Jointly published by Akadémiai Kiadó, Budapest and Springer, Dordrecht

# Brazilian articles in international journals on Limnology

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We assessed the contribution of Brazilian limnologists (freshwater ecologists) in international journals in the period 1970–2004. Brazilian contribution was low and regular in the 1970's, but increased steeply after 1980 with no signs of stabilization until the present. Articles authored by Brazilians tend to be less cited than articles authored by non-Brazilians, although this difference is reduced in co-authored articles with international researchers. Brazilian articles are not distributed homogenously among the sub-areas of Limnology, but present some biases that can be explained by intellectual legacy. Brazil has invested since the 1970's in establishing postgraduate courses in Brazil and in the last years has turned the focus to a better qualification of these courses. We believe these are the main reasons for the conspicuous development of Brazilian Limnology.

# Introduction

Scientific production in Latin America increased steeply in the last 20 years. Between 1998 and 2001, the number of articles published in journals indexed by the Institute for Scientific Information (ISI) tripled (5,609 to 16,329) (HILL, 2004). Most of these articles are from authors in Brazil, Mexico, Argentina, and Chile (HILL, 2004), the countries with the highest investment in research and development in the region (MACILWAIN, 1999a). Brazil rank first in the region, and during the same period (1998– 2001) experienced an increase even above the average, quadruplicating its number of articles (1,766 to 7,205) (HILL, 2004). Despite the remarkable increase in scientific production, the Brazilian percent share of articles produced in the world is still low (1.21% for the 1997–2001 period), as is the percent of citations received by Brazilian publications (0.71% for the period 1997-2001) (KING, 2004). Compared to the 149 top performing countries in the period 1993-2003, Brazil occupies rank 22 and 25 in number of articles and citations respectively in the ISI database. However, impact of Brazilian articles in terms of received citations is low and the country ranks 94 among the 149 top countries (data from ISI Essential Science Indicators consulted in August 2005 - http://www.in-cites.com/research/2004/march\_22\_2004-4.html).

Received September 14, 2005

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In recent years, a number of studies have examined in detail the performance of Brazil in selected fields, such as Health Sciences (PEREIRA & ESCUDER, 1999), Management Sciences (PEREIRA et al., 2000), and Psychiatry (LETA et al., 2001; FIGUEIRA et al., 2003). In this paper we examine the development of Limnology (the study of inland waters) in Brazil in the period 1970–2004. We restricted our focus to Brazilian publications in journals indexed by ISI, which currently does not include any Brazilian journal in the field. Our study thus does not deal exactly with the total trend in the field, but specifically how Brazilian Limnology has evolved in the international scenario.

Brazil is the fifth largest country with 8,547,403 km<sup>2</sup>, and includes 53% of South American waters and 12% of all continental waters in the world. Despite harboring a reduced number of natural lakes, huge water basins are located within Brazil, such as the Amazon (6,112,000 km<sup>2</sup>), Paraná (877,000 km<sup>2</sup>) and São Francisco (634,000 km<sup>2</sup>). The country also encompasses most of the Pantanal, a flat area seasonally flooded in the heart of South America of nearly 250,000 km<sup>2</sup>. Additionally, Brazil has most of its energy derived from hydroelectric plants, which include huge man-made lakes (reservoirs) (TUNDISI, 1980). With such a variety of freshwater ecosystems, Brazil leads inland water biodiversity in the world (AGOSTINHO et al., 2005). Taking into account the huge numbers cited above, we should expect a good development of Brazilian Limnology; if not in relation to that observed in developed countries, at least in relation to other science fields within the country.

In short, we asked: i) What is the relative contribution of Brazilian Limnology in international journals? ii) Is there any trend in this contribution during the period 1970–2004? iii) Is the contribution of Brazilian limnologists spread among journals or is concentrated in a particular group? iv) Do Brazilian articles receive the same frequency of citations than articles from other countries? v) What is the effect of type of co-authorship, number of authors and article length on the frequency of citation? vi) Is the Brazilian contribution equally spread among sub-areas or concentrated in a few of them? vii) Which Brazilian states and institutions are responsible for most of the articles published in international journals?

# Methods

We assessed the contribution of Brazilian articles in international journals in two ways. Firstly, we selected 13 international journals on limnology indexed by Thomson ISI (formerly Institute for Scientific Information) (www.isiknowledge.com) (Table 1). Selected journals were chosen from the 83 journals listed by ISI in the fields "Limnology" and "Marine and Freshwater Biology". The list of selected journals in which most of the articles were restricted to taxonomy/systematics (e.g. *Aquatic* 

Insects), terrestrial (e.g. Amazoniana) or marine (e.g. Coral Reefs) systems or are indexed in ISI for few years (e.g. Aquatic Ecology). Searches were restricted to the period 1970-2004, although some journals appeared after 1970 and in some cases journals were indexed only after a given year. The period covered in our analysis for each journal is shown in Table 1. We obtained the number of articles published by each journal and the number of these in which "Brazil" or "Brasil" appeared in the address field. From the search obtained above, we (i) analyzed the percentage of Brazilian articles in all journals against year, and (ii) the percentage of Brazilian articles in the period 2000–2004 against the Impact Factor of each journal in 2003. For item (i), we first fitted a simple linear regression and analyzed the residuals. This simple model was not adequate and we thus fitted a second order polynomial model. As the linear and quadratic terms of this model usually presents high collinearity (correlation among predictor terms), which could cause problems in fitting (KUTNER et al., 2004), we employed orthogonal polynomials. Additionally, we explored the observed relationship by tree regression in order to identify trend-periods in the interval 1970–2004. The method initially cut the predictor variable in two segments, each one composed by observations similar to each other. The process then follows partitioning the segments from the previous step. The partition process may stop in one branch (segment) or continue in both (KUTNER et al., 2004). The relationship percentage of Brazilian articles in the period 2000–2004 against the Impact Factor of each journal in 2003 (item (ii) above) was first explored by use of linear regression. Given the particular (triangular) arrangement of the data in the scatter diagram, we also tested whether such pattern could be generated by chance. We used the software Ecosim (GOTELLI & ENTSMINGER, 2001), module "Macroecology" to test the hypothesis that data were concentrated in the lower left hand corner of the diagram.

In the second part of our assessment, we conducted a detailed analysis regarding Brazilian articles published in *Hydrobiologia*, the journal containing the greatest number of Brazilian articles (Table 1). *Hydrobiologia* has a wide audience and publishes articles in all sub-fields of Limnology with no bias regarding organisms (e.g. algae, insects and fishes), type of ecosystem (e.g. natural and artificial lakes, streams and rivers) and approach (e.g. development of methods, taxonomy, experiments and survey-based studies). *Hydrobiologia* is indexed by Thomson ISI since 1971. However, we restricted this detailed analysis to the period 1978–2004, as only one Brazilian paper appeared in the journal in the period 1971–1977. The search was keyed to "Brazil" or "Brasil" appearing in the address field. For each abstract, we identified the year of publication, type of ecosystem, biological group, and institution. Articles with authors from different institutions were sorted as domestic or international. In the last case, we identified the partner countries. In all cases, we did not use references when the information contained in their abstracts were not clear or enough. Additionally, we contrasted the number of citations received by Brazilian articles with all other articles

published in *Hydrobiologia*. As old articles likely will receive more citations than those published recently, data on citations received by Brazilians or non-Brazilians was controlled for year of publication using an Analysis of Covariance (ANCOVA). As the number of publications belonging to Brazil are only a small fraction of the non-Brazilian publications, we used in the ANCOVA the mean number of citations per year and per origin (Brazil, non-Brazil) in our analysis.

We also contrasted the number of citations received by Brazilian articles according to the type of collaboration (non-collaborative, domestic, international) using Generalized Linear Models (family distribution = Poisson). In this analysis, year was considered a continuous variable and type of collaboration a factor with three levels. We tested the relationship between the numbers of authors and pages of articles published on *Hydrobiologia* against the number of citations received by these articles using the Pearson correlation coefficient.

Table 1. List of journals on Limnology indexed by Institute for Scientific Information (ISI) used to estimate the international contribution of the Brazilian Limnology

Journal	Code	Period	Published	Brazilian
			articles	articles
Aquatic Botany	AqBot	1977-2004	2053	24
Archiv für Hydrobiologie	AfH	1970-2004	3342	49
Canadian Journal of Fisheries and Aquatic Sciences <sup>1</sup>	CJFAS	1970-2004	9752	7
Freshwater Biology	FB	1974-2004	2725	12
Hydrobiologia	Hyd	1971-2004	12571	284
International Review of Hydrobiology <sup>2</sup>	IRH	1977-2004	1406	16
Journal of Freshwater Ecology	JFE	1981-2004	1136	0
Journal of Plankton Research	JPR	1982-2004	2523	32
Journal of the North American Benthological Society	JNABS	1989–2004	784	3
Limnology and Oceanography	LO	1970-2004	5715	18
Marine and Freshwater Research <sup>3</sup>	MFR	1970-2004	2615	9
River Research and Applications <sup>4</sup>	RR	1992-2004	524	6
Water Research	WR	1970-2004	9555	67
Total			54701	527

<sup>1</sup> From 1970–1979 as Journal of the Fisheries Research Board of Canada

<sup>2</sup> From 1977–1997 as Internationale Revue der Gesammten Hydrobiologie

<sup>3</sup> From 1970–1994 as Australian Journal of Marine and Freshwater Research

<sup>4</sup> From 1992–2001 as Regulated Rivers Research Management

# Results

The percentage of Brazilian articles in the period 1970-1980 was very low, the maximum occurring in 1977 (0.3%; 3 out of 999) (Figure 1). In many years of this decade, no article had Brazil in the address field of the selected journals. After 1980, we

observed a clear trend of increase in the participation of Brazil in the international scenario (Figure 1). In this period (1981–2004), the maximum occurred in 2001 when Brazil accounted for 2.2% of the published articles in limnology (48 out of 2176). The relationship depicted in Figure 1 was successfully fitted by a second order model (linear term p < 0.001; quadratic term p = 0.022). The exploratory regression tree method first partitioned the predictor variable (year) in Figure 1 at 1983.5. The second step of the analysis left intact the segment 1970–1983.5, but partitioned the segment 1983.5–2004 at 1999.5. The first segment (1970–1983.5) corresponds to the first period cited above when Brazilian contributions were low and relatively constant in time. The second period (1983.5–1999.5) reflects the continuous increase in participation of Brazil in the international scenario. The third and most recent period (1999.5–2004) shows a similar increasing trend observed in the previous period but at a steeper rate.



Figure 1. Percentage of Brazilian articles in relation to the total of articles published in the period 1970–2004 by 13 international journals in Limnology indexed by the Institute for Scientific Information (ISI). The list of journals and their period of coverage is shown in Table 1. The fitted curve is  $Y = 4.6811 - 0.1520*Year + 0.0012*Year^2$ . The quadratic term is significantly different of zero (test using orthogonal polynomials, p = 0.022)

Percentage of Brazilian contributions in international journals is variable in lowimpact journals but tended to be low and less variable in high-impact ones (Figure 2). Two deviants of the average relationship deserve comments. No Brazilian article appeared in Journal of Freshwater Ecology in the period. In contrast, Brazilians are authors in 4.78% of the articles that appeared in Hydrobiologia in the period 2000-2004. For this last journal, the maximum contribution made by Brazilian limnologists occurred in 2001 and was 6.81% (28 out of 411). We tested whether there was a significant relationship in percentage of Brazilian papers in a journal and its impact factor (Figure 2). Given the non-homogeneity of variances at different values of the predictor variable, we first transformed the response variable to square root. This transformation was chosen according to the Box-Cox procedure (KUTNER et al., 2004). The regression coefficient was negative, but not significant (p = 0.458). We observed that the transformation applied to the response variable was not enough to have homogeneity of variances at all values of the predictor variable. We thus used a second approach and tested whether data were concentrated in the lower left hand corner of the diagram, i.e. whether there was high scattering of data (low and high values of the response) at low values of the predictor variable and low scattering (only low values of the response) at high values of the predictor variable. Eleven out of the 13 data points were included in the lower left corner. There was not enough evidence to reject the null hypothesis that such concentration of data could be produced by chance (p = 0.32).

In order to evaluate the qualitative impact of the Brazilian Limnology in international journals, we carried out a detailed evaluation of the number of citations received by Brazilian articles in *Hydrobiologia* since 1982. There was a significant interaction in the proportional difference between citation frequencies of Brazilian and non-Brazilian with time since publication (interaction between "year" and "country": ANCOVA  $F_{1,42} = 12.10$ ; p = 0.001) (Figure 3). Brazilian articles tended to be less cited than articles authored by non-Brazilians, although this effect has decreased in recent years, as indicated by the significant interaction term.

The subject most studied by Brazilian limnologists and published in *Hydrobiologia* was plankton ecology (45.9%), particularly the sub-fields zooplankton ecology and taxonomy (25.2%). Marine invertebrate organisms were studied in 14.4% of the articles, followed by macrophytes (12.6%), benthic invertebrates (9.9%) and fish ecology (9.5%). Basic physical and chemical characterization of water was the subject with the lowest frequency in *Hydrobiologia* (7.7% of the articles). Regarding environment, the class with highest frequency was lentic waters (lakes and reservoirs; 44.3% of the articles), followed by studies in marine environments (including coastal lagoons; 25.7%) and lotic systems (streams and rivers; 18%). Only 4.2% of the articles were done in floodplains (lakes and rivers of seasonally flooded areas that were studied at the same time). Estuaries and mangroves were studied in 6% and 1.8%, respectively,



Figure 2. Percentage of Brazilian articles in the period 2000–2004 and impact factor of journals in 2003. Data from 13 international journals indexed by the Institute for Scientific Information (ISI). Key to the abbreviations of journals is in Table 1



Figure 3. Number of citations received by Brazilian articles (open circles) and non-Brazilian articles (filled circles) published in *Hydrobiologia* in the period 1982–2004

of the articles published in *Hydrobiologia* during the period analyzed. According to a Spearman's rank correlation analysis, we were unable to detect any significant trend in the proportion of studies within each research topic described above in the period 1990–2004 (for all fields, p > 0.05).



Figure 4. Percentage of the total Brazilian articles published in *Hydrobiologia* in the period of 1978 to 2004 according to the state of the author(s) (A) and institution (B). States: SP = São Paulo; PR = Paraná; RJ = Rio de Janeiro; AM = Amazonas; PE = Pernambuco; MG = Minas Gerais; GO = Goiás; RN = Rio Grande do Norte; SC = Santa Catarina; RS = Rio Grande do Sul; DF = Distrito Federal. Institutions: USP = Universidade de São Paulo; UFRJ = Universidade Federal do Rio de Janeiro; UEM = Universidade Estadual de Maringá; UNESP = Universidade Estadual Paulista;
UFSCAR = Universidade Federal de São Carlos; INPA = Instituto Nacional de Pesquisas da Amazônia; UFPR = Universidade Federal do Paraná; UFMG = Universidade Estadual de Campinas;
FURG = Fundação Universidade Federal do Rio Grande; IIE = Instituto Internacional de Ecologia;
UFRGS = Universidade Federal do Rio Grande do Sul; UFRN = Universidade Federal do Rio Grande do Norte; UFPB = Universidade Federal da Paraíba; FIOCRUZ = Fundação Oswaldo Cruz;
UFPE = Universidade Federal de Pernambuco; UERJ = Universidade do Estado do Rio de Janeiro; INST PESC = Instituto de Pesca

According to a geopolitical criterion, most of the studies were done in São Paulo, Paraná, Rio de Janeiro, and Amazonas (Figure 4a). Also, nearly all publications are based in government-supported universities or research institutes (Figure 4b).

Most of the Brazilian articles appearing in *Hydrobiologia* were non-collaborative, done by author(s) at a single institution (56.1% of articles). Domestic collaborations were found in 13.6% of the analyzed articles. Articles with international co-authorships accounted for 30.3% of the total and were most frequent with institutions from USA, England and Poland (Figure 5). Brazilian institutions with more co-authorship with USA were Instituto Nacional de Pesquisas da Amazônia (INPA; four in a total of 16 articles) and Universidade Federal do Rio de Janeiro (UFRJ; two articles). Contributions with England institutions were more frequent at Universidade Federal do Rio de Janeiro (UFRJ; two in a total of 12 articles). Most of the contributions with Poland were done with authors at Universidade Estadual de Maringá (UEM).



Figure 5. Countries of the co-authors appearing in collaborative Brazilian articles

In our analysis of the effects of type of co-authorship and time since publication on the citation counts of Brazilian articles, the interaction term was not significant (Deviance = 0.24, 2 df, p = 0.89). Number of citations received by Brazilian articles was affected by type of collaboration (non-collaborative, domestic, international) (Deviance = 34.46, 2 df, p < 0.001). Specifically, co-authored articles with international researchers tended to receive more citations (adjusted mean = 3.543, SE = 0.432,

n = 67) when compared to articles produced in a single institution (adjusted mean = 2.091, SE = 0.317, n = 124) or in two or more domestic institutions (adjusted mean = 2.477, SE = 0.654, n = 30).

The relationship between the length of articles authored by Brazilians in *Hydrobiologia* and the number of citation received by these articles was significant (r = 0.27; p < 0.001). We did not find a significant relationship between the number of authors and number of citation (r = 0.02; p = 0.669).

# Discussion

We could identify three phases regarding the contribution of Brazil to international Limnology in the period 1970–2004. Between 1970 and 1983, the Brazilian production in international journals was scarce, including years in which no articles had Brazil in its address field. After 1983, the relative contribution of Brazilian articles increased steeply, notably after 1999, with no sign of stabilization until the present. Despite this marvelous positive trend, most of the Brazilian contribution is directed to low-impact journals. For a science community not used to publish abroad, as revealed by the proportion of Brazilian articles in 1970–1980, we interpret this trend as a natural one, the first step.

Brazilian articles published in *Hydrobiologia* tended to receive fewer citations than articles from other countries. Also, Brazilian articles resulting from collaborations with authors from other countries received more citations than that resulting from domestic collaborations or no-collaboration. A similar pattern is observed in a recent study dealing with Management Sciences in Brazil (PEREIRA et al., 2000) and follow the general pattern noted by LEWISON (1991) and MENEGUINI (1996).

Despite the preponderancy of lotic systems (streams, rivers) and their large associated floodplains (e.g. Amazon, Panatanal) over lentic systems (standing waters) in Brazil, most of the Brazilian studies are done at natural and artificial lakes. Accordingly, taxonomic groups most frequently studied are those composing the plankton, important components in lentic systems but of limited importance in lotic systems. This finding may be explained by the effect of intellectual legacy. Important Brazilian limnologists in 1970's, which were the advisors of most current professional limnologists, worked and are still working on plankton ecology in lentic ecosystems (mainly in man-made lakes). In fact, TUNDISI (1980) commented on studies done in aquatic ecology in Brazil up to that date and only cites studies related to natural or man-made lentic ecosystems.

Around 70% of all Brazilian studies in *Hydrobiologia* were done by authors in four (São Paulo, Paraná, Rio de Janeiro and Amazonas) out of the 26 states in Brazil. Accordingly, the three institutions hosting the highest number of articles are located in the first three states cited above. Prominence of São Paulo is largely due to a solid state

agency of research (Fundação de Amparo à Pesquisa do Estado de São Paulo -FAPESP), which have granted research projects regularly for decades. The role of FAPESP is widely recognized elsewhere (ANDERSON, 1989; PEREIRA et al., 1998; MACILWAIN, 1999b). Paraná and Rio de Janeiro have relative well developed research centers and are also major states in other research fields (VELLOSO et al., 2004). Amazonas, when compared to other Brazilian states, is a minor research center and so the number of international publications in Limnology is noticeable. A possible explanation for such finding is the international collaboration with USA (as discussed below). The two most productive institutions in Limnology, Universidade de São Paulo (USP) and Universidade Federal do Rio de Janeiro (UFRJ), are also the major universities in Brazil. The large contribution by Universidade Estadual de Maringá (UEM) is due to an excellence-center in Limnology (NUPELIA), which has benefited from a multidisciplinary team that works intensively with international collaboration, receiving constant grants from different governmental and private institutions (e.g. Itaipú-Binacional, one of the largest hydroelectric plants in the world). Among the most productive centers in Brazil, the low number of Limnology articles from Universidade Estadual de Campinas (UNICAMP) (ANDERSON, 1989) is remarkable and likely reflects their traditional graduate course focused on evolutionary ecology of terrestrial ecosystems.

According to LEIMU & KORICHEVA (2005) longer papers may receive more citations than do shorter ones. Presumably, "longer papers have higher visibility in a journal and have more content that can be cited". In addition, the length of an article might also imply a quality element given the high competition for journal space. Additionally, "papers with more authors can receive more citations than did papers with fewer authors" (LEIMU & KORICHEVA, 2005). This may be related to an increased frequency of self-citations in multi-authored papers and "...the higher the number of authors, the larger the network of scientists that might know of one of them and, thus, cite them" (LEIMU & KORICHEVA, 2005). We found that Brazilian papers in *Hydrobiologia* have a weak but significant correlation between the length of an article (number of pages) and number of citation, corroborating the expectation above. However we did not find a correlation between number of authors and number of citations.

In many developing countries, including Brazil, there has been an increasing awareness of the need to develop science. In these countries, institutionalization of science is recent when compared to Europe and USA (VELLOSO et al., 2004). Brazil implanted in the end of 1960's a plan to develop its then incipient postgraduate system (Plano Nacional de Pós-Graduação) (the plan for the period 2005–2010 is described in CAPES, 2004). Brazilian universities received high-quality professionals from developed nations and sent many graduate students to universities in USA and Europe. Concomitantly, the number of granted fellowships increased steeply during decades (GUIMARÃES & HUMANN, 1995; LETA et al., 1998; CAPES, 2004). Cooperative projects

with international research centers were firmed, some of them currently still active. Accordingly, the number of PhD researchers formed each year increased, and resulted in a surplus of qualified people in traditional centers (e.g. São Paulo state), directing them to less developed centers. In fact, post-docs were uncommon in 1980's and contrasts to the current situation where people go for a second pos-doc before getting a permanent job. We argue that these investments in formation of human resources and its resulting effect on competition for permanent jobs resulted in an outstanding improvement in the average qualification of researchers, measured here as increasing proportions of Brazilian articles in international journals. Investments for funding projects apparently had a minor role in the increasing importance of the Brazilian contribution. In fact, the distinct and regular trend of increasing production of articles contrasts with the irregularity of investments for funding projects (LETA et al., 1998).

Additionally to the increasing investments in fellowships made in the last 30 years, we believe a second factor has been involved in the increasing participation of Brazil in international Limnology, namely the Brazilian evaluation system of postgraduate courses carried every two years since 1976 (GUIMARÃES & HUMANN, 1995). As the scores obtained by courses are used to decide the distribution of funds and fellowships, rules proposed by the national agency for graduate courses (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES) have been immediately followed by the courses. One of these rules is the qualification of publications. In the last years, the agency has pressed Brazilian scientists and students to publish as much as possible in high-quality international journals. For example, in Ecology-Limnology field a journal is best scored (termed "Qualis A") if (1) it is in a restricted list of Brazilian journals, (2) a Brazilian journal indexed by ISI (irrespective of impact factor; currently no Brazilian journal on Limnology is indexed) or (3) is an ISI-indexed international journal with impact factor > 0.5. Journals included in the first case above are planned to be best scored until 2007, when only cases two and three will be used to classify a journal in the best class. Taking in account the regularity and influence of CAPES evaluation (GUIMARÃES & HUMANN, 1995; CAPES, 2004), we speculate that the increasing proportion of Brazilian articles in international journals will continue in the following years and most pronouncedly in average-impact journals.

Despite the achievements discussed above, we are concerned about growing problems of water quality and quantity in the country. The myth of an inexhaustible resource must be extirpated from Brazilian society. Applied and theoretical Brazilian limnologists should use their increasing international presence in favor of this urgent task, advisoring and pressing governmental and non-governmental agencies concerned with water quality and quantity.

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LMB received a research fellowship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and PC a student fellowship from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). ASM thanks the graduate course "Mestrado em Ecologia e Evolução" hosted at Universidade Federal de Goiás for the opportunity to visit Goiânia in 2004 and which allowed us the planning of this article.

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