



## Scientometric trends of freshwater benthic invertebrates studies in Brazil

Cienciometria dos estudos de invertebrados bentônicos de água doce no Brasil

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**Cite as:** Brandimarte, A.L. and Melo, A.L.U. Scientometric trends of freshwater benthic invertebrates studies in Brazil. *Acta Limnologica Brasiliensia*, 2016, vol. 28, e20.

**Abstract: Aim:** The aim of this paper is to analyze trends in the literature concerning benthic invertebrates in Brazil, mainly the number of published papers and approaches used. **Methods:** The Ph.D. database of the Lattes Platform (CNPq) was used as the source of information for the period 1970-2014. We searched for the terms “benthos”, “macroinvertebrates”, and “zoobenthos” in the titles and keywords of the papers listed on the platform. Papers were classified into the following categories: *Systematics*, *Life History*, *Ecology*, and *Divulagation*. These categories were further divided into subcategories. The percentage of papers in every major category and subcategory was calculated. **Results:** The search introduced 1,573 papers, which were mainly related to *Ecology* and *Systematics*. From 1970 to 2009, the number of papers published per decade increased exponentially, and the upward trend continues. The number of papers concerning *Systematics*, especially in *Taxonomy*, is increasing. Of the papers in *Ecology* category, those about *Structure*, *Dynamics*, and *Distribution* of the fauna have been increasing since the 1980s, and there has been an evident increase in the production of papers related to environmental damage in the last decade. The rate of production of papers concerning the role of invertebrates in ecosystems and the effects of different *Spatial Scales* has been increasing since the 2000s. **Conclusion:** There is a clear tendency towards the increased continuity of paper production concerning freshwater benthic invertebrates, and relatively new approaches as *Conservation* and *Exotic Species* are becoming relevant.

**Keywords:** paper production; systematics; life history; ecology; divulgation.

**Resumo: Objetivo:** Analisar a principais tendências relativas à produção de artigos relacionados a invertebrados bentônicos no Brasil, principalmente no que se refere ao número de trabalhos publicados e abordagens utilizadas. **Métodos:** A base de dados de doutores da Plataforma Lattes (CNPq) foi utilizada como a fonte de informação para o período 1970-2012, usando-se os termos “bentos”, “macroinvertebrados” e “zoobentos” constantes do título ou palavras chaves dos artigos científicos listados na plataforma. Os artigos citados nesta plataforma foram agrupados nas categorias: *Sistemática*, *História de Vida*, *Ecologia* e *Divulgação*, as quais foram divididas em subcategorias. Calculou-se a abundância relativa (%) de categorias e subcategorias. **Resultados:** Foram analisados 1.573 artigos, os quais foram relacionados principalmente às categorias *Ecologia* e *Sistemática*. A produção de artigos aumentou exponencialmente de 1970 a 2009 e os dados posteriores mostram tendência de continuidade de tal aumento. Ainda há uma produção crescente sobre *Sistemática*, com dominância de artigos relacionados à *Taxonomia*. Dentro da categoria *Ecologia*, artigos sobre *Estrutura*, *Dinâmica* e



*Distribuição* da fauna têm aumentado desde a década de 1980 e há um aumento evidente da produção relacionada a impactos ambientais na última década. A produção de artigos relacionados ao papel dos invertebrados nos ecossistemas e o efeito de diferentes *Escalas Espaciais* têm aumentado a partir da década de 2000. **Conclusão:** Há uma clara tendência de continuidade do aumento da produção de artigos relacionados aos invertebrados bentônicos, com abordagens mais recentes, como *Conservação e Espécies Exóticas*, se tornando relevantes.

**Palavras-chave:** produção de artigos; sistemática; história de vida; ecologia; divulgação.

## 1. Introduction

Since science is a production system whose products are papers and other publications, it is possible to quantify its results (Spinak, 1998). The evaluative bibliometrics, i.e., the use of publication and citation analyses as indicators of science output, is one of the primary methods of science quantification (Drew et al., 2016).

The results of research are, in part, a product of the historical context. Therefore, any effort to analyze the papers on freshwater benthic invertebrates in Brazil should be based on the development of this science in that country. Only then it would be possible to understand the tendencies associated with paper production.

The earliest studies were mainly made by foreign researchers, among them Herman Kleerekoper (a Dutch scientist who made his studies in several Brazilian areas) and Ernst Fittkau (a German entomologist who was in Amazonia). Although he was not a benthologist, Kleerekoper reported on benthic invertebrates in the longitudinal zones of Mogi-Guaçu River in his essential book “Introdução ao Estudo da Limnologia” (Kleerekoper, 1944). In the same text, the author already made a reference to the relevance of the biota of reference sites to the assessment of pollution, an idea that is pivotal for current benthologists. Starting in the 1960s, Fittkau conducted ecological studies on Amazonian Chironomidae, publishing several papers on this topic (e.g., Fittkau, 1967, 1971). Nevertheless, the studies on freshwater benthic invertebrates were relatively sparse and only had a boost in the mid-1970s, when more Brazilian scientists were being trained, in part as a result of the creation of the early graduate courses in zoology. The Course of Biological Sciences (Entomology) of the Federal University of Paraná, created in 1969, was the first, followed by the Course of Zoology of the University of São Paulo in 1970.

The first coordinator (from 1970 to 1972) of the latter course was Claudio Froehlich, who had been studying the zoology of benthic insects, using immatures (mainly Plecoptera) since the 1960s (e.g., Froehlich, 1960, 1969). In the 1970s,

Dr Froehlich supervised the graduate studies of Aristides de Almeida Rocha and Gisela Yuka Shimizu. Their master’s and Ph.D. theses pioneered the use of benthic invertebrates as bioindicators of eutrophication in Brazilian reservoirs, but these works did not lead to publication. The master thesis of Giovanni Strixino, completed in 1971, was also supervised by Froehlich. In the early 1980s, Giovanni Strixino and Susana Trivinho Strixino were already producing papers about benthic invertebrates, more specifically Chironomidae (e.g., Strixino & Trivinho-Strixino, 1982; Trivinho-Strixino & Strixino, 1981). Also in the 1980s, people, such as Norma Würdig and Alice Takeda, who had not completed their graduate studies in freshwater ecosystems began to work in this area and over time became a reference among professionals working with freshwater benthic invertebrates. Dr Würdig completed her Ph.D. in 1984 studying ostracods in the lagoons of Rio Grande do Sul State, but in the late 1980s she began to publish papers on freshwater ostracodes (Würdig & Freitas, 1988). Dr Takeda finished her Ph.D. in 1988 working with *Spartina alterniflora*, but she had already published her first work on freshwater benthos in 1990 (Takeda et al., 1990). The above-mentioned researchers were concentrated in Southeast and South regions of Brazil. In North region, the Swiss geneticist Ilse Walker, that begun to work in the INPA (National Institute of Amazon Researches) in 1976, also changed and directed her focus to the invertebrates, becoming a specialist on benthic food webs (e.g., Walker, 1978). Some relevant names were probably forgotten in this brief history about the start of studies on freshwater benthic invertebrates in Brazil. Clearly, this oversight did not diminish the importance of their contribution to the development of that area of study.

From that initial period, the number of Brazilian scientists dedicated to the freshwater zoobenthos increased substantially, and a considerable number of them were students of the previously cited people. This increase occurred simultaneously with the flourishing of graduate courses on the core areas of zoology and ecology in the country. We can use

the data from the Brazilian Federal Agency for the Support and Evaluation of Graduate Education (CAPES, 2016) to get an idea about the rate of implementation of these courses. Between 1969 and 1981, the number of graduate courses in zoology in Brazil reached ten. Twelve new courses were created between 1994 and 2003, and fifteen between 2012 and 2015. The core area of ecology, in turn, was established with five graduate courses in 1976. New courses were added slowly until 2000, when they reached a total of seventeen. However, from 2004 until 2010, twenty new courses were created, and in 2015, the total reached fifty-six.

Considering the history of the research on benthic invertebrates in Brazil, this study uses evaluative biometrics to analyze the dominant trends in research based on the number of published papers and the approaches used.

## 2. Material and Methods

The Lattes Platform, i.e. the Brazilian data bank on science and technology production maintained by the National Council for Scientific and Technological Development (CNPq), was used as the source of information because it contains the greatest number of *curricula vitae* of Brazilian scientists other than foreign researchers working in Brazil.

Only the Ph.D. database was used, bearing in mind that papers published by masters, undergraduates, and technicians have a high

probability of having a Ph.D. as coauthor, so those papers would also appear in the Ph.D. curricula. The search by subject for the terms “benthos”, “macroinvertebrates”, and “zoobenthos”, each in turn (in Portuguese and English), in the paper title or keywords resulted in about 1,300 curricula to be analyzed for the period 1970-2014. We considered only people working in freshwater environments, leaving 280 curricula actually used (Table 1).

From the bibliographic production of each researcher, we used only the reports published in scientific journals, from now on denominate simply papers. First of all, these papers were distributed among four broad categories: *Systematics*, *Life History*, *Ecology*, and *Divulagation*. The three first categories were further classified into subcategories. *Systematics* was subdivided into a) *Inventories/Records/Occurrence/Lists*, grouping papers that deal with inventories and lists of organisms, records of occurrence and geographic distribution of *taxa*; and b) *Systematics/Taxonomy*, including the description of species and studies involving phylogenetic relationships. Papers related to *Life History* were classified according to the subcategories a) *Anatomy/Biometry*; b) *Bionomy/Behaviour*; c) *Growth/Body Development*; d) *Physiology*; and e) *Reproduction/Life Cycle*. Finally, the broad category *Ecology* was subdivided into a) *Bioindicators*, related to the use of benthic macroinvertebrates as indicators of anthropic impacts; b) *Conservation*, relating benthic invertebrates and conservation degree of

**Table 1.** Names of researchers whose curricula were used in this paper.

Adauto de Souza Ribeiro	Leonardo Maltchik Garcia
Adriana Teresita Jorcin Delgado	Livia Maria Fusari
Adriano Caliman Ferreira da Silva	Lorraine André Isoldi
Adriano Sanches Melo	Luciana Carvalho Bezerra de Menezes
Afonso Pelli	Luciana Garcia Angonesi
Alaide Aparecida Fonseca Gessner	Luciane Ayres Peres
Alcimar do Lago Carvalho	Lúcio Cadaval Bedê
Alex Bager	Ludgero Cardoso Galli Vieira
Alex Pires de Oliveira Nuñer	Ludmilla Oliveira Ribeiro
Alexandre Giovanelli	Luís Fernando Marques Dorvillé
Alice Michiyo Takeda	Luis Mauricio Bini
Alois Eduard Schafer	Luiz Antonio Martinelli
Ana Asuncion Huamantincó Araujo	Luiz Henrique Ronchi
Ana Emilia Siegloch	Luiz Ubiratan Hepp
Ana Lúcia Brandimarte	Manoel Inácio Silva Filho
Ana Lucia Fonseca	Marcel Okamoto Tanaka
Ana Lucia Henriques de Oliveira	Marcel Rodrigo Cavallaro
Ana Lucia Suriani Afonso	Marcelo da Silva Moretti
Analu Egydio dos Santos	Marcelo Luiz de Souza
Anderson Ferreira	Marcia Divina de Oliveira
André Rinaldo Senna Garraffoni	Márcia Regina Russo
André Trevisan	Marcia Regina Spies
Andréa Bialezki	Márcia Santos de Menezes
Andréa Lúcia Teixeira de Souza	Marcia Thais Suriano
Andrea Novelli	Marcos Callisto de Faria Pereira

**Table 1.** Continued...

Andreia Aparecida Guimarães Strohschoen	Marcos Gomes Nogueira
Angela Manzolillo Sanseverino	Marcos Paulo Figueiredo de Barros
Anna Paula Luzia	Marcus Vinicius Morini Querol
Antonio Fernando Monteiro Camargo	Margarida Flores Roza-Gomes
Björn Gücker	Maria Alice Penna Firme dos Santos
Bruce Rider Forsberg	Maria Cristina Dreher Mansur
Bruno Spacek Godoy	Maria Cristina Pons da Silva
Carla Bender Kotzian	Maria da Conceição Tavares Frigo
Carla Ferreira Rezende	Maria do Carmo Calijuri
Carlos Edwar de Carvalho Freitas	Maria José do Nascimento Ferreira
Carlos Rafael Lugo-Ortiz	Maria Julia Martins Silva
Carolina Bittencourt de Abreu	Maria Margarida Granate Sá e Melo Marques
Carolina Buso Dornfeld	Maria Paula Delicio
Carolina Coelho Sokolowicz	Maria Virginia Urso-Guimaraes
Caroline Silva Neubern de Oliveira	Mariana Egler
Cecilia Volkmer-Ribeiro	Mariana Silveira Guerra Moura e Silva
Celio Ubirajara Magalhaes Filho	Marilza Maia Herzog
Cesar João Benetti	Mario Antonio Navarro da Silva
Christiane Heemann	Mario Donizeti Domingos
Claudence Moreira dos Santos	Marlene Sofia Arcifa
Claudia Eiko Yoshida	Marlus Bueno Silva
Claudia Padovesi Fonseca	Mateus Pepinelli
Claudia Tasso Callil	Maurea Nicoletti Flynn
Claudio Gilberto Froehlich	Mauricio Anaya
Cleber Palma Silva	Mauricio Camargo-Zorro
Colin Robert Beasley	Maurício Lopes de Faria
Cristina Márcia de Menezes Butakka	Mauricio Mello Petrucio
Cristina Stenert	Mauricio Pereira Almerão
Daniel de Brito Fragoso	Milton Norberto Strieder
Daniel Forsin Buss	Mônica Ceneviva Bastos
Daniela Cambeses Pareschi	Monica de Cassia Souza Campos
Daniela Maeda Takiya	Monica Luisa Kuhlmann
Daniele Sayuri Fujita	Mônica Mungai Chacur
Danielle Anjos dos Santos	Nadja Gomes Machado
Darcilio Fernandes Baptista	Nelson Ferreira Junior
Dayse Lucy Medeiros Carneiro Resende	Neusa Hamada
Demétrio Luis Guadagnin	Nilza Cristina Buttow
Domingos Sávio Barbosa	Norma Luiza Würdig
Douglas Fernando Peiró	Odete Rocha
Ednilson Paulino Queiroz	Odila Rigolin de Sa
Eduardo Cargnin Ferreira	Oswaldo Campos Junior
Eduardo Perico	Otávio Froehlich
Elidiomar Ribeiro da Silva	Otoniel Geter Lauz Ferreira
Elisa Yokoyama Lisandro	Pablo Moreno Souza Paula
Elisete Ana Barp	Paulina Maria Maia Barbosa
Elvio Sergio Figueredo Medeiros	Paulino Barroso Medina Júnior
Elynton Alves do Nascimento	Paulo Augusto Zaitune Pamplin
Emerson Machado de Carvalho	Paulo De Marco Júnior
Eneida Maria Eskinazi Sant'Anna	Paulo Henrique Costa Corgosinho
Enrique Querol Chiva	Paulo Roberto Pagliosa Alves
Erlei Cassiano Keppeler	Paulo Roberto Pereira de Araujo
Eudes de Souza Correia	Pedro Antonio Zagatto
Eustáquio José Machado	Péricles Leonardo Fernandes
Evanilde Benedito	Pitágoras da Conceição Bispo
Evelise Nunes Fragoso de Moura	Plínio Barbosa de Camargo
Fabiana Schneck	Raoul Henry
Fabiano Botta Tonissi	Raphael Ligeiro Barroso Santos
Fabio de Oliveira Roque	Regina Mayumi Kikuchi
Fabio Kiyohara	Reinaldo Luiz Bozelli
Fabio Laurindo da Silva	Ricardo Marcelo Geraldi
Fábio Ricardo da Rosa	Riccardo Mugnai
Flavio da Costa Fernandes	Rita de Cassia Farani Assis
Francisco Antonio Rodrigues Barbosa	Roberta Sebastiany França
Francisco de Assis Esteves	Roberta Zani da Silva
Francisco José Pegado Abílio	Roberto da Gama Alves
Frederico Falcão Salles	Roberto de Moraes Lima Silveira
Gabriel de Paula Paciencia	Roberto Munehisa Shimizu
Geuza Cantanhêde da Silva	Rodrigo König

**Table 1.** Continued...

Gilza Maria de Souza-Franco	Rodrigo Lopes Ferreira
Giovanni Battista Mario Aldo Strixino	Roger Paulo Mormul
Gisela Yuka Shimizu	Ronaldo Angelini
Gisele Luziane de Almeida	Ronaldo Figueiró Portella Pereira
Giuliano Buzá Jacobucci	Rosana da Graça Nadolny Loyola
Grazielle Wolff de Almeida Carvalho	Rosane Maria Lanzer
Guilherme Rossi Gorni	Rosemary Cristina Souza Davanso
Guilherme Schnell e Schühli	Rosilene Luciana Delariva
Heliana Rosely Neves Oliveira	Rosines Luciana da Motta
Hélio Gerso Konrad	Rozane Maria Restello
Henrique Paprocki	Ruth Leila Ferreira Keppler
Herbet Tadeu de Almeida Andrade	Saionara Eliane Salomoni
Humberto Fonseca Mendes	Sandra Aparecida Padilha Magalhães Fraga
Inga Ludmila Veitenheimer Mendes	Sandra Maria de Melo
Ivana de Freitas Barbola	Sandro Santos
Jandira Liria Biscalquini Talamoni	Sebastiao Jose de Oliveira
Janet Higuti	Sergio Ernani Nogueira Cleto Filho
Janine Oliveira Arruda	Sérgio Renato Noguez Piedras
Jansen Fernandes de Medeiros	Sergio Schwarz da Rocha
Jean Pierre Henry Balbaud Ometto	Sheyla Regina Marques Couceiro
Jelly Makoto Nakagaki	Sidinei Magela Thomaz
João Anderson Fulan	Sílvia Beatriz Coutinho Visoni
Joao Jose Fonseca Leal	Silvia Leitão Dutra
Joel Augusto Muniz	Silvio Jacks dos Anjos Garnés
Jorge Luiz Nessimian	Solange Martone Rocha
Jose Carlos Nascimento de Barros	Sonia Silveira Ruiz
José Eloy dos Santos Júnior	Sueli Caleffi
José Francisco Gonçalves Júnior	Susana Trivinho Strixino
José Lopes	Tadeu de Siqueira Barros
José Marcelo Rocha Aranha	Takako Matsumura Tundisi
José Moacir Ferreira Ribeiro	Takako Watanabe
José Reinaldo Pacheco Pelej	Timothy Peter Moulton
José Souto Rosa Filho	Ulisses Gaspar Neiss
José Valdecir de Lucca	Uwe Horst Schulz
Joseline Molozzi	Vanessa Gazulha
Judith Font Batalla	Vania Filippi Goulart Carvalho Pereira
Juliana Simião Ferreira	Vera Lúcia Crisci Bispo
Juliano José Corbi	Vera Lucia Lopes Pitoni
Julio Ferraz de Queiroz	Victor Lemes Landeiro
Juno Soares Vieira	Vinicius Fortes Farjalla
Karina Ocampo Righi Cavallaro	Virginia Sanches Uieda
Karine Delevati Colpo	Welber Senteio Smith
Karl Matthias Wantzen	William Severi
Kathia Cristhina Sonoda Braga	Wilson Massamitu Furuya
Kennedy Francis Roche	Yara Moretto
Leandro Gonçalves Oliveira	Ynglea Georgina de Freitas Goch
Leny Célia da Silva Correia	Zuleika Beyruth

aquatic and terrestrial ecosystems; c) *Exotic Species*, besides the effect of occurrence of non-native species in ecosystems could be included in other categories, e.g., *Conservation*, we prefer to maintain a specific subcategory due to the increasing introduction and effects of exotic species worldwide; d) *Feeding Habits/Trophic Relationships/Food Chains and Webs*, including the papers related to dietary issues; e) *Other Interactions/Associations*, dealing with relationships which do not involve trophic interaction; f) *Methodology*, grouping papers about sampling of organisms and other methodologic issues; g) *Paleolimnology*; h) *Processes*, related to the role of benthic invertebrates in the

functioning of ecosystems (e.g., in the detritus degradation); i) *Spatial Scales*, related specifically to the comparison of the effect of different scales on the benthic community; j) *Structure/Dynamic/Distribution*, including papers about composition, density, biomass, richness and diversity of organisms, and temporal and spatial changes in the structure of populations or communities; k) *Toxicology*, including the use of benthic invertebrates in ecotoxicological studies; l) *Volunteer Monitoring*, grouping papers related to the use of benthic invertebrates as indicators of water quality by volunteer people; and m) *Other Approaches* (e.g.,

factors that affect the colonization by benthic organisms).

We calculated the relative abundance (%) of categories to the total of papers and the subcategories to the total in each category.

### 3. Results and Discussion

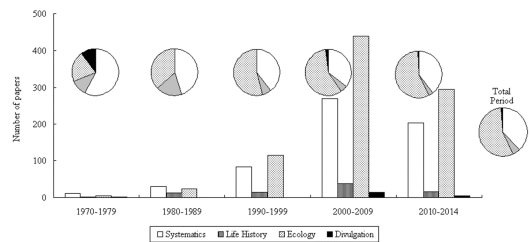
As in other countries, the Brazilian science development depends broadly on the governmental policies and support for science and technology. There are two major national institutions related to this subject in the country, both of them created in 1951. The National Council for Scientific and Technological Development (CNPq) aims to foster and foment scientific and technological development, as well as contributing to the formulation of national policies of science and technology. An interesting record of the history of CNPq genesis can be found in Motoyama (1985). Besides supplying funds and grants to research, as does CNPq, the Federal Agency for the Support and Evaluation of Graduate Education (CAPES) has an important role in the expansion and consolidation of *stricto sensu* graduate courses. In 1995, CAPES was restructured and became responsible for the following and evaluation of those courses (CAPES, 2008). In this sense, the increased number of graduate courses in zoology and ecology, mainly from the middle of the 1990's till now, came out of the joint efforts of CAPES and Brazilian universities. Moreover, Brazilian states have their research foundations that also provide researchers with funds and grants. Among them, FAPESP in São Paulo State (1960) and FAPERGS in the Rio Grande do Sul State (1964) are the oldest. The work of all these institutions contributed to the increase of scientists in Brazil, among them a large number of people studying benthic invertebrates.

On to the scientific production of those professionals, we analyzed 1,573 papers published between 1970 and 2014 that were mainly related to *Ecology and Systematics* (Figure 1). From 1970 to 2009, paper production increased exponentially (Figure 2). Moreover, in the period from 2010 to 2014 the total of published papers already amounted to circa 70% (68.2%) of the production of the decade from 2000 to 2009. The increase of paper publication became more marked from the 1990s, reflecting the increasing support for the science in Brazil from that time onwards.

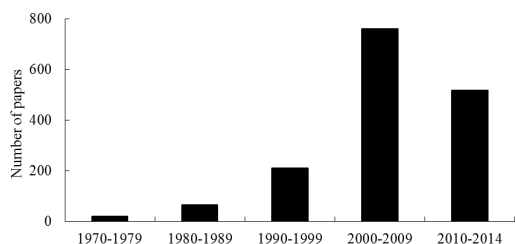
On relation to the different categories of papers, we suspected that the production of *Life History* papers had been underestimated. Possibly, a

considerable number of authors working on that issue were not using the terms “benthos”, “macroinvertebrates”, or “zoobenthos” in their papers. The same could be true of papers related to *Systematics*. Nevertheless, there has been an increasing production of papers on *Systematics*, with most of the papers focusing on *Taxonomy* (Table 2). This fact demonstrates that the knowledge about freshwater benthic invertebrate fauna is still incomplete in Brazil, and we need to continue hardly working on this issue.

Concerning the category *Ecology*, although scientific works associating benthic invertebrates and environmental changes have been performed since the 1970s, the production of papers related to this issue only had an evident increase in the 2000s. This fact becomes especially apparent by the increase in papers on *Conservation*, *Exotic species*, and the use of invertebrates as *Bioindicators* (Table 2). With the increased impact on waterbodies we found an increased use of benthic invertebrates as indicators and correlated papers about them. Another consequence was the concern with the aquatic biota conservation, including those invertebrates. The increment on papers about *Conservation* is in part a result of the increase of professionals concerned about it and prepared



**Figure 1.** Numbers and relative abundance of papers published per decade (excepting the 2010-2014 period), concerning the broad categories of studies in freshwater benthic invertebrates in Brazil.



**Figure 2.** Total production of papers concerning freshwater benthic invertebrates per decade (excepting the 2010-2014 period) in Brazil.

to deal with this issue, but there is also a rising demand to solve environmental problems related to habitat degradation, coupling the stoppage or minimization of impact and habitat restoring. Moreover, conservation and exotic species are closely related issues. Since new records of exotic species are increasing in Brazil, so is the knowledge about their impacts on native biota, and more papers about non-native species are being produced.

In the last decades, the scope of the scientific approaches used for benthic invertebrates is expanding. Papers concerning the role of invertebrates in *Food Chains and Webs* and other *Processes* in the ecosystems are achieving greater relevance since the 2000s, though still with a low relative abundance. The same is true for papers on the effects of different *Spatial Scales*. Despite this shift in approach, traditional descriptive papers, such as those concerning local *Structure, Dynamics, and Distribution* of fauna, are numerous and growing in number (Table 2). Sometimes these papers are considered to be regionally constrained and without interest to be published in high impact journals, which could be discouraging for some researchers. However, they continue to be important because Brazilian freshwater benthic fauna is still barely known, and now we cannot set aside these approaches as our counterparts in

developed countries. The increase in the number of papers related to *Divulcation* since the 2000s (Table 2) followed the popularization of science. However, this production remains modest, showing that perhaps Brazilian benthologists have only recently woken up to the relevance of informing about benthic invertebrates and their role in aquatic environments. In this sense, our delay in the use of volunteer biomonitoring is also comprehensible. In other countries, the role of volunteers in the monitoring of freshwaters is recognized for decades. In the U.S., e.g., volunteer practices have been in use since the 1990s and the Environmental Protection Agency considers that data gathered by volunteers can be used in state reports on the environmental quality of water bodies (USEPA, 1997). However, though studies using bioindicators began in the 1970s in Brazil, papers concerning the use of volunteer data arose only over the last five years covered by this research (e.g., Buss, 2008; França & Callisto, 2012).

This paper presented the first attempt of scientometric analysis of papers concerning freshwater benthic invertebrates in Brazil. Further research should seek refinements, such as the categorization of papers by environment (e.g., lentic/lotic; lakes/reservoirs/rivers/streams), organization levels (e.g., individuals, populations,

**Table 2.** Numbers and relative abundance (parentheses) of four broad categories of papers concerning Brazilian benthic invertebrates from 1970 to 2014.

		1970-1979	1980-1989	1990-1999	2000-2009	2010-2014
<b>ECOLOGY</b>	Bioindicators	0 (0.0)	3(12.5)	28 (24.6)	96 (21.9)	75 (25.5)
	Conservation	0 (0.0)	0 (0.0)	0 (0.0)	5 (1.1)	14 (4.8)
	Exotic species	0 (0.0)	2 (8.3)	2 (1.8)	33 (7.5)	19 (6.5)
	Feeding habits/Trophic relationships/Food chains and webs	1 (25.0)	1 (4.2)	9 (7.9)	34 (7.7)	14 (4.8)
	Other interactions/Associations	2 (50.0)	0 (0.0)	3 (2.6)	14 (3.2)	5 (1.7)
	Methodology	0 (0.0)	1 (4.2)	8 (7.0)	32 (7.3)	21 (7.1)
	Paleolimnology	0 (0.0)	0 (0.0)	3 (2.6)	6 (1.4)	0 (0.0)
	Processes	0 (0.0)	0 (0.0)	2 (1.8)	35 (8.0)	27 (9.2)
	Spatial scales	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.9)	10 (3.4)
	Structure/Dynamic/Distribution	0 (0.0)	12 (50.0)	48 (42.1)	125 (28.5)	75 (25.5)
<b>SYSTEMATICS</b>	Toxicology	0 (0.0)	0 (0.0)	0 (0.0)	10 (2.3)	4 (1.4)
	Volunteer monitoring	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.0)
	Other approaches	1 (25.0)	5 (20.8)	11 (9.6)	45 (10.3)	27 (9.2)
	Inventories/Records/ Occurrence/Lists	4 (36.4)	6 (20.7)	24(28.9)	55 (20.4)	40 (19.6)
	Systematics/Taxonomy	7 (63.6)	23 (79.3)	29 (71.1)	215 (79.6)	164 (80.4)
<b>LIFE HISTORY</b>	Anatomy/Biometry	2 (100.0)	2 (16.7)	6 (42.9)	14 (37.8)	6 (37.5)
	Bionomy/Behaviour	0 (0.0)	0 (0.0)	1 (7.1)	5 (13.5)	5 (31.3)
	Growth/Body development	0 (0.0)	7 (58.3)	4 (28.6)	9 (24.3)	2 (12.5)
	Fisiology	0 (0.0)	0 (0.0)	1 (7.1)	1 (2.7)	0 (0.0)
	Reproduction/Life cycle	0 (0.0)	3 (25.0)	2 (14.3)	8 (21.6)	3 (18.8)
<b>DIVULGATION</b>	Total	2	0	0	14	4

communities), geographic area (as new research groups are arising out of the South and Southeastern regions where the researchers are concentrated), dissemination (e.g., national or international journal, open or no open access journal, citation index), impact (e.g., the impact factor of each publication area) and collaboration networks. As there is relevant information published in books and chapters, these data could also be included.

## Acknowledgements

Authors are grateful to anonymous referees whose suggestions greatly improved the paper.

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Received: 30 June 2016

Accepted: 19 October 2016