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Brazilian scientific production on phytoplankton studies: national determinants and international comparisons

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(With 5 figures)

Abstract

In this study, we determined the temporal trends of publications by Brazilian authors on phytoplankton and compared these trends to those of other Latin American countries as well as to the 14 countries ranking ahead of Brazil in terms of scientific publication. To do this, we investigated phytoplankton studies published in an international database (Thomson-ISI). The data showed that Brazil plays an important role among other Latin American countries in the publication of these studies. Moreover, the trend of studies published on phytoplankton in Brazil was similar to trends recorded in the developed countries of the world. We conclude that studies can be more deliberately targeted to reduce national and international asymmetries by focusing on projects with large spatial scales and projects that concentrate on less-studied geographic regions, thus encouraging increased productivity in remote areas of the country. Associated with this is a necessary increase in high-impact journal publications, increasing the quantity and quality of Brazilian scientific studies on phytoplankton and, consequently, their global visibility.

Keywords: Brazil, global rating, latin america, scientometrics.

Produção científica brasileira sobre estudos fitoplanctônicos: determinantes nacionais e comparações internacionais

Resumo

Esse estudo teve por objetivo determinar a tendência temporal das publicações sobre fitoplâncton de autores brasileiros e comparar essa tendência com outros países latino-americanos, bem como aos 14 principais países em termos de publicação científica. Para isso, investigou-se artigos sobre fitoplâncton disponível em uma base de dados internacionais (Thomson-ISI). A tendência da produção científica de autores brasileiros foi superior a maioria dos países latino-americanos. Além disso, essa tendência foi similar ao dos países desenvolvidos do mundo. Conclui-se que futuros estudos devem buscar reduzir as assimetrias nacionais e internacionais, concentrando trabalhos em grandes escalas espaciais e em regiões geográfica menos estudadas, incentivando assim, o aumento da produtividade em áreas remotas do país. Associado a isso, destaca-se a importância de aumento de publicações de brasileiros em revistas de alto impacto, aumentando a quantidade e qualidade dos estudos científicos brasileiros sobre o fitoplâncton e, consequentemente sua visibilidade internacional.

Palavras-chave: Brasil, taxa global, américa-latina, cienciometria.

1. Introduction

The evaluation of scientific production in many areas of research has been a recent subject of discussion in the academic community (Carneiro et al., 2008; Quixabeira et al., 2010; White et al., 2005). The purpose of these evaluations is to determine trends and biases in the generation of scientific studies. More specifically, the goal is to increase our understanding of the scientific asymmetries that exist between developed and less-developed countries in the publication of scientific research, as developed countries often produce a greater quantity of scientific publications than less-developed countries (Meneghini et al., 2008). Furthermore, understanding international and regional asymmetries in scientific publications may aid in the decision-making process of financial agencies and help target incentives for the formation of human resources.

Considering the scientific production of countries in all knowledge areas, the United States of America (USA) ranks first with 7,063.329 papers published between 1996 and 2012 (available: http://www.scimagojr.com/countryrank.php; access date in August 2013). Brazil ranks fifteenth with 461,118 papers. Despite the fact that the number of scientific publications in developed countries is quantitatively greater than that of less-developed countries, the rate of increase in publications from less-developed countries is higher in comparison to developed countries (Packer and Meneghini, 2007; Holmgren and Schnitzer, 2004). In addition to the total number of papers, another important metric for comparing the scientific production of different countries is the number of citations per document. According to the data available in the Scimago Journal & Country Rank, the USA presented an index of 20.45 citations/documents, while Brazil has 10.09 citations/documents.

The trends and biases in scientific production have been evaluated within various areas of research, such as global climate change (Nabout et al., 2012), phytoplankton (Carneiro et al., 2008) and other groups of organisms (Brito et al., 2009; Padial et al., 2008; Nabout et al., 2010). In fact, phytoplankton has been studied in various fields of science such as ecology (e.g., Soininen et al., 2011), human health (e.g., Bauer et al., 2010) and bioprospecting (e.g., Nascimento et al., 2013). Furthermore, studies on phytoplankton communities have increased significantly over the years (Carneiro et al., 2008), suggesting a growing interest in this group of organisms.

Therefore, the aim of this study was to determine the temporal trend of publications by Brazilian authors on phytoplankton compared with the scientific production of other Latin American countries as well as the 14 countries ahead of Brazil in the global ranking of scientific production. To accomplish this, we investigated papers about phytoplankton in an international database (e.g., Thomson ISI). In the case of Brazilian papers on phytoplankton, we evaluated: i) the journals that have published the most papers by Brazilian authors, ii) the ecosystems most frequently studied in published papers (coastal, marine or continental), iii) the geographical spatial scale used in published papers (local or regional), iv) the state of origin of the first author of Brazil and location of the study area, as well as the Gross Domestic Product (GDP) and number of graduate programs (GP) in these locations, and v) the partnerships with researchers from other countries. It is important to mention that this study does not reflect a comprehensive account of Brazilian phytoplankton research, as we did not include papers present in local databases. On the other hand, this overview of Brazilian scientific production provides critical information as Brazilian researchers face pressures to increase the quantity and quality of their country's scientific production.

2. Material and Methods

Data collection - The first step in data collection was to determine the number of papers about phytoplankton written by Brazilian authors. The database used was the Thompson-ISI (Web of Science), and the term used to search was "Phytoplankton *". We searched for papers that contain that word in the title, abstract or list of keywords between the years 1991 and 2011. All papers on the topic of phytoplankton written by Brazilian authors were selected, using the terms ("Brazil OR Brazil") in the country tab. The second step in data collection was to obtain the number of papers on phytoplankton for each country in Latin America (a total of 20 countries) and for the first 14 countries in the global rankings (available at: http://www.scimagojr.com/countryrank.php, access date in August 2013). In this step, the search term remained the same as before, however, for each country we conducted a search using the name of the country.

Data analysis - The temporal trend of scientific literature on phytoplankton created in Brazil and in other countries was evaluated by calculating a Pearson correlation ($P<0.05$) between the number of papers and the year of publication. The Pearson correlation coefficients for each country were then compared to one another using a *t* test ($P<0.05$; Zar, 1999). This process was used to compare the trend of scientific production in Brazil to other countries.

To investigate the influence of GDP and GP on scientific production (in reference to the location of the study area), we used a partial linear regression analysis. GDP data for each Brazilian state were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE, available at: www.ibge.br, access date in December 2012). Data on GP included on the 2011 Biodiversity committee were obtained from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, available at: www.capes.gov.br, access date in December 2012). The assumptions of regression analysis were tested; however, a lack of spatial independence in the sample data (states) can increase incidents of Type I error (Legendre and Legendre, 1998). Therefore, to investigate the determinants of scientific production among Brazilian states, spatial filters were added as an additional spatial variable. Nine spatial filters were generated from a PCNM (principal coordinates of neighbour matrices) using the geographical coordinates of Brazilian states (Griffith and Peres-Neto, 2006; Nabout et al., 2009). However, only one filter was selected based upon the criterion that most minimises the residual in the spatial model.

Multiple regression using three partial predictors (GDP, GP and a spatial filter) generated the following eight partial components (R^2): [a] purely explained by GDP, [b] purely explained by GP, [c] purely explained by the spatial filter, [d] shared component between GDP and GP, [e] shared component between GDP and the spatial filter, [f] shared component between GP and the spatial filter, [g] component shared by GDP, GP and the spatial filter and [h] residual component. To obtain the partial regression and spatial filters we used the SAM program V.4 (Rangel et al., 2010).

3. Results

We found 33,021 papers published on phytoplankton between 1991 and 2011 (all countries in database), of which 553 were published by Brazilian authors. Furthermore, the

scientific production of Brazilian authors on phytoplankton has been increasing over the last 20 years (see Figure 1).

Other countries have also shown an increase in the number of publications written about phytoplankton over the years (as shown in Table 1). However, considering only Latin American countries, Brazil had one of the highest increases in scientific production on phytoplankton (as indicated by the correlation coefficients shown in Table 1).

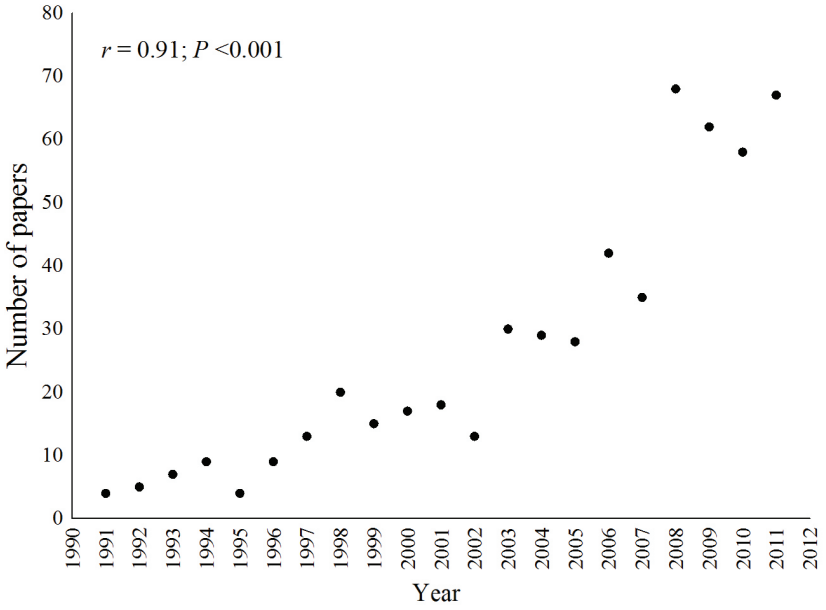


Figure 1. Temporal trends (1991-2011) of papers about phytoplankton, published by Brazilian authors available in the Thomson ISI database.

Table 1. Temporal trends of papers about phytoplankton in Latin American countries registered in the Thomson ISI database.

Country	Temporal trend (*r*)	Nr. years	Nr. papers	Compared with Brazil (*P*)
Brazil	0.91*	21	553	
Argentina	0.90*	21	433	0.72
Belize	-	2	2	-
Bolivia	0.50	3	9	0.02
Chile	0.85*	21	281	0.17
Colombia	0.64*	11	29	0.06
Costa Rica	-0.13	11	21	0.0004
Ecuador	-	6	6	-
El Salvador	-	0	0	-
French Guiana	-	2	3	-
Guatemala	-	0	0	-
Guyana	-	0	0	-
Honduras	-	0	0	-
Mexico	0.86*	21	426	0.38
Nicaragua	0.58	8	4	0.37
Panama	0.31	7	8	0.03
Paraguay	-	1	1	-
Peru	0.08	8	18	0.0063
Suriname	-	0	0	-
Uruguay	0.72*	17	70	0.064
Venezuela	0.27	20	69	0.0004

The Pearson r is the correlation coefficient between the number of papers and the time (years). The asterisk (*) indicates the significant *r*-values. Overall correlation coefficients were compared with the correlation coefficients of Brazil (column "compared with Brazil"). The trace (-) indicates the absence of correlation because of a low number of observations ($n < 3$) or null variance in scientific production. Significant values are in boldface.

Countries such as Argentina, Chile, Colombia, Uruguay and Mexico displayed similar increases in temporal scientific production on phytoplankton (as shown in Table 1).

Brazil was rated fifteenth in the global ranking for scientific production (available at: http://www.scimagojr.com/countryrank.php; access date in August 2013) but, considering only studies on phytoplankton, the number of publications from Brazil was greater than the number from South Korea (ranked 14th in the global classification). Moreover, the trend of Brazilian scientific production on phytoplankton was similar to the trends displayed by countries ranked at the top of the global classification. This result indicates that the scientific production on phytoplankton in Brazil is increasing at the same magnitude as scientific production in major countries (as shown in Table 2).

A characterisation of 553 Brazilian papers on phytoplankton shows that the journal Hydrobiologia has published the greatest quantity of Brazilian papers. Moreover, among the top 20 journals that published articles by Brazilians, eight are based in Brazil (see Figure 2). Most studies have been developed in Brazilian continental ecosystems (62%), followed by studies in coastal (23%) and marine ecosystems (15%). This result is consistent with the fact that most journals publish studies exclusively in aquatic environments or both continental and marine. The Journal of Coastal Research, that is specific to coastal topics, appears in the sixth position (see Figure 2).

In reference to the spatial scale of the study, 62% of Brazilian papers focused on local scales, while 38% focused on regional scales. Despite the predominance of studies completed on a local scale, there has been an increase in the number of Brazilian studies focusing on either spatial scale. In addition, the correlation coefficient (indicating the trend in number of papers) associated with regional-scale studies was higher than that associated with local-scale studies. In 2011, the number of regional-scale papers exceeded the number of local-scale papers (see Figure 3). It is important to consider that the term "local-scale" refers to studies that were completed on a small spatial scale, such as a single aquatic ecosystem or a small region (even if this includes multiple aquatic ecosystems). Alternatively, regional-scale studies are those completed on a large spatial scale (> 100 km), for which it is possible to collect data on various factors, such as regional climate and dispersion.

The state of origin of most first authors as well as the majority of study area locations, were located in southeastern and southern Brazil (see Figure 4). These two variables (i.e., location of study area and state of origin of the author) are strongly correlated ($r = 0.94$, $P < 0.0001$). In this study, 41.2% of the scientific production of Brazilian states could be attributed to the number of graduate programs (Component [a]; see Figure 5). This was the only component that proved significant ($P<0.05$), indicating that GDP and spatial distribution does not influence the production of scientific papers per state.

The majority of Brazilian studies on phytoplankton have been carried out by more than one author. In fact, only 2.8% of the articles have a single author's name associated with them. This result shows that Brazilian authors often develop their work in cooperation with other researchers. Most Brazilian studies were completed in partnership with other Brazilians. However, Brazilian authors also collaborate with international researchers. Among the articles analysed, collaboration was displayed between researchers of 37 different nationalities. The

Table 2. Temporal trends of the papers about phytoplankton produced by all countries (except Brazil) and the fourteen top-rated countries in the world ranking of scientific production.

Rank	Country	Temporal trend (*r*)	Nr. year	Nr. papers	Compared with Brazil (*P*)
	Global	0.86*	21	33021	0.38
1	United State of America	0.95*	21	10288	0.47
2	China	0.89*	21	1537	0.61
3	United Kingdom	0.92*	21	3098	0.99
4	Germany	0.93*	21	2913	0.83
5	Japan	0.94*	21	1853	0.65
6	France	0.94*	21	2858	0.65
7	Canada	0.75*	21	2772	0.07
8	Italy	0.95*	21	1170	0.47
9	Spain	0.95*	21	1948	0.47
10	India	0.85*	21	637	0.32
11	Australia	0.93*	21	1486	0.83
12	Russia	0.84*	20	869	0.28
13	South Korea	0.95*	21	396	0.47
14	Netherlands	0.78*	21	1441	0.11

The Pearson *r* is the correlation coefficient between the number of papers and the time (years). The asterisk (*) indicates the significant *r*-values. Overall, correlation coefficients were compared with the correlation coefficients of Brazil (column "compared with Brazil").

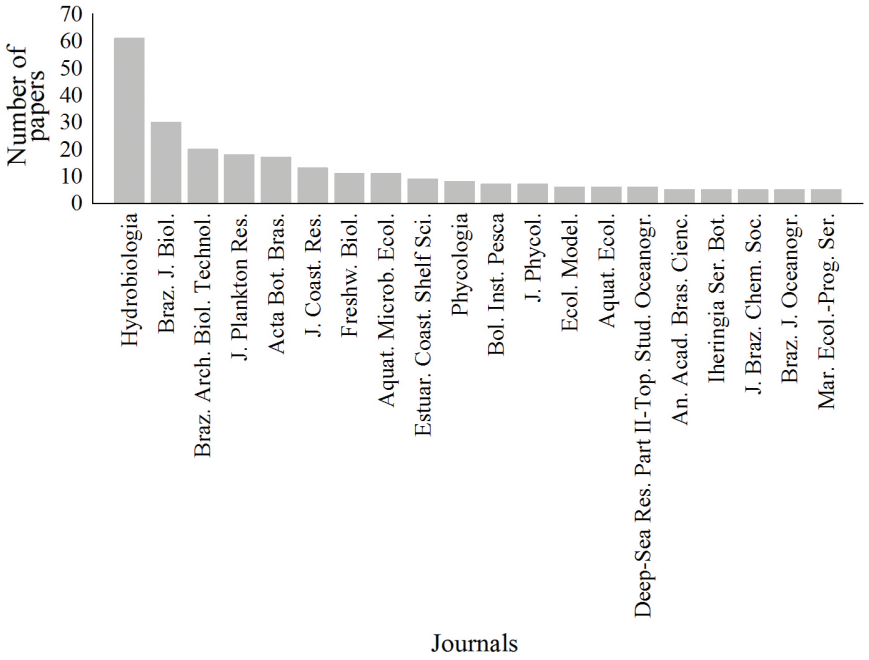


Figure 2. Main journals with publications about phytoplankton, published by Brazilian authors available in the Thomson ISI database.

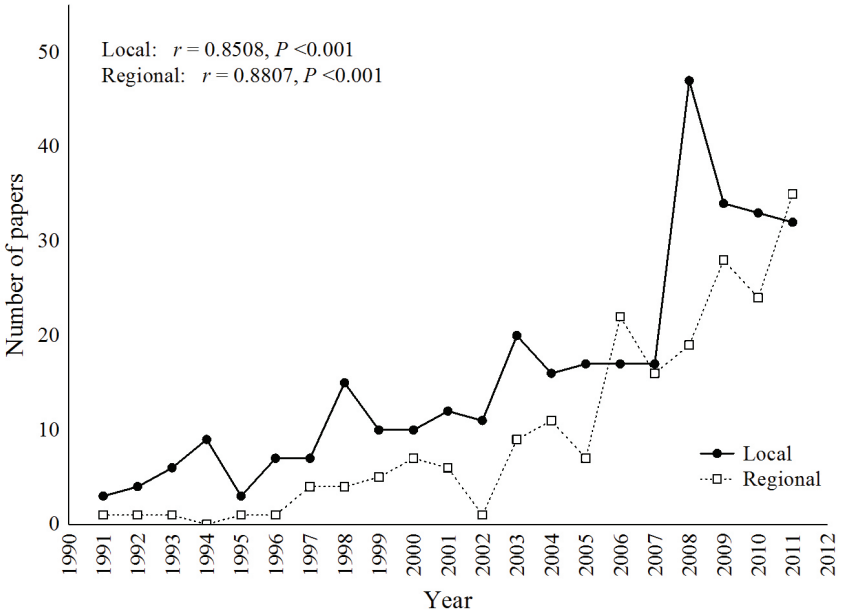


Figure 3. Geographic scale of Brazilian authors published in the Thomson ISI database.

United States has the largest number of papers published in cooperation with Brazil (55 papers), followed by France (35 papers), England (20 papers), Canada (19 papers) and Germany (17 papers).

4. Discussion

In recent years, the scientific production of Brazil has increased sharply (see Melo et al., 2006; King, 2004). Other Latin American countries have also experienced an increase in their number of published papers. Among Latin American countries, Brazil, Mexico and Argentina have been the most prominent in scientific literature (Glänzel et al., 2006). These countries were also mostly responsible for the scientific production of phytoplankton studies in Latin America. This fact suggests that there is a great deal of similarity between the trends in scientific production of phytoplankton studies and trends in other

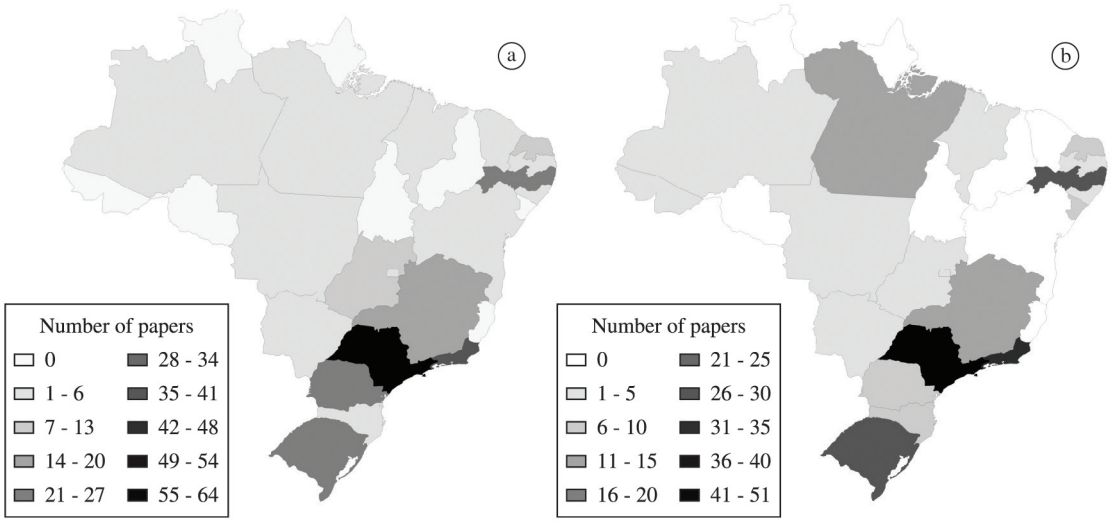
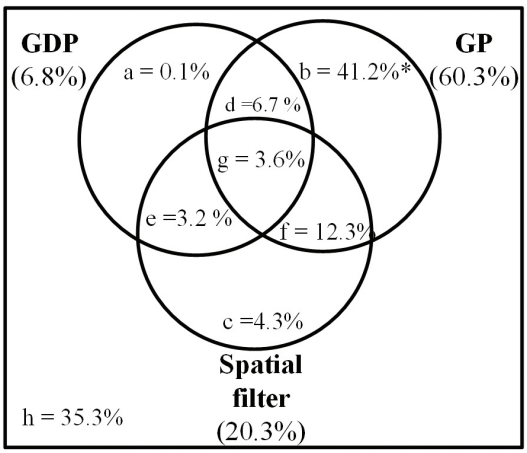


Figure 4. Geographic distribution of the scientific production about phytoplankton in the Brazilian states: (a) displays the distribution of the state of origin of the first author and (b) displays the distribution of study area locations.



Total (61.8%)

Figure 5. Relative contribution of factors determining Brazilian scientific production on phytoplankton by states. * indicates $P<0.05$; GDP = Gross Domestic Product; GP = number of graduate programs. The spatial filters were obtained by the PCNM method (see materials and methods).

areas of research among these Latin American countries (Glänzel et al., 2006).

Latin American countries are very heterogeneous from an economic and social standpoint, but some of them have attempted to work internationally in regard to scientific research. This increase in international collaboration could be because young, Latin American researchers are incentivised to study abroad (Garcia et al., 2012). Countries such as Brazil, Argentina and Chile have taken action to promote graduate programs. These actions consist of grants to study abroad, researcher exchange programs and financial incentives to research centres (Garcia et al., 2012; Triunfol, 2007).

There was no significant difference between scientific trends in Brazil and those from other countries with more publications than Brazil, even when compared with the top-rated countries in the publication ranking. However, it is important to highlight that the quality of the papers and the journals, which are measured by the number of times cited and the impact factor, respectively, were not measured. In a scientometric study, a low citation level was detected for publications from Latin American authors that did not collaborate with researchers from developed countries (Meneghini et al., 2008). Although the increase in Brazilian scientific production is similar to that of developed countries, these publications remain rarely cited. Moreover, among the total number of citations of Brazilian papers (3,259,864 citations; available in http://www.scimagojr.com/countryrank.php, access in August 2013), 34.2% are self-citations (total of 1,151,280 self-citations; available in same database). This proportion of self-citation is higher than that of some other countries (United Kingdom, Germany, Japan), but less than that of China and the USA, with proportions of 54.4% and 48.2%, respectively (however, theses countries are first in global rankings). Thus, considering the importance of scientific production (quality and quantity), the next challenge for Brazilian researchers is to publish in journals with a high impact factor and, consequently, to obtain a greater number of citations. This should certainly be the focus of any scientist in Brazil.

In addition to the international asymmetries, we also observed internal asymmetries within Brazil regarding the number of studies from authors in southern and southeastern Brazil and studies focusing on locations within the same regions. The states of São Paulo, Rio de Janeiro, Paraná e Rio Grande do Sul are responsible for the majority of Brazilian research because they have the biggest research centres. For this reason, the principal factor explaining

the amount of scientific production on phytoplankton was the number of graduate programs. Graduates have been the engine of science and technology in Brazil (Borges, 2008), and even with the increases in graduate programs (see www.capes.gov.br), it is still necessary to wait until these researchers achieve professional maturity.

International partnerships have attracted funding agencies, and some authors have already highlighted the influence that international collaborations have had on the increase of Latin American scientific production (Meneghini et al., 2008; Packer and Meneghini, 2007; Triunfol, 2007). The USA has been Brazil's main collaborator in regard to phytoplankton research. Papers resulting from collaboration with researchers from the USA are associated with high citation numbers in the area of Ecology (Leimu and Koricheva, 2005). In general, a greater proportion of multinational articles report on topics that cover a large study area, for instance, plant distribution, geophysics and astronomy (Abt, 2007a).

Another global trend in scientific production appeared in this study is the scarcity of publications written by a single author. Scientific projects are increasingly complex, and these projects demand skills from many areas (Abt, 2007b; Nabout et al., 2015). Articles with more than four authors, for instance, have more citations and, consequently, involve several institutions from different areas (Leimu and Koricheva, 2005; Hsu and Huang, 2011). In addition, it is commonly understood that the most important metric in measuring article quality is the number of times it is cited, independent of other quantitative attributes (e.g.: page number, author number, author prestige; see Padial et al., 2010).

The majority of phytoplankton studies worldwide are concentrated in marine ecosystems, however Brazilian studies focus mainly on continental ecosystems. These environments are mainly represented by shallow lakes (natural or artificial) and contain approximately 25% of the world's freshwater algae diversity (Agostinho et al., 2005). Reservoirs are the most-studied ecosystems among these Brazilian freshwater ecosystems (Huszar and Silva, 1999).

In general, Brazilian phytoplankton studies take place on a local geographic scale, but we detected an increase in the number of studies completed on a regional scale. This dominance of local studies has been reported in many scientific areas (see Nabout et al., 2012). However, studies at either a regional or global scale are capable of relating larger theory frameworks (e.g.: duality between neutral and niche theories; see Howeth and Leibold, 2010; Vanormelingen et al., 2008), and their trends relate more to the availability of financial and technological resources (e.g.: remote sensing, Keatley et al., 2011). In the case of phytoplankton studies, the search for biogeographic patterns has demanded regional-scale studies (see Cermeño et al., 2010; Stomp et al., 2011).

In summary, this study shows a pattern in regard to the scientific production of phytoplankton studies by Brazilian authors. Among the findings, we highlight the importance of Brazilian scientific production in the context of Latin America. In addition, the trends of Brazilian studies are similar to global trends. New studies should target national asymmetries, with a focus on large spatial scales and on less-studied regions. Additionally, it is necessary to publish in international journals with a high impact factor to increase the quality and quantity of scientific production about phytoplankton in Brazil.

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