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ECOSYSTEMS

Bibliometric analysis of peer-reviewed literature on the Patos Lagoon, southern Brazil

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Abstract: Coastal lagoons provide several ecological resources and services with their functioning being mainly investigated in temperate areas. The Patos Lagoon, a subtropical system in southern Brazil, is one of the largest chocked coastal lagoons in the world. It provides habitat for numerous organisms and a range of ecosystem services. We performed a bibliometric analysis to identify and analyze the characteristics of studies carried out in the Patos Lagoon based on articles published in peer-reviewed journals indexed in the Science Citation Index Expanded database of Clarivate Analytics Web of Science and Scopus database. We found 360 articles published between 1965 and 2019 in 150 journals. The number of articles has increased in the last decades mainly resulting from national collaborative efforts. Most articles were published by Brazilian research institutions. Most studies were performed in the Patos Lagoon estuary, a Long-term Ecological Research program´s study site. Our study thus highlights the importance of long-term projects to the comprehension of subtropical coastal lagoons functioning and indicates knowledge gaps that must be addressed in future studies.

Key words: coastal lagoon, long-term research, subtropical estuary, scientific production, Scopus, Web of Science.

INTRODUCTION

Coastal lagoons are transitional ecosystems located at the terrestrial and marine interface, covering approximately 13% of coastal areas worldwide (Pérez-Ruzafa et al. 2011). Such ecosystems are highly productive, providing a range of resources and ecosystem services (Barbier et al. 2011). The Patos Lagoon (henceforth PL; 30° - 32°S; 50° - 52°W), located on the subtropical coast of the Rio Grande do Sul state, in southern Brazil, is one of the largest choked coastal lagoons in the world with an average length of 250 km, an average width of 40 km and surface of 10,360 km^2 (Kjerfve 1986). The upper and mid areas of the PL are dominated by freshwater whereas an estuary occupies the lower, southern end of the lagoon, with brackish waters covering ~ 10% of its total surface (Seeliger & Odebrecht 2010). The Patos Lagoon estuary (henceforth PLE) is predominantly composed of shallow bays (< 1.5 m depth) with subtidal and intertidal unvegetated and vegetated (i.e., seagrasses and macroalgal beds and salt marshes) soft bottoms, and artificial hard substrates, as well as intermediate to deep areas and channels (up to 6 m depth; Seeliger 2001). The local hydrodynamics is mainly controlled by interactive effects of rainfall in the drainage basin (200,000 km^2) and prevailing northeastern (NE) and southwestern (SW) winds since tidal influences are negligible (Möller et al. 2001). These driving factors set the balance between freshwater discharges and seawater intrusions from the Atlantic Ocean through a narrow channel (Möller et al. 2001). This balance regulates seasonal trends of water

salinity and level in the estuarine region with high freshwater discharges (i.e., winter/spring) and NE winds resulting in lower salinities, while higher values of salinity are found during dry seasons (summer/autumn) when southern winds pump saltwater into the estuary (Möller et al. 1996, 2001, Möller & Fernandes 2010).

The PL provides habitat for numerous organisms, including birds (Dias et al. 2017), crustaceans (Pereira & D'Incao 2012, Noleto-Filho et al. 2017) and fishes (Vieira et al. 2010) with endemic, threatened, and/or endangered species (Bertaco et al. 2016). Also, its estuarine region supports important feeding, reproduction, and nursery habitats for many commercially important species (Odebrecht et al. 2017), as well as home to a resident population of common bottlenose dolphins, *Tursiops truncatus* (Fruet et al. 2011, 2015). At the same time, the PL supports a wide range of socio-economic activities including aquaculture, agriculture, artisanal fisheries, industrial and port, and navigation and leisure (Odebrecht et al. 2008, 2010). However, despite its significant ecological and socio-economic values, the PL has been exposed to multiple anthropogenic threats such as chemicals contamination (Medeiros et al. 2005, Garcia et al. 2010, Wallner-Kersanach et al. 2016, Pereira et al. 2018), the introduction of invasive species (Barbosa & Melo 2009, Neuhaus et al. 2016), overfishing (Reis & D'Incao 2000, Haimovici & Cardoso 2016, Noleto-Filho et al. 2017), eutrophication processes (Niencheski & Zepka Baumgarten 2007, Baumgarten & Niencheski 2010) and consequent opportunistic macroalgae and toxic cyanobacterial blooms (Yunes et al. 1998, Lanari & Copertino 2017), and anthropogenic climate change (Asmus et al. 2019). Natural impacts also occur driven by remote, large-scale climatic phenomenon El Niño Southern Oscillation (ENSO; Odebrecht et al. 2011). Characterized by warm and cold phases (*El Niño* and *La Niña* events, respectively), ENSO events occur every 3-5 years (Wang et al. 2016) triggering interannual variations in rainfall regional patterns in southern South America (Grimm et al. 1998). Such rainfall changes are translated into freshwater discharges below (i.e., dry periods; *La Niña* events) and above (i.e., wet periods; *El Niño*) historical means, leading to simultaneous changes in water physico-chemical conditions and sediments dynamics that affect biological communities and ecological processes (Bemvenuti & Colling 2010, Copertino & Seeliger 2010, Possamai et al. 2018). Natural, ENSO-driven impacts may also interact with anthropogenic ones, negatively affecting the Patos Lagoon´s estuarine functioning (Odebrecht et al. 2011).

Bibliometric analysis is a systematic approach used to quantitatively evaluate the scientific literature in a specific research field (Hood & Wilson 2001). Bibliometric analysis can employ performance analysis and science mapping analysis (i.e., maps of networks) to identify knowledge gaps, hotspots, patterns and trends thereby providing ideas for future scientific research (see Moral-Muñoz et al. 2020 for review). In aquatic ecosystems, bibliometric analysis has been performed to quantify and characterize the scientific literature carried out in coastal lagoons from Tabasco in Mexico (Espinoza-Tenorio et al. 2015), South African estuaries (Olisah & Adams 2021), Great Lakes of North America (Song et al. 2016), Lancang-Mekong River (Junlin et al. 2020), Mekong River (Sui et al. 2015), Taihu Lake (Zhang et al. 2016), and Yangtze River (Chen et al. 2018). We conducted a bibliometric analysis on scientific studies carried out in the Patos Lagoon based on articles published in peer-reviewed journals indexed in the Science Citation Index Expanded - Web of Science and Scopus databases. More specifically, this analysis aimed to (i) investigate the temporal distribution of articles publication;

(ii) summarize the main characteristics of the research output, such as the most influential journals, authors, articles, countries, research institutions, and keywords; (iii) analyze scientific collaboration among countries and research institutions; and (iv) analyze the representation of different geographical regions and environmental compartments investigated. These findings will show trends and knowledge gaps that may help researchers to guide future studies in the Patos Lagoon and identify future scientific collaborations.

MATERIALS AND METHODS

We used the Science Citation Index Expanded (SCI-EXPANDED) database of Clarivate Analytics Web of Science (WoS) and Scopus database to search the scientific studies carried out in the Patos Lagoon (updated on 5 March 2020). We conducted the search using the terms "Lagoa dos Patos" or "Patos Lagoon" or "Laguna dos Patos" in the field 'topics' (Paper title, Abstract, Author Keywords, and Keywords plus) from WoS and in 'Paper title, Abstract, and Keywords' from Scopus. In our search were considered only scientific articles (i.e., primary research articles) to avoid data publication (see Olisah & Adams 2020 for more details).

We followed the four phases (i.e., identification, screening, eligibility, and included) of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) to select articles (Moher et al. 2009; Figure 1). The initial search resulted in a total number of 576 articles after excluding duplicates. In the screening phase, we checked the title and abstract of the 576 articles and no study was removed. In the eligibility phase, we manually checked 576 full-text articles to (i) remove studies carried in adjacent areas of the PL and (ii) select only studies (observational, experimental, or

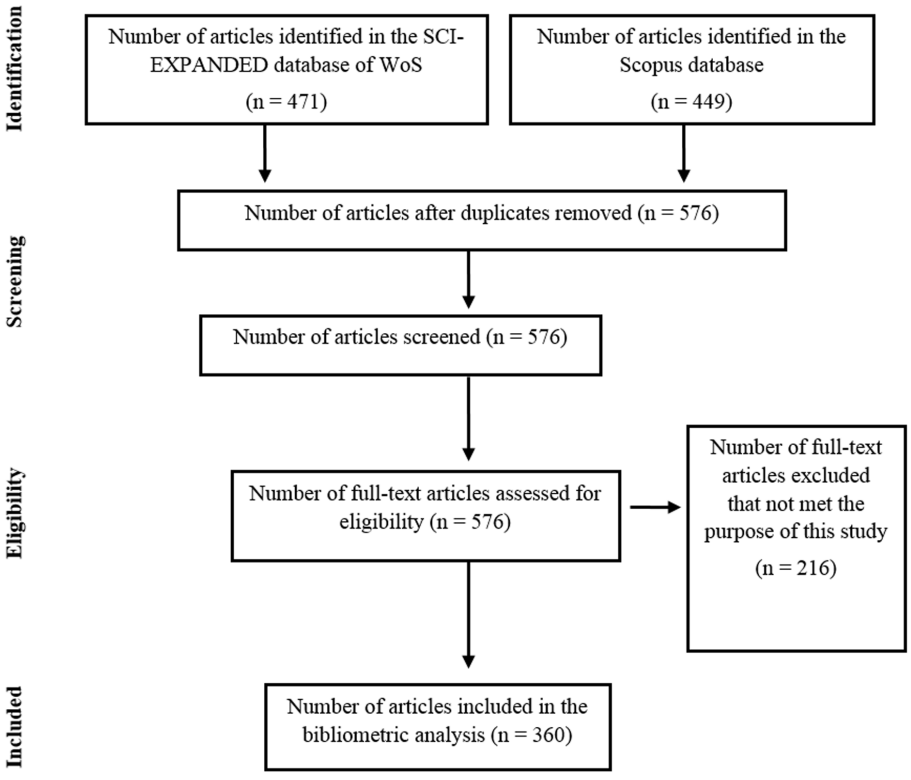

Figure 1. Summary of the process for identifying studies carried out in the Patos Lagoon.

model) that were performed in the PL, as well as laboratory studies in which test organisms were collected in the PL. Therefore, 360 articles were used for our bibliometric analysis. The list of selected articles is available in the Supplementary Material - Table SI.

We obtained the following information for each article: (i) year of publication, (ii) language, (iii) journal, (iv) number of authors, (v) number of citations, (vi) country and research institution of the authors, (vii) region of the PL investigated (i.e., the whole lagoon system, limnic or estuarine areas), (viii) environmental compartment (biota, sediment or water column), and (iv) authors keywords. Studies published by authors from England, North Ireland, Scotland, and Wales were classified as from the United Kingdom (Li et al. 2014).

The regression tree was used to identify temporal trend in the number of studies carried out in PL (De'ath & Fabricius 2000; see Tourinho et al. 2020 for a similar use of this method). A Spearman's correlation test was used to evaluate the temporal trend of the number of journals and the number of authors per article. The number of articles was used to identify the most productive authors. We used the first author address as a criterion to assign the collaborations and following the classification of Li et al. (2009), we classified the articles into four types of collaboration: (i) "single-country article" articles with authors within the same country, (ii) "internationally collaborative article" articles with authors from multiple countries, (iii) "single-research institution article" articles with authors within the same research institution, and (iv) "inter-institutionally collaborative article" articles with authors from distinct research institutions. The Wilcoxon signed-rank test (Lam & Longnecker 1983) was used to test the significance of the difference between the types of collaboration.

To the map of author keywords, words related to the PL that we used as search terms (i.e., Lagoa dos Patos, Patos Lagoon, and Laguna dos Patos) and its location (e.g., Brazil, Rio Grande do Sul, southern Brazil) were deleted because the name of the lagoon and its location cannot represent the research hotspot (Zhang et al. 2016). Secondly, keywords with the same meaning were grouped. For instance, "El Niño", "La Niña" and "ENSO" were categorized as "El Niño/La Niña/ENSO" and "PAHs" and "Polycyclic Aromatic Hydrocarbons" were categorized as "PAHs".

Language, journal, number of authors, region and environmental compartment investigated, and types of collaboration were all analyzed R environment (R Core Team 2021). The most productive authors and most cited articles were determined using the bibliometrix package (Aria & Cuccurullo 2017). The regression tree was performed using the *rpart* package (Therneau et al. 2012). The chord diagram was created using the *circlize* package (Gu et al. 2014). The VOSviewer software was used to created map of collaboration network (i.e., country and institution research) and map of author keywords (Van Eck & Waltman 2010).

RESULTS

We found 360 studies carried out in the PL published in journals indexed in SCI-EXPANDED database of WoS and Scopus database. The first article was published in 1965, and the years with the highest number of articles were 2009 (n = 27), 2006 (n = 26) and 2018, 2019 (n =25, each; Figure 2). The regression tree analysis partitioned the predictor variable, year of publication, into two periods: before and after 2003. The period from 1965 to 2003 had fewer studies carried out in the PL than the period from 2004 to 2019 (Figure 2). English was the predominant language,

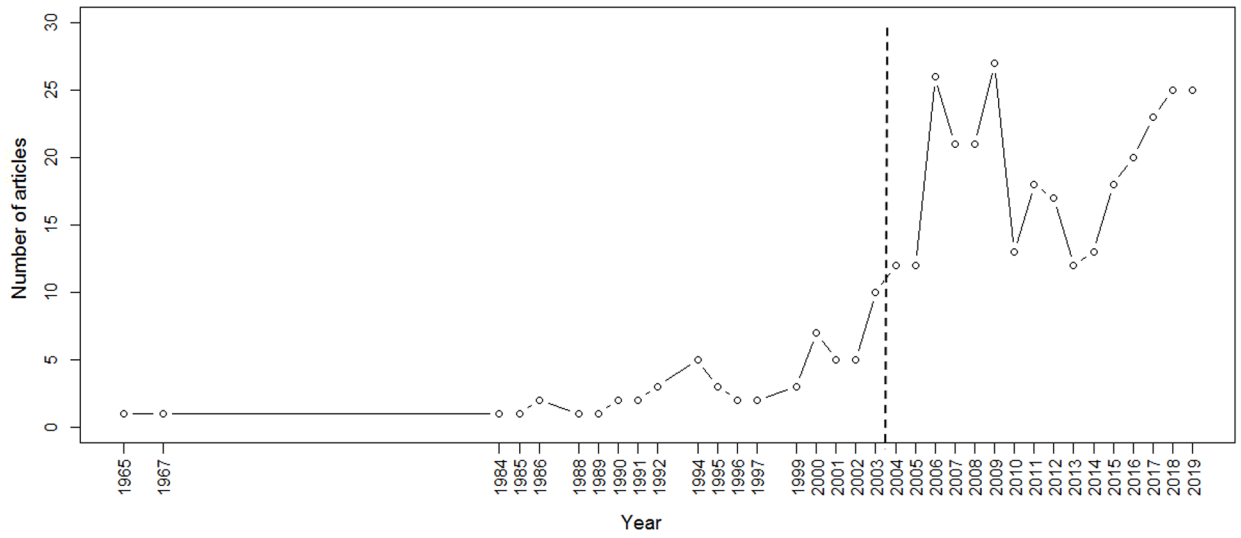

Figure 2. Temporal distribution of studies carried out in the Patos Lagoon indexed in the Web of Science and Scopus databases. The dashed line indicates the year (2003.5) in which the dataset is partitioned into two segments, according to the regression tree analysis.

appearing in 318 articles, followed by Portuguese (n = 39), Spanish (n = 2) and French (n = 1).

The Patos Lagoon's articles were published in 150 journals. Among these journals, 89 contained only one article and 26 only two articles. The eight journals that published eight or more articles from the PL accounted for 27.5% (n = 99) of the total publications. *Journal of Coastal Research* published the most articles (n = 27), followed by *Estuarine, Coastal and Shelf Science* (n = 16), and *Estuaries and Coasts* (n = 11) (Figure 3). The number of journals increased over the years (Spearman's rho = 0.93, P < 0.001, n = 35).

Regarding authorship, 25% of the articles were authored by one to two authors (n = 13 with a single author and n = 78 with two authors). Articles with three, four, five and six authors represented 68% of published contributions. The mean number of authors per article ± S.E. was 3.82 ± 0.11. From 1965 to 2019, the number of articles authored by three (Spearman's rho = 0.67, P < 0.001, n = 26) and four or more authors (Spearman's rho = 0.83, P < 0.001, n = 23) increased. The number of articles written by a single (Spearman's rho = -0.22, P = 0.53, n = 10) and two authors (Spearman's rho = -0.35, P = 0.06, n = 30) did not show an increase over the years. The researchers Vieira JP (n = 24) and Abreu PC (n = 23) were ranked the first and second most productive authors. In addition, the eight most productive authors were affiliated to Universidade Federal do Rio Grande (FURG) (Table I).

The most cited article was entitled "Natural and anthropogenic hydrocarbon inputs to sediments of Patos Lagoon Estuary, Brazil" authored by Medeiros et al. (2005), with 129 citations (Table II). Other most cited articles were by Möller et al. (2001), by Costa et al. (2003) and by Garcia et al. (2001), which received 117, 107 and 96 citations, respectively (Table II). The majority of studies were carried out in the Patos Lagoon estuary. It is also interesting to note that the most cited articles included authors from Brazil (n = 10) and United States of America (n = 4 each), and France, Japan, and United Kingdom (n = 1) (Table II).

Excluding 10 articles that had no address information about the authors, 13 countries

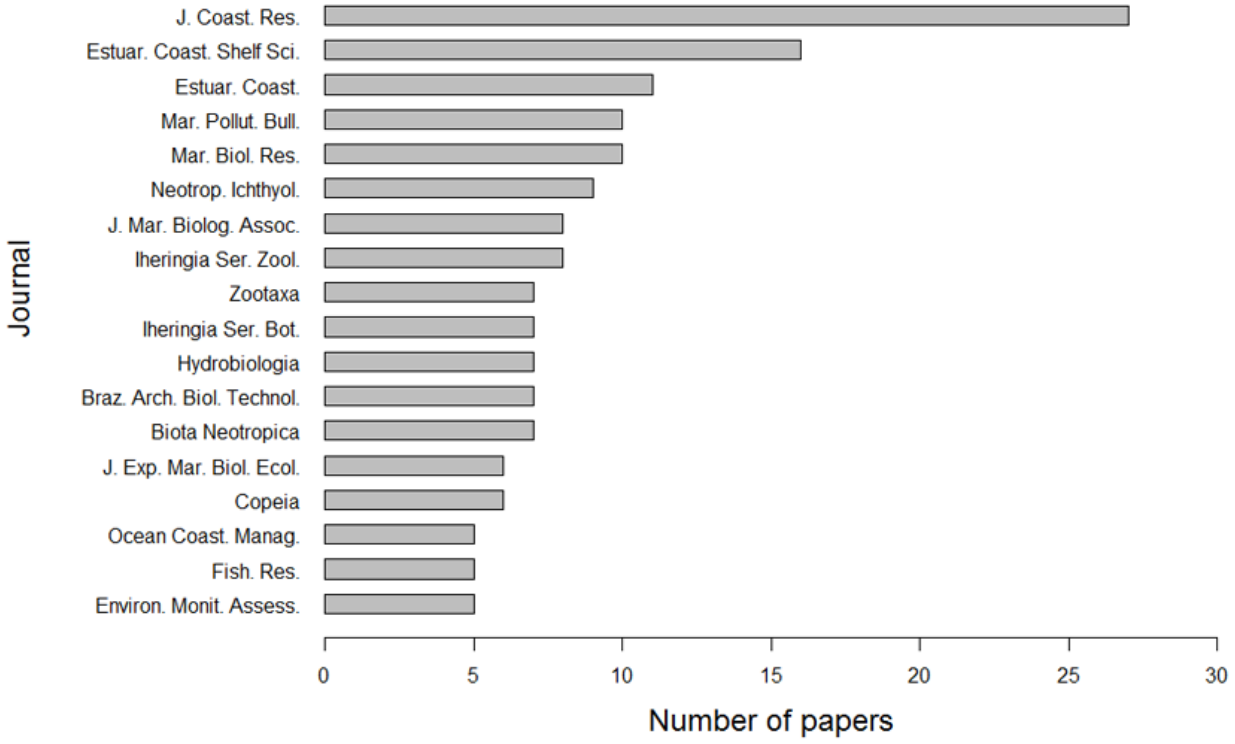

Figure 3. Journals that published five or more studies carried out in Patos Lagoon until December 2019. J. Coast. Res. = Journal of Coastal Research; Estuar. Coast. Shelf Sci. = Estuarine Coastal and Shelf Science; Estuar. Coast. = Estuaries and Coasts; Mar. Pollut. Bull. = Marine Pollution Bulletin; Mar. Biol. Res. = Marine Biology Research; Neotrop. Ichthyol. = Neotropical Ichthyology; J. Mar. Biolog. Assoc. = Journal of the Marine Biological Association of the United Kingdom; Iheringia Ser. Zool. = Iheringia Serie Zoologia; Iheringia Ser. Bot. = Iheringia Serie Botanica; Braz. Arch. Biol. Technol. = Brazilian Archives of Biology and Technology; J. Exp. Mar. Biol. Ecol. = Journal of Experimental Marine Biology and Ecology; Ocean Coast. Manag. = Ocean & Coastal Management; Fish. Res. = Fisheries Research; Environ. Monit. Assess. = Environmental Monitoring and Assessment.

and 49 research institutions published studies performed in the PL. Brazil was the country with the highest number of published studies, accounting for 91% (n = 320) of the total articles (Table III). The Universidade Federal do Rio Grande (FURG) was the most productive research institution (n = 229), followed by Universidade Federal do Rio Grande do Sul (UFRGS, n = 35; Table III). In addition, the number of single-country articles was higher than that of internationally collaborative articles (paired Wilcoxon test V = 436, P < 0.001, n = 32). The number of single-research institution articles was equal to the inter-institutionally collaborative articles (paired Wilcoxon test V = 198, P = 0.92, n = 32).

Brazil was the only country that presented scientific collaboration with all the countries in the network, especially with United States of America (USA), United Kingdom (UK) and Argentina (Figure 4a). Among the research institutions, FURG connected to most institutions in the collaboration network, but with a low representation of international research institutions (e.g., The University of Queensland - Australia, Skidaway Institute of Oceanography - USA, Texas A&M University - USA, University of Plymouth - UK, and Universidade do Porto - Portugal) (Figure 4b).

Most of the studies were carried out in the Patos Lagoon estuary (n = 252), followed by the Patos Lagoon whole system (n = 77) and the

Table I. The eight most productive authors that published studies carried out in the Patos Lagoon until December 2019. TP = total number of articles.

Author	Research institution*	TP
Vieira JP	Universidade Federal do Rio Grande – Brazil	24
Abreu PC	Universidade Federal do Rio Grande – Brazil	23
Garcia AM	Universidade Federal do Rio Grande – Brazil	19
D'Incao F	Universidade Federal do Rio Grande – Brazil	18
Niencheski LF	Universidade Federal do Rio Grande – Brazil	18
Möller OO	Universidade Federal do Rio Grande – Brazil	15
Fernandes EHL	Universidade Federal do Rio Grande – Brazil	14
Odebrecht C	Universidade Federal do Rio Grande – Brazil	13

***Research institution was the same in all articles published by the author.**

limnic region (n = 31). Articles with a focus on the biota (n = 261) were more represented than those focused on water column (n = 42) or sediment (n = 35) parameters. Moreover, investigations on the biota were relatively more frequent in the estuarine area compared to other regions (n = 191; Figure 5).

The analysis of the keywords revealed that 916 words were used within the articles. Estuary was the most abundant keyword with 34 occurrences, and was followed by "Patos Lagoon estuary" (n = 24), "taxonomy" (n= 16), "sediments" (n = 13),"El Niño/La Niña/ENSO" and "*Farfantepenaeus paulensis*" (each one with 9 occurrence) (Figure 6). These keywords were mainly related to clusters 1 and 2, the red and green clusters, respectively (Figure 6).

DISCUSSION

During the period 1965-2019, a total of 360 articles on the Patos Lagoon was published in indexed journals in the SCI-EXPANDED database of WoS and Scopus database. The number of scientific studies performed in the PL has followed an upward trend, with an increase in the last decade. This tendency is consistent with the increase in global scientific production in aquatic ecosystems (Liao & Huang 2014) since the scarcity of water resources and the degradation of aquatic ecosystems by anthropogenic activities (Millennium Ecosystem Assessment 2005) have become major global challenges to the 21st century (Shevah 2015), including in coastal ecosystems (Lotze et al. 2006, Hossain et al. 2020). Among the top 10 most cited articles in our study area, three studies investigated anthropogenic threats (PAHs, Medeiros et al. 2005; trace-metals, Niencheski et al. 1994; and toxic cyanobacterial blooms, Matthiensen et al. 2000) and two investigated natural phenomenons (ENSO, Garcia et al. 2001, 2003, Fernandes et al. 2002) that the PL has been exposed to. Moreover, in our analysis of the author keywords the word "ENSO" was in the cluster 1 (red cluster) along with "estuary", "assemblage structure", freshwater discharge", and "Neotropical fishes". For instance, the studies of Garcia et al. (2001, 2003) evaluated the effects of ENSO episodes on the dynamics of the shallow-water fish assemblage of the PLE. In parallel, PAHs and other words related to degradation of aquatic ecosystem were well represented in the author keywords of the studies performed in the PL, mainly in the cluster 2 (green cluster) along with "effluents",

Table II. Characteristics of the top 10 most cited articles. TC-2019 = Total citations; TC/Y = Average annual citations since publication.

Title	Author(s) (Publication year)	Author(s) Country(s)	Journal	TC2019	TC/Y
Natural and anthropogenic hydrocarbon inputs to sediments of Patos Lagoon Estuary, Brazil	Medeiros et al. (2005)	Brazil, United States of America	Environment International	129	8.6
The influence of local and non-local forcing effects on the subtidal circulation of Patos Lagoon	Möller et al. (2001)	Brazil, France	Estuaries	117	6.15
Plant zonation in irregularly flooded salt marshes: relative importance of stress tolerance and biological interactions	Costa et al. (2003)	Brazil	Journal of Ecology	107	6.68
Dynamics of the shallow-water fish assemblage of the Patos Lagoon estuary (Brazil) during cold and warm ENSO episodes	Garcia et al. (2001)	Brazil, United States of America	Journal of Fish Biology	96	5.64
Effects of 1997-1998 El Nino on the dynamics of the shallow-water fish assemblage of the Patos Lagoon Estuary (Brazil)	Garcia et al. (2003)	Brazil, United States of America	Estuarine, Coastal and Shelf Science	76	4.47
The present status of artisanal fisheries of extreme Southern Brazil: an effort towards community-based management	Reis & D'Incao (2000)	Brazil	Ocean & Coastal Management	68	3.57
Distribution of particulate trace-metal in Patos Lagoon Estuary (Brazil)	Niencheski et al. (1994)	Brazil, United States of America	Marine Pollution Bulletin	66	2.53
[D-Leu(1)] microcystin-LR, from the cyanobacterium Microcystis RST 9501 and from a Microcystis bloom in the Patos Lagoon estuary, Brazil	Matthiensen et al. (2000)	United Kingdom, Brazil, Japan	Phytochemistry	66	3.66
Nursery of the pink shrimp *Farfantepenaeus paulensis* in cages with artificial substrates: Biofilm composition and shrimp performance	Ballester et al. (2007)	Brazil	Aquaculture	65	5
The Patos Lagoon hydrodynamics during an El Nino event (1998)	Fernandes et al. (2002)	Brazil	Continental Shelf Research	62	3.44

"Patos Lagoon estuary", and "sediments". For instance, pollution (e.g., trace metals, sterols, and PAHs) have been analyzed in sediments (e.g., Garcia et al. 2010, Martins et al. 2017, Pereira et al. 2018), while nutrient concentrations have been analyzed in the context of the water quality on shrimp farm systems and to the receiving water environment in PLE (e.g., Freitas et al. 2008, Cardozo et al. 2011, Cardozo & Odebrecht 2014). In fact, this trend coincided with the development of international initiatives, such as Strategic Plan for Biodiversity from the

Table III. Characteristics of the 13 countries (upper table) and of the 6 most-productive research institutions (bottom table) that published studies carried out in the Patos Lagoon until December 2019. TP = total number of articles, CP = internationally collaborative articles or inter-institutionally collaborative articles, SP = single-country articles or single-research institution articles.

Country	TP	SP	CP
Brazil	320	253	67
Argentina	8	1	7
United States of America	6	2	4
Portugal	4	0	4
United Kingdom	4	1	3
Australia	1	0	1
Canada	1	0	1
Chile	1	0	1
France	1	0	1
Mexico	1	0	1
Peru	1	0	1
Russia	1	0	1
Uruguay	1	0	1
Research institution	**TP**	**SP**	**CP**
Universidade Federal do Rio Grande – Brazil	229	147	82
Universidade Federal do Rio Grande do Sul – Brazil	35	16	19
Universidade Federal do Rio de Janeiro – Brazil	8	2	6
Pontifícia Universidade Católica do Rio Grande do Sul – Brazil	8	4	4
Fundação Zoobotânica do Rio Grande do Sul – Brazil	8	5	3
Universidade Federal de Pelotas – Brazil	8	4	4

Convention on Biological Diversity from 2011 to 2020 (CBD 2010), Goal 7 (ensure environmental sustainability) from Millennium Development Goals from 2000 to 2015 (Weststrate et al. 2019) and Goal 14 (conservation and sustainable use of the oceans, seas and marine resources) in the Agenda 2030's Sustainable Development Goals (SDGs) from 2015 to 2030 (Neumann et al. 2017). Within Goal 14, the targets 14.2 and 14.5 are on the management and protection of coastal areas and ecosystems (Neumann et al. 2017). Other possible explanation could be related to the growth in investments in science and technology in Brazil (Massarani 2013, McManus & Neves 2020), as between 2004 and 2013 there was a nearly steadily increase in the research funding in Brazil (Fernandes et al. 2017), contributing directly to the development of studies in several areas of scientific knowledge (Regalado 2010), including Brazilian aquatic biodiversity and ecosystems (Azevedo et al. 2010, Dias et al. 2016, Carvalho & Tejerina-Garro 2019, Junqueira et al. 2020, Tourinho et al. 2020). Despite the growing number of studies conducted in the PL, it is important to mention the current Brazilian policy of cuts in science (Fernandes et al. 2017) which will likely affect the development of future studies.

The English was the predominant language in the PL articles since it is the preferred language of communication in the scientific community (Vasconcelos et al. 2007). A great variety of journals was used to publish the studies conducted in the PL, with an increased number

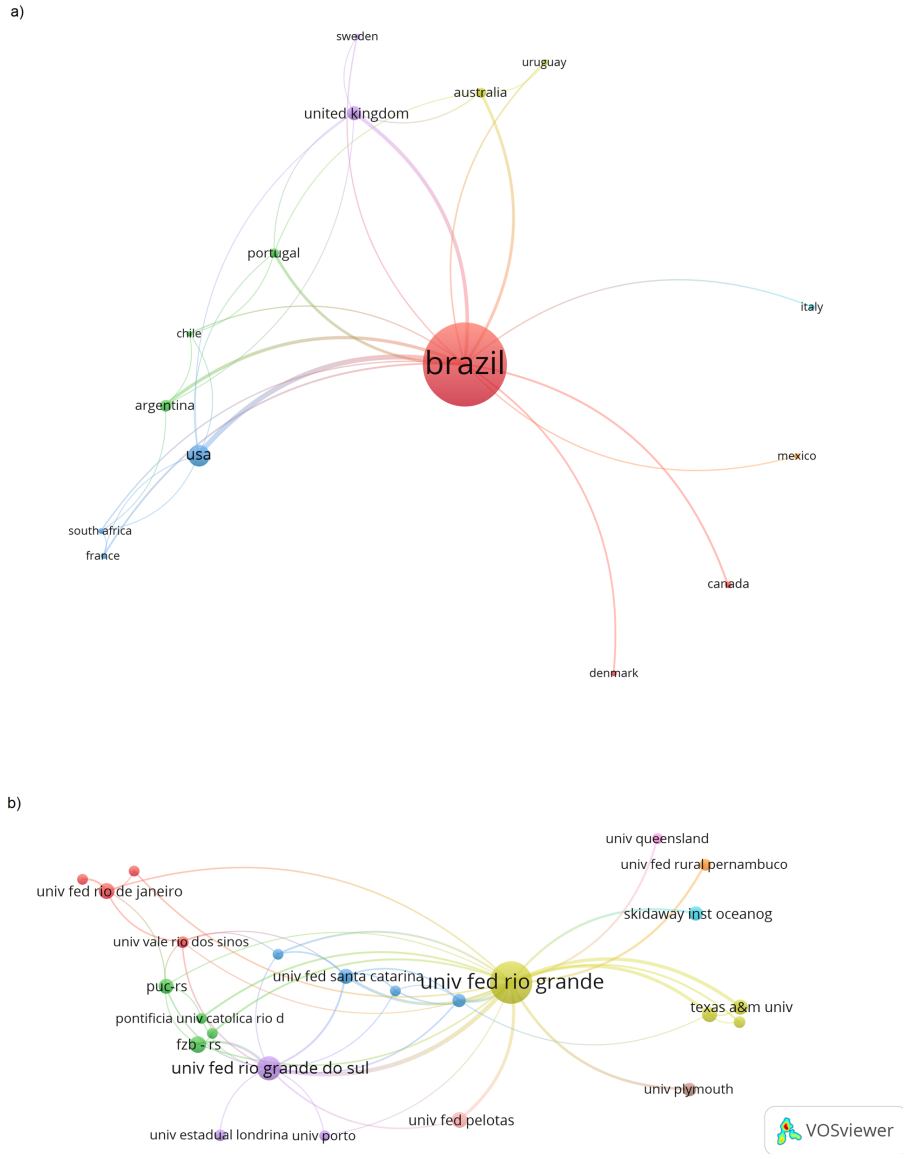

Figure 4. Map of collaboration between countries (a) and between research institutions (b). Size of circles represent the number of occurrences of each term, the line represents the link between two circles (terms) and the thicker the line, the closer the relationship between terms.

throughout the years. For instance, articles were published in journals in the areas of biodiversity & conservation (e.g., *Biota Neotropica*), fisheries (e.g., *Fisheries Research*), toxicology (e.g., *Ecotoxicology and Environmental Safety*), and water resources (e.g., *Water Resources Research*). This is positive, showing that the scientific community has given attention to a greater variety of areas of scientific knowledge in the PL. Moreover, *Journal of Coastal Research*, *Estuarine Coastal and Shelf Science*, and *Estuaries and Coasts* were the main publishers, who cover a broad, international audience focused on the investigation of coastal systems. As these three journals cover all fields of coastal research, this seems to be the most reasonable choice.

Brazil and the Universidade Federal do Rio Grande (FURG) led the ranking of published studies likely related to the location of the PL on the coast of Rio Grande do Sul state in southern Brazil. At the same time, our results showed that the most productive authors were from FURG. Accordingly, Olisah & Adams (2021) analyzed the research on South African estuaries and

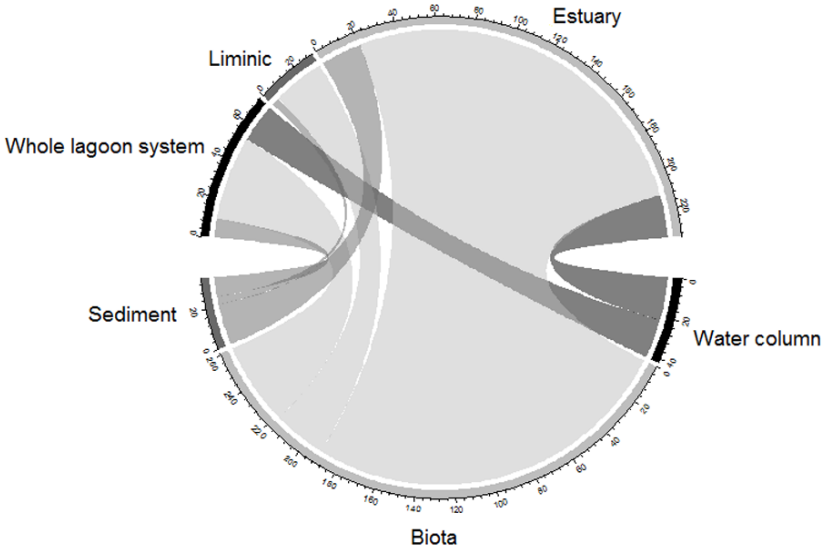

Figure 5. Number of studies carried per region of the PL investigated (Whole lagoon system, Limnic and Estuary) (top) and number of studies per environmental compartment (Water column, Biota, Sediment) (bottom), and the thickness of the lines represents the linkages between the region and environmental compartment, displayed as chord diagram created using the *circlize* package (Gu et al. 2014).

showed that the most productive research institutions were in, or close, to coastal areas. Moreover, FURG is considered an excellence-center in coastal and ocean ecosystems studies in Brazil as well as in South America, reflex of their traditional undergraduate course focused on oceanology (Marega-Imamura et al. 2020) and many *stricto sensu* graduate programs that have aquatic ecosystems as the main research theme. In fact, graduate programs in public universities are the main producers of Brazilian scientific production (Leta et al. 2006, Helene & Ribeiro 2011). In addition, Leta (2005) used publications from the period 1997-2002 to perform a bibliometric study on Brazilian human resources and scientific output in oceanography, while Marega-Imamura et al. (2020) investigated the scientific collaboration networks in research on human threats to cetaceans in Brazil using scientific literature published from 1986 to 2016. These bibliometric studies showed that FURG was the second and third research institution that published most studies, respectively.

The number of multi-authored articles has increased over the years in our study area, hence corroborating global trends of enhanced scientific production (Abt 2007) and collaboration (Whitfield 2008). However, the number of single-country articles were higher than that of internationally collaborative studies. Simultaneously, the number of single-research institution articles was equal to the inter-institutionally collaborative articles. These results suggest prevailing domestic scientific collaborations in the PL studies, which agrees with findings reported by bibliometric studies on Brazilian scientific output (Leta & Chaimovich 2002, Sidone et al. 2016). This low representation of internationally collaborative articles may be associated with the global view of the researcher (Neves et al. 2019). Another possible explanation for this is the existence of geographical distance among countries and socioeconomic and linguistic barriers (Parreira et al. 2017, Junlin et al. 2020). Therefore, we argue that the increasing number of internationally published articles in the PL here found did not translate in enhanced international collaboration in the study area.

There was a clear dominance of studies performed in the estuarine region of the Patos Lagoon, which is supported by the predominant use of “estuaries’’ and “Patos Lagoon estuary”

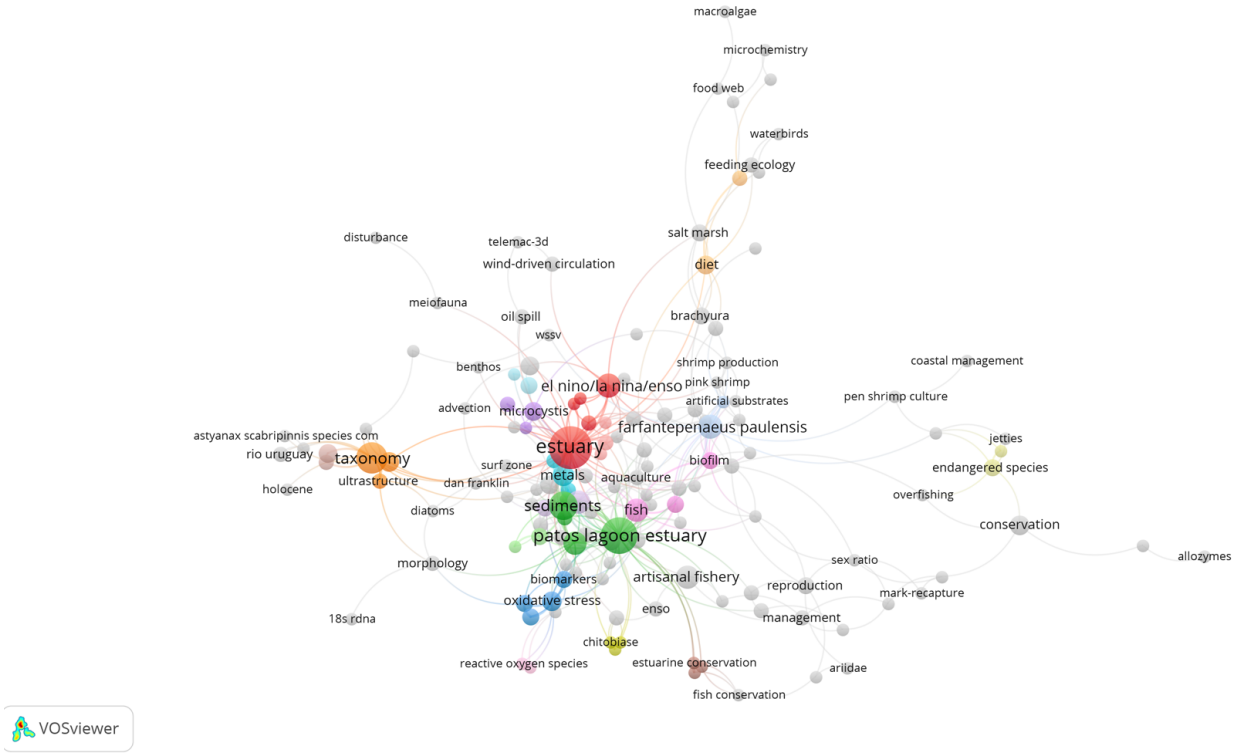

Figure 6. Map of author keywords. Size of circles represent the number of occurrences of each term, the line represents the link between two circles (terms) and the thicker the line, the closer the relationship between terms, and different colors represent different topic clusters.

as keywords, which were also represented in the most cited articles. Publications concentrated in scientific journal focused on coastal systems also supported this assertion. This bias towards the estuarine area may result from the accessibility and geographical proximity to the FURG. In general, research sites based near universities are more convenient in terms of logistics (i.e., time spent traveling and less costly; Thaina et al. 2019). However, it is also noteworthy that the PLE and its adjacent marine coast is one of the study sites of the Brazilian Long-term Ecological Research Program (BR-LTER). Long-term ecological programs play a central role in the understanding of ecosystems functioning and the detection of alterations through field-based monitoring that produce extensive datasets on local biodiversity and physicochemical parameters (Vihervaara et al. 2013). Since 1998, the biota of the PLE have been monitored by FURG researchers, providing insights on its annual and interannual variations and their environmental driving forces (e.g., Odebrecht et al. 2010). The establishment of a BR-LTER site in the PLE may thus explain the increased scientific production from 2003 and the simultaneous focus on the influence of multi-year El Niño Southern Oscillation climatic events and anthropogenic impacts on local biota. In the last 20 years, the BR-LTER in the PLE has originated several scientific outputs, including special issues in journals (Odebrecht et al. 2017), books and books chapters (e.g., Odebrecht et al. 2010, Seeliger & Odebrecht 2010). This accumulated scientific production therefore highlights the importance of long-term, integrated, ecosystem-level monitoring efforts that are still scarce for

most coastal ecosystems worldwide (Kennish & Paerl 2010, Vihervaara et al. 2013).

Among the articles analyzed in our study, biota was relatively more investigated than other environmental compartments (sediment and water column), especially in the PLE. This fact may stem from the high ecological relevance of the PLE in sustaining the life cycle of important fishery resources (Odebrecht et al. 2017) such as the pink shrimp (*Farfantepenaeus paulensis*; Pérez Farfante 1967) (e.g., Soares et al. 2004, Vianna & D'Incao 2006, Ballester et al. 2007, Peixoto et al. 2013, Noleto-Filho et al. 2017, Ruas et al. 2019), which was represented in the most cited articles (Ballester et al. 2007) and also appeared among the most abundant keyword, the whitemouth croaker (*Micropogonias furnieri*; Desmarest 1823) (e.g., de Figueiredo & Vieira 2005, Mendoza-Carranza & Vieira 2008, Costa et al. 2014, Franzen et al. 2019) and the grey-mullet (*Mugil platanus*; Günther 1880) (e.g., Eiras et al. 2007, Vieira et al. 2008). Indeed, the most studied estuarine areas worldwide have been selected in accordance to their regional economic and ecological importance (Olisah & Adams 2021). The PLE is also habitat of the common bottlenose dolphin (*Tursiops truncatus*; Montagu 1821) (e.g., Fruet et al. 2011, 2015, Righetti et al. 2019), one of the twenty most charismatic organisms in the world (Albert et al. 2018). In fact, charismatic species and species of economic interest are factors that may influence the choice of organism in scientific research, resulting in a larger number of articles (Jarić et al. 2015). Additionally, the comprehension of the environmental drivers of local biota abundance and distribution, and its role on ecological processes, is within the scope of the BR-LTER program study sites (Tundisi 2013). Biota was also highly studied in PLE, possibly due to the existence of *stricto sensu* graduate programs from FURG (e.g., the Graduate Program in Biological Oceanography) that have aquatic organisms as the main research focus.

Our bibliometric analysis showed an increase in the number of published studies performed in the PL, especially in the last sixteen years. It is noteworthy that the 360 articles published in SCI-EXPANDED database of WoS and Scopus database used in to our bibliometric analysis do not represent the total of scientific research in the PL. For instance, as mentioned earlier, the BR-LTER´s studies in the PLE have generated books (*e.g.*, Seeliger & Odebrecht 2010) and books chapters (*e.g.*, Odebrecht et al. 2011) as well as other sources of information on the PL such as grey literature and scientific literature published in local/regional journals (*e.g.,* Atlântica). However, to our knowledge, this is the first assessment the scientific production in the PL through bibliometric methods. Our analysis focused on identifying and quantifying the language, number of authors, the most cited articles, type of scientific collaboration, author keywords, and the most productive journals, countries, and research institutions, as well as characteristics of the studies carried out in PL (i.e., investigated regions and environmental compartments). Most articles were published in English, with *Journal of Coastal Research* being the dominant journal and most studies originating from Brazil and the Universidade Federal do Rio Grande (FURG) was the most productive research institution. However, some gaps need to be addressed, such as the low number of internationally collaborative publications, the few studies focused on abiotic compartments and performed in limnic areas. We suggest that the consolidated knowledge on the ecosystem functioning and the local biota in the Patos Lagoon estuary can contribute to meta-analyses and comparisons among distinct geographic areas (e.g., Pilotto et al. 2020), hence fostering future international research

collaborations. In addition, the approach used here may be useful to other coastal lagoons to identify their knowledge gaps and, consequently, to assist in future studies.

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REFERENCES

ABT HA. 2007. The future of single-authored papers. Scientometrics 73: 353-358.

ALBERT C, LUGUE GM & COUCHAMP F. 2018. The twenty most charismatic species. PLOS ONE 137: e0199149.

ARIA M & CUCCURULLO C. 2017. Bibliometrix: a R-tool for comprehensive science mapping analysis. J Inf Secur 11: 959-975.

ASMUS ML, NICOLODI J, ANELLO LS & GIANUCA K. 2019. The risk to lose ecosystem services due to climate change: A South American case. Ecol Eng 130: 233-241.

AZEVEDO PG, MESQUITA FO & YOUNG RJ. 2010. Fishing for gaps in Science: a bibliographic analysis of Brazilian freshwater ichthyology from 1986 to 2005. J Fish Biol 76: 2177-2193.

BALLESTER ELC, WASIELESKY W, CAVALLI RO & ABREU PC. 2007. Nursey of the shrimp *Farfantepenaeus paulensis* in cages with artificial substrates: biofilm composition and shrimp performance. Aquaculture 269: 355-362.

BARBIER E, HACKER S, KOCH E, STIER A & SILLIMAN BR. 2011. The value of estuarine and coastal ecosystem services. Ecol Monogr 81: 169-193.

BARBOSA FG & MELO AS. 2009. Modelo preditivo de sobrevivência do Mexilhão Dourado (*Limnoperna fortunei*) em relação a variações de salinidade na Laguna dos Patos, RS, Brasil. Biota Neotropica 9: 407-412.

BAUMGARTEN MG & NIENCHESKI LFH. 2010. A coluna sedimentar como reservatório e fonte de nutrientes em enseadas estuarinas. Trop Oceanogr 38: 88-105.

BEMVENUTI CE & COLLING LA. 2010. As Comunidades De Macroinvertebrados Bentônicos. In: Seeliger U & Odebrecht C (Eds), O Estuário da Lagoa dos Patos. Um Século de Transformações. 1ª ed., Rio Grande: Universidade Federal do Rio Grande - FURG, p. 101-114.

BERTACO VA, FERRER J, CARVALHO FR & MALABARBA LR. 2016. Inventory of the freshwater fishes from a densely collected area in South America – a case study of the current knowledge of Neotropical fish diversity. Zootaxa 4138: 401-440.

CARDOZO AP, BRITTO VO & ODEBRECHT O. 2011. Temporal variability of plankton and nutrients in shrimp culture ponds vs. adjacent estuarine water. Pan-Am J Aquat Sci 6: 28-43.

CARDOZO AP & ODEBRECHT C. 2014. Effects of Shrimp pond water on phytoplankton: importance of salinity and trophic status of the receiving environment. Aquac Res 45: 1600-1610.

CARVALHO RA & TEJERINA-GARRO FL. 2019. Spatial and temporal trends in freshwater fish research: the case of three neotropical river basins from Goiás State, Central Brazil. Acta Limnol Bras 31: e-e25.

CBD. 2010. Decision adopted by the conference of the parties to the Convention on Biological Diversity at its tenth meeting X/2. In: Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets, 10th Conference of the Parties, Nagoya, Japan.

CHEN D, BI B, LUO ZH, YANG YM, WEBBER M & FINLAYSON B. 2018. A scientometric review of water research on the Yangtze River. Appl Ecol Environ Res 16: 7969-7987.

COPERTINO M & SEELIGER U. 2010. Hábitats de Ruppia maritima e algal. In: Seeliger U & Odebrecht C (Eds), O Estuário da Lagoa dos Patos: um século de transformações. Editora da FURG, Rio Grande, p. 92-98.

DE'ATH G & FABRICIUS KE. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology 81: 3178-3192.

DE FIGUEIREDO GM & VIEIRA JP. 2005. Diel feeding daily food consumption and the predatory impact of whitemouth croaker (*Micropogonias furnieri*) in an estuarine environment. Marine Ecol 26: 130-139.

DIAS RA, MAURICIO GN & BUGONI L. 2017. Birds of the Patos Lagoon estuary and adjacent coastal Waters, southern Brazil: species assemblages and conservation implications. Marine Biol Res 13: 108-120.

DIAS MS ET AL. 2016. Trends in studies of Brazilian stream fish assemblages. Natureza & Conservação 14: 106-111.

EIRAS JC, ABREU PC, ROBALDO R & PEREIRA JÚNIOR J. 2007. *Myxobolus platanus* n. sp. (Myxosporea, Myxobolidae), a

parasite of *Mugil platanus* Günther, 1880 (Osteichthyes, Mugilidae) from Lagos dos Patos, RS, Brazil. Arq Bras Med Vet Zootec 59: 895-898.

ESPINOZA-TENORIO A ET AL. 2015. From intuition to scientific knowledge? Publications on coastal lagoons from Tabasco, Mexico. Interciencia 40: 448-456.

FERNANDES EHL, DYER KR, MÖLLER OO & NIENCHESKI LFH. 2002. The Patos lagoon hydrodynamics during an El Nino event (1998). Cont Shelf Res 22: 1699-1713.

FERNANDES GW ET AL. 2017. Dismantling Brazil's Science threatens global biodiversity heritage. Perspect Ecol Conserv 15: 239-243.

FRANZEN MO, MUELBERT JH & FERNANDES EH. 2019. Influence of wind events on the transport of early stages of *Micropogonias furnieri* (Desmarest, 1823) to a subtropical estuary. Lat Am J Aquat Res 47: 536-546.

FREITAS U, NIENCHESKI LFH, ZARZUR S, MANZOLLI RP, VIEIRA JPP & ROSA LC. 2008. Influência de um cultivo de camarão sobre o metabolismo bêntico e a qualidade da água. Rev Bras Eng Agríc Amb 12: 293-301.

FRUET PF, DAURA-JORGE FG, MÖLLER LM, GENOVES RC & SECCHI ER. 2015. Abundance and demography of bottlenose dolphins inhabiting a subtropical estuary in the Southwestern Atlantic Ocean. J Mammalogy 96: 332-343.

FRUET PF, SECCHI ER, DI TULLIO JC & KINAS PG. 2011. Abundance of bottlenose dolphins, *Tursiops truncatus* (Cetacea: Delphinidae), inhabiting the Patos Lagoon estuary, southern Brazil: implications for conservation. Zoologia (Curitiba) 28: 23-30.

GARCIA AM, VIEIRA JP & WINEMILLER KO. 2001. Dynamics of the shallow-water fish assemblage of the Patos Lagoon estuary (Brazil) during cold and warm ENSO episodes. Journal of Fish Biology 59: 1218-1238.

GARCIA AM, VIEIRA JP & WINEMILLER KO. 2003. Effects of 1997-1998 El Niño on the dynamics of the shallow-water fish assemblage of the Patos Lagoon Estuary (Brazil). Est Coast Shelf Sci 57: 489-500.

GARCIA MR, MIRLEAN N, BAISCH PR & CARAMÃO EB. 2010. Assessment of polycyclic aromatic hydrocarbon influx and sediment contamination in an urbanized estuary. Environ Monitor Assess 168: 269-276.

GRIMM AM, FERRAZ SET & GOMES J. 1998. Precipitation anomalies in Southern Brazil associated with El Niño and La Niña events. J Climate 11: 2863-2880.

GU Z, GU L, EILS R, SCHLESNER M & BRORS B. 2014. Circlize implements and enhances circular visualization in R. Bioinformatics 30: 2811-2812.

HAIMOVICI M & CARDOSO LG. 2016. Long-term changes in the fisheries in the Patos Lagoon estuary and adjacent coastal waters in Southern Brazil. Marine Biol Res 13: 1-16.

HELENE AF & RIBEIRO PL. 2011. Brazilian scientific production, financial support, established investigators and doctoral graduates. Scientometrics 89: 677-686.

HOOD WW & WILSON C. 2001. The literature of bibliometrics, scientometrics, and informetrics. Scientometrics 52: 291-314.

HOSSAIN MD, GAIN ANIMESH K & KIMBERLY G. 2020. Sustainable coastal social-ecological systems: how do we define "coastal"? Int J Sust Dev World Ecol 27: 577-582.

JARIĆ I, KNEŽEVIĆ-JARIĆ J & GESSNER J. 2015. Global effort allocation in marine mammal research indicates geographical, taxonomic and extinction risk related biases. Mammal Rev 45: 54-62.

JUNLIN R, ZIGIAN P & XUE P. 2020. Emerging trends and new developments in Lancang-Mekong River: a bibliometric visualization analysis. River Res Appl 36: 862-871.

JUNQUEIRA NT, MAGNAGO LF & POMPEU PS. 2020. Assessing fish sampling effort in studies of Brazilian streams. Scientometrics 123: 841-860.

KENNISH MJ & PAERL HW. 2010. Coastal Lagoons: Critical Habitats of Environmental Change. In: Kennish MJ & Paerl HW (Eds), Coastal Lagoons: Critical Habitats of Environmental Change. CRC Press, Boca Raton, p. 1-16.

KJERFVE B. 1986. Comparative oceanography of coastal lagoons. In Wolfe DA (Ed), Estuarine Variability. New York, NY: Academic Press, p. 63-82.

LANARI M & COPERTINO M. 2017. Drift macroalgae in the Patos Lagoon Estuary (southern Brazil): effects of climate, hydrology and wind action on the onset and magnitude of blooms. Marine Biol Res 13: 36-47.

LAM FC & LONGNECKER MT. 1983. A Modified Wilcoxon Rank Sum Test for Paired Data. Biometrika 70: 510-513.

LETA J. 2005. Human resources and scientific output in Brazilian science. Aslib Proceedings 57: 217-231.

LETA J & CHAIMOVICH H. 2002. Recognition and international collaboration: The Brazilian case. Scientometrics 53: 325-335.

LETA J, GLANZEL W & THIJS B. 2006. Title: Science in Brazil. Part 2: Sectoral and Institutional Research Profiles. Scientometrics 67: 87-105.

LIAO J & HUANG Y. 2014. Global trend in aquatic ecosystem research from 1992 to 2011. Scientometrics 98: 1203-1219.

LI L, HU J & HO YS. 2014. Global performance and trend of QSAR/QSPR research: a bibliometric analysis. Mol Informatics 33: 655-668.

LI L-L, DING G, FENG N, WANG M-H & HO Y-S. 2009. Global stem cell research trend: bibliometric analysis as tool for mapping of trends form 1991 to 2006. Scientometrics 80: 39-58.

LOTZE HK, LENIHAN HS, BOURQUE BJ, BRADBURY RH, COOKE RG, KAY MC, KIDWELL SM, KIRBY MX, PETERSON CH & JACKSON JB. C. 2006. Depletion, degradation, and recovery potential of estuaries and costal seas. Science 312: 1806-1809.

MAREGA-IMAMURA M, MICHALSKI F, SILVA K, SCHIAVETTI A, LE PENDU Y & OLIEIRA LC. 2020. Scientific collaboration networks in research on human threats to cetaceans in Brazil. Marine Policy 112: 103738.

MARTINS CC, FILMANN G & MONTONE RS. 2007. Natural and anthropogenic sterols inputs in surface sediments of Patos Lagoon, Brazil. J Braz Chemical Society 18: 106-115.

MASSARANI L. 2013. Brazil's Science investment reaches record high. Nature.

MATTHIENSEN A, BEATTIE KA, YUNES JS, KAYA K & CODD GA. 2000. [D-Leu1] Microcystin-LR, from the cyanobacterium Microcystis RST 9501 and from a Microcystis bloom in the Patos Lagoon estuary, Brazil. Phytochemistry 55: 383-387.

MCMANUS C & NEVES AAB. 2020. Funding research in Brazil. Scientometrics 126: 801-823.

MEDEIROS PM, BÍCEGO MC, CASTELAO RM, DEL ROSSO C, FILLMANN G & ZAMBONI AJ. 2005. Natural and anthropogenic hydrocarbon inputs to sediments of Patos Lagoon Estuary, Brazil. Environ Intern 31: 77e87.

MENDOZA-CARRANZA M & VIEIRA J. 2008. Whitemouth croaker *Micropogonias furnieri* (Desmarest, 1823) feeding strategies across four Southern Brazilian estuaries. Aquat Ecol 42: https://doi.org/10.1007/s10452-007-9084-4.

MILLENIUM ECOSYSTEM ASSESSMENT. 2005. Ecosystems and human well-being: wetlands and water. World Resources Institute.

MOHER D, LIBERATI A, TETZLAFF J, ALTMAN DG & PRISMA GROUP. 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Medicine 6: e1000097.

MÖLLER OO, CASTAING J, SOLOMON C & LAZURE P. 2001. The influence of local and non-local forcing effects on the subtidal circulation of Patos Lagoon. Estuaries 24: 297-311.

MÖLLER OO & FERNANDES EH. 2010. Hidrologia e hidrodinamica. In: Seeliger U & Odebrecht C (Eds), O estuário da Lagoa dos Patos: um século de transformações. Universidade Federal de Rio Grande, Rio Grande, RS, Brazil, p. 17-27.

MÖLLER OO, LORENZZENTTI JA, STECH J & MATH MM. 1996. The Patos Lagoon sum-mertime circulation and dynamics. Cont Shelf Res 16: 335-351.

MORAL-MUÑOZ, JÁ, HERRERA-VIEDMA E, SANTISTEBAN-ESPEJO A & COBO MJ. 2020. Software tools for conducting bibliometric analysis in Science: an up-to-date review. El Prof Inf 29: e290103.

NEVES TK, LAVARDA RAB & MARTINS CB. 2019. Práticas estratégicas de internacionalização de programas de pós-graduação: estudo de caso em uma universidade pública do Sul do Brasil. Rev Eletr Negóc Int 14: 93-110.

NEUHAUS EB, ANTONETTI DA & SCHULZ UH. 2016. The invasive fish *Acestrorhynchus pantaneiro* Menezes, 1992 in Southern Brazil: occurrence and food niche overlap with two native species. J Appl Ichthyol 32: 1107-1112.

NEUMANN B, OTT K & KENCHINGTON R. 2017. Strong sustainability in coastal areas: a conceptual interpretation of SDG 14. Sustain Sci: 1019-1035.

NIENCHESKI LF & ZEPKA BAUMGARTEN MG. 2007. Water quality in Mangueira Bay: anthropic and natural contamination. J Coast Res 47: 56-62.

NOLETO-FILHO EM, PUCCIARELLI P, FELIPE L & DUMONT C. 2017. Spatial and temporal variation in juvenile size distribution of the pink shrimp (*Penaeus paulensis*) in the Patos Lagoon Estuary, Brazil. Marine Biol Res 13: 62-73.

ODEBRECHT C, ABREU PC, BEMVENUTI CE, COPERTINO M, MUELBERT JH, VIEIRA JP & SEELIGER U. 2008. The Patos Lagoon estuary and anthropogenic impacts in the last decades (1979-2008). Atlantica: 437-460.

ODEBRECHT C, ABREU PC, BEMVENUTI CE, COPERTINO M, MUELBERT JH, VIEIRA JP & SEELIGER U. 2010. The Patos Lagoon Estuary, Southern Brazil: biotic responses to natural and anthropogenic impacts in the last decades (1979–2008). In Coastal Lagoons: Critical Habitats of Environmental Changes, Kennish MJ & Paerl PW (Eds), CRC Press: Boca Raton, FL, p. 433-455.

ODEBRECHT C, SECCHI ER, ABREU PC, MUELBERT JH & UIBLEIN F. 2017. Biota of the Patos Lagoon Estuary and adjacent marine coast: long-term changes induced by natural and human-related factors. Marine Biol Res 13: 3-8.

ODEBRECHT C, ABREU PC, BEMVENUTI CE, COPERTINO M, MUELBERT JH, VIEIRA JP & SEELIGER U. 2011. The Patos Lagoon Estuary, Southern Brazil: Biotic Responses to Natural and Anthropogenic Impacts in the Last Decades (1979-2008). In: Kennish MJ & Paerl HW (Eds), Coastal Lagoons:

Critical Habitats of Environmental Change. CRC Press, Boca Raton, FL, p. 433-455.

OLISAH C & ADAMS JB. 2021. Analysing 70 years of research output on South African estuaries using bibliometric indicators. Estuar Coast Shelf Sci 252: 107285.

PARREIRA MR, MACHADO KB, LOGARES R, DINIZ-FILHO JAF & NABOUT JC. 2017. The roles of geographic distance and socieconomic factors on international collaboration amon ecologists. Scientometrics 113: 1539-1550.

PEIXOTO S, DE ALCANTARA LOPES DL & WASIELESKY W. 2013. Estuarine cage culture of pink shrimp *Farfantepenaeus brasiliensis* at different stocking densities. J Shellfish Res 32: 559-563.

PEREIRA N & D'INCAO F. 2012. Relationship between rainfall, pink shrimp harvest (*Farfantepenaeus paulensis*) and adult stock, associated with El Nino and La Nina phenomena in Patos Lagoon, southern Brazil. J Mar Biol Assoc UK 92: 1451-1456.

PEREIRA TL, WALLNER-KERSANACH M, COSTA LF, COSTA DP & BAISCH PRM. 2018. Nickel, vanadium, and lead as indicators of sediment contamination of marina, refinery, and shipyard areas. Environ Sci Pollut Res 25: 1719-1730.

PÉREZ-RUZAFA A, MARCOS C, PÉREZ-RUZAFA I & PÉREZ-MARCOS M. 2011. Coastal lagoons: "transitional ecosystems" between transitional and coastal Waters. J Coast Conserv 15: 369-392.

PILOTTO F ET AL. 2020. Meta-analysis of multidecadal biodiversity trends in Europe. Nature Communications 11: 3486. https://doi.org/10.1038/s41467-020-17171-y.

POSSAMAI B, VIEIRA JP, GRIMM AM & GARCIA AM. 2018. Temporal variability (1997-2015) of trophic fish guilds and its relationships with El Niño events in a subtropical estuary. Estuar Coast Shelf Sci 202: 145-154.

REGALADO A. 2010. Brazilian science: riding a gusher. Science 330: 1306-1312.

REIS & D'INCAO. 2000. The present status of artisanal fisheries of extreme Southern Brazil: an effort towards community-based management. Ocean & Coastal Management 43: 585-595.

RIGHETTI BPH ET AL. 2019. Biochemical and molecular biomarkers in integument biopsies of free-ranging coastal bottlenose dolphins from southern Brazil. Chemosphere 225: 139-149.

RUAS V, RUFENER M & D'INCAO F. 2019. Distribution and abundance of post-larvae and juvenile pink shrimp *Farfantepenaeus paulensis* (Pérez Farfante, 1967) in a subtropical estuary. J Mar Biol Assoc UK 99: 923-932.

THAINA L, DOS SANTOS JW, CORREIA RA, LADLE RJ & MALHADO ACM. 2019. Known unknowns: filling the gaps in scientific knowledge production in the Caatinga. Plos One 14: e0219359.

THERNEAU T, ATKINSON B & RIPLEY B. 2012. rpart: Recursive Partitioning. R package version 4.1-0.

TOURINHO MP, COSTA APT, MARTINS KP, BANDEIRA MGS & BARBOSA FG. 2020. Scientific knowledge on threatened species of the Brazilian Red List: freshwater fish as a case study. Environ Biol Fish 103: 719-731.

TUNDISI JG. 2013. Pesquisas Ecológicas de Longa Duração: uma Abordagem Essencial ao Estudos de Ecossistemas e seus Processos. In: Tabarelli M, Rocha CFD, Romanowski HP, Rocha O & Lacerda LD (Eds), PELD-CNPq Dez Anos do Programa de Pesquisas de Longa Duração no Brasil: Achados, Lições e Perspectivas. Editora Universitária UFPE, Recife, 446 p.

SEELIGER U. 2001. The Patos Lagoon estuary. In: Seeliger U, Lacerda LD & Kjerfve B (Eds), Coastal Marine Ecosystems of Latin America, Springer, New York, NY, p. 167-183.

SEELIGER U & ODEBRECHT C. 2010. O estuário da Lagoa dos Patos: Um século de transformações. Rio Grande: Editora da FURG, p. 180.

SHEVAH Y. 2015. Water resources, water scarcity challenges, and perspectives. In: Water challenges and solutions on a global scale. Am Chem Soc 1206: 185-219.

SIDONE OJG, HADDAD EA & MENA-CHALCO JP. 2016. A ciência nas regiões brasileiras: evolução da produção e das redes de colaboração científica. Transinformação 28: 15-32.

SOARES R, PEIXOTO S, BEMVENUTI C, WASIELESKY W, D'INCAO F, MURCIA N & SUITA S. 2004. Composition and abundance of invertebrate benthic fauna in *Farfantepenaeus paulensis* culture pens (Patos Lagoon estuary, Southern Brazil). Aquaculture 239: 199-215.

SONG AM, HICKEY GM, TEMBY O & KRANTZBERG G. 2016. Assessing transboundary scientific collaboration in the Great Lakes of North America. J Great Lakes Res 42: 156-161.

SUI X, CHEN Y, LU Z & CHEN Y. 2015. A bibliometric analysis of research papers related to the Mekong River. Scientometrics 105: 419-434.

VAN ECK NJ & WALTMAN L. 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84: 523-538.

VASCONCELOS SMR, SORENSON MM & LETA J. 2007. Scientist-friendly policies for non-native English-speaking

authors: timely and welcome. Braz J Med Biol Res 40: 743-747.

VIANNA M & D'INCAO F. 2006. Evaluation of by-catch reduction devices for use in the artisanal pink shrimp (*Farfantepenaeus paulensis*) fishery in Patos Lagoon, Brazil. Fish Res 81: 331-336.

VIEIRA JP, GARCIA AM & GRIMM AM. 2008. Evidences of El Nino effects on the mullet fishery of the Patos Lagoon estuary. Brazil Arch Biol Technol 51: 433-440.

VIEIRA JP, GARCIA AM & MORAES LE. 2010. A assembléia de peixes. In: Seeliger U & Odebrecht C (Eds), O Estuário da Lagos dos Patos: um século de transformações. Editorada FURG, Rio Grande, p. 79-90.

VIHERVAARA P ET AL. 2013. Using long-term ecosystem service and biodiversity data to study the impacts and adaptation options in response to climate change: insights from the global ILTER sites network. Curr Opin Environ Sustain 5: 53-66.

WALLNER-KERSANACH M, MIRLEAN N, BAUMGARTEN MGZ, COSTA LF & BAISCH PRM. 2016. Temporal evolution of the contamination in the southern area of the Patos Lagoon estuary, RS, Brazil. J Integr Coast Zone Manag 16: 263-279.

WANG C, DESER C, YU J-Y, DINEZIO P & CLEMENT A. 2016. El Niño-Southern Oscillation (ENSO): A review. In: Glymn P, Manzello D & Enochs I (Eds), Coral Reefs of the Eastern Pacific. Springer Science Publisher, p. 85-106.

WESTSTRATE J, DIJKSTRA G, ESHUIS J, GIANOLI A & RUSCA M. 2019. The sustainable development goal on water and sanitation: learning from the Milennium Development Goals. Social Indicators Research 143: 795-810.

WHITFIELD J. 2008. Collaboration: Group theory. Nature 455: 720-723.

YUNES JS, NIENCHESKI LF, SALOMON P, PARISE M, BEATTIE KA, RAGGETT SL & CODD GA. 1998. Effect of nutrient balance and physical factors on blooms of toxic cyanobacteria in the Patos Lagoon, southern Brazil. Internationale Vereinigung für Theoretishe und Angewandte Limnologie: Verhandlungen 26: 1796-800.

ZHANG Y, YAO X & QIN B. 2016. A critical review of the development, current hotspots, and future directions of Lake Taihu research from the bibliometrics perspective. Environ Sci Pollut Res 23: 12811-12821.

SUPPLEMENTARY MATERIAL

Table SI. List of all papers used in the present study.

How to cite

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Author contributions

Fabiana Gonçalves Barbosa: Conceptualization and design of study, Acquisition of data, Analysis and interpretation of data, Drafting the manuscript, Writing – review & editing. Marianna Lanari: Analysis and interpretation of data, Drafting the manuscript, Writing – review & editing.