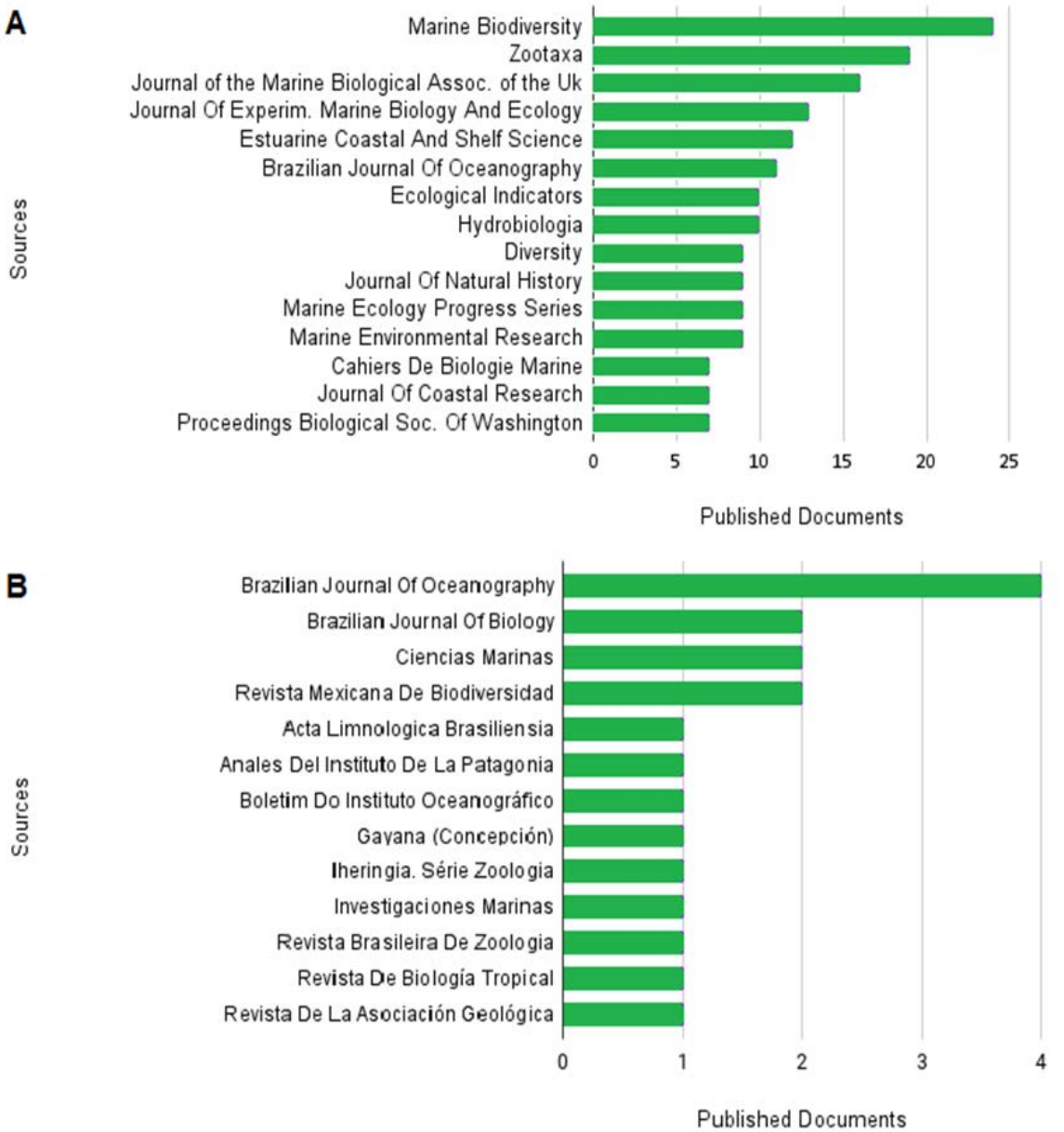

Figure 2. The 15 most important publishing sources on Scopus/WoS (A) and all publishing sources on SciELO (B) related to benthic meiofauna by Latin American researchers from 1990 to 2021

Table 2. Most relevant documents (i.e., most cited) on the benthic meiofauna produced by Latin American researchers from 1990 to 2021 on Scopus/WoS. TC = Total citations; TCY = Total Citations per year.

Document Title	Authors	Sources / Subject	TC	TCY
Deep, diverse and definitely different: unique attributes of the world's largest ecosystem	Ramirez-Llodra et al., 2010	Biogeosciences / Deep ocean ecosystems	395	32.9
Global Patterns and Predictions of Seafloor Biomass Using Random Forests	Wei et al., 2010	Plos One / Global seafloor	217	18.1
An integrated approach to fast and informative morphological vouchering of nematodes for applications in molecular barcoding	De Ley et al., 2005	Philosophical Transactions of the Royal Society B: Biological Science / Taxonomy	192	11.3
Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning	Pusceddu et al., 2014	Proceedings of the National Academy of Sciences and Marine Ecology / Deep sea ecosystem; Ecosystem ecology	177	22.1
Metagenetic community analysis of microbial eukaryotes illuminates biogeographic patterns in deep-sea and shallow water sediments	Bik et al., 2012	Molecular Ecology / Deep ocean ecosystems; Phylogeography	123	12.3
El Niño and similar perturbation effects on the benthos of the Humboldt, California, and Benguela Current upwelling ecosystems	Arntz et al., 2006	Advances in Geosciences / Oceanography	102	6.37
Oxygenation episodes on the continental shelf of central Peru: Remote forcing and benthic ecosystem response	Gutierrez et al., 2008	Progress in Oceanography / Oceanography	92	6.57
Articulating archiannelids: Phylogenomics and annelid relationships, with emphasis on meiofaunal taxa	Andrade et al., 2015	Molecular Biology and Evolution / Phylogeny	91	13
Meiofaunal distributions on the Peru margin: relationship to oxygen and organic matter availability	Neira et al., 2001	Deep-Sea Research / Deep Ocean ecosystems	85	4.04
Effect of the burrowing crab *Chasmagnathus granulata* (Dana) on the benthic community of a SW Atlantic coastal lagoon	Botto and Iribarne, 1999	Journal of Experimental Marine Biology and Ecology / Ecosystem and community ecology	80	3.47

Our document collection included 1026 authors (970 on Scopus/WoS and 56 on SciELO); of which only 10 were single authors (Table 1).

Based on our bibliometric analyses, we found 25 countries in the Scopus/WoS affiliation field from 1990 to 2021. Among these, 15 countries lie outside of Latin America (especially Belgium, Denmark, the United States, Germany, and Italy, which together compose more than 20% of all publications) and 10, within it (Table 3). Brazil had the largest number of published documents (160), followed by Mexico, the United States of America, Argentina, and Belgium, with 41, 24, 22, and 22 documents, respectively. A total of 11 documents showed no data on corresponding authors' country of origin. Thus, we excluded them from this specific analysis. Moreover, information on corresponding authors' country of origin was unavailable on SciELO. Considering the 15 most important affiliations, seven were Brazilian, followed by Chilean universities. We also found two major foreign universities with a large participation in the publication of documents on benthic meiofauna in Latin America: Ghent University and University of Copenhagen, from Belgium and Denmark, respectively. Note that Brazil is the most influential country regarding scientific research on benthic meiofauna in Latin America, with a wide participation from its authors, affiliations, and countries.

Correlation analysis shows a significant correlation ($p < 0.05$) between the number of produced documents and several country indicator variables. Area size ($r = 0.9705$) and research spending ($r = 0.9963$) showed the most significant correlation with produced documents, total population ($r = 0.9126$), and GDP ($r = 0.8756$) (Hypothesis d and e). The other considered variables (e.g., marine protected areas) showed no significant correlation with the number of produced documents.

Table 3. Publication frequency and documents on the benthic meiofauna in marine and coastal environments produced by Latin America researchers and coauthors outside the region from 1990 to 2021.

Most Publishing Countries			Latin American Countries		
Country	**Documents**	**Publication Frequency**	**Country**	**Documents**	**Publication Frequency**
BRAZIL	160	0.43	BRAZIL	160	0.59
MEXICO	41	0.11	MEXICO	41	0.15
USA	24	0.06	ARGENTINA	22	0.08
ARGENTINA	22	0.05	CHILE	20	0.07
BELGIUM	22	0.06	CUBA	11	0.04
CHILE	20	0.05	COLOMBIA	4	0.01
DENMARK	12	0.03	VENEZUELA	4	0.01
CUBA	11	0.03	PERU	2	0.007
GERMANY	10	0.03	URUGUAY	2	0.007
ITALY	8	0.02	ECUADOR	1	0.003

Table 4. Number of mentions of different institutions with publications abouts marine meiofauna from 1990 to 2021 considering Latin American researchers and coauthors outside this region.

Affiliation	Documents	Country
UNIVERSIDADE FEDERAL DE PERNAMBUCO	76	Brazil
GHENT UNIVERSITY	51	Belgium
UNIVERSIDADE FEDERAL DO PARANÁ	45	Brazil
UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO	39	Mexico
UNIVERSITY OF COPENHAGEN	30	Denmark
UNIVERSIDADE DE SÃO PAULO	29	Brazil
UNIVERSIDADE FEDERAL DO PARÁ	13	Brazil
UNIVERSIDAD DE LA HABANA	12	Cuba
UNIVERSIDADE FEDERAL DO ESTADO DO RIO DE JANEIRO	12	Brazil
UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO	12	Brazil
UNIVERSIDAD CATÓLICA DEL NORTE	11	Chile
UNIVERSIDADE FEDERAL DE SÃO PAULO	11	Brazil
FLORIDA STATE UNIVERSITY	10	U.S.A
UNIVERSIDAD DE CONCEPCIÓN	10	Chile
UNIVERSIDAD DE LOS LAGOS	10	Chile

Bibliometric networks

Our collaboration network grouped authors into 13 clusters, with the main groups led by “Di Domenico, M,” “Garraffoni, A,” “Lee, M,” “Venekey, V,” “Fonseca, G,” “Santos, P,” “Santos, G,” “Netto, S” “Genevois, V,” “Sellanes, J,” “Gallucci, F,”

"Esteves, A," and "Vanreusel, A" (Figure 3). We can geographically divide these clusters into groups of authors from Brazil, Mexico, and other Latin American collaborators. In total, seven clusters are specific to groups of authors from different Brazilian regions; one, to collaborators from Mexico; and the others, to an association between the remaining countries, especially Chile and Argentina.

Authors used 1870 keywords, 992 of which were unique. "Nematode" occurred the most (68 instances), followed by "copepoda," "biodiversity," and "taxonomy," with 67, 59, and 48 occurrences, respectively. We found that six clusters that related to the following research topics: two to zoology, two to physical and chemical pollutants, five to climate change and oceanographic themes, and one to fundamental ecology concepts (Figure 4). Regarding ecology, we found keywords such as "biodiversity," "macrofauna," "ecosystem," "ecology," "estuarine," "sediment," "sandy beach," "pollution," "organic enrichment," and "intertidal," totaling 224 occurrences. "Biodiversity," "estuarine," and "sandy beaches" were commonly linked to ecological research on populations, communities, and ecosystems. "Sediment" and "intertidal" were commonly linked to studies on biodiversity and behavioral patterns and the words "pollution" and "organic enrichment" usually related to bioindicators of environmental quality. Published studies related to oceanography were usually linked to keywords such as "climate change," "deep sea," and "acidification," which commonly related to physicochemical change processes in the ocean due to anthropic impacts, such as changes in water temperature or pH.

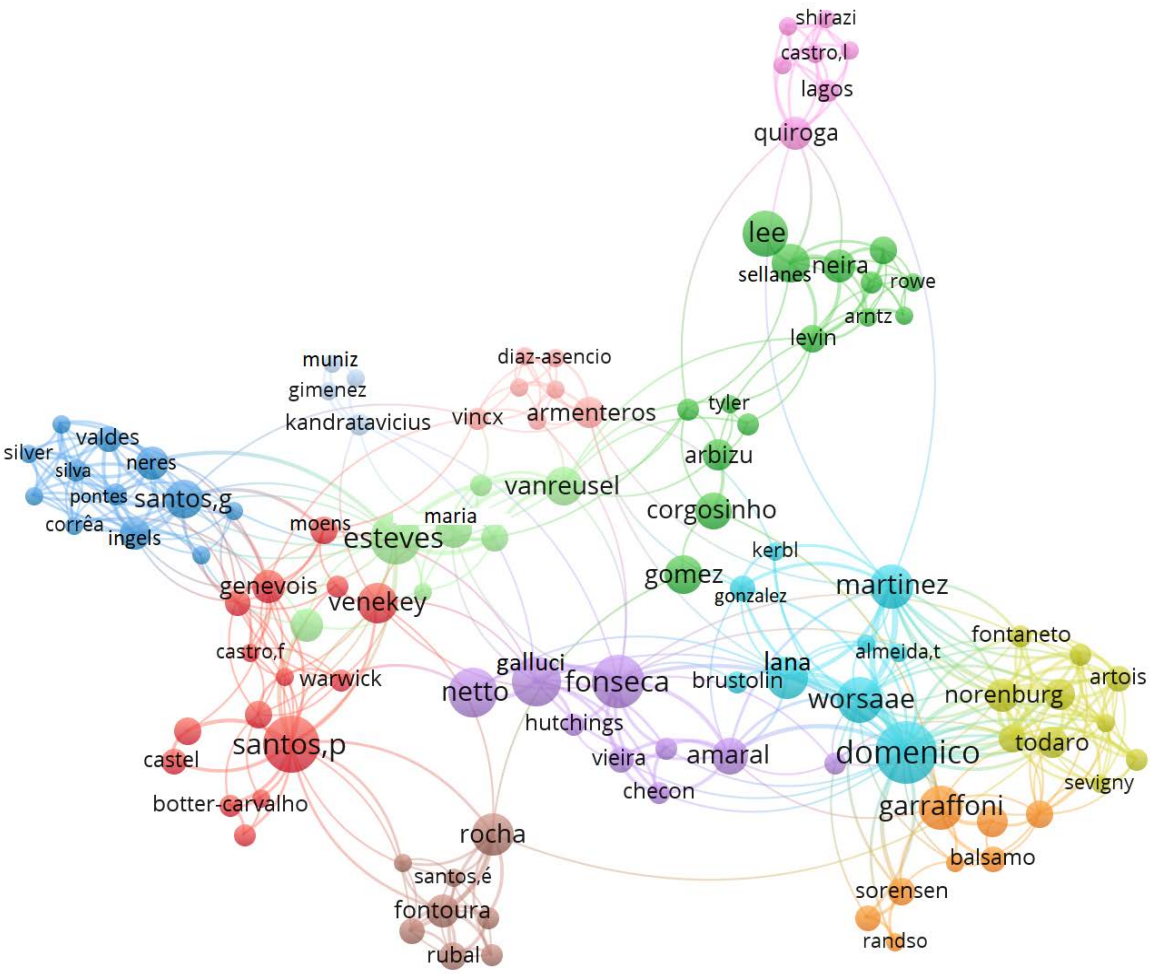

Figure 3. Collaboration network between authors of studies on the benthic meiofauna of coastal and marine environments by Latin American researchers based on the number of published documents.

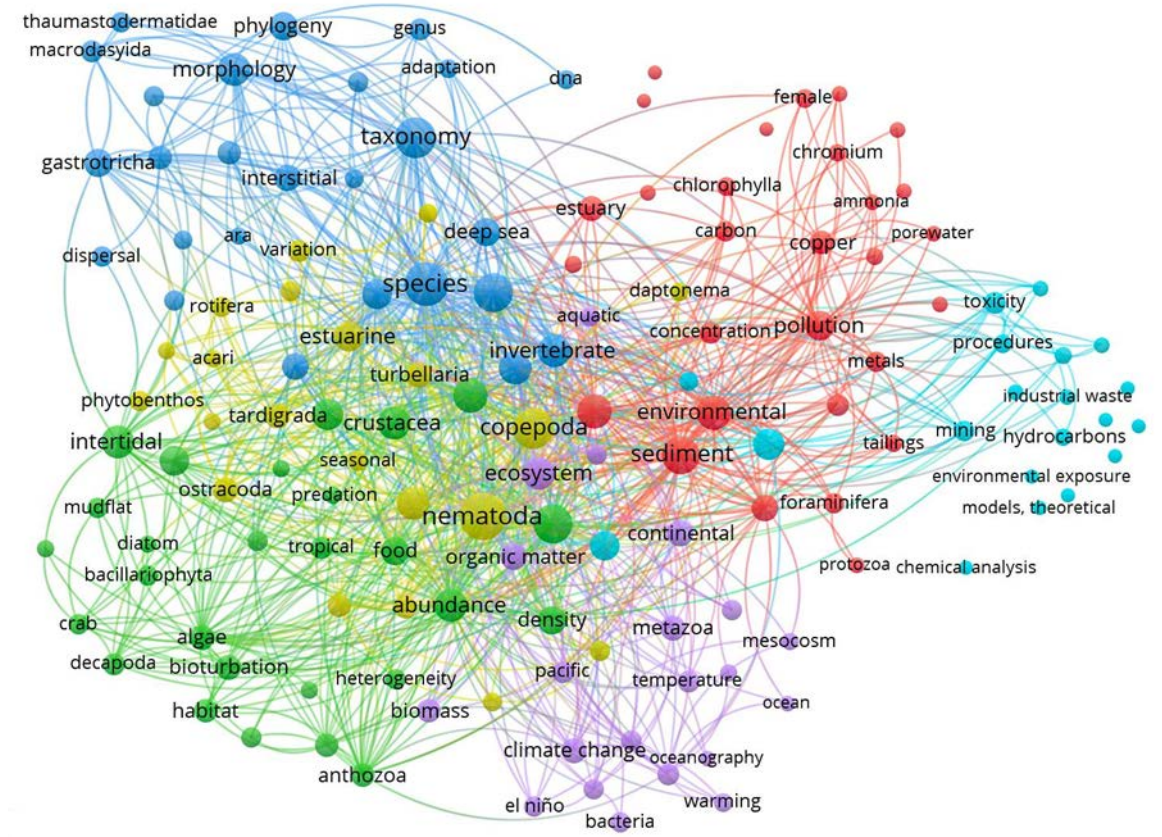

Figure 4. Keyword co-occurrence relationships in all documents on meiofauna since 1990. The most frequent keywords are represented with larger circles, which evince the relations between these words by colors.

DISCUSSION

This study shows that the Latin American research on meiofauna has accumulated a significant amount of knowledge that is growing steadily, reaching at least 380 international peer-reviewed documents. It also shows that different countries contribute in varying manners; that knowledge is centralized around a few countries, authors, affiliations, and sources; and research strongly focuses on taxonomy, pollution, and other ecological fields.

Our evaluation of the chosen publications supports our initial bibliometric hypotheses. Analysis shows a noticeable growth in the number of publications over time and a positive correlation between country size and resources and the number of produced publications. We also observed a significant asymmetry, in which a select group of specialists produced most publications featured in a limited number of journals.

Bibliometric descriptors

Scientific production per annum showed an initial growing period in the decades of 1990 and 2000 on WoS/Scopus data. However, approximately 13 documents have been annually published in recent years. This initial increase agrees with the global trend of ocean science publications, which has annually grown at a 4-9% rate (Ehler and Douvere, 2009). But the stagnation in the last few years (Figure 1A) could indicate that the meiofauna scientific community has reached its maximum capacity, possibly due to a lack of taxonomic specialists (Herman and Heip, 1988), interest from new scholars, or even financial support for this academic community. Thus, the number of authors (which can represent the size of the academic community specialized in meiofauna) could be relatively smaller than other academic specializations. Average annual citations (Figure 1B) show no clear temporal pattern, having several

peaks and troughs, with a maximum peak in 2010 and a decrease toward the end of the period stemming from the decrease in number of citations since insufficient time has passed for more recent articles to be cited (Larivière et al., 2008).

For example, Uruguay produced 900 scientific articles on marine sciences over 28 years (Lercari, 2021), of which we only included two documents as less than 1% of them refer to meiofauna. Comparing studies on benthic communities, Brazil published 176 documents on the ecology of sandy beach macrofauna (Amaral et al., 2016) and benthic communities larger (in size) than meiofauna, whereas studies on sandy beach meiofauna from all scientific areas comprised only 49 documents (Maria et al., 2016). From 1992 to 2021, only 19 documents were published on SciELO (mostly by Brazilian authors).

The number of articles per country broadly follows the trend for all areas of knowledge. For example, according to the Alper-Doger Science Index (2021), Brazil (followed by Mexico, Argentina, Colombia, and Chile) has the highest general scientific production of Latin American countries. Adams et al. (2021) showed similar results, mentioning Brazil as the largest producer of scientific research. Brazil is followed by Mexico, Chile, Argentina, and Colombia as the most significant general science producers. The UNESCO Science report (2021) shows an increase in researches published in Latin American scientific journals from 2015 to 2019, followed by Chile, Uruguay, and Argentina, which have the strongest publication levels in the region. The number of documents produced by Latin American countries was associated with various characteristics of each country, such as population size, coastline length, and economic factors such as GDP (Szteren and Lercari, 2022). The U.S. production of papers on meiofauna triples that of Latin America, whereas Europe had almost 60% of all papers published on the subject during the studied period. We expected this, as Europe and the U.S. are world leaders in scientific production in all areas of knowledge, which in turn is reflected in meiobenthic studies (Fontelo and Liu, 2018).

It has been widely shown that scientific production is related to the financial budget dedicated to science (Moya-Anegón and Herrero-Solana, 1999; Butler, 2004; Pan et al., 2012; Bornmann and Mutz, 2015). For example, a strong correlation has been shown between financial growth indicators and the increase in marine science publications (Ehler and Douvere, 2009). Coincidently, our correlation analysis showed its strong relationship with economic and geographic indicators.

Significant funding directly attracts researchers to the academic community, provides additional funding for data acquisition, and consequently increases the publication of results (Moya-Anegón and Herrero-Solana, 1999; Pan et al., 2012). However, the analysis of productivity in research and development should consider the economic factors directly related to research and institutional contexts determining who produce scientific research (Powell and Dusdal, 2017).

The importance of publications from each country agrees with findings on the most prominent affiliations among 15 institutions with the highest number of published documents. Notably, seven are based in Brazil (namely, Universidade Federal de Pernambuco, Universidade Federal do Paraná, Universidade Federal do Pará, Universidade Federal de São Paulo, Universidade de São Paulo, Universidade Federal do Estado do Rio de Janeiro, and Universidade Federal do Rio de Janeiro). These institutions collectively account for 46.7% of all publications as main publisher or collaborator (Table 4). Moreover, Ghent University (Belgium) and the University of Copenhagen (Denmark) greatly collaborate (mainly with Brazilian universities) in the publication of scientific documents on meiofauna in Latin America. In Brazil, studies on meiofauna mainly focus on two regions: southeastern São Paulo and Paraná and northeastern Pernambuco. The Brazilian Southeast is the most relevant in studies about the benthic meiofauna of sandy beaches (Maria et al., 2016). The most relevant Brazilian universities in this study also feature among the 10 Brazilian universities with the most significant research developments according to U-multirank, a multidimensional ranking system that classifies universities in an international scale based on specific performance indicators (Prado, 2021; Prado and Campos, 2021).

Verônica Fonsêca-Genevois (Genevois, V) (see Figure 3) had an important influence on collaboration with foreign universities in the 1990s and 2000s, mainly with Ghent University, both in the production of documents related to benthic meiofauna and in the specialization and training of Brazilian students within a Master's program focused on nematology (Santos et al., 2014). Additionally, internationalization strategies in Chile proved to be very important for Chilean authors to publish documents in foreign journals, resulting in a collaborative approximation to the foreign community and Latin America in the last two decades (Koch and Vanderstraeten, 2018). Uddin et al. (2015) showed that Universidad Nacional Autónoma de Mexico significantly contributed to documents published in Mexico up to 2014 and was the most important affiliate in the country, enabling Mexico to be a great international collaborator (42.21% of all its publications referred to internationally-collaborated documents).

Most publications on meiofauna were in non-Latin American journals, especially European (e.g., Marine Biodiversity, Zootaxa, and the Journal of the Marine Biological Association of the UK). These publications focused on topics such as ecology, marine biology, oceanography, and zoology, without specific emphasis on meiofauna. The journals Marine Biodiversity (24 documents) and Zootaxa (19 documents) had the highest number of publications, whereas the only significant Latin American source was Ocean and Coastal Research, with 11. We may attribute this trend to the international nature of research (many of which involved foreign collaborators) or to the impact of a journal (attracting researchers to publish in it). Note the lack of a specialized journal for meiofauna studies as we found none on Scopus and Web of Science. Creating such an editorial space could potentially promote new areas of research and collaboration networks for meiofauna studies. By classifying studies according to how often they are cited, we could theoretically explore the scientific influence of a study and its related area (Radicchi et al., 2008). Thus, our collection has two types of articles: those that approach and aim to study meiofauna as their main object and those whose object of study include the meiofauna as a secondary focus. For example, the two most cited articles in our collection (Ramirez-Llodra et al., 2010; Wei et al., 2010) refer to the ecology of deep environments, highlighting the role of meiofauna in these ecosystems. However, the third and fifth most cited articles (of Law et al., 2005; Bik et al., 2012) focus on meiofauna, studying it by molecular biology techniques (barcoding). This breakdown shows the relative importance of meiofauna as a discipline per se. In most cases, meiofauna features as a part of an investigation, rather than its primary focus. This is worrisome due to the aforementioned importance of meiofauna, which due to the lack of knowledge of this component and their small number of research groups would condition advancement of the understanding of marine ecological processes in Latin America.

Of the topics the most cited papers addressed, oceanography (Arntz et al., 2006; Gutiérrez et al., 2008) and ecological studies (Botto and Iribarne, 1997; Pusceddu et al., 2014) seem to receive the most attention in studies primarily related to deep marine environments (Pusceddu et al., 2014) (Neira et al., 2001; Ramírez-Llodra et al., 2010; Bik et al., 2012). Thus, four of the 10 most cited articles (totaling 24.56% of all citations) refer to deep sea studies. These also average 17.84 citations each, higher than the total average citations per document (Table 1). Coincidently, the most frequent keywords (Figure 4) are related to documents focused on oceanography and ecology topics, closely related to the themes of the most cited works. Finally, we should mention that five of the 10 documents were published in the 2010s; four in the 2000s, and the remaining ones in the late 1990s.

Bibliometric networks

Brazil has the most prolific scientific production in Latin America and strong collaboration with Mexico, Chile, Argentina, and Venezuela (Leta et al., 2013). Analysis of individual collaboration of the main authors showed a connection between Brazilian authors (Lana, Domenico, Fonseca-Genevois, Esteves, Venekey) and the main authors from Mexico (Gomez, Martinez) — the second largest producer of documents on meiofauna and the second Latin American country to invest the most

in research and number of researchers (Lancho-Barrantes and Cantú-Ortiz, 2019). Investment in research, intentional resources, and academic institutions play important roles in international collaboration for scientific research (Jones et al., 1994). Brazilian authors (Maria, Esteves, Fonseca-Genevois, Santos, Domenico) also have links with important foreign authors to conduct studies on meiofauna in Latin America. Collaborators come from Belgium (Vincx, Venekey, Moens), Denmark (Worsaee) and the United States (Norenberg). Fonseca-Genevois, an important researcher, collaborated with nematological researchers from universities in Denmark and Belgium in the 1990s and with Brazilian researchers on their specialization during the current decade, providing Brazil with a new approach to ecological studies (Santos et al., 2014). Results show the benefits of collaborating with universities and countries with larger investments in research and infrastructure. Collaborations with Ghent University and the University of Copenhagen are still undergoing and producing new studies (Vafeiadou, 2016; Vafeiadou et al., 2018; Herranz et al., 2021).

Our collaboration network analysis showed distinct clusters corresponding to different taxa and geographic regions. Brazilian researchers led most of these clusters, with Gustavo Fonseca being a major collaborator in international Brazilian research on meiofaunal assemblages, primarily in the Nematoda group. His main collaborators were Fabiane Gallucci, Tatiana Maria, Virág Venekey, and Sérgio Netto, Brazilian researchers who also focused on this taxon. We found another collaboration network in the Nematoda group, led by Brazilian authors Veronica Fonseca-Genevois, André Esteves, Virág Venekey, Tatiana Maria, and Gabriel dos Santos and Ann Vanreusel from Belgium. In the Annelida and Kinorhyncha groups, Maikon Di Domenico emerged as a leader, with significant collaborations from Brazilian authors Paulo Lana, Cecilia Amaral, and André Garraffoni and Katrine Worsaee from Denmark. For ecological and zoological studies on meiofauna copepods, Carlos Rocha from Brazil and Samuel Gómez from Mexico featured as prominent researchers and important collaborators in the dissemination of studies on this taxon in the region. Carlos Rocha can be considered one of the most important active scientists specializing in copepods due to his extensive literary production since the 1980s, describing and reviewing new taxa and morphological characters.

Despite being a highly respected scientist in the fields of ecology, biology, and oceanography, Paulo Lana failed to rank among the top authors according to number of publications on meiofauna during the studied period. Nonetheless, his 10 publications significantly promoted collaborations among the leading authors in this area. Lana served as a member of the Advisory Committee on Oceanography with CNPq (National Council for Scientific and Technological Development, Brazil) and played a key role as a researcher at the Universidade Federal do Paraná, one of the affiliations with the highest number of publications on meiofauna. Additionally, he supervised Sergio Netto's master's and doctoral research at Plymouth, who, in turn, supervised Gustavo Fonseca and Fabiane Gallucci, two of the main authors who published on meiofauna in Latin America.

Our analysis of keyword co-occurrence highlights the prevalence of traditional research topics in the field. Species morphological taxonomy seems to be a relevant research subject. Intertwined with it, we find the identity of the most studied meiofaunal taxa and ecological themes such as density, predation, etc. Thus, Nematoda and Copepoda have been the most commonly studied taxa in meiobenthos since the end of the last century (e.g., in Brazilian waters, 42.1% of all published documents focused on one of these taxa) (Fonseca et al., 2014). These keywords show the largest network of links both in general and when compared to other taxa. They are related to taxonomic, ecological, and biogeographical studies linked to terms such as "taxonomy," "zoology," "taxa," "pollution," "carbon," "metal," "biomonitoring," "distribution," "offshore," and "deep sea." Taxonomic studies mainly focus on describing and revising new species, primarily organized in the 1990s and the first decade of this century. Ecological studies investigate environmental quality, as these taxa serve as bioindicators. Biogeographical research focuses on distributing these taxa from the coastal zone

across the deep sea. Other relevant keywords, such as "community," "biodiversity," "sediment," "species," and "taxonomy," are more general and refer to a variety of topics in science on meiofauna.

On the other hand, sediment pollution and toxicity (Giere, 2009; Balsamo et al., 2012) emerge as a group of research lines for which meiofauna configures important biological tools to evaluate anthropic impacts. Finally, the link between meiofauna, oceanography, and climate change seems to be a relevant line of research. However, note the remarkable absence of more current and modern research topics that have been proposed as perspectives worthy of study in the field (Giere, 2009). For example, our review has neither research using concepts related to the analysis of biodiversity by molecular methods, on distribution and dispersion nor on the functional role of meiobenthos as it relates to interactions with microbiota and macrofauna.

CONCLUSION

Our review quantified for the first time the scientific research efforts focused on marine benthic meiofauna in Latin American countries, showing a steady growth in the production of academic studies in the international literature. Although we made no direct comparisons with other marine biology disciplines, the meiofaunal research community seems small, consisting of a few research groups of professionals concentrated in very few institutions. We also showed an important asymmetry in production by country as Brazil accounted for almost 50% of all Latin American publications. Production magnitude was correlated to country size and economic aspects. Although Latin American countries have a weak collaborative network, we evinced a strong collaboration with nonregional countries.

Regarding the conceptual content of the chosen studies, the most cited research had no relation with leading authors, affiliations, and countries, which we hypothesize results from a relationship between the leading authors of study papers and other countries (especially the United States and Europe), which invest more in research, dissemination, and scientific collaboration than Latin America. Studies on meiofauna over the decades have mostly focused on the taxonomy and ecology of intertidal environments. Other topics addressed include global warming, physicochemical changes in oceans, pollution, contamination and degradation of marine ecosystems, bioturbation, ecological interactions with microorganisms and other benthic organisms (such as macrofauna), and taxonomic and ecological interactions with morphodynamics.

However, recent worldwide research has highlighted certain important aspects the professional community studying meiofauna can strengthen. Although some articles in Latin America have evaluated the relation between meiofauna and environments affected by anthropization, there remains a lack of understanding of ecological responses to specific disturbances (Schratzberger et al., 2009; Buma, 2015; Duarte, 2015). Some international research on meiofauna also relates this to the trophic role of meiofauna, its relation with the introduction of invasive species (Reise et al., 2006; Molnar et al., 2008), or the effects of bottom trawl fishing (Halpern and Floeter, 2008; Pusceddu et al., 2014), topics scarcely addressed in Latin American studies. The three major hubs of global research — the United States, Europe, and Asia (including China, Japan, and South Korea) — shows a growing trend of scientific studies on previously unexplored areas of meiofauna (which Latin American countries are yet to evaluate), showing knowledge gaps between regions. These studies include eDNA metabarcoding analyses (Brannock et al., 2018; Gielings et al., 2021), molecular interactions with microplastics and metal pollution (Gambi et al., 2020; Allouche et al., 2022; Rauchschwalbe et al., 2022), the effects of global warming on meiofaunal associations (Zeppilli et al., 2015; Kiko et al., 2017), and new methodologies to identify and classify species (Kitahashi et al., 2018). We hope that collaborations between local and foreign institutions and researchers will give rise to new multidisciplinary studies on meiofauna in these unexplored areas, which would strengthen the advancement of knowledge of meiofauna in our region and elucidate the understanding of this still poorly known community in the world (compared to other marine groups such as macrofauna, megafauna, and nektonic and planktonic organisms).

We hope our analysis will improve understanding of knowledge produced on meiofauna, with particular emphasis on increasing regional and international collaboration by multidisciplinary cooperation. While most studies were conducted in Brazil and Mexico, it would be desirable to develop research in less-favored territories to expand knowledge and promote the conservation of meiofaunal assemblages in the region. This could be achieved by strengthening communication between research groups (such as scientist and student exchanges and in-person or online meetings) and the formation of collaborative networks aimed at seeking funding for regional projects. Further research should prioritize the co-authorship of new publications covering a wide range of latitudinal and depth scales or interocean studies.

ACKNOWLEDGMENTS

We would like to thank the two anonymous reviewers for their in-depth reading of our study and for their sound suggestions, which undoubtedly led to a substantial improvement of our review. We also thank researcher Miguel Monteiro Moretta (Mamirauá Institute, Brazil) for helping us with the first correction of the translation of this manuscript. Special thanks to the members of the UNDECIMAR Laboratory for their assistance and to the Sectoral Comission of Scientific Research/Comisión Sectorial de Investigación Científica (CSIC) from University of Republic (Uruguay) for supplying the funds for science research and development.

This work is part of Bernardo Baldeija's Master Thesis ("Meiofauna as bioindicators: effects of urbanization on estuarine beaches in Montevideo, Uruguay") at PEDECIBA-BIOLOGÍA. This research was partially supported by CSIC-Grupos (N°32), CSIC VUSP M2, PEDECIBA, and SNI ANII.

We would like to give special recognition to Dr. Paulo da Cunha Lana, for his dedication and important contributions to the knowledge of meiofauna in Latin America.

AUTHOR CONTRIBUTIONS

B.B.: Conceptualization; Investigation; Methodology; Results and Discussion; Writing – original draft; Writing – review & editing;

D.L.: Supervision; Conceptualization; Methodology; Results and Discussion; Writing – review & editing;

REFERENCES

AD SCIENTIFIC INDEX. 2021. World Scientist and University Rankings 2021. Accessed: https://www.adscientificindex.com/

Allouche, M., Ishak, S., Ali, M. B., Hedfi, A., Almalki, M., Karachle, P. K., Harrath, A. H., Abu-Zied, R. H., Badraoui, R. & Boufahja, F. 2022. Molecular interactions of polyvinyl chloride microplastics and beta-blockers (Diltiazem and Bisoprolol) and their effects on marine meiofauna: Combined in vivo and modeling study. *Journal of Hazardous Materials*, *431*, 128609. DOI: https://doi.org/10.1016/j.jhazmat.2022.128609

Amaral, A. C. Z., Corte, G. N., Filho, J. S. R., Denadai, M. R., Colling, L. A., Borzone, C., Veloso, V., Omena, E. P., Zalmon, I. R., Rocha-Barreira, C. de A., Souza, J. R. B. de, Rosa, L. C. da & Almeida, T. C. M. de. 2016. Brazilian sandy beaches: characteristics, ecosystem services, impacts, knowledge and priorities. *Brazilian Journal of Oceanography*, *64*(spe2), 5–16. DOI: https://doi.org/10.1590/s1679-875920160933064sp2

Aria, M. & Cuccurullo, C. 2017. bibliometrix : An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. DOI: https://doi.org/10.1016/j.joi.2017.08.007

Arntz, W. E., Gallardo, V. A., Gutiérrez, D., Isla, E., Levin, L. A., Mendo, J., ... & Wolff, M. 2006. El Niño and similar perturbation effects on the benthos of the Humboldt, California, and Benguela Current upwelling ecosystems. *Advances in geosciences*, 6, 243-265.

Balsamo, M., Semprucci, F., Frontalini, F. & Coccioni, R. 2012. Meiofauna as a Tool for Marine Ecosystem Biomonitoring. *In*: Cruzado, A. (ed.), *Marine Ecosystems* (pp. 78–104). London: InTech. DOI: https://doi.org/10.5772/34423

Bik, H. M., Sung, W. A. Y., De Ley, P., Baldwin, J. G., Sharma, J., Rocha-Olivares, A. X. A. Y. Á. C. A. T. L., & Thomas, W. K. 2012. Metagenetic community analysis of microbial eukaryotes illuminates biogeographic patterns in deep-sea and shallow water sediments. *Molecular Ecology*, 21(5), 1048-1059.

Bornmann, L. & Mutz, R. 2015. Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. *Journal of the Association for Information Science and Technology*, *66*(11), 2215–2222. DOI: https://doi.org/10.1002/asi.23329

Botto, F. & Iribarne, O. 1997. Effect of the burrowing crab Chasmagnathus granulata (Dana) on the benthic community of a SW Atlantic coastal lagoon. *Journal of Experimental Marine Biology and Ecology*, *241*(2), 263–284. DOI: https://doi.org/10.1016/s0022-0981(99)00089-1

Brannock, P. M., Learman, D. R., Mahon, A. R., Santos, S. R. & Halanych, K. M. 2018. Meiobenthic community composition and biodiversity along a 5500 km transect of Western Antarctica: a metabarcoding analysis. *Marine Ecology Progress Series*, *603*, 47–60. DOI: https://doi.org/10.3354/meps12717

Briner, R. B. & Denyer, D. 2012. Systematic Review and Evidence Synthesis as a Practice and Scholarship Tool. *In*: Rousseau, D. M. (ed.), *The Oxford Handbook of Evidence-Based Management* (pp. 112–129). Oxford University Press. DOI: https://doi.org/10.1093/oxfordhb/9780199763986.013.0007

Buma, B. 2015. Disturbance interactions: characterization, prediction, and the potential for cascading effects. *Ecosphere*, *6*(4), 1–15. DOI: https://doi.org/10.1890/es15-00058.1

Butler, D. 2004. Science searches shift up a gear as Google starts Scholar engine. *Nature*, *432*(7016), 423–423. DOI: https://doi.org/10.1038/432423a

Clasing, E. 1976. Fluctuaciones anuales de la meiofauna en la marisma de chinquihue (puerto montt, chile). *Studies on Neotropical Fauna and Environment*, *11*(3), 179–198. DOI: https://doi.org/10.1080/01650527609360503

Cobb, N. A. 1920. One hundred new nemas (type species of 100 new genera). *Contributions to a Science of Nematology*, *9*, 217–343. DOI: https://doi.org/10.11646/phytotaxa.18.1.1

Corrêa, D. D. 1991. Dr Eveline du Bois-Reymond Marcus. *Hydrobiologia*, *227*(1), xxi–xxvi. DOI: https://doi.org/10.1007/bf00027573

Costa, C., Fanelli, E., Marini, S., Danovaro, R. & Aguzzi, J. 2020. Global Deep-Sea Biodiversity Research Trends Highlighted by Science Mapping Approach. *Frontiers in Marine Science*, *7*. DOI: https://doi.org/10.3389/fmars.2020.00384

Courtial, J. P. & Callon, M. 1991. Indicators for the identification of strategic themes within a research programme. *Scientometrics*, *21*(3), 447–457. DOI: https://doi.org/10.1007/bf02093980

de la Cruz, E. & Vargas, J. A. 1987. Abundancia y distribución vertical de la meiofauna en la playa fangosa de Punta Morales, Golfo de Nicoya, Costa Rica. *Revista De Biología Tropical*, *35*(2), 363–367.

Delecroix, B. & Epstein, R. 2004. Co-word analysis for the non-scientific information example of Reuters Business Briefings. *Data Science Journal*, *3*, 80–87. DOI: https://doi.org/10.2481/dsj.3.80

De Ley, P., De Ley, I. T., Morris, K., Abebe, E., Mundo-Ocampo, M., Yoder, M., ... & Thomas, W. K. 2005. An integrated approach to fast and informative morphological vouchering of nematodes for applications in molecular barcoding. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1462), 1945-1958.

Duarte, T. L. P., R. C. S, Oliveira, R. E. M. C. C., Motta, E. L. S., Da Silva, A. F., Pessanha, A. L. M., Dias. 2015. Distribuição da meiofauna em dois habitats estuarinos da Apa do Rio Mamanguape (NE BRASIL). *Biofar: Revista de Biologia e Farmácia*, *10*(3).

Dujardin, F. 1851. Sur un petit animal marin, l'Echinodère, formant un type intermédiaire entre les Crustacés et les Vers. *Annales des Sciences naturelles* (3) Zoologie, 15, 158–173

Eck, N. J. van & Waltman, L. 2007. VOS: A New Method for Visualizing Similarities Between Objects. *In*: Decker, R. & Lenz, H. J. (eds.), *Studies in Classification, Data Analysis, and Knowledge Organization* (pp. 299–306). Berlin: Springer. DOI: https://doi.org/10.1007/978-3-540-70981-7_34

Eck, N. J. van & Waltman, L. 2009. How to normalize cooccurrence data? An analysis of some well-known similarity measures. *Journal of the American Society for Information Science and Technology*, *60*(8), 1635–1651. DOI: https://doi.org/10.1002/asi.21075

Eck, N. J. van & Waltman, L. 2017. Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, *111*(2), 1053–1070. DOI: https://doi.org/10.1007/s11192-017-2300-7

Egghe, L. 1987. An exact calculation of Price's law for the law of Lotka. *Scientometrics*, *11*(1–2), 81–97. DOI: https://doi.org/10.1007/bf02016632

Egghe, L. & Rousseau, R. 2011. Theory and practice of the shifted Lotka function. *Scientometrics*, *91*(1), 295–301. DOI: https://doi.org/10.1007/s11192-011-0539-y

Ehler, C. & Douvere, F. 2009. *Marine spatial planning: a step-by-step approach toward ecosystem-based management*. Paris: UNESCO.

Fonseca, G., Norenburg, J. & Domenico, M. D. 2014. Editorial: diversity of marine meiofauna on the coast of Brazil. *Marine Biodiversity*, *44*(3), 459–462. DOI: https://doi.org/10.1007/s12526-014-0261-0

Fontelo, P. & Liu, F. 2018. A review of recent publication trends from top publishing countries. *Systematic Reviews*, *7*(1), 147. DOI: https://doi.org/10.1186/s13643-018-0819-1

Gambi, C., Canals, M., Corinaldesi, C., Dell'Anno, A., Manea, E., Pusceddu, A., Sanchez-Vidal, A. & Danovaro, R. 2020. Impact of historical sulfide mine tailings discharge on meiofaunal assemblages (Portmán Bay, Mediterranean Sea). *Science of The Total Environment*, *736*, 139641. DOI: https://doi.org/10.1016/j.scitotenv.2020.139641

Gee, J. M. 1989. An ecological and economic review of meiofauna as food for fish. *Zoological Journal of the Linnean Society*, *96*(3), 243–261. DOI: https://doi.org/10.1111/j.1096-3642.1989.tb01830.x

Giard, A. 1904. Sur une faunule charactéristique des sables à diatomées d'Ambleteuse. C R Séanc Soc Biol Paris 56: 107–165

Gielings, R., Fais, M., Fontaneto, D., Creer, S., Costa, F. O., Renema, W. & Macher, J.-N. 2021. DNA Metabarcoding Methods for the Study of Marine Benthic Meiofauna: A Review. *Frontiers in Marine Science*, *8*. DOI: https://doi.org/10.3389/fmars.2021.730063

Giere, O. 2009. *Meiobenthology* (2nd ed.). Berlin: Springer Berlin Heidelberg. DOI: https://doi.org/10.1007/978-3-540-68661-3

Guo, Y., Chen, X. & Liu, A. 2010. The Research Status on Meiofauna in China by Use of Bibliometric Analysis. *In*: *2010 International Conference on Challenges in Environmental Science and Computer Engineering* (pp. 507–510). Wuhan: IEEE. DOI: https://doi.org/10.1109/cesce.2010.50

Gutiérrez, D., Enríquez, E., Purca, S., Quipúzcoa, L., Marquina, R., Flores, G., & Graco, M. 2008. Oxygenation episodes on the continental shelf of central Peru: Remote forcing and benthic ecosystem response. *Progress in Oceanography*, 79(2-4), 177-189

Guzmán, H. M., Obando, V. L. & Cortés, J. 1987. Meiofauna associated with a Pacific coral reef in Costa Rica. *Coral Reefs*, *6*(2), 107–112. DOI: https://doi.org/10.1007/bf00301379

Halpern, B. S. & Floeter, S. R. 2008. Functional diversity responses to changing species richness in reef fish communities. *Marine Ecology Progress Series*, *364*, 147–156. DOI: https://doi.org/10.3354/meps07553

Herman, P. M. J. & Heip, C. 1988. On the use of meiofauna in ecological monitoring: Who needs taxonomy? *Marine Pollution Bulletin*, *19*(12), 665–668. DOI: https://doi.org/10.1016/0025-326x(88)90386-4

Herranz, M., Park, T., Domenico, M. D., Leander, B. S., Sørensen, M. V. & Worsaae, K. 2021. Revisiting kinorhynch segmentation: variation of segmental patterns in the nervous system of three aberrant species. *Frontiers in Zoology*, *18*(1). DOI: https://doi.org/10.1186/s12983-021-00438-5

Hirsch, J. E. 2005. An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences*, *102*(46), 16569–16572. DOI: https://doi.org/10.1073/pnas.0507655102

Hulings, N. C. & Gray, J. S. 1971. A manual for the study of meiofauna. *Smithsonian Contributions to Zoology*, (78), 1–84. DOI: https://doi.org/10.5479/si.00810282.78

Jones, C. G., Lawton, J. H. & Shachak, M. 1994. Organisms as Ecosystem Engineers. *In*: Samson, F. B. & Knopf, F. L. (eds.), *Ecosystem Management* (pp. 130–147). New York: Springer. DOI: https://doi.org/10.1007/978-1-4612-4018-1_14

Kiko, R., Kern, S., Kramer, M. & Mütze, H. 2017. Colonization of newly forming Arctic sea ice by meiofauna: a case study for the future Arctic? *Polar Biology*, *40*(6), 1277–1288. DOI: https://doi.org/10.1007/s00300-016-2052-5

Kitahashi, T., Watanabe, H. K., Tsuchiya, M., Yamamoto, Hideyuki & Yamamoto, Hiroyuki. 2018. A new method for acquiring images of meiobenthic images using the FlowCAM. *MethodsX*, *5*, 1330–1335. DOI: https://doi.org/10.1016/j.mex.2018.10.012

Koch, T. & Vanderstraeten, R. 2018. Internationalizing a national scientific community? Changes in publication and citation practices in Chile, 1976–2015. *Current Sociology*, *67*(5), 723–741. DOI: https://doi.org/10.1177/0011392118807514

Lancho-Barrantes, B. S. & Cantú-Ortiz, F. J. 2019. Science in Mexico: a bibliometric analysis. *Scientometrics*, *118*(2), 499–517. DOI: https://doi.org/10.1007/s11192-018-2985-2

Larivière, V., Archambault, É. & Gingras, Y. 2008. Long-term variations in the aging of scientific literature: From exponential growth to steady-state science (1900–2004). *Journal of the American Society for Information Science and Technology*, *59*(2), 288–296. DOI: https://doi.org/10.1002/asi.20744

Lercari, D. 2021. Analysis of three decades of research in marine sciences in Uruguay through mapping of science and bibliometric indexes. *Latin American Journal of Aquatic Research*, *49*(1), 1–17. DOI: https://doi.org/10.3856/vol49-issue1-fulltext-2584

Leta, J., Thijs, B. & Glänzel, W. 2013. A macro-level study of science in Brazil: seven years later. *Encontros Bibli: Revista Eletrônica de Biblioteconomia e Ciência Da Informação*, *18*(36), 51–66. DOI: https://doi.org/10.5007/1518-2924.2013v18n36p51

Luukkonen, T., Tijssen, R. J. W., Persson, O. & Sivertsen, G. 1993. The measurement of international scientific collaboration. *Scientometrics*, *28*(1), 15–36. DOI: https://doi.org/10.1007/bf02016282

Majdi, N., Schmid-Araya, J. M. & Traunspurger, W. 2020. Preface: Patterns and processes of meiofauna in freshwater ecosystems. *Hydrobiologia*, *847*(12), 2587–2595. DOI: https://doi.org/10.1007/s10750-020-04301-2

Majdi, N. & Traunspurger, W. 2015. Free-living nematodes in the freshwater food web: a review. *Journal of Nematology*, *47*(1), 28–44.

Maria, T. F., Wandeness, A. P. & Esteves, A. M. 2016. State of the art of the meiofauna of Brazilian Sandy Beaches. *Brazilian Journal of Oceanography*, *64*(spe2), 17–26. DOI: https://doi.org/10.1590/s1679-875920160946064sp2

Medeiros, L. R. A. 1987. Conhecimento sobre meiobentos no Brasil e relato de um caso da costa sudeste-sul brasileira: Síntese de conhecimentos. *Publicação Aciesp*, *54*, 348–379.

Mengist, W., Soromessa, T. & Legese, G. 2020. Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX*, 7, 100777.

Molnar, J. L., Gamboa, R. L., Revenga, C. & Spalding, M. D. 2008. Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment*, *6*(9), 485–492. DOI: https://doi.org/10.1890/070064

Montanara, A. C. di, Baldrighi, E., Franzo, A., Catani, L., Grassi, E., Sandulli, R. & Semprucci, F. 2022. Free-living nematodes research: State of the art, prospects, and future directions. A bibliometric analysis approach. *Ecological Informatics*, *72*, 101891. DOI: https://doi.org/10.1016/j.ecoinf.2022.101891

Moya-Anegón, F. D. & Herrero-Solana, V. 1999. Science in america latina: A comparison of bibliometric and scientific-technical indicators. *Scientometrics*, *46*(2), 299–320. DOI: https://doi.org/10.1007/bf02464780

Neira, C., Sellanes, J., Levin, L. A., & Arntz, W. E. 2001. Meiofaunal distributions on the Peru margin:: relationship to oxygen and organic matter availability. *Deep Sea Research Part I: Oceanographic Research Papers*, 48(11), 2453-2472.

Pan, R. K., Kaski, K. & Fortunato, S. 2012. World citation and collaboration networks: uncovering the role of geography in science. *Scientific Reports*, *2*(1), 902. DOI: https://doi.org/10.1038/srep00902

Peters, H. P. F. & Raan, A. F. J. van. 1991. Structuring scientific activities by co-author analysis. *Scientometrics*, *20*(1), 235–255. DOI: https://doi.org/10.1007/bf02018157

Peters, H. P. F. & Raan, A. F. J. van. 1993. Co-word-based science maps of chemical engineering. Part II: Representations by combined clustering and multidimensional scaling. *Research Policy*, *22*(1), 47–71. DOI: https://doi.org/10.1016/0048-7333(93)90032-d

Powell, J. J. W. & Dusdal, J. 2017. Science Production in Germany, France, Belgium, and Luxembourg: Comparing the Contributions of Research Universities and Institutes to Science, Technology, Engineering, Mathematics, and Health. *Minerva*, *55*(4), 413–434. DOI: https://doi.org/10.1007/s11024-017-9327-z

Prado, A. 2021. Performances of the brazilian universities in the "u-multirank" in the period 2017-2020. *SciELOPreprints*. DOI: https://doi.org/10.1590/scielopreprints.2351

Prado, A. F. B. A. & Campos, A. L. S. de. 2021. Using the "U-Multirank" to Compare the Performances of Brazilian Universities withLatin American Countries in Academic and Industry Products. *In*: *Anais do XX Colóquio Internacional de Gestão Universitária*. Florianópolis: Universidade Federal de Santa Catarina.

Pusceddu, A., Gambi, C., Corinaldesi, C., Scopa, M. & Danovaro, R. 2014. Relationships between Meiofaunal Biodiversity and Prokaryotic Heterotrophic Production in Different Tropical Habitats and Oceanic Regions. *PLoS ONE*, *9*(3), e91056. DOI: https://doi.org/10.1371/journal.pone.0091056

R CORE TEAM. 2020. A language and environment for statistical computing.

Radicchi, F., Fortunato, S., & Castellano, C. 2008. Universality of citation distributions: Toward an objective measure of scientific impact. *Proceedings of the National Academy of Sciences*, 105(45), 17268-17272. DOI: 10.1073/pnas.0806977105

Ramirez-Llodra, E., Brandt, A., Danovaro, R., De Mol, B., Escobar, E., German, C. R., ... & Vecchione, M. 2010. Deep, diverse and definitely different: unique attributes of the world's largest ecosystem. *Biogeosciences*, 7(9), 2851-2899.

Rauchschwalbe, M.-T., Höss, S., Haegerbaeumer, A. & Traunspurger, W. 2022. Long-term exposure of a free-living freshwater micro- and meiobenthos community to microplastic mixtures in microcosms. *Science of The Total Environment*, *827*, 154207. DOI: https://doi.org/10.1016/j.scitotenv.2022.154207

Reise, K., Olenin, S. & Thieltges, D. W. 2006. Are aliens threatening European aquatic coastal ecosystems? *Helgoland Marine Research*, *60*(2), 77–83. DOI: https://doi.org/10.1007/s10152-006-0024-9

Rueda-Clausen, G. C., C, V.-R. G. & CE, R.-C. P. 2005. Indicadores bibliométricos: origen, aplicación, contradicción y nuevas propuestas. *MedUNAB*, *8*(1), 29–36.

Santos, G. A. P., Moens, T., Valdes, Y. & Larrazabal, M. E. L. 2014. Verônica da Fonsêca-Genevois and the rise of meiofauna studies in Brazil. Life and contribution of a pioneer, in memoriam. *Marine Biodiversity*, *44*(3), 229–236. DOI: https://doi.org/10.1007/s12526-014-0251-2

Santos, S., Neto, F. C. R., Oliveira, M., Corrêa, M. M. & Parahyba, R. B. V. 2022. The neglected area of meiobenthos: a bibliometric analysis in the status of research on freshwater meiofauna. *Authorea*. DOI: https://doi.org/10.22541/au.165348918.80457866/v1

Schratzberger, M. & Ingels, J. 2018. Meiofauna matters: the roles of meiofauna in benthic ecosystems. *Journal of Experimental Marine Biology and Ecology*, *502*, 12–25. DOI: https://doi.org/10.1016/j.jembe.2017.01.007

Schratzberger, M., Lampadariou, N., Somerfield, P. J., Vandepitte, L. & Berghe, E. V. 2009. The impact of seabed disturbance on nematode communities: linking field and laboratory observations. *Marine Biology*, *156*(4), 709–724. DOI: https://doi.org/10.1007/s00227-008-1122-9

Singh, V. K., Singh, P., Karmakar, M., Leta, J. & Mayr, P. 2021. The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis. *Scientometrics*, *126*(6), 5113–5142. DOI: https://doi.org/10.1007/s11192-021-03948-5

Szteren, D. & Lercari, D. 2022. Marine mammal research in South America: 30 years of publication efforts and collaborative networks. *Latin American Journal of Aquatic Research*, *50*(2), 251–266. DOI: https://doi.org/10.3856/vol50-issue2-fulltext-2810

Uddin, A., Singh, V. K., Pinto, D. & Olmos, I. 2015. Scientometric mapping of computer science research in Mexico. *Scientometrics*, *105*(1), 97–114. DOI: https://doi.org/10.1007/s11192-015-1654-y

UNESCO. 2021. Global Ocean Science Report 2020: Charting Capacity for Ocean Sustainability (pp. 93–133). Paris: Bernan Associates.

Vafeiadou, A.-M., Bretaña, B. L. P., Colen, C. V., Santos, G. A. P. & Moens, T. 2018. Global warming-induced temperature effects to intertidal tropical and temperate meiobenthic communities. *Marine Environmental Research*, *142*, 163–177. DOI: https://doi.org/10.1016/j.marenvres.2018.10.005

Vafeiadou, A. M., Bretaña, B., Santos, G., &. Moens. T. 2016. Do tropical and temperate meiobenthic communities respond similarly to climate change? *In*: *23rd former Benelux congress of Zoology* (p. 97).

Vanreusel, A., Groote, A. D., Gollner, S. & Bright, M. 2010. Ecology and Biogeography of Free-Living Nematodes Associated with Chemosynthetic Environments in the Deep Sea: A Review. *PLoS ONE*, *5*(8), e12449. DOI: https://doi.org/10.1371/journal.pone.0012449

Vargas, J. A. 1988. A survey of the meiofauna of an Eastern Tropical Pacific intertidal mud flat. *Revista de Biología Tropical*, *36*(2B), 541–544. DOI: https://doi.org/10.15517/rbt.v36i2b.23894

Wei, C. L., Rowe, G. T., Escobar-Briones, E., Boetius, A., Soltwedel, T., Caley, M. J., ... Narayanaswamy, B. E. 2010. Global patterns and predictions of seafloor biomass using random forests. *PloS one*, 5(12), e15323.

Zeppilli, D., Sarrazin, J., Leduc, D., Arbizu, P. M., Fontaneto, D., Fontanier, C., Gooday, A. J., Kristensen, R. M., Ivanenko, V. N., Sørensen, M. V., Vanreusel, A., Thébault, J., Mea, M., Allio, N., Andro, T., Arvigo, A., Castrec, J., Danielo, M., Foulon, V., Fumeron, R., Hermabessiere, L., Hulot, V., James, T., Langonne-Augen, R., Bot, T. L., Long, M., Mahabror, D., Morel, Q., Pantalos, M., Pouplard, E., Raimondeau, L., Rio-Cabello, A., Seite, S., Traisnel, G., Urvoy, K., Stegen, T. V. D., Weyand, M. & Fernandes, D. 2015. Is the meiofauna a good indicator for climate change and anthropogenic impacts? *Marine Biodiversity*, *45*(3), 505–535. DOI: https://doi.org/10.1007/s12526-015-0359-z