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Fishing for gaps in science: a bibliographic analysis of Brazilian freshwater ichthyology from 1986 to 2005

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To investigate Brazilian freshwater ichthyology, from 1986 to 2005, a bibliometric analysis was conducted using abstracts downloaded from *The Web of Science* database searching for the key-words 'fish', 'pisces', 'teleostei' and the address field having the word 'Brazil'. The results of this study showed that Brazilian freshwater ichthyology publications have been increasing during the study period. This process is a consequence of a series of investments that the Brazilian Government has made. Furthermore, data analyses identified scientific areas where there was a lack of scientific knowledge (*e.g.* studies of species threatened with extinction and certain hydrologic basins). Research institutions from the north-east and northern region of Brazil had the lowest participation in scientific productivity, which was a reflection of their regions poorer economic situation. This study showed that scientific productivity in Brazilian ichthyology was a direct reflection of state investment in research. Furthermore, data in this study follow expected statistical probabilities, for example, fishes from the most diverse families were the most studied. Thus, the study shows that great progress has been made by Brazilian ichthyologists in the last 20 years; however, due to the mega diversity of fishes in Brazil, much remains to be done if many species are to become known to science and to be saved from extinction. This it seems will depend on continued and further investment by Brazilian Government funding agencies, as Brazilian ichthyologists have demonstrated their capacity to generate high quality information about their study species.

Key words: fishes; fresh water; gap analyses; neotropical; scientific production; teleostei.

INTRODUCTION

What is the situation of research on the freshwater fishes of Brazil? What has been done? What needs to be done? What could be improved? These questions need to be addressed and answered without delay because the current degradation of Brazil's inland waters will have lasting consequences for biodiversity, human well-being and livelihoods. The present article deals with the contribution of scientific information to the conservation of freshwater fishes, an issue that is central to the scientific study of and the sustainable management of fish stocks. For example, the São Francisco River supports one of the major Brazilian fisheries, and is a significant resource for generating socioeconomic improvement to a great part of the country but, after many years of degradation, the amount of fishes captured decreased from 11·7 kg

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fisherman^{-1} day^{-1} in 1987 to 3·1 kg fisherman^{-1} day^{-1} in 1999, at the Pirapora Rapids (Godinho & Godinho, 2003).

The Neotropical region is known for its mega diversity of fishes with *c*. 4500 described species. The estimated total number of Neotropical fishes is between 6000 and 8000 (Schäfer, 1998; Reis *et al*., 2003; Buckup *et al*., 2007). Brazil is the largest country in the Neotropical region (8 547 404 km^2) and has the most freshwater fish species. Currently, 2587 described freshwater fishes exist in Brazil, which represents *c*. 22% of the world's freshwater fish species (Buckup & Menezes, 2003; Buckup *et al*., 2007). Neotropical fishes contribute 13% of all vertebrate biodiversity, occurring in <0·003% (by volume) of the total world's water.

Nevertheless, some authors argue that the precise number of species in Brazilian inland waters is not only unknown but difficult to estimate because numerous hydrographic basins have never been sampled, the number of researchers and infrastructure required for sampling and monitoring are insufficient, aquatic inventories have, until recently, been few, information is scattered and often difficult to access, and a number of groups need major taxonomic revisions (Agostinho *et al*., 2005).

Gap analyses have been used in conservation programmes to indicate geographic areas to be preserved or even species that need to be conserved (Lipow *et al*., 2004; Oldfield *et al*., 2004; Yip *et al*., 2004; Shaffer & Costa, 2006; Trisurat, 2007). This concept of preservation and conservation could equally be applied to other areas such as ichthyology. Azevedo *et al*. (2006) undertook a bibliometric analysis of the literature related to environmental enrichment and were able to identify some areas of concerns, such as failing in experimental design. Such analyses are becoming even more important due to the various crises facing human society, in the case of ichthyologic research the ecological crisis (Angermeier, 2007). A bibliometric analysis on Brazilian ichthyology would determine which kind of studies have already taken place and what studies are necessary. This type of analysis is facilitated by online scientific article databases (*e.g.* The Web of Science) and reference management software (*e.g.* Endnote 5).

The goal of this study was not to provide a theoretical review of Brazilian freshwater ichthyology, but to analyse quantitatively this area of research so that realistic recommendations could be made in relation to gaps in present knowledge. Furthermore, by limiting the study to articles produced with at least one author with an address in Brazil, it is possible to estimate the potential of this country to conduct studies about its ichthyofauna. Beyond this, this study attempted to investigate how economic factors have been affecting scientific productivity in Brazil as well as freshwater fishes conservation.

MATERIALS AND METHODS

The data presented here were collected from the scientific articles database, The Web of Science. It is considered to be the largest multidisciplinary database available online (Azevedo *et al*., 2006). From *The Web of Science*, it is possible to obtain full articles, abstracts and bibliographic references. Moreover, journals available have been analysed by the Journal of Citation Reports, an authority that evaluates the quality of scientific journals globally (Thomson Scientific, 2005). Besides this, *The Web of Science* has truly international coverage, an important characteristic since some databases are limited to certain sort of publications (Melfi, 2005).

For this study, the keywords 'fish', 'pisces' and 'teleostei' were used to search for articles. Additionally, the word 'Brazil' was used in the address field, as the goal of this study was to investigate only Brazilian-based research. The research was limited from 1986 to 2005 (inclusive) as this comprised the time from the end of military government, moving through the economic instability of the 1990s and terminated in the economically stable and growth period of the new millennium in Brazil (MacLachlan, 2003). Initially, 1445 article abstracts were found and downloaded into a reference manager software (Endnote 5; www.endnote.com). Then, each abstract was analysed to confirm that it was indeed about Brazilian freshwater ichthyology. Six hundred and eighty-two articles were rejected from the database (many about saltwater fishes, molecular biology techniques and repeated papers).

Data in this study, therefore, refer to the content of 763 abstracts downloaded from The Web of Science in September, 2006. Although it would be better to analyse full articles, this proved to be logistically impossible. Azevedo *et al*. (2006) demonstrated that the use of abstracts can produce highly satisfactory results in bibliometric analyses, since they usually contain all relevant information. There were occasions, however, when the abstracts did not have all the necessary information, in these cases data were classified as unknown and were shown as such in the results.

The following data were collected from each abstract: (1) year of publication, (2) fish species and family, (3) conservation status of the species, (4) if the species was exotic to Brazil, (5) scientific area (*e.g.* systematics, physiology and behaviour) of the paper, (6) journal of publication and its impact factor for 2005, (7) geographical region of research and institution (state or country) for corresponding author and (8) the hydrological in which basin research was performed. It is important to note that the taxonomy of fish species found in The Web of Science was confirmed using the *Fishbase* website (http://www.fishbase.org).

Although the journal *Neotropical Ichthyology* does not belong to the database of *The Web of Science*, it is a relevant journal for Brazilian research. It emerged in 2003 as an alternative for international dissemination of scientific research, mostly Brazilian studies, concerning the Neotropical fish species. Thus, it is important to carry out a similar analysis to that previously described on the articles published in this journal. There were 307 articles on freshwater fish species in the period from 2003 to 2009. The following data were collected from each abstract: (1) fish species and family, (2) conservation status of the species, (3) if the species was exotic to Brazil, (4) scientific area of the paper and (5) the hydrological basin in which research was performed. These data were treated separately, since the publications started in 2003 and referred to a single journal.

Data relating to how many post-graduate research programmes, universities and other scientific institutions that exist in Brazil were collected from the appropriate websites of the Brazilian Government [Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Financiadora de Estudos e Projetos (FINEP) and Ministério da Ciência e Tecnologia. Indicadores nacionais de ciência e tecnologia (MCT)]. In Brazil, scientific journals are ranked by CAPES through their system QUALIS into three categories (A, B and C), which are based on median impact factors for the scientific area in question. Thus, an article QUALIS A has an impact factor equal to or greater than the median for its scientific area, an article QUALIS B has a impact factor from greater than zero to the median for its scientific area and finally a QUALIS C article is one that comes from a journal with no impact factor (CAPES, 2008).

Data were analysed using the Anderson–Darling test to see whether they met the requirements for parametric statistics, which they did not; therefore, only non-parametric statistical tests were applied. The Spearman's rank correlation to investigate relationships between variables was used in this study. All analyses were conducted in Minitab 13 for Windows. Number of analysed cases varied according to information available in each abstract, therefore, N may be smaller than the total number of abstracts (763).

RESULTS

The number of articles published from 1986 to 2003 increased gradually with the exception of 1987, where only three (0·39%) articles were registered. In 2004 and

2005, there was a considerable increase in scientific publication, representing 18·19% ($N = 139$) and 19·50% ($N = 149$) of all articles in the database. It is important to note that until 2004 the highest number of publications occurred in 1995 (7·33%, $N = 56$). A Spearman's rank correlation between year and number of articles was positive and significant ($r_s = 0{\cdot}755$, $N = 20$, $P < 0{\cdot}001$). This result was expected due to the leap in scientific productivity in 2004 and 2005. Therefore, correlation was performed again, but without the years 2004 and 2005; it was also positive (less strongly) and significant ($r_s = 0{\cdot}664$, $N = 18$, $P < 0{\cdot}01$).

Brazilian freshwater fish studies were performed in 145 institutions: 94 Brazilian and 51 from 15 other countries (Argentina, Australia, Belgium, Canada, France, Germany, Hungary, Japan, Netherlands, Poland, Portugal, Spain, U.K. and U.S.A.). From the 27 Brazilian states, 16 were represented with articles in the database; notably Sao Paulo State (south-east region) contributed to 39·34% ($N = 299$) of the articles (Table I). Therefore, as expected, the three Brazilian institutions with the highest number of publications were from this state: Federal University of Sao Carlos (12·84%, $N = 98$), University of Sao Paulo (11·40%, $N = 87$) and State University of Sao Paulo (UNESP–Botucatu) (8·13%, $N = 62$) (Table II). The two foreign countries with the highest participation in scientific productivity were the U.S.A. (3·29%, $N = 25$) and Portugal (2·63%, $N = 20$).

TABLE I. Brazilian freshwater ichthyology scientific production (1986–2005) by the most prolific Brazilian states and their academic institutions

State	UNIV*	PPG†	Number of articles+	%‡	%§
São Paulo	38	57	299	39·34	44·36
Paraná	11	17	117	15·39	17·36
Rio de Janeiro	18	25	77	10·13	11·42
Amazonas	2	10	60	7·89	8·90
Minas Gerais	22	24	44	5·79	6·53
Rio Grande do Sul	16	21	38	5·00	5·64
Mato Grosso	3	2	8	1·05	1·19
Santa Catarina	12	6	8	1·05	1·19
Distrito Federal	2	5	6	0·79	0·89
Acre	1	1	5	0·66	0·74
Bahia	8	10	5	0·66	0·74
Pará	4	6	2	0·26	0·29
Pernambuco	5	9	2	0·26	0·29
Ceará	5	7	1	0·13	0·15
Goiás	4	3	1	0·13	0·15
Mato Grosso do Sul	5	4	1	0·13	0·15
Total	—	—	674	88·33	—
Countries	—	—	86	12·76	—

+, total number of articles (N) published about freshwater fish in Brazil (1986–2005).
*, Number of universities for each state (INEP, 2007).
†, Number of post-graduate research programmes for each state, according to (CAPES, 2007).
‡, Percentage of total number of articles in the database ($N = 763$).
§, Percentage of total number of articles in Brazilian regions ($N = 674$).

TABLE II. Brazilian freshwater ichthyology scientific production (1986–2005) by the most prolific institutions

National institutions	Number of articles*	%**
UFSCar	98	12·84
USP	87	11·40
UNESP–Botucatu	62	8·13
INPA	54	7·08
UE Maringá	45	5·90
UFRJ	33	4·33
UE Londrina	23	3·01
UFPR	21	2·75
UFMG	18	2·36
UNICAMP	17	2·23
PUC-RS	16	2·10
UE Rio de Janeiro	11	1·44
Instituto Oswaldo Cruz	10	1·31
PUC Minas	10	1·31
UFRS	10	1·31
Total	515	67·49
Other institutions	248	32·50

*, total number of articles (N) published about freshwater fish in Brazil (1986–2005).
**, Percentage of total number of articles in the database ($N = 763$).

A correlation between wealth [gross internal product (IBGE, 2004)] of each Brazilian state and number of articles published for each state was positive and significant ($r_s = 0{\cdot}702$, $N = 16$, $P < 0{\cdot}01$). A correlation comparing number of universities (public and private) and number of articles produced by each state was positive, but not significant ($r_s = 0{\cdot}486$, $N = 16$, $P > 0{\cdot}05$).

There are 68 research groups related to freshwater ichthyology in Brazil according to CNPq (2007) with the following state distribution: Sao Paulo 15, Minas Gerais and Parana nine, Amazonas and Rio Grande do Sul six, Mato Grosso do Sul, Rio de Janeiro and Santa Catarina five, Mato Grosso four, Para two and Bahia and Pernambuco one. A correlation between number of articles for each state and number of freshwater ichthyology research groups was positive and significant ($r_s = 0{\cdot}781$, $N = 16$, $P < 0{\cdot}001$).

Articles about freshwater fishes in Brazil were published in a wide variety of biological journals ($N = 187$ journals; Table III). Considering the Brazilian Government's classification system of articles QUALIS: 51·24% ($N = 391$) of articles were A, 41·42% ($N = 316$) were B, 1·18% ($N = 9$) were C and 6·16% ($N = 47$) were not classified by the QUALIS system. The mean ± S.E. impact factor (IF) of the journals was $0{\cdot}782 \pm 0{\cdot}170$.

In the present study, articles were classified in 13 scientific areas. Many articles were about genetics, representing 28·70% of total (Table IV). This dominance of genetics was closely related to a rise in study of genetic in general in Brazil: as confirmed by a positive and significant correlation between number of fish genetic articles and number of genetic articles in general ($r_s = 0{\cdot}865$, $N = 20$, $P < 0{\cdot}001$).

TABLE III. Number of publications in main journals 1986–2005 used by authors in this study (*The Web of Science* database)

Journal title	Country of Publication	Number of articles*	%	Q[a] (IF[b])
Genetics and Molecular Biology	Brazil	56	7·34	B (0·373)
Caryologia	Italy	42	5·50	B (0·295)
Genetica	Netherlands	30	3·39	A (1·772)
Revista Brasileira de Zootecnia	Brazil	30	3·39	B (0·250)
Copeia	U.S.A.	27	3·54	A (0·974)
Journal of Fish Biology	U.K.	24	3·14	A (1·188)
Brazilian Archives of Biology and Technology	Brazil	23	3·01	B (0·131)
Brazilian Journal of Medical and Biological Research	Brazil	19	2·49	B (0·859)
Aquaculture	Netherlands	18	2·36	A (1·374)
Zootaxa	New Zealand	17	2·23	A (0·612)
Total		286	37·48	—
Other journals		477	62·52	—

*, total number of articles (N) published about freshwater fish in Brazil (1986–2005); %, percentage of total number of articles of the database ($N = 763$).
Q[a], QUALIS from 2005 (most recent available), classified in the area of 'Biological Sciences I' (CAPES, 2008).
IF[b], impact factor of the journals for 2005.

There were 445 species and 52 families of fish in the *The Web of Science* database. The most studied species was *Oreochromis niloticus* (L.) ($N = 50$, 5·05%) (Table V). There were 24 exotic species, which constituted 11·31% of publications. Fourteen species (Table VI) from the database were present in the threatened species lists of

TABLE IV. Number of articles published by research areas concerning freshwater fishes in Brazil 1986–2005 (*The Web of Science* database)

Area	Number of articles	%
Genetic	219	28·70
Physiology	86	11·27
Systematics	81	10·62
Morphology	75	9·83
Ecology	74	9·70
Parasitology	74	9·70
Aquaculture	67	8·78
Toxicology	46	6·03
Behaviour	20	2·62
Paleontology	8	1·05
Nutrition	6	0·79
Conservation	3	0·39
Microbiology	3	0·39

%, percentage of total number of articles of the database ($N = 763$).

TABLE V. Number of articles published on freshwater fish species in Brazil 1986–2005 (*The Web of Science* database)

Species	Number of articles	%
*Oreochromis niloticus**	50	5·05
Astyanax scabripinnis	34	3·43
Hoplias malabaricus	32	3·23
Piaractus mesopotamicus	24	2·42
Colossoma macropomum	22	2·22
*Oncorhynchus mykiss**	18	1·81
Rhamdia quelen	17	1·71
Pseudoplatystoma corruscans	16	1·61
Leporinus friderici	15	1·51
Prochilodus lineatus	15	1·51
Brycon cephalus	12	1·21
Astyanax altiparanae	11	1·11
Hoplosternum littorale	11	1·11
Arapaima gigas	10	1·01
Total	287	28·93
Other species	705	71·07

%, percentage of total number of species from the articles of *The Web of Science* database ($N = 992$).
*, exotic species.

IUCN (2006), Ministério do Meio Ambiente (MMA, 2007), Fundação Biodiversitas (Machado *et al*., 2005) and CITES (2007). These 14 species represented almost 4% ($N = 30$) of published articles.

The most studied family was the Characidae ($N = 321$; 31·13%), which also has the greatest number of species (Table VII). A correlation between number of articles for each family and number of described species for each family was positive and significant ($r_s = 0{\cdot}567$, $N = 52$, $P < 0{\cdot}001$). Also correlated was the number of articles for each family and estimated number of species for each family (data from Reis *et al*., 2003) and the result was positive and significant ($r_s = 0{\cdot}639$, $N = 52$, $P < 0{\cdot}001$).

A large difference was found between the number of studies in each of Brazil's hydrological basins. The Amazon and Parana River basins, together, represented 71·68% ($N = 243$) of the total number of articles from the 12 hydrological basins (Table VIII). It is important to note the small number of articles from occidental north-eastern Atlantic Ocean and oriental north-eastern Atlantic Ocean basins, which together represented 0·59% ($N = 2$) of total published articles. A correlation between size of basins and number of articles published about them was positive and significant ($r_s = 0{\cdot}599$, $N = 12$, $P < 0{\cdot}05$). A similar correlation was performed between number of endemic species from each basin and number of articles published from each basin; the result was positive and significant ($r_s = 0{\cdot}809$, $N = 12$, $P < 0{\cdot}001$). To calculate estimated fish species diversity from hydrological basins Welcomme's (1979) regression $N = 0{\cdot}169\ A^{0{\cdot}552}$ (P. Petry, pers. data) was used. A correlation was performed between estimated number of species (regression of Welcomme) for each basin and number of articles for each basin, the result was positive, but not significant ($r_s = 0{\cdot}419$, $N = 12$, $P > 0{\cdot}05$).

TABLE VI. The number (N) of fish species listed in the *The Web of Science* database threatened with extinction and their relation to lists of Brazilian fish species in need of conservation

IUCN[a] (n), $N = 21$	MMA[b] (n), $N = 132$	BIODIVERSITAS[c] (n), $N = 135$	CITES[d] (n), $N = 8$
Arapaima gigas (10)	*Brycon opalinus* (1)	*Brycon opalinus* (1)	*Arapaima gigas* (10)
Pimelodella kronei (1)	*Brycon orbignyanus* (7)	*Brycon orbignyanus* (7)	
	Bryconamericus lambari (1)	*Bryconamericus lambari* (1)	
	Characidium vestigipinne (1)	*Characidium vestigipinne* (1)	
	Conorhynchos conirostris (1)	*Conorhynchos conirostris* (1)	
	Delturus parahybae (2)	*Delturus parahybae* (2)	
	Mimagoniates lateralis (1)	*Mimagoniates lateralis* (1)	
	Pimelodella kronei (1)	*Ossubtus xinguense* (1)	
	Simpsonichthys boitonei (1)	*Pimelodella kronei* (1)	
	Sternarchorhynchus britskii (1)	*Simpsonichthys boitonei* (1)	
	Trichogenes longipinnis (1)	*Sternarchorhynchus britskii* (1)	
	Trichomycterus paolence (1)	*Trichogenes longipinnis* (1)	
		Trichomycterus paolence (1)	

[a], IUCN, International Union for Conservation of Nature (2006).
[b], MMA, Ministério do Meio Ambiente (2007).
[c], Biodiversitas Foundation (Machado *et al*., 2005).
[d], CITES, Convention on International Trade in Endangered Species of Wild Fauna and Flora (2007); n, number of articles for each species present in the *The Web of Science* database.

Among the 307 articles concerning freshwater fishes analysed from the journal *Neotropical Ichthyology*, most were about systematics (46·0%; $N = 141$), ecology (26·0%; $N = 80$), conservation (7·2%; $N = 22$), genetic (6·2%; $N = 19$), morphology (5·2%; $N = 16$) and behaviour (4·9%; $N = 15$). Less studied areas were pathology (0·7%; $N = 2$), aquaculture and physiology (1·6%; $N = 5$; in each of them). Studies reported 35 families, the most studied being: Characidae (21·8%; $N = 131$), Loricariidae (9·1%; $N = 55$) and Pimelodidae (7·0%; $N = 42$). The number of species studied was 503, being *Pimelodus maculatus* Lacépède (1·6%; $N = 9$), *Rhamdia quelen* (Quoy & Gaimard) (1·4%; $N = 8$), *Hoplias malabaricus* (Bloch) (1·0%; $N = 6$), *Prochilodus lineatus* (Valenciennes) and *Salminus brasiliensis* (Cuvier) (0·9%; $N = 5$; for each of them). Only 2·0% of articles were about exotic species [*O. niloticus, Clarias gariepinus* (Burchell)] and 1·0% was about species threatened with extinction. The ranking of hydrological basins sampled was as follows:

TABLE VII. Total number of published articles (N) in Brazil by freshwater fish families 1986–2005 (*The Web of Science* database)

Family	Described species*	Estimated species†	Number of articles	%
Characidae	952	1352	321	31·13
Cichlidae	406	571	96	9·31
Loricariidae	673	973	88	8·54
Pimelodidae	83	128	64	6·21
Anostomidae	138	163	59	5·72
Erythrinidae	15	30	47	4·56
Prochilodontidae	21	21	40	3·88
Callichthyidae	177	222	39	3·78
Heptapteridae	186	238	27	2·62
Rivulidae	235	270	23	2·23
Trichomycteridae	171	226	21	2·04
Gymnotidae	19	29	20	1·94
Curimatidae	97	107	19	1·84
Salmonidae	66	—	19	1·84
Parodontidae	23	29	14	1·36
Total			897	87·00
Other families			134	13·00

%, percentage of total number of species from the articles in Web of Science database ($N = 992$).
*, number of described species (Reis *et al*., 2003).
†, estimated number of species (Reis *et al*., 2003).

(1) Amazon (28·6%, $N = 73$), (2) Parana (28·2%; $N = 72$), (3) Tocantins-Araguaia (11·0%; $N = 28$), (4) south-east Atlantic Ocean (9·8%, $N = 25$), (5) Uruguay (5·1%; $N = 13$), (6) east Atlantic Ocean and Sao Francisco (4·7%, $N = 12$; each of them), (7) Paraguay (4·3%; $N = 11$), (8) South Atlantic Ocean (2·7%; $N = 7$) and (9) occidental north-eastern Atlantic Ocean (0·8%; $N = 2$).

DISCUSSION

Brazil's scientific production has increased steadily over the past 20 years. In 1995, Brazil contributed to 0·83% of the world's scientific production and 1·44% in 2001 (Izique, 2002). This growth is linked to the stabilizing the Brazilian economy in the 1990s (Mettenheim, 2004), which gave rise to new initiatives such as: the Program of Support for Nuclei of Excellence in 1996 (PRONEX); the Millennium Science Initiative in 2001, and the Sectorial Fund CT-Hidro, which specifically supports ichthyological research (Vieira, 2001; Neves *et al*., 2004; FINEP, 2007). This growth is important but there is still much to do, considering the mega biodiversity of species in Brazil (Lundberg *et al*., 2000; Nelson, 2006; Buckup *et al*., 2007) and its ongoing environmental degradation (Agostinho *et al*., 2005). One option may be to increase private research funding, as practised in more developed countries (NSF, 2004), as a means to increasing scientific knowledge.

Around 35% of the 145 institutions in articles from *The Web of Science* database were from other countries. In contrast to the majority of developed countries,

TABLE VIII. Ranking of the most studied Brazilian hydrological basins from the total number (N) of articles published (1986–2005) in *The Web of Science* database (1986–2005)

Hydrographic basins*	Hydrographic ecoregions	Area (km^2)	Species wealth	Endemic species	Estimated species†	Number of articles per basin	%‡	%§
Amazônica	Rio Negro	3 800 000	616	140	235	127	16·60	37·46
	Guiana Amazônica		750	35	251			
	Terras baixas da Amazônia		1050	210	220			
	Xingu		126	37	231			
	Escudo Brasileiro		330	20	198			
	Tapajós-Juruena		115	49	223			
Paraná	Alto Paraná	879 860	176	61	313	116	15·16	34·22
	Iguaçu		49	26	78			
South-east Atlantic	araíba do Sul	229 872	79	31	76	24	3·14	7·08
	Ribeira do Iguapé		100	31	48			
	Fluminense		84	29	34			
Paraguai	Paraguai	1 100 000	312	78	247	21	2·74	6·20
São Francisco	São Francisco	645 067	161	86	270	19	2·48	5·60
Tocantins–Araguaia	Tocantins-Araguaia	967 059	313	132	298	11	1·44	3·25
Atlântico Sul	Costa Brasileira do Sul	185 856	78	24	56	8	1·04	2·36
	Bacia da Lagoa dos Patos		129	30	135			
	Tramandão-Manpituba		97	15	24			
Parnaíba	Maranhão-Piauí	344 112	87	20	198	5	0·65	1·47
East Atlantic	Mata Atlântica	374 677	142	81	235	4	0·52	1·18
Uruguai	Alto Uruguai	174 612	145	15	85	2	0·26	0·59
	Baixo Uruguai		213	22	168			
Occidental north-east Atlantic	Estuário do Amazonas	254 100	381	20	253	1	0·13	0·30
Oriental north-east Atlantic	Caatinga e Riachos Costeiros	287 348	79	31	173	1	0·13	0·30

*, division of Brazilian territory in hydrographic units, according to resolution number 32 of 15 October 2003 from Conselho Nacional de Recursos Hídricos.
†, calculation of species diversity, according to the size of hydrographic basin (Welcomme, 1979).
‡. percentage total number of articles of database ($N = 763$).
§, percentage total number of articles of the hydrographic basins ($N = 339$). Number and percentage of articles from the hydrological basins present in the database are given, the other basins did not have any articles, and therefore are not listed.

science in Brazil is heavily based in the public sector (70% of Brazilian scientists; MCT, 2005). In the U.S.A., for example, a large proportion of scientists work for the private sector (NSF, 2004). The majority of scientific production occurred in southern and south-east regions of Brazil, especially in the State of São Paulo (leader in scientific production). This reflects greater investment made in research by richer Brazilian states (Leta *et al*., 2006). Legally, all Brazilian states should dedicate 1% of their budget to scientific research; however, in practice only richer states do this (FAPESP, 2007). This situation is worrying, because it implies that if a poor state is important from a conservation perspective few financial resources will be available for research.

The non-significant correlation between number of universities for each state and number of publications for each state can be explained by the fact that some institutions, such as the National Institution of Amazonian Research (INPA), are dedicated to undertake research with freshwater fishes. Thus, although the State of Amazonas has only two universities, it was fourth in the ranking of scientific productivity due to the presence of INPA (Table II).

Articles considered in this study, in terms of impact factor, can be classified as being below average, only 41% were QUALIS A (*i.e.* had an impact factor equal to the median for the area of biological sciences). The same result was observed in India where most scientific papers are published either in non-Science Citation Index (SCI) journals or low-impact journals of poor visibility, and even those papers appearing in higher impact factor journals are not much cited (Jayashree & Arunachalam, 2000).

A close relationship between scientific research and socioeconomic development has spurred an interest in identifying not only where research is being conduct but also by whom (Annan, 2003). For example, a recent review showed that per dollar invested by their nations in research and development, scientists in Latin America countries produce a greater number of scientific publications than did their counterparts in the U.S.A. and Canada (Holmgren & Schnitzer, 2004). On the other hand, scientists from Latin America produce fewer total publications and rarely contribute to the premier scientific journals. Therefore, they rarely achieve the status necessary to become regularly cited (Holmgren & Schnitzer, 2004). Similar results were found by Galvez *et al*. (2000), who found that Western Europe, North America and Asia, which accounted for 85% of all papers listed in the SCI (1991–1998). In contrast, countries in Africa contributed only 1% of total publications, and Latin America ranked low in terms of total productivity, despite steady growth in scientific output from scientists in Argentina, Brazil, Chile and Mexico.

A considerable heterogeneity was found in relation to areas present in ichthyological studies and increased by multidisciplinary nature of many studies. The results suggested a predominance of genetic studies (Tables III and IV). The significant correlation that increase in number of fish genetic studies follows a national and worldwide tendency to invest in genetic research (Brown *et al*., 2005).

The need for studies with freshwater fish species is increasing because recent assessments suggest that >30% of them are threatened (IUCN, 2006). Only three of the 763 articles considered were directly about conservation of Brazilian fish fauna. Certainly, the lack of studies relating to conservation of freshwater fishes should serve as a warning in such a species-rich country (Lundberg *et al*., 2000; Buckup *et al*., 2007; Rosa & Lima, 2008). A quick count of papers published in *Conservation Biology* from 1997 to 2001 (Abell, 2002) showed that only 7% have some relation to freshwater species (primarily amphibians). This suggests that the conservation community has not given freshwater fishes the attention they require. Another neglected area was microbiology with only three articles in the database. This area also deserves special attention from Brazilian researchers since it is important to understand the mortality of fishes in their natural environment, the health issues on fish farms (Austin, 2006), and it is also a tool for studies on conservation trends.

Brazilian ichthyologists have been diverse in their selection of species: this is positive since there is an increasing need to augment the knowledge about Brazilian freshwater fishes, due to their diversity and anthropogenic effects they are suffering (Agostinho *et al*., 2005). The most studied native species [*e.g. Piaractus mesopotamicus* (Holmberg), *Colossoma macropomum* (Cuvier), *R. quelen* and *Pseudoplatystoma corruscans* (Spix & Agassiz)] are considered of economic and commercial interest to Brazil (Agostinho & Zalewski, 1996; Goudling & Barthem, 1997). Thus, the great quantity of research on these species may be positive since fish farming can decrease the pressure on wild fish populations.

Interestingly, the most studied species was *O. niloticus*, an exotic species (Table V). This species has been a target for laboratory studies in physiology, morphology and genetics, because it is relatively easy to maintain (Fernandes & Rantin, 1989; Wassermann & Afonso, 2003). *Oreochromis niloticus* is also much studied because of its qualities, such as fast growth, easy feeding adaptation, good feed conversion and mass gain (Zanoni *et al*., 2000; Boscolo *et al*., 2001). Being an exotic species in Brazil, *O. niloticus* has also been a target of ecological studies to evaluate its diverse effects, because it is a highly competitive species (Figueredo & Giani, 2005). This large number of studies on *O. niloticus* contrasts with the situation of many native Brazilian species. In a review of Indian publications about fisheries and aquaculture between 1988 and 1997, many of the papers concerned exotic species (Ponniah, 2001).

Few (9% of 152) Brazilian fish species threatened with extinction have been studied, and only 14 of them were present in the *The Web of Science* database. There is a large difference in the number of species threatened with extinction between global lists (IUCN, 2006 *v*. CITES, 2007) and national lists (Machado *et al*., 2005 *v*. MMA, 2007; Table VI). These lists of threatened species are extremely important to plan strategies and determine priorities for conservation (Gärdenfors *et al*., 2001; Machado *et al*., 2005). Different systems are applied to demonstrate the level of threat; it can be local, national or global. Garcia & Marini (2006) while analysing threatened species lists of Brazilian birds indicated that national lists have more threatened species than global lists. These divergences tend to diminish confidence in decisions to be taken relative to conservation and difficult implantation of public polices. Local organizations can have difficulties to raise international funds, because sponsors, wrongly, believe that global lists are more accurate (Rodríguez *et al*., 2000). Some national lists also have problems, as pointed out by Rosa & Lima (2008), concerning the commercially important species, *Zungaro jahu* (Ihering). This species was accidentally omitted from the national Red List of Brazilian Government, and this mistake needs to be remedied urgently.

The significant correlation between number of endemic species per basin and number of articles per hydrological basin suggests that researchers tend to study species from larger basins, probably due to greater endemism. Such preference was verified by the significant correlation between size of basins and number of articles per basin. Species that have a wide distribution between basins cause confusion concerning the total number of species for a basin. Priority areas for conservation, hotspots, require an elevated number of endemic species of plants and animals (Myers *et al*., 2000); under this definition, Brazilian ichthyologists have done the right thing in concentrating on larger hydrological basins. For river and wet areas, conservation programmes should adopt the concept of umbrella species, using endemic migratory fishes as key elements in the maintenance of freshwater fish diversity in Brazil. These species are important in this context, because they are highly dependent on the integrity of large basin areas (Agostinho *et al*., 2005).

The occidental north-eastern Atlantic Ocean and oriental north-eastern Atlantic Ocean basins had few articles, despite their small size, the number of studies in these areas was very low and this is worrying. Bhat (2003) documented the diversity and composition of freshwater fishes in river system in the central western Ghats, India, and found that there was 25% endemicity among a species richness of 92. Nguyen & De Silva (2006) demonstrated that the ln species richness index (number of species to basin area ratio $\times$ 1000) was significantly correlated to the ln basin area for the major river systems on Asia. This relationship differs from that derived by Welcomme (2000), for African rivers, where it is based on $\log_{10}$ transformed data. These differences are indicative of the need for each of the regions of the world to be dealt as separate entities rather than by grouping all river basins of the world together (Oberdorff *et al*., 1995). Nguyen & De Silva (2006) also showed that fish species richness is not necessarily correlated to river basin size.

Data analysed from the journal *Neotropical Ichthyology* suggest new trends in freshwater ichthyology in Brazil. Brazilian researchers have paid more attention to basic studies such as systematics and ecology, which, according to Abell (2002), are essential tools for developing strategies for conservation and preservation of species. Studies on conservation have also increased, and most of them were related to fish passages in reservoirs, an important issue upon which Brazilian researchers cannot agree about their real effectiveness (Pelicice & Agostinho, 2008; Godinho & Kynard, 2009).

Fewer articles concerning exotic species were found (only 2%). This fact is positive since there was a greater investment on studies of native species, especially in aquaculture that is one of the main ways for the accidental introduction of alien species. Only 1% of articles, however, were about species threatened with extinction. Unfortunately, there is relatively little information on the distribution and biology of freshwater fishes threatened with extinction. While filling the gaps in the knowledge about these species is highly desirable and should be stimulated, the most effective strategy would be to protect areas known to harbour endangered species (Rosa & Lima, 2008). Families with the highest number of species (Characidae, Pimelodidae and Loricariidae) and basins with larger areas were the most studied, reflecting the positive trend as previously discussed concerning the data from *The Web of Science* database.

In conclusion, while this study shows that much good research has been and continues to be conducted by Brazilian ichthyologists, there is still much to do. Perhaps most worrying was the small number of studies on fish species threatened with extinction, and the fact that investment in research is heavily dependent on each state's economic situation.

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References

Abell, R. (2002). Conservation biology for the biodiversity crisis: a freshwater follow-up. *Conservation Biology* **16,** 1435–1437. doi: 10.1046/j.1523-1739.2002.01532.x

Agostinho, A. A. & Zalewski, M. (1996). *A Planície alagável do alto rio Paraná: importância e preservação* [Upper Paraná River Floodplain: Importance e Preservation]. Maringá: EDUEM.

Agostinho, A. A., Thomaz, S. M. & Gomes, L. C. (2005). Conservation of the biodiversity of Brazil's inland waters. *Conservation Biology* **19,** 646–652. doi: 10.1111/j.1523-1739.2005.00701.x

Angermeier, P. L. (2007). The role of fish biologists in helping society build ecological sustainability. *Fisheries* **32,** 9–20.

Annan, K. (2003). A challenge to the world's scientists. *Science* **299,** 1485. doi: 10.1126/science.299.5612.1485

Austin, B. (2006). The bacterial microflora of fish, revised. *Scientific World* **6,** 931–945. doi: 10.1100/tsw.2006.181

Azevedo, C. S., Cipreste, C. F. & Young, R. J. (2006). Environmental enrichment: a GAP analysis. *Applied Animal Behaviour Science* **102,** 1–15. doi: 10.1016/j.applanim.2006.05.034

Bhat, A. (2003). Diversity and composition of freshwater fishes in streams of Central Western Ghats, India. *Environmental Biology of Fishes* **68,** 25–38. doi: 10.1023/A:1026017119070

Boscolo, W. R., Hayashi, C., Soares, C. M., Furuya, W. M. & Meurer, F. (2001). Desempenho e características de carcaças de machos revertidos de tilápia do Nilo, *Oreochromis niloticus*, linhagem tailandesa e comum, nas fases iniciais e de crescimento. *Revista Brasileira de Zootecnia* **30,** 1391–1396.

Brown, K. M., Baltazar, G. A. & Hamilton, M. B. (2005). Reconciling nuclear microsatellite and mitochondrial marker estimates of population structure: breeding population structure of Chesapeake Bay striped bass (*Morone saxatilis*). *Heredity* **94,** 606–615. doi: 10.1038/sj.hdy.6800668

Buckup, P. A., Menezes, N. A. & Ghazzi, M. S. (2007). *Catálogo das Espécies de Peixes de Água Doce do Brasil*. Rio de Janeiro: Museu Nacional.

Fernandes, M. N. & Rantin, F. T. (1989). Respiratory responses of *Oreochromis niloticus* (Pisces, Cichlidae) to environmental hypoxia under different thermal conditions. *Journal of Fish Biology* **35,** 509–519. doi: 10.1111/j.1095-8649.1989.tb03002.x

Figueredo, C. C. & Giani, A. (2005). Ecological interactions between Nile tilapia (*Oreochromis niloticus*, L.) and the phytoplanktonic community of the Furnas Reservoir (Brazil). *Freshwater Biology* **50,** 1391–1403. doi: 10.1111/j.1365-2427.2005.01407.x

Galvez, A., Maqueda, M., Martinez-Bueno, M. & Valdivia, E. (2000). Scientific publication trends and the developing world. *American Scientist* **88,** 526–533.

Garcia, F. I. & Marini, M. A. (2006). Estudo comparativo entre as listas global, nacional e estaduais de aves ameaçadas no Brasil. *Natureza & Conservação* **4,** 11–23.

Gärdenfors, U., Hilton-Taylor, C., Mace, G. M. & Rodríguez, J. P. (2001). The application of IUCN Red List criteria at regional levels. *Conservation Biology* **15,** 1206–1212. doi: 10.1111/j.1523-1739.2001.00112.x

Godinho, A. L. & Kynard, B. (2009). Migratory fishes of Brazil: life history and fish passage needs. *Rivers Research and Applications* **25,** 702–712.

Godinho, H. P. & Godinho, A. L. (2003). *Águas, peixes e pescadores do São Francisco das Minas Gerais*, 1st edn. Belo Horizonte: Edipucmg.

Goudling, M. & Barthem, R. (1997). *The Catfish Connection: Ecology, Migration, and Conservation of Amazon Predators*. New York, NY: Columbia University Press.

Holmgren, M. & Schnitzer, S. A. (2004). Science on the rise in developing countries. *PLoS Biology* **2,** 10–13. doi: 10.1371/journal.pbio.0020001

Jayashree, B. & Arunachalam, S. (2000). Mapping fish research in India. *Current Science* **79,** 613–620.

Leta, J., Glanzel, W. & Thijs, B. (2006). Science in Brazil. Part 2: sectoral and institutional researches profiles. *Scientometrics* **67,** 87–105. doi: 10.1556/Scient.67.2006.1.6

Lipow, S. R., Vance-Borland, K., Clair, J. B. S., Henderson, J. & McCain, C. (2004). Gap analysis of conserved genetic resources for forest trees. *Conservation Biology* **18,** 412–423. doi: 10.1111/j.1523-1739.2004.00072.x

Lundberg, J. G., Kottelat, M., Smith, G. R., Stiassny, M. L. J. & Gill, A. C. (2000). So many fishes, so little time: an overview of recent ichthyological discovery in continental waters. *Annals of the Missouri Botanical Garden* **87,** 26–62.

Machado, A. B. M., Martins, C. S. & Drummond, G. M. (2005). *Lista da fauna brasileira ameaçada de extinção: Incluindo as listas das espécies quase ameaçadas e deficientes em dados*. Belo Horizonte: Fundação Biodiversitas.

MacLachlan, C. M. (2003). *A History of Modern Brazil: The Past Against the Future*. New York, NY: Rowman and Littlefield.

Melfi, V. (2005). The appliance of science to zoo-housed primates. *Applied Animal Behavior Science* **90,** 97–106. doi: 10.1016/j.applanim.2004.08.017

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Fonseca, G. A. B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403,** 853–858. doi: 10.1038/35002501

Nelson, J. S. (2006). *Fishes of the World*, 4th edn. New York, NY: John Wiley & Sons.

Nguyen, T. & De Silva, S. (2006). Freshwater finfish biodiversity and conservation: an Asian perspective. *Biodiversity and Conservation* **15,** 3543–3568. doi: 10.1007/s10531-005-0312-8

Oberdorff, T., Hugueny, B. & Guegan, J. F. (1995). Global patterns of fish species richness in rivers. *Ecography* **18,** 345–352. doi: 10.1111/j.1600-0587.1995.tb00137.x

Oldfield, T. E. E., Smith, R. J., Harrop, S. R. & Leader-Williams, N. (2004). A gap analysis of terrestrial protected areas in England and its implications for conservation policy. *Biological Conservation* **120,** 303–309. doi: 10.1016/j.biocon.2004.03.003

Pelicice, F. M. & Agostinho, A. A. (2008). Fish-passage facilities as ecological traps in large neotropical rivers. *Conservation Biology* **22,** 180–188. doi: 10.1111/j.1523-1739.2007.00849.x

Ponniah, A. G. (2001). Research and policy requirement for sustainable utilisation of India's fish germplasm resoucers. In *Sustainable Indian Fisheries* (Pandian, T. J., ed.), pp. 213–224. New Delhi: National Academy of Agricultural Science.

Reis, R. E., Kullander, S. O. & Ferrari, C. J. Jr. (2003). *Check List of the Freshwater Fishes of South and Central America*. Porto Alegre: Edipucrs.

Rodríguez, J. P., Ashenfelter, G., Rojas-Suárez, F., Fernández, J. J. G., Suárez, L. & Dobson, A. P. (2000). Local data are vital to worldwide conservation. *Nature* **403,** 241. doi: 10.1038/35002183

Rosa, R. S. & Lima, F. C. T. (2008). Os peixes brasileiros ameaçados de extinção. In *Livro Vermelho da Fauna Brasileira Ameaçada de extinção* (Machado, A. B. M., Drummond, G. M. & Paglia, A. P., Org., eds), pp. 9–285. Brasília: Ministério do Meio Ambiente.

Shaffer, S. A. & Costa, D. P. (2006). A database for the study of marine mammal behavior: gap analysis, data standardization, and future directions. *IEEE Journal of Oceanic Engineering* **31,** 82–86.

Schäfer, S. A. (1998). Conflict and resolution: impact of new taxa on phylogenetic studies of the Neotropical cascudinhos (Siluroidei: Loricariidae). In *Phylogeny and Classification of Neotropical Fishes* (Malabarba, L. R., Reis, R. E., Vari, R. P., Lucena, Z. M. S. & Lucena, C. A. S., eds), pp. 375–400. Porto Alegre: Edipucrs.

Trisurat, Y. (2007). Applying gap analysis and a comparison index to evaluate protected areas in Thailand. *Environmental Management* **39,** 235–245. doi: 10.1007/s00267-005-0355-3

Vieira, C. L. (2001). Brazil: new industry taxes boost science budget. *Science* **291,** 1685. doi: 10.1126/science.291.5509.1685

Wassermann, G. J. & Afonso, L. O. B. (2003). Sex reversal in Nile tilapia (*Oreochromis niloticus* Linnaeus) by androgen immersion. *Aquaculture Researches* **34,** 65–71. doi: 10.1046/j.1365-2109.2003.00795.x

Welcomme, R. L. (1979). *Fisheries Ecology of Floodplain Rivers*. New York, NY: Longman Inc.

Welcomme, R. L. (2000). Fish biodiversity in floodplains and their associated rivers. In *Biodiversity in Wetlands: Assessment, Function and Conservation*, Vol. 1 (Gopal, B., Junk, W. J. & Davis, J. A., eds), pp. 61–87. Leiden: Backhuys Publishers.

Yip, J. Y., Corlett, R. T. & Dudgeon, D. (2004). A fine-scale gap analysis of the existing protected area system in Hong Kong, China. *Biodiversity and Conservation* **13,** 943–957. doi: 10.1023/B:BIOC.0000014463.32427.cf

Zanoni, M. A., Filho, M. C. & Leonhardt, J. H. (2000). Performance de crescimento de diferentes linhagens de tilápia do Nilo, *Oreochromis niloticus* (Linnaeus, 1757), em gaiolas. *Acta Scientiarum* **22,** 683–687.

Electronic References

Buckup, P. A. & Menezes, N. A. (2003). *Catálogo dos peixes marinhos e de água doce do Brasil*, 2nd edn. Rio de Janeiro: Museu Nacional. Available at http://www.mnrj.ufrj.br/catalogo

CAPES. (2007). Relação de Cursos Recomendados e Reconhecidos. *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*. Available at http://servicos.capes.gov.br/projetorelacaocursos/jsp/grandeAreaDet.jsp

CAPES. (2008). Manual WebQualis 3.0. *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*. Available at http://www.capes.gov.br/avaliacao/qualis

CITES. (2007). Resources: CITES species database. *Convention of International Trade in Endangered Species of Wild Fauna and Flora*. Available at http://www.cites.org/eng/resources/species.html

CNPq. (2007). Plataforma Lattes. *Conselho Nacional de Desenvolvimento Científico e Tecnológico*. Available at http://buscatextual.cnpq.br/buscatextual/buscapesq.jsp

FAPESP. (2007). Constituição de 1989. História, Leis, Artigo 271. *Fundação de Amparo a Pesquisa do Estado de São Paulo*. Available at http://www.fapesp.br/materia.php?data[id_materia]=29

FINEP. (2007). CT-Hidro Fundo Setorial de Recursos Hídricos. O que é o CT-Hidro? *Financiadora de Estudos e Projetos*. Available at http://www.finep.gov.br/fundos_setoriais/ct_hidro/ct_hidro_ini.asp

IBGE. (2004). Estatística por Tema: Contas regionais. Tabela: Contas regionais do Brasil em 2004. *Instituto Brasileiro de Geografia e Estatística*. Available at http://www.ibge.gov.br/home/estatistica/economia/contasregionais/2004/tabela06.pdf

INEP. (2007). Educação Superior. Cadastro das instituições de educação superior. *Instituto Nacional de Estudos e Pesquisas Educacionais*. Available at http://www.educacaosuperior.inep.gov.br/funcional/lista_ies.asp

IUCN. (2006). IUCN Red List of Threatened Species. *União Internacional para a Conservação da Natureza e dos Recursos Naturais*. Available at http://www.iucnredlist.org/research/research-basic

Izique, C. (2002). *Produção crescente. Revista de Pesquisa FAPESP Ciência & Tecnologia*. São Paulo: Política de C & T. Available at http://www.revistapesquisa.fapesp.br/?art=1984&bd=1&pg=1&lg

MCT. (2005). Dados sobre recursos humanos. *Ministério da Ciência e Tecnologia*. *Indicadores nacionais de ciência e tecnologia*. Available at http://www.mct.gov.br/estat/ascavpp/ingles/3_Recursos_Humanos/tabelas/tab3_4_1.htm

Mettenheim, K. (2004). *From the Economics of Politics to the Politics of Monetary Policy in Brazil*. Available at http://www.brazil.ox.ac.uk/workingpapers/Kurt%20von%20Mettenheim%2054.pdf

MMA. (2007). *Espécies Brasileiras Ameaçadas de Extinção, Sobreexplotadas ou Ameaçadas de Sobreexplotação*. Available at http://www.mma.gov.br/port/sbf/fauna/index.html

Neves, M. A. S., Coelho, G. M., Lemos, C. & Maldonado, J. (2004). *Trends in Oil & Gas in Brazil: A Methodological Approach. EU-US Seminar: New Technology Foresight, Forecasting & Assessment Methods, Seville*. Available at http://forera.jrc.ec.europa.eu/fta/papers/Papers%20from%20posters/Trends%20in%20Oil%20&%20Gas%20in%20Brazil.pdf

NSF. (2004). *Division of Science Resources Statistics. Science and Engineering Indicators*. Available at http://www.nsf.gov/statistics/showpub.cfm?TopID=14&SubID=31

Thomson Scientific. (2005). *Products: Web of Science®*. Available at http://www.scientific.thomson.com/products/wos