

Scientometric analysis of freshwater fisheries in Brazil: repeating past errors?

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Received: 7 June 2012 / Accepted: 2 August 2012 / Published online: 11 August 2012
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Abstract Freshwater fisheries are mainly small-scale activities and occur mostly in developing countries. These fisheries are recognized for its chronic lack of data and incipient knowledge when compared to large-scale fisheries, despite its socio-economic and food security relevance. Brazil is a good model of small-scale freshwater fisheries country because it shares similar characteristics and shortcomings of many other countries in South America, Africa and Asia, where these activities prevail. This work aims to carry out a broad and comprehensive analysis of the approaches and limitations of Brazilian freshwater fisheries studies through a scientometric analysis. We conducted an exhaustive survey of scientific platforms such as the Web of Knowledge Thomson Reuters (ISI), Scientific Electronic Library

Online (SciELO), Google Scholar and CNPq Lattes Curriculum Vitae Database. We found that the platforms ISI and SciELO were limited for this area of knowledge as they recovered only 47 % of the 186 studies reviewed. Brazilian freshwater fisheries studies were published in 72 journals and were conducted by 234 researchers, with very few specialists. On average the data processing into scientific information took 5 years, and half of the studies were conducted in short time scale (less than 2 years long) mostly by research institutions and universities. The number studies declined since the year 2008, after the creation of the Ministry of Fisheries and Aquiculture, which indicate that the fallacy of disregarding scientific knowledge may be permeating decision making agencies as already happen in the past in Brazil. The combination of these factors may cause slow and inefficient decision-making and management based on the best available science. Our results also highlighted the importance of multidisciplinary in the training of human resources to work in the fishing sector.

Keywords Inland fisheries · Stock assessments · Reservoir · River · Floodplain · Amazon

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Introduction

The world human population, which exceeded 7 billion in 2011 (Bloom 2011), consumed 130.8 million tons of fish in the same year (FAO 2012). Freshwater

fisheries are valuable suppliers to meet the growing demand for fish, its recorded production has increased almost linearly since 1950 (Welcomme 2011). Inland fisheries in developing countries are relevant both for food security, as protein suppliers, and for poverty prevention, as source of income and employment (World Bank et al. 2010). About 56 million workers in developing countries and 2 million in developed countries work on freshwater fisheries. Of the 9 billion dollars generated annually from the inland fisheries catches, 8 billion dollars come from developing countries (World Bank et al. 2010).

Fisheries of developed countries are in general, well studied; but the small-scale fisheries in developing countries may have its importance underestimated, since the national statistics of these countries have gaps (Garibaldi 2012), a problem of particular concern for inland fisheries (Welcomme 2011). In order to better estimate the magnitude of small-scale fisheries, the Fisheries and Agriculture Organization of the United Nations (FAO) devised the “Big Numbers Project”. Its preliminary results reinforced the fact that freshwater fisheries are greatly underreported due to its attributes of being mostly informal and much dispersed activities (World Fish Center and FAO 2008). Recent reviews on the state of world fisheries in general overlook omit small-scale and freshwater fisheries (e.g., Hilborn et al. 2003).

Deeply understanding fishing systems, especially small-scale fisheries, is an arduous task, because they are complex socio-ecological systems that need to be studied from different angles in a holistic manner, due to its multidisciplinary (McClanahan et al. 2009). Activities involved in fisheries science can be divided into monitoring, research and decision-making (Charles 2001). In a classic view, fisheries science is dominated by studies of fisheries ecology. However, both studies related to fisheries economy and the social processes should be included and analyzed together with the ecology of the resources (Castello 2008). Another key factor in fisheries science is the involvement of diverse stakeholders (Vieira et al. 2005), which include governmental institutions, international agencies, universities, private sector, organized civil society and fisher organizations (Charles 2001). Therefore, studies about management and governance are also critical to the understanding of fisheries systems (Castro and Mcgrath 2003; Agostinho et al. 2004a; Gomes et al. 2004; Castello et al. 2009).

In view of the complexity of fisheries systems, its socioeconomic relevance, and the chronic overlooking of small-scale fisheries in general and of freshwater fisheries in particular, there is an pressing need to assess the what has been learnt in the field of freshwater fisheries. Brazil is a good model to represent the small-scale inland fisheries country, because is one of the majors global producers of fish originating from inland fisheries (World Bank et al. 2010) and it partially encompasses the first and fourth largest hydrographic basins in the world (Amazon River basin and Plata River basin, respectively, Quirós 1990). Moreover, this country presents a typical framework of problems, such as the lack of systematization of national fishing statistics, which are likely to be shared among other countries that have relevant inland fisheries production. Although reported in periodic bulletins, the national fisheries statistics should be treated with caution since the national system for collecting these data is not reliable due to the lack of funding allotted for its functioning since the mid-1970s (Petrere 1995). Many studies have criticized the quality and quantity of fisheries data in Brazil (Welcomme 1990; Petrere 1995; Agostinho et al. 2007a; Junk et al. 2007), additionally, the available fisheries data is frequently or scattered in the scientific literature (Petrere 1989) or in unpublished internal reports that are difficult to access (Agostinho et al. 2007a). The precariousness of fisheries data associated with a high level of uncertainty in this area of knowledge (Kinas 1996) and the difficulty for decision-making institutions to carry out monitoring and management leads to poor utilization and over-exploitation of some of these resources in developing countries such as Brazil (Petrere 1986; Agostinho et al. 2007a; Mateus and Penha 2007).

In this work, we conducted a scientometric analysis of freshwater fisheries studies in Brazil in order to identify the following aspects: subject, funding agency, type of environment, types of fisheries; statistical/scientific tools, sampling coverage, temporal and spatial scale. In addition, an index was proposed that represents the time interval from data collection to the production of scientific information. Our objective was to contribute to the scientometrics of fisheries science, and also to provide information that can alert and help decision-making institutions. Studies using scientometric analyses have generate bold understanding of the performance of specific

areas of science. In Brazil, these techniques have been used in health sciences (Pereira and Escuder 1999), management sciences (Pereira et al. 2000), psychiatry (Leta et al. 2001; Figueira et al. 2003) and limnology (Melo et al. 2006).

Methodology

The theme of the analysis of this work was the studies on freshwater fisheries in Brazil. We made an exhaustive survey of the scientific literature. The search was done in two steps with the objective of obtaining an adequate representativity of these studies. The first was finalized in August 2011 and was carried out in the scientific platforms Thomson Reuters Web of Knowledge (ISI), Scientific Electronic Library Online (SciELO) and Google Scholar, while the second was performed in the platform Lattes, which is a *Curriculum Vitae* Database of the National Council for Scientific and Technological Development (CNPq; The National Research Council of Brazil). The studies found were tabulated in an electronic spreadsheet.

In the ISI and Google Scholar platforms, searches were initially made with the following terms (freshwater*; +; fish*; +; Brazil*), (Inland*; +; fisheries*; +; Brazil*) and (wetland*; +; fisheries*; +; Brazil*), but these terms yielded many non-relevant studies. Thus, in these platforms, the final search was carried out with the following terms (fishery; +; Brazil; +; fish*; -; marine; -; coastal; -; sea) combined with the operator “or” with other terms (fisheries; +; Brazil; +; fish*; -; marine; -; coastal; -; sea). Using this search format, all the works found in the exploratory phase were recovered in addition to other relevant ones. In the SciELO platform, the search term was “fisheries.” The order of the platforms searched was: ISI, SciELO and, lastly, Google Scholar. The authors of at least four studies were identified and a search was made in their curricula in the Lattes platform. As more studies were added to the database, a new search of curricula was carried out, following the same criterion. All the studies found in these searches were inspected to verify whether they truly addressed aspects relative to freshwater fisheries. For studies indexed in ISI, a temporal series was constructed of the number of citations that they obtained. With the purpose of finding the first study available in

the scientific literature about inland fisheries in Brazil, the references of the earlier studies were tracked.

The tabulation of the studies included information about the publication (year of publication, journal, index platform, authors and their institutions of origin and institutions providing financial or logistical support cited in the acknowledgments), the data utilized (data collected and initial and final dates of the collection of data), the study area (type of environment and localization) and the statistical tools utilized. When the investigator cited more than one institutional affiliation, only the main one was considered.

The studies were categorized with respect to the ecological level of organization (ecosystem, community, population), or whether they emphasized human aspect of fishing, and to the theme investigated. The following themes were defined *a priori*: Stock assessment; Ecology of fisheries; Human ecology; Economics; Fishery statistics; Local ecological knowledge; Genetics; Management; Impacts of dams on fishing; Legislation; Selectivity of fishing gears; and Socio-economics. Most of these themes are specific, while some are general. In the theme Ecology of fisheries we included descriptions of fisheries landings, analysis of fish catches according to explanatory variables such as abiotic factors, fishery location, and fishing gear, among others; prediction of captures; analysis of fish discard; and characterization of the fisheries fleets. The category Management encompasses studies related to conflicts in fisheries, analysis of fishery agreements and/or regimes of use; comparison of two or more different fisheries strategies; and analyses of management guidelines.

The studies were also classified according to the hydrographic basin in which they were conducted. The map of the hydrographic basin was generated from the data obtained by the System of Hydrological Information (HidroWeb, <http://hidroweb.ana.gov.br/>) of the National Agency of Waters (Agência Nacional de Águas 2011) utilizing the ArcExplorer program.

The institutions of origin of the investigators were categorized with respect to the type institutional in Research Institutions (all research institutions, centers and institutes of the Brazilian government or not, which can belong to universities), state and federal universities, international agencies, agencies of the federal, state or municipal government, private sector and organized civil society. The institutions cited as source of funding or logistical support were

categorized as CNPq (the main funding agency for research in Brazil), other government agencies (e.g., ministries, IBAMA—the National Environmental Agency, in charge of enforcement and environmental licensing—, ICMBio—National Environmental Agency, in charge of the Federal Protected Areas—and state environmental agencies), international agencies, public universities, foundations for research support/assistance, research institutions (all research institutions, centers and institutes of the national government or not, which can belong to universities), energy sector (public and private), organized civil society and private sector. The category CNPq was separate from the category government, because it could mask the other governmental institutions, due to its high participation.

Results

Search platforms and journals

Our study revealed that the publication in scientific journals of studies on freshwater fisheries in Brazil began in 1978, with two articles about Amazonian fisheries (Petrere 1978a, b), followed by two additional studies in 1983 (Petrere 1983a; Petrere 1983b). After 1983, with exception of 1987 and 1992, studies have been published every year (Fig. 1). Searches in the ISI and SciELO platforms showed in total 450 and 289 studies, respectively, and of these, only 88 pertained to freshwater fisheries in Brazil. Nonetheless, 186 studies were tabulated: 59, 29, 16 and 82

were found through ISI, SciELO, Google Scholar and Lattes, respectively. The number of citations for the 59 total studies found using the ISI platform was 386 (Fig. 1), 13 studies were cited at least 13 times, resulting in an H index of 13.

The first two studies on fisheries, cited above, were published in *Acta Amazonica*, a journal that published studies in the area of freshwater fisheries up to the date of this review, leading the list of journals that published the most studies in this topic (Table 1). However, this journal only publishes studies about the Amazon region. The 186 studies tabulated were published in 72 different journals, with an average of 2.5 studies published per journal; only 44 % of these journals had more than one study published each (Table 1). The dominant language of the publications was English; 103 (55 %) articles were in English versus 83 (45 %) in Portuguese.

Research institutions and funding agencies

The reviewed studies were conducted by 234 scientists. Although the number of authors was high in relation to the number of studies, nine of them authored more than 10 studies and 173 authors (74 %) published only one study each (Table 2). The 234 researchers were affiliated to 114 different institutions. More than half of the studies were completed by scientist of only four institutions: those of UNESP-Rio Claro (São Paulo State University at Rio Claro) carried out 18 % of the studies, Nupélia (Center for Research in Limnology, Ichthyology and Aquaculture) 13 %, UFAM (Federal University of

Fig. 1 Number of studies published per year (*black line*) and the number of times that the studies of the ISI platform were cited in the same platform per year (*gray bar*)

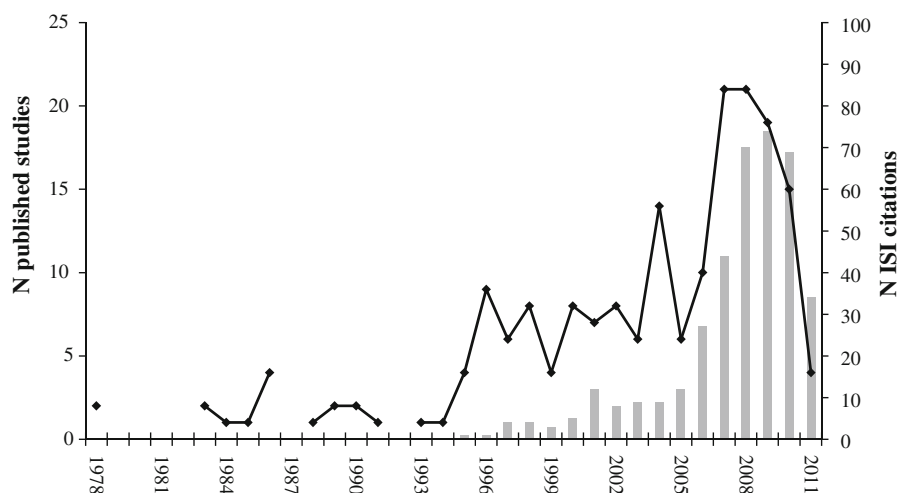


Table 1 Number of articles (N) on freshwater fisheries in Brazil per journal

Journal	N	Journal	N
Acta Amazonica	24	Neotropical Ichthyology	3
Brazilian Journal of Biology	16	Zoologia	3
Fisheries Management and Ecology	13	Brazilian Archives of Biology and Technology	2
Boletim do Instituto de Pesca	9	Brazilian Journal of Ecology	2
Fisheries Research	9	Canadian Journal of Fisheries and Aquatic Sciences	2
Acta Scientiarum Biological Sciences	5	Ciência e Cultura	2
Hiléia—Revista de direito ambiental da Amazônia	5	Environment Development and Sustainability	2
River Research and Applications	5	Environmental Management	2
Acta Scientiarum (formerly Revista UNIMAR; both extinct) ^a	5	Interciencia	2
Papers do NAEA	4	Italian Journal of Zoology	2
Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas	4	Journal of Applied Ichthyology	2
Novos Cadernos NAEA ^b	4	Pan-American Journal of Aquatic Sciences	2
IBAMA. Coleção Meio Ambiente. Série Estudos Pesca	3	Reviews in Fish Biology and Fisheries	2
Amazoniana	3	Revista Brasileira de Ecologia	2
Aquatic Ecosystem Health & Management	3	Revista Brasileira de Engenharia de Pesca	2
Boletim do Museu Paraense Emílio Goeldi. Zoologia	3		

Only the journals with 2 or more publications were listed. The journals that changed names are shown with their current name

^a An Acta Scientiarum was extinct, giving rise to several distinct journals belonging to the Acta Scientiarum Collection

^b Núcleo de Altos Estudos Amazônicos (NAEA)

Table 2 Number of studies on freshwater fisheries published per scientist, proportion of studies by type of institution, institutions of origin of the scientist and the type of institution provider of financial and/or logistic support

Human resources				Financial support			
Scientist	N	Type of institution	%	Institution	%	Type of institution	%
Petrere, M.	35	Research institutions	38.7	UNESP—RC	17.7	CNPq	36.6
Agostinho, A. A.	18	State University	35.5	Nupélia	13.4	Government	34.4
Gomes, L. C.	18	Federal University	34.9	UFAM	12.9	International Agencies	30.1
Batista, V. S.	16	International Institutions	16.7	INPA	11.8	Public Universities	16.7
Ruffino, M. L.	16	Federal Government	16.1	IBAMA	9.1	Foundations of Research Support	12.9
Freitas, C. E. C.	14	Private Sector	4.3	NAEA	8.1	Research Institutions	10.8
Almeida, O. T.	12	State Government	1.6	MPEG	5.9	Energy Sector	8.1
McGrath, D. G.	12	Municipal Government	1.6	UEG	4.3	Organized Civil Society	8.1
Isaac, V. J.	10	Organized Civil Society	1.6	UFAL	4.3	Private Sector	1.1

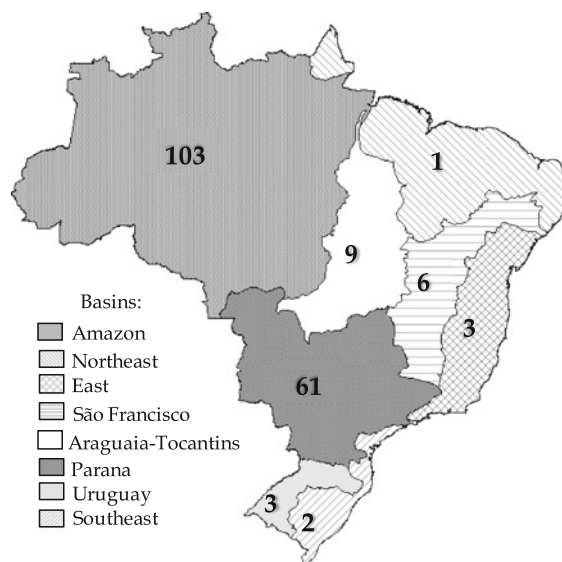
UNESP—RC São Paulo State University at Rio Claro, Nupélia Center for Research in Limnology, Ichthyology and Aquaculture, UFAM Federal University of Amazonas, INPA National Institute of Amazonian Research, IBAMA Brazilian Institute of Environment and Renewable Natural Resources, NAEA Center for Advanced Amazonian Studies, MPEG Paraense Emílio Goeldi Museum, UEG State University of Goiás, UFAL Federal University of de Alagoas

Amazonas) 13 % and INPA (National Institute of Amazonian Research) 12 % (Table 2). Financial and logistic support of these studies was awarded by 121 institutions: CNPq was cited in 36.6 % of the studies, other government agencies funded 34.1 % of the

studies, and international agencies were cited in 30.1 % of the studies. The Energy Sector, which may impose major changes in freshwater habitats due to dam construction, funded 8.1 % of the studies (Table 2).

Geographic distribution

The Amazon is the most studied basin (103 studies, 55 %), although only 8 studies (4 %) were about the Amazon region as a whole (Fig. 2). The second most studied basin was the Parana basin (a grouping of the Parana and Paraguai sub-basins), with 61 (33 %) studies (Fig. 2). The sub-basins of the Parana and Paraguai rivers were studied in 47 (25 %) and 15 (8 %) of the articles, respectively. Only one study covered the Plata River basin as a whole (composed of the the Parana, Paraguai and Uruguai rivers sub-basins). The North, Southeast, South, Central-West and Northeast regions of Brazil were topic of 108, 28, 27, 25 and 7 studies, respectively. The entire country was treated in a comprehensive analysis only in 5 studies (Fig. 2). The reservoirs were considered as the sole systems of analysis in 39 (21 %) studies. The remaining of the studies was in rivers (free flooding or dammed) and/or flood-plains. Artisanal fisheries (subsistence or commercial) were the studied exclusively, or in combination with other themes, in 174 (94 %) studies, while the rest (12, 6 %) studies focused on fishing at the industrial (3), recreational (8) and ornamental fisheries (1) levels.



State	N
Amazonas	62
Pará	45
Paraná	25
São Paulo	24
Mato Grosso	13
Mato Grosso do Sul	11
Minas Gerais	9
Bahia	5
Goiás	5
Acre	3
Rio Grande do Sul	3
Rondônia	3
Distrito Federal	2
Maranhão	2
Alagoas	1
Amapá	1
Ceará	1
Paraíba	1
Pernambuco	1
Piauí	1
Rio Grande do Norte	1
Roraima	1
Santa Catarina	1
Sergipe	1
Tocantins	1
Entire Amazon	8
Brazil	5

Fig. 2 Geographical distribution of the studies according to basin and State of Brazil. The hydrographic basins were standardized according to Agência Nacional de Águas (2011)

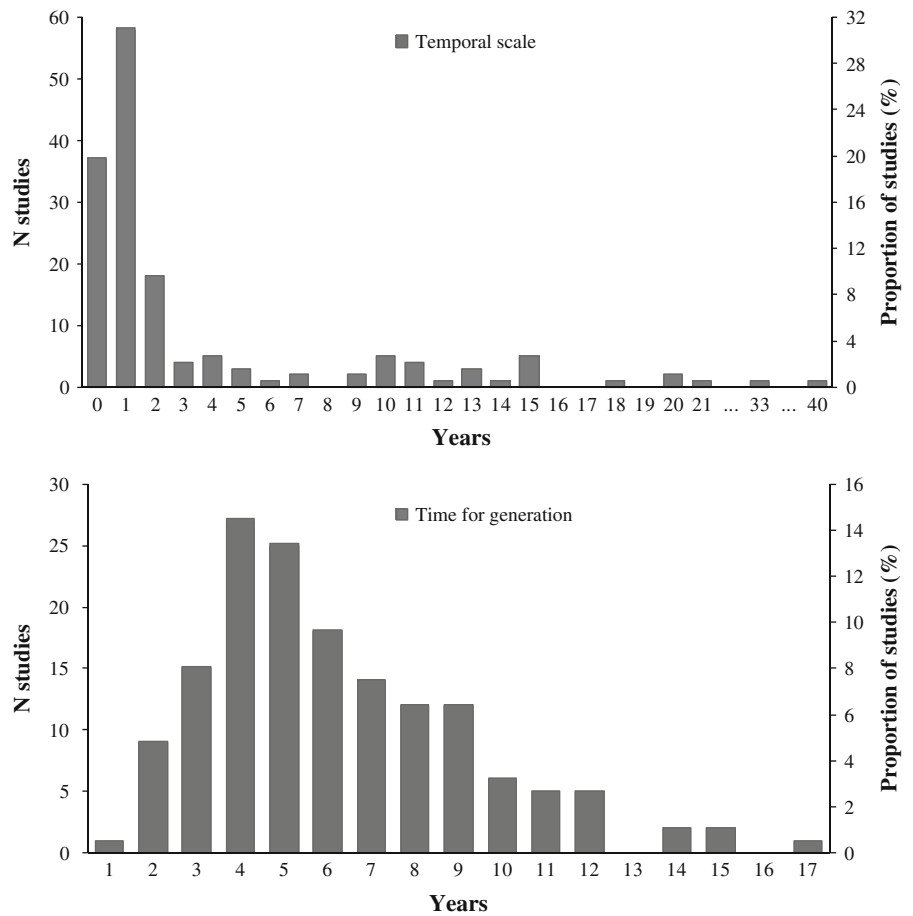
Temporal scale of the studies and time for generation of scientific information

The temporal scale of the studies was defined as the length between the first and last date of data collection, regardless of the sampling frequency. More than half the studies (51 %) had a temporal scale of up to 2 years, 20 % spanned less than 1 year, 9 % included 3–9 years of sampling and only 13 % were long term studies of over 10 years (Fig. 3).

The time for generation of scientific information was defined as the meantime between the last date of data collection and the publication of the study, that is, the moment when the data became accepted as scientific information. The time for generation of scientific information on inland fisheries was 5.2 ± 3 years; 8 % of the studies took more than 10 years (Fig. 3). In addition, seven studies did not mention the sampling dates.

Most studies (104) were undertaken at community level (that is were multispecific studies), followed by population (monospecific, 48), human (focus of analysis being the fishers, 33) and ecosystem (3) levels. The most studied species was the tambaqui *Colossoma macropomum* CUVIER, 1818 (7 studies). The spotted sorubim *Pseudoplatystoma corruscans*, pacu *Piaractus*

Fig. 3 Above histogram of the temporal scale of the study (period between the first and last collection, in years). Below histogram of the disponibilization of the scientific information (period between the last date of data collection and date of publication of the study, in years)



mesopotamicus and jarqui *Semaprochilodus taeniurus* were the target of 3 studies each.

Subjects/themes studied

The main themes of the reviewed studies from 1978 to 1986 were Ecology of Fisheries, Fisheries statistics, Fisheries stock assessment and Selectivity of fishing gears (Fig. 4). In this period, fisheries studies were dominated by the landing information and its analyses. More than half of the studies up to 2001 were about Fisheries ecology. This theme declined after 2002 and reached about 30 % of the studies between 2007 and 2011 (Fig. 4). General reviews on fisheries statistics and its methodology were published at rate of one every 10 years. Stock assessments were published in all periods, but notably in the first half of the 1990s. The proportion of studies about fisheries Management grew at the end of the 1980s and reached the peak after 2007 (Fig. 4). From 1995 to 1998, some studies

focused on the impacts of river dams on fisheries, a theme that regained interest after 2007. The human factor was not taken into consideration until 1996, when one publication on Human ecology came out. Since 1997, articles regarding social and economic questions rose to high numbers, reaching about 20 % of the studies up to 2001 and 30 % between 2002 and 2006 (Fig. 4). More than 40 % of the studies published from 2007 to 2011 were about the social, economic and/or management issues (Fig. 4). In the last decade, traditional and local ecological knowledge became the focus of several studies. Other themes that arose recently, although in low proportion, are those about Fisheries legislation and Fisheries genetics (Fig. 4), the latter consisted of only two publications in 2010.

Statistical/scientific tools utilized

The scientific tools used in the studies were categorized into 13 types (Fig. 5). The studies that only described

Fig. 4 Subjects treated in studies of fisheries in freshwater aquatic environments in Brazil up to August 2011

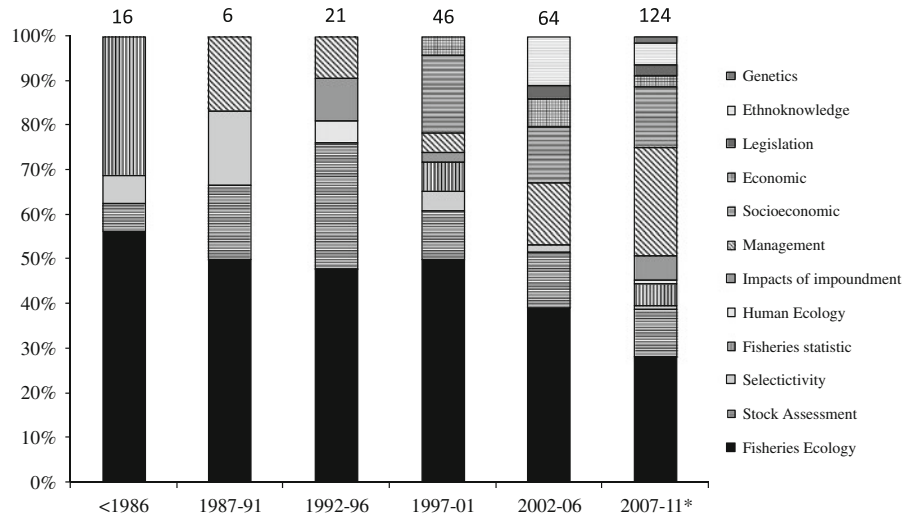
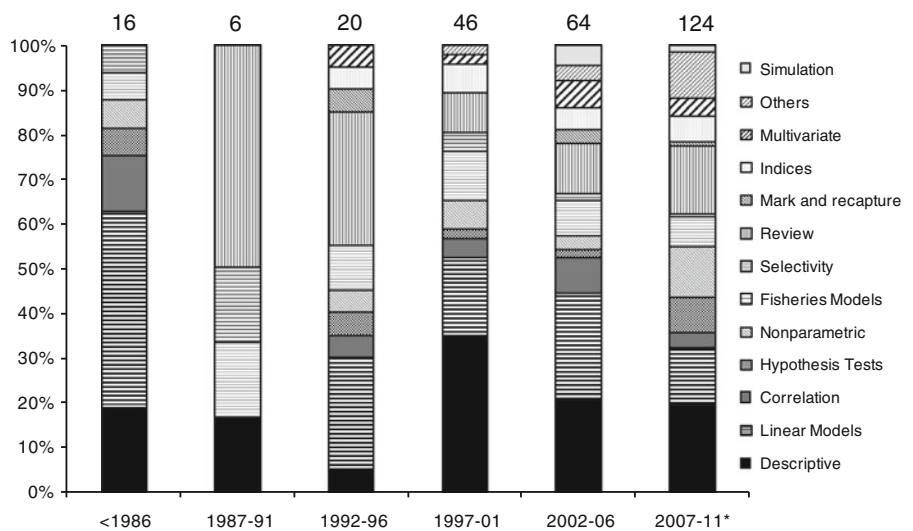


Fig. 5 Scientific tools utilized in studies of fisheries in freshwater aquatic environments in Brazil up to August 2011



the catch, catch per unit of effort (cpue), size distribution, relative frequencies or questionnaires results were classified as Descriptive. Descriptive studies were the most frequent ones, representing 21 % of all the studies and corresponding to 17 and 55 % of the studies on Fisheries ecology and socioeconomics (also including those purely on economics), respectively. The second type of tools most utilized were linear models (analysis of variance, linear regression and analysis of covariance) in 18 % of all the studies and 34 % of the studies on Fisheries ecology. Half of the studies on Fisheries ecology were Descriptive or utilized linear models. The review was another very frequently used tool, 61 % Fisheries ecology and management studies were

reviews. In the 1990s, studies emerged that utilized mark and recapture techniques, multivariate analyses (PCA, CA, DCA, MDS and cluster analysis) and indices (indices of diversity, dominance and similarity), as the main tools (Fig. 5). Among the studies that applied fisheries models, 15 (68 %) used yield per recruit models. The Schaefer and spawning biomass per recruit models, surplus production model and stock-recruit relations composed the remainder of the category Fisheries models. From 1997 to 2001, a new tool was applied, stable isotopes (classified as others in Fig. 5). As of 2004, studies using Simulation techniques (such as Ecopath with Ecosim and risk analysis) were published (Fig. 5). All the studies on Gear

selectivity and Fisheries legislation made use of the fit of selectivity curves and literature reviews, respectively, as scientific tools.

Discussion

The main government agencies related to scientific research in Brazil, CNPq and CAPES (Coordination for the Improvement of Higher Education Personnel; *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*), were created in 1950 and 1951. However, the first step towards the start of fisheries research in the country was the creation of the Superintendency for the Development of Fishing (SUDEPE; *Superintendência do Desenvolvimento da Pesca*) by Delegated Law No. 10 in 1962, which had on its mandate the fulfillment of scientific studies in order to base the updates of laws related to fisheries or fisheries resources. In 1967, the Fisheries Research and Development Program was formed in Brazil by Decree No. 60.401 and in 1968 the Decree No. 63.164 concerned with exploration and research on Brazil's continental shelf, territorial seas, and continental waters. In this last decree, research was defined as any activity concerning filming and recording, and it was authorized only by previous audience with the Brazilian Navy (*Ministério da Marinha*).

A relevant policy for the development of national fisheries was that of fiscal incentives established by Decree No. 221 of 1967 and in force up to 1972. Tax deductions were made for investments in fisheries projects, which increased substantially the fishing capacity and lead to overfishing of some stocks (Abdallah and Sumaila 2007). However, in SUDEPE's first 10 years, the systematization of research was unsuccessful; from 1967 to 1972 no allotment of fiscal incentives for research and of fisheries stocks assessment was made (Giulietti and Assumpção 1995). In 1980, the Decree No. 85.394 included the Fisheries Research and Development Program in Brazil in the basic structure of SUDEPE and transformed it into the Institute of Fisheries Research and Development. Before this law, only two scientific studies about freshwater fisheries had been conducted in Brazil (Petrere 1978a, b), both published in *Acta Amazonica*, created in 1971.

With the end of the military regime, the new constitution of 1988 and the creation of IBAMA in

1989, the number of studies regarding Brazilian freshwater fisheries increased. This trend was also found for ichthyological studies of Brazilian freshwater environments Azevedo et al. (2010). Between the creation of the Special Secretariat of Aquaculture and Fisheries (SEAP; *Secretaria Especial de Aquicultura e Pesca*) in 2003 and of the Chico Mendes Institute of Conservation of Biodiversity (ICMBio) in 2007, the number of studies increased again, reaching a peak of scientific production in the years of 2007 and 2008. However, in the year of the creation of the Ministry of Fisheries and Aquaculture (MPA; *Ministério da Pesca e Aquicultura*), the number of studies declined, with 21, 19, 15 and 4 studies being published respectively in the years of 2008, 2009, 2010 and 2011 (first semester only). This trend may be an indication that MPA is repeating the same mistakes as SUDEPE, which focused its efforts and funding exclusively on the increase in fisheries production and failed to promote scientific research and decision-making based on science. The number of studies published increased markedly between 1994 and 1997, nearly 5 years after the creation of IBAMA, which was the average time for generation of scientific information that we found in this study. In contrast, the decline in the publication of studies after 2008 coincided with the 5th anniversary of the creation of SEAP. In addition, the shift of research focus from fisheries to aquaculture production could have also accounted for this decrease on inland fisheries studies. This situation of hindering of fisheries research is worrisome and may lead to the perpetuation of errors and bad habits of decision-making without taking the scientific results into account (Petrere 1989; Agostinho et al. 2004a).

With regard to indexing platforms, it should be pointed out that the ISI platform does not contain the majority of the studies in the fisheries area found in our analysis, where only 31 % the studies were recovered. This finding can be attributed to the relevance of national scientific communication which, depending on the scientific subject, can be more expressive than international communication (Meneghini et al. 2006). These authors also pointed out the importance of the SciELO platform for the recovery of regional studies for Brazilian science (Meneghini et al. 2006). Our study also demonstrated the importance of the Lattes platform as an alternative way of searching when performing scientiometric studies. This platform is one of the cleanest databanks of research scientists in

existence (Lane 2010) and a suitable tool for analyzing Brazilian scientific productivity (Leite et al. 2011). As already noted by other authors, the utilization of ISI indicators to evaluate scientific projects and the performance of the researchers by the agencies stimulating research should be viewed with caution (Meneghini et al. 2006), since it does not adequately include national scientific communications, of particular importance for some subjects, such as Brazilian freshwater fisheries.

Scientific studies in the area of fisheries are published in a much dispersed manner and of difficult access, as previously pointed out by Petrere (1989). This fact demonstrates the need for journals that meet the demand of this area of knowledge, bringing together multidisciplinary studies, especially those with fisheries as the main theme, which was also pointed out by Castello (2008). However, it is important to note that this work was about studies published in scientific journals and did not consider other relevant sources of information on inland fisheries publications such as books (e.g., Okada et al. 1996; Ruffino 2005; Agostinho et al. 2007a), FAO reports (e.g., Petrere and Agostinho 1993; Agostinho et al. 1994; Quirós 2004) and COMASE documents (Coordinating Committee of Environmental Activities of the Energy Sector; *Comité Coordenador das Atividades de Meio Ambiente do Setor Elétrico*; Comase 1994).

Many researchers published studies on freshwater fisheries in Brazil, of those 74 % published only one article. This showed that the majority of the authors are not dedicated exclusively to fisheries science. Few research scientists published more than 10 studies, which indicate the lack of specialists in the area. Perhaps this is the result of the small number of graduate programs with the main emphasis on fisheries. CAPES, which is the solely regulator of high education in Brazil, recognizes seven graduate programs in Brazil that may allow for fisheries studies in general (marine and freshwater; *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* 2011). Brazilian scientific productivity is correlated with the quantity of master's and doctoral scholarships, which emphasizes the importance of investments in capacity building (Leta et al. 1998). Moreover, Brazilian scientific productivity is more influenced by human factors than by equipment and other material facilities (Fonseca et al. 1997).

The researchers who published the most scientific studies about inland fisheries had diverse academic training; only one was an undergraduate on Fisheries Engineering. In addition, it was observed that the requisites of an open competition for positions at the Ministry of Fisheries and Aquaculture restricted the required training to undergraduate in engineering (MPA Announcement 001/2010, May 11, 2010). The Research Institutions were the main institutional representatives of the research scientists, particularly Nupélia, INPA, Center for Advanced Amazonian Studies (NAEA) and Emilio Goeldi Paraense Museum. These institutions do not have fisheries as the main research theme but are those that produce the most knowledge in the area, demonstrating the importance multidisciplinary in fisheries science. Public universities also stand out, because they represent the institutions of some of the few specialists in the subject. Also, those specialists did not belong to academic departments exclusive for fisheries. The majority of the Brazilian scientific community is affiliated with public universities (Leite et al. 2011). At the institutional level, the influence of the international community should be emphasized, mainly by the financial support of the studies.

In our review, the first study conducted outside the Amazon basin was in the Cuiaba River (Pantanal) and indicated the dependence of the system river-floodplain on the seasonal hydrological cycle for maintenance of the structure of the assemblages of fishes, especially the migratory fishes, and anticipated the likely impacts that the Manso Reservoir could have on the system (Ferraz de Lima 1986). In 1989, the second study not exclusive for the Amazon basin was published, which was a review of the fisheries in Brazilian rivers (Petrere 1989). In this study, the formation of reservoirs was again indicated as one of the main threats to freshwater fisheries. Therefore, it is possible to infer that the reason for initiating studies on fisheries in other localities was the damming of rivers (for hydropower generation), because of their enormous environmental impact especially due to the resultant change in the hydrological flood of the river, the main forcing function of fluvial system (Junk et al. 1989). These damming generate changes in the structure of the ichthyological community which, besides an environmental impact, causes a large social impact, because artisanal fisheries are affected by the substitution of migratory species of high commercial

value by species of low value (Hoeninghaus et al. 2009). In the second half of the 1990s, the impacts of the formation of the reservoirs began to be studied (e.g., Ribeiro et al. 1995; Petrere 1996; Silvano and Begossi 1998). The emergence of these studies can be associated with the fact that COMASE organized a work group, composed of diverse group of scientists, in order to systematize knowledge of the Energy Sector and provide elements to establish directives on aquatic fauna management, through the Seminar on Aquatic Fauna and Brazilian Energy Sector, initiated in 1993 (COMASE 1994).

The results of this research corroborated the claim that the Amazon basin is the most studied one (Petrere 1995). This basin was the target of important fisheries monitoring programs of initiated by Petrere (1978a, b) and by the IARA and ProVarzea projects (Isaac and Ruffino 2000; Ruffino 2008). This region also relies on distinguished research institutions such as INPA (Azevedo et al. 2010), Federal University of Amazonas, NAEA and Emilio Goeldi Paraense Museum. The Parana River basin was the second most studied one (Fig. 2). The sub-basin of the Parana River is the best studied in South America according to Petrere (1995), due to Nupélia and its agreement with *Itaipu Binacional*. The fisheries monitoring system in Itaipu reservoir by Nupélia started in 1987 and it has assembled a time series of almost 25 years of data, one of the longest in Brazil (Okada et al. 2005). Another well-studied environment in this sub-basin is the floodplain of the upper Parana River, which through various partnerships between Nupélia, FIN-EP, CNPq and Multidisciplinary Environment Study Group (GEMA—*Grupo de Estudos Multidisciplinares do Ambiente*), has been monitored since 1986 (Agostinho et al. 2004b). In the case of the sub-basin of the Paraguai River, there were initiatives of fisheries monitoring such as the Fisheries Control System of Mato Grosso do Sul, in place between 1994 and 2003 and the Fisheries Control and Monitoring System of Mato Grosso started in 2006 (Catella et al. 2008). The Tocantins River basin, through a partnership between Brazil and France (CNPq and OR-STOM), had a project overseen by INPA, between 1980 and 1988, for the monitoring of the lower Tocantins and Central Amazonia (Mérona 1990). The Northeast basin was investigated by a single study, despite the large quantity of data collected by DNOCS since 1950 (Gurgel and Fernando 1994). While these

initiatives of fisheries monitoring relied on the partnership between several national and international institutions, the mandate to manage the National System of Fisheries Statistics has been shifted around several agencies over the years such as the Brazilian Institute of Geography and Statistics (IBGE), IBAMA and currently MPA. This situation has contributed to the loss of this information's credibility (Petrere 1995; Freire and Oliveira 2007).

Despite the existence of programs for long term fisheries monitoring, most of the studies have a short time scale, which hinders conclusions about the dynamics of fisheries stocks. The short term of the studies combined with the lack of standardization of the data collection, especially data on fisheries effort, prevents quantitative comparisons between studies (Agostinho et al. 2007a). After data collection further analyses need to be done in order to translate the data into scientific information in which to base the decision-making (Charles 2001). However, the long time spend for the transformation of the data into scientific information is worrisome. We showed that the scientific information is made available, on average, more than 5 years later after the conclusion of the study, which prevents the development of management policies based on the scientific results. These facts taken together contribute to turn the decision-making and management slow, inefficient, and mainly ineffective processes.

The only industrial freshwater fishery in the country targets the “piramutaba” catfish (*Brachyplatystoma vaillantii*) at the mouth of the Amazon River (Petrere 1995). Industrial fisheries are characterized by their enhanced capacity for concentrated fishing in a monospecific strategy. Although this fishery focuses on a specific stock, there is large amount of discard, including individuals smaller than 40 cm are not used (Bayley and Petrere 1989). Studies on population dynamics and stock assessment would be appropriate in this strategy (Coates et al. 2004), but no scientific study with these aims in the scope of this review was found.

The dominant fisheries strategy in Brazil is multi-specific fishery (Petrere 1995). Many authors contest the utilization of monospecific models and conclude that multispecific models respond better to this situation (Bayley and Petrere 1989; Mérona 1995; Coates et al. 2004). However, in predominant multispecific fishing, the efforts of fisheries are concentrated on

species of high commercial value, which over the years have been overfished (Petrere 1986; Agostinho et al. 2007b; Junk et al. 2007; Mateus and Penha 2007). Therefore, it is necessary to make multispecific evaluations, but the assessments of the most socio-economically important stocks must be realized too, to carry out a combined management (Bayley and Petrere 1989). Another option is the ecosystem approach, which though recently has contributed to the management of Brazilian freshwater fisheries, where three studies on this subject are included in this review (e.g., Angelini et al. 2006a, b).

The high complexity of Brazilian freshwater fisheries is related to the large fish and habitat diversity (Agostinho et al. 2007b), wide range of stakeholders (Vieira et al. 2005) and the multiplicity of fisheries' strategies (Bayley and Petrere 1989). National fishing is dominated by artisanal/subsistence or food fisheries, but industrial, recreational and ornamental fisheries also needed to be studied and managed, which requires adequate scientific literature. Unfortunately, this study demonstrated that the quantity of research for these fishery sectors is far from satisfactory (Carvalho and Medeiros 2005; Pelicice and Agostinho 2005; Frédou et al. 2010).

Conclusion

The multidisciplinary of inland fisheries was confirmed by the diversity of journals utilized as paths for scientific dissemination, the large number of authors with few studies published, the low proportion of specialists, the wide diversity of subjects studied, and the variety of scientific tools utilized. The multidisciplinary should be the focus of training and capacity building of human resources to work in fisheries, regardless whether on the scientific, decision-making, administrative, legislative and/or production sector.

The ISI and SciELO platforms appeared to be limited for determining the main scientific publications on the subject of inland fisheries. The scientific studies are published in a much dispersed way, and they are in general of difficult access, showing the need for journals that meet the demand of this area of knowledge, bringing together multidisciplinary studies, with fisheries as the main theme. However, it was observed that there is plenty of information on inland fisheries and that the subjects of studies are evolving

and diversifying in order to meet the needs of the area. The problem seems to be more related to the availability of these studies.

The scientific studies on freshwater fisheries in Brazil are mostly of reduced time scale and take a long time to transform the data into scientific information (publication). The number of studies decreased after 2008, when the Ministry of Fisheries and Aquaculture was created, indicating that this new agency may be repeating the errors of the past of not basing the decision-making on relevant scientific information. All these factors combined can turn the decision-making and fisheries management slow and mainly inefficient processes. The scenario found in Brazil may also represent the reality of many other countries in South America, Africa and Asia, where inland fisheries represents an activity of great relevance.

Acknowledgments We thank the Coordination for the Improvement of Higher Education Personnel (CAPES; *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*) for financial support, Luiz Carlos Gomes and Horácio Ferreira Júlio Jr. for reviewing the paper, José Augusto Ferraz de Lima for providing unpublished reports.

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