

Brazilian cladoceran studies: where do we stand?

Elmoor-Loureiro¹, L. M. A.

¹Laboratório de Zoologia, Universidade Católica de Brasília - QS 7 lote 1, Bloco M-331, Taguatinga, DF, 72030-170 - e-mail: lourdes@ucb.br

Abstract

Hundred-twelve taxonomic and limnological reports on the occurrence and distribution of cladoceran species in Brazil were analyzed. Most were published between 1976 and 2000, when the number of limnological studies increased. Two-thirds of the species, however, were first recorded from Brazil before 1950. The water bodies studied are concentrated in certain regions, so there is no data on cladocerans for large areas of the country. Half the species found in Brazil are presumed cosmopolitan, and two-thirds are non-planktonic. These results are discussed in respect to Frey's principle of non-cosmopolitanism, revealing the limitations of present knowledge of Brazilian cladocerans. The need for further studies is also considered.

Key words: Cladocera, geographical distribution, non-cosmopolitanism, limnology, taxonomy.

Introduction

The cladoceran microcrustaceans are traditionally considered as herbivorous members of the lacustrine plankton. However, they live in almost all lentic environments, and even in lakes, reservoirs and pools their distribution is not restricted to the limnetic zone. They are in fact an important group in the littoral community, where they live associated with macrophyte roots and sediment. There are also cladocerans inhabiting groundwater (Dumont, 1995; Reid, 1984) and bromeliad phytotelmata (Frey, 1980).

The pioneer study by Ihering (1895) on Brazilian "Phyllopodos" presented the first cladoceran record from Brazil. A few years later, Sars (1901) published his well-known paper on freshwater Entomostraca of South America, including the first cladoceran species list for Brazil. Sars' article was the main reference for several generations of researchers.

From 1900 through 1930, studies on Brazilian cladocerans were carried out by the European specialists Stingelin, Spandl, and Brehm. There were also important contributions by Bergamin, the first Brazilian cladoceran specialist.

After a century of studies, more than a hundred freshwater cladoceran species have been recorded from Brazil (Elmoor-Loureiro, 1997). However, how should we interpret the available data? Where do we stand at present in regard to knowledge of cladoceran taxonomy and distribution in this country? The present study analyzes the available data on cladoceran taxonomy and distribution, and discusses the need for future studies.

Material and Methods

Research articles, academic theses, and books on the occurrence and distribution of freshwater cladocerans in Brazil have been classified into two categories: taxonomic (species descriptions, occurrence reports, discussions of synonymy and biogeography) and limnological (which provide species lists, independent from their main purpose). These publications were also grouped in 25-year periods.

Data from these publications were used to generate a species list, including the year when each species was first recorded from Brazil, and the number of species in each cladoceran family. Doubtful

records and junior synonyms (see Elmoor-Loureiro, 1998) were not included in the species list. In order to compare with the number for worldwide fauna (Korovchinsky, 1996), the data were transformed into percentages.

The species were classified into three categories according to their known geographical range (Elmoor-Loureiro, 1998; Orlova-Bienkowskaja, 1998): Neotropical, New World, and "cosmopolitan" (occurring in the Americas and at least in one other continent). They are also classified according to their typical family habitat: planktonic (Holopedidae, Sididae, Bosminidae, Moinidae, and Daphniidae) and non-planktonic (Chydoridae, Macrothricidae, and Ilyocryptidae).

The species distribution is listed by Brazilian state and the Federal District. The total number of species in each Federation unit is provided.

Unpublished data from 11 samples were also included: one from near Poconé (Mato Grosso), another from Juparanã Lake (Espírito Santo), two from the Federal District, three from the vicinity of Salvador (Bahia; leg. Eduardo M. Silva), and four from Minas Gerais (Jequitinhonha River and Jaíba; leg. Maria Beatriz G. S. Dabés).

To analyze sampling effort, the Brazilian territory was divided into two-degree quadrilaterals. The number of water bodies sampled in each quadrilateral was recorded, independent of their size or the sampling frequency.

Results

Hundred-twelve publications on the occurrence of cladocerans in Brazil were assembled: 61 taxonomic and 51 limnological (Table I). Most were published between 1976 and 2000, although the 1926-1950 period is also important (Fig. 1). Taxonomic publications predominated until 1950, after which the number of general limnological studies increased (Fig. 1).

Up to now, 118 freshwater cladoceran species have been recorded from Brazil (Appendix 1). Two-thirds of them were recorded before 1950 (Fig. 2).

The relative number of species within each family for the Brazilian fauna is similar to that worldwide (Table II). However, in the Brazilian fauna, the proportion of Daphniidae is smaller and the proportion of Bosminidae and Ctenopoda is higher.

Half the species are considered "cosmopolitan" and two-thirds are non-planktonic (Table III). Considering these two parameters together, the "cosmopolitan" non-planktonic species are the most numerous group (ca. one-third of the total).

Cladocerans have been recorded from almost all Brazilian states (Appendix 1). The states with most species recorded are São Paulo, Rio Grande do Sul, Pará, Amazonas, Mato Grosso do Sul, and Pernambuco.

Although some water bodies have been sampled in all Brazilian regions, they are irregularly distributed and concentrated in the southeast (especially in São Paulo), Pernambuco, and central Amazonia (Fig. 3). This map also reveals the existence of immense areas for which data are lacking.

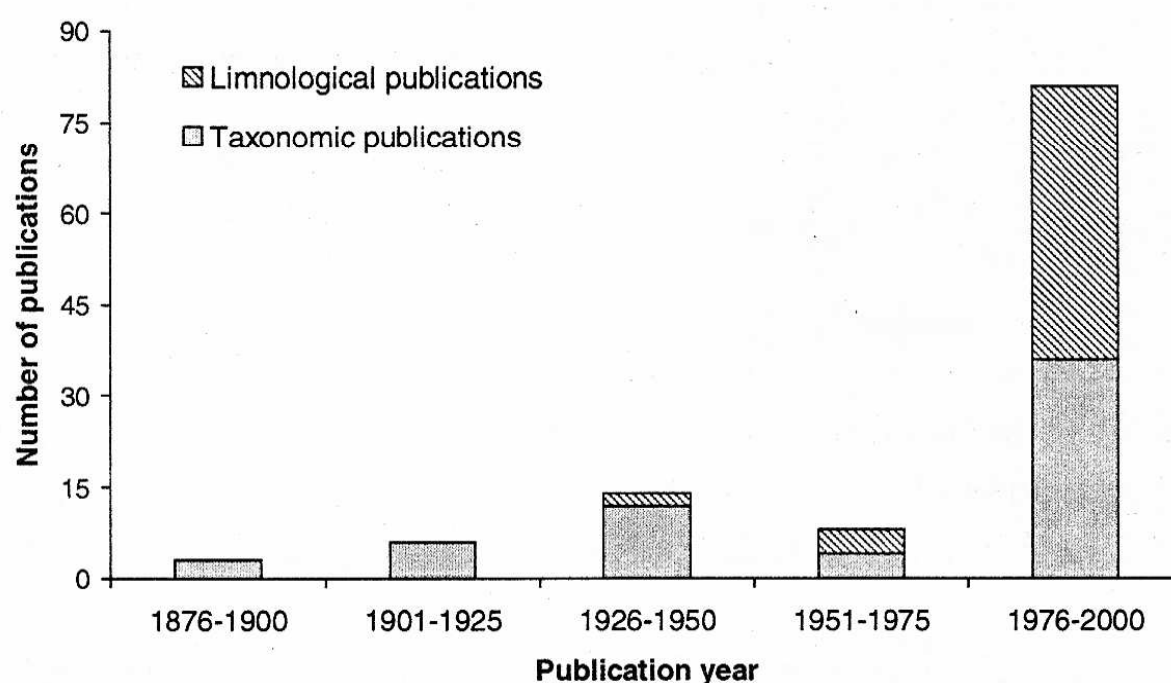


Figure 1: Number of publications on cladoceran species occurrence in Brazil, in accordance to their nature and their publication year.

Table I: List of publications on occurrence and distribution of cladoceran species in Brazil, in accordance to their nature and to Brazilian Federation units (UF); publications related to more than two units are listed on separate ()

UF	Taxonomical Publications	Limnological Publications
AC		Sendacz and Melo Costa (1991)
AL	Brehm (1937)	Schubart (1942)
AM	Brandorff (1976); Herbst (1967); Korinek (1981); Korovchinsky (1985); McNair (1976, 1980); Orlova-Bienkowskaja (1995); Paggi and Rocha (1999); Rey and Vasquez (1989); Stingelin (1904a); Smirnov (1984, 1988, 1998)	Brandorff (1978); Brandorff and Andrade (1978); Brandorff <i>et al.</i> (1982); Hardy (1980); Marlier (1967); Robertson and Hardy (1984); Thomasson (1953, 1955)
BA	Elmoor-Loureiro (1997)	
DF	El-moor (1981); Elmoor-Loureiro (1988, 1990)	Branco and Cavalcanti (1999); Reid (1984); Starling (2000)
GO	Elmoor-Loureiro (1997)	Lansac-T ha <i>et al.</i> (1999)
MA		Reid and Turner (1988); Rocha <i>et al.</i> (1998)
MG	Deevey and Deevey (1971)	Bonecker <i>et al.</i> (1996, 1997); DabØ (1995); DabØ <i>et al.</i> (1990); Freire and Pinto-Coelho (1986); Landa and MourguØ-Schurter (1999); Rolla <i>et al.</i> (1990) Santos (1980); Santos <i>et al.</i> (1994); Silva and Pinto-Coelho (1986); Tundisi <i>et al.</i> (1997)
MS	Daday (1905); Dumont and Pensaert (1983)	Bonecker <i>et al.</i> (1997); Esp ndola <i>et al.</i> (1996); Lansac-T ha <i>et al.</i> (1993, 1995, 1997); Lima <i>et al.</i> (1996)
MT		Green (1972)
PA	Deevey and Deevey (1971); Smirnov (1985, 1998); Stingelin (1904b-c; 1909)	Bozelli (1992); Robertson (1980); Robertson and Hardy (1984)
PE	Brehm (1937; 1938); Brehm and Thomsen (1936)	Neumann-Leit ^a o <i>et al.</i> (1989); Schubart (1938, 1942)
PI	Spandl (1926)	
PR	Velho <i>et al.</i> (2000)	Campos <i>et al.</i> (1996); Lansac-Toha <i>et al.</i> (1993); Lopes <i>et al.</i> (1997); Nunes <i>et al.</i> (1996); Tomm <i>et al.</i> (1992)
RR	Smirnov and Santos-Silva (1995)	
RS	Daday (1902); Dumont and Pensaert (1983); Frey (1987b); Ihering (1895); Montœand Gloeden (1986); Richard (1897)	Bohrer <i>et al.</i> (1988)
SC	Ihering (1895); Richard (1897)	
SP	Bergamin (1931, 1935, 1939a-c; 1940a-b, 1941); Elmoor-Loureiro (2000); Frey (1982); Korovchinsky (1985); Matsumura-Tundisi and Smirnov (1984); Rajapaksa and Fernando (1987); Sars (1900, 1901); Sinev (1998)	Arcifa (1984); Arcifa <i>et al.</i> (1998); Arcifa-Zago (1976); Henry and Nogueira (1999); Matsumura-Tundisi and Tundisi (1976); Neumann-Leit ^a o <i>et al.</i> (1991); Nogueira and Panarelli (1997); Sendacz and Kubo (1999)
—	Elmoor-Loureiro (1997; 1998); Goulden (1968); Green (1981); Korovchinsky (1992); Kotov and Dumont, 2000; Matsumura-Tundisi (1984); Orlova-Bienkowskaja (1998); Smirnov (1974, 1976, 1992, 1996)	
Total	61	51

Appendix 1: List of cladoceran species found in Brazil and their distribution on Brazilian states, from literature data (●) and original data (○).

	AC	AL	AM	BA	DF	ES	GO	MA	MG	MS	MT	PA	PE	PR	PI	RR	RS	SC	SP
HOLOPEDIDAE																			
<i>Holopedium amazonicum</i>			●								●	●							
SIDIDAE																			
<i>Diaphanosoma birgei</i>			●	●	●		●		●	●	●	●		●			●		●
<i>Diaphanosoma brevireme</i>	●		●	●					●	●			●	●			●		●
<i>Diaphanosoma fluviatile</i>			●							●		●					●		
<i>Diaphanosoma polyspina</i>			●									●					●		
<i>Diaphanosoma spinulosum</i>	●		●				●			●	●	●	●	●	●		●		●
<i>Latonopsis australis</i>		●	●		●				○		○		●				●		
<i>Neodiaphanosoma bergamini</i>			●																
<i>Pseudosida bidentata</i>			●								●						●		●
<i>Pseudosida ramosa</i>			●	○					○		○								
<i>Sarsilatona behningi</i>			●																
<i>Sarsilatona serricauda</i>			●					●		●		●							●
<i>Sida crystallina</i>																	●		●
BOSMINIDAE																			
<i>Bosmina hagmanni</i>			●		●		●		●	●	●	●		●			●		●
<i>Bosmina huaronensis</i>														●			●		●
<i>Bosmina longirostris</i>					●	○		●	●	●		●		●			●		●
<i>Bosmina tubicen</i>	●		●	○	●		●		●	●		●		●			●		●
<i>Bosminopsis brandorffi</i>			●								●	●					●		●
<i>Bosminopsis deitersi</i>	●		●		●		●	●	●	●	●	●		●			●		●
<i>Bosminopsis negrensis</i>			●																
MOINIDAE																			
<i>Moina micrura</i>		●			●			●	●	●			●				●		●
<i>Moina minuta</i>	●		●			○	●		●	●		●	●	●	●		●		●
<i>Moina reticulata</i>	●		●						●	●		●							●
<i>Moina rostrata</i>			●									●							
<i>Moinodaphnia macleayi</i>		●		○					○	●			●						●
DAPHNIIDAE																			
<i>Ceriodaphnia cornuta</i>	●		●		●		●	●	●	●	●	●		●	●		●		●
<i>Ceriodaphnia laticaudata</i>																			●
<i>Ceriodaphnia pulchella</i>			●																●
<i>Ceriodaphnia quadrangula</i>																	●		●
<i>Ceriodaphnia reticulata</i>			●									●					●		●
<i>Ceriodaphnia richardi</i>																			●
<i>Ceriodaphnia silvestrii</i>					●		●										●		●
<i>Daphnia ambigua</i>																	●		●
<i>Daphnia gessneri</i>			●		●		●		●	●		●		●			●		●
<i>Daphnia laevis</i>									●										●
<i>Daphnia parvula</i>														●					●
<i>Scapholeberis armata</i>										●									●
<i>Scapholeberis spinifera</i>																	●		●
<i>Simocephalus acutirostratus</i>		●							○				●						●
<i>Simocephalus daphnoides</i>																	●		●
<i>Simocephalus latirostris</i>			●									●	●						●
<i>Simocephalus semisseratus</i>									○										●
<i>Simocephalus serrulatus</i>							●		●	●							●		●
<i>Simocephalus vetulus</i>													●				●		●
ILYOCRYPTIDAE																			
<i>Ilyocryptus sordidus</i>								●											●
<i>Ilyocryptus spinifer</i>			●		●		●		●	●	●	●	●	●		●	●		●

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follows

	AC	AL	AM	BA	DF	ES	GO	MA	MG	MS	MT	PA	PE	PR	PI	RR	RS	SC	SP
MACROTHRICIDAE																			
<i>Macrothrix laticornis</i>									●	●	●							●	●
<i>Macrothrix mira</i>			●																
<i>Macrothrix paulensis</i>			●		●						○		●			●			●
<i>Macrothrix sioli</i>			●																
<i>Macrothrix spinosa</i>					○		●			●		●	●			●			●
<i>Macrothrix superaculeata</i>			●									●				●			
<i>Macrothrix triserialis</i>		●								●	●	●	●					●	●
<i>Onchobunops tuberculatus</i>										●									
<i>Streblocerus pygmaeus</i>			●		●							●							●
CHYDORIDAE																			
Eurycercinae																			
<i>Eurycercus lamellatus</i>														●				●	
Chydorinae																			
<i>Alonella brasiliensis</i>			●						○							●			●
<i>Alonella clathratula</i>					●			●		●									●
<i>Alonella dentifera</i>										●		●		●				●	●
<i>Alonella granulata</i>													●						
<i>Alonella hamulata</i>		●									●	●	●						
<i>Alonella lineolata</i>																			●
<i>Anchistropus ominosus</i>												●							
<i>Chydorus dentifer</i>			●									●	●						●
<i>Chydorus eurynotus</i>		●	●		●				●	●	●	●	●	●				●	●
<i>Chydorus nitidulus</i>																			●
<i>Chydorus parvireticulatus</i>			●									●							●
<i>Chydorus pubescens</i>					○				●	●	●	●	●					●	●
<i>Chydorus sphaericus</i>			●					●	●	●			●					●	●
<i>Chydorus ventricosus</i>																			●
<i>Dadaya macrops</i>		●		○								●	●						●
<i>Disparalona leptorhyncha</i>					●			●		●		●	●						●
<i>Disparalona dadayi</i>			●		●		●		●	●	●	●	●	●					●
<i>Dunhevedia odontoplax</i>										●		●	●	●			●	●	●
<i>Ephemeroporus barroisi</i>			●	○	●				●		●	●	●			●			●
<i>Ephemeroporus hybridus</i>									●		●	●						●	●
<i>Ephemeroporus tridentatus</i>																●			●
<i>Pleuroxus aduncus grupo</i>										●	●								
<i>Pleuroxus denticulatus</i>																			●
<i>Pleuroxus similis</i>																			●
<i>Pseudochydorus globosus</i>									●			●							●
Aloninae																			
<i>Acroperus harpae</i>			●		●				○	●								●	●
<i>Alona broanensis</i>																			●
<i>Alona cambouei</i>										●			●						
<i>Alona davidi</i>		●									●		●					●	●
<i>Alona guttata</i>					●			●	●					●					●
<i>Alona incredibilis</i>			●																
<i>Alona monacantha</i>										●					●	●	●		●
<i>Alona ossiani</i>																			●
<i>Alona poppei</i>													●						
<i>Alona pulchella</i>		●									●		●						

	AC	AL	AM	BA	DF	ES	GO	MA	MG	MS	MT	PA	PE	PR	PI	RR	RS	SC	SP	
<i>Alona quadrangularis</i>																				●
<i>Alona rectangula</i>					●		●		●		●					●				
<i>Alona rustica</i>					●															●
<i>Biapertura affinis</i>					●		●		●	●	●	●	●	●		●	●			●
<i>Biapertura intermedia</i>		●		○	●		●		○	●	●	●	●	●						●
<i>Biapertura karua</i>					●				○	●	●	●	●			●	●			●
<i>Biapertura verrucosa</i>		●							●		●	●	●							●
<i>Camptocercus australis</i>			●									●								
<i>Camptocercus dadayi</i>										●										●
<i>Celsinotum laticaudatum</i>																●				
<i>Euryalona brasiliensis</i>													●							
<i>Euryalona orientalis</i>		●									●	●	●			●	●			●
<i>Graptoleberis testudinaria</i>										●	●									●
<i>Kurzia latissima</i>										●		●		●			●			●
<i>Kurzia longirostris</i>																				●
<i>Leydigia ciliata</i>							●				●									
<i>Leydigia ipojucae</i>													●							
<i>Leydigia propinqua</i>													●							
<i>Leydigia schubarti</i>													●							
<i>Leydigiopsis brevirostris</i>										●			●							
<i>Leydigiopsis curvirostris</i>									○	●	○	●	●	●						●
<i>Leydigiopsis megalops</i>																				●
<i>Leydigiopsis ornata</i>		●											●							
<i>Notoalona sculpta</i>												●								●
<i>Oxyurella ciliata</i>										●										●
<i>Oxyurella longicaudis</i>		●									○		●							●
Number of species	07	15	41	08	26	02	17	10	36	43	34	42	36	23	04	15	47	02	71	

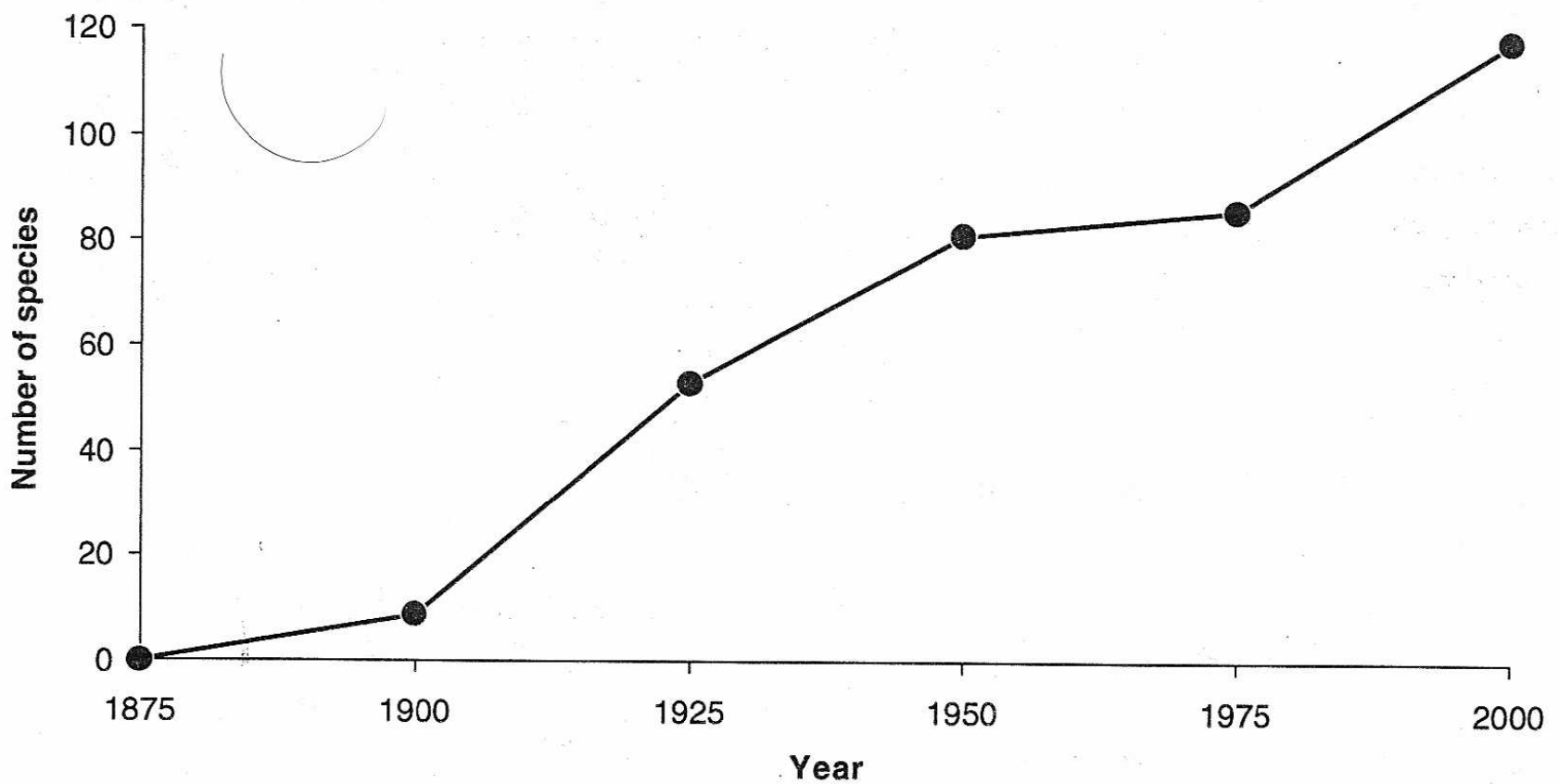


Figure 2: Evolution of the number of cladoceran species known in Brazil.

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Table II: Relative number of species (%) in each cladoceran family, for the worldwide fauna (Korovchinsky,1996) and for Brazilian fauna (this paper).

Family	Worldwide Fauna	Brazilian Fauna
Holopedidae + Sididae (Ctenopoda)	7	11
Bosminidae	3	6
Daphniidae	24	16
Moinidae	5	4
Ilyocryptidae	3	2
Chydoridae	10	8
Total		

Table III: Number of cladoceran species found in Brazil in accordance to their known geographical distribution and to their habit.

	Neotropical	New World	Cosmopolitan	TOTAL
Planktonic	20	8	16	44
Non-planktonic	32	6	36	74
TOTAL	53	14	52	118

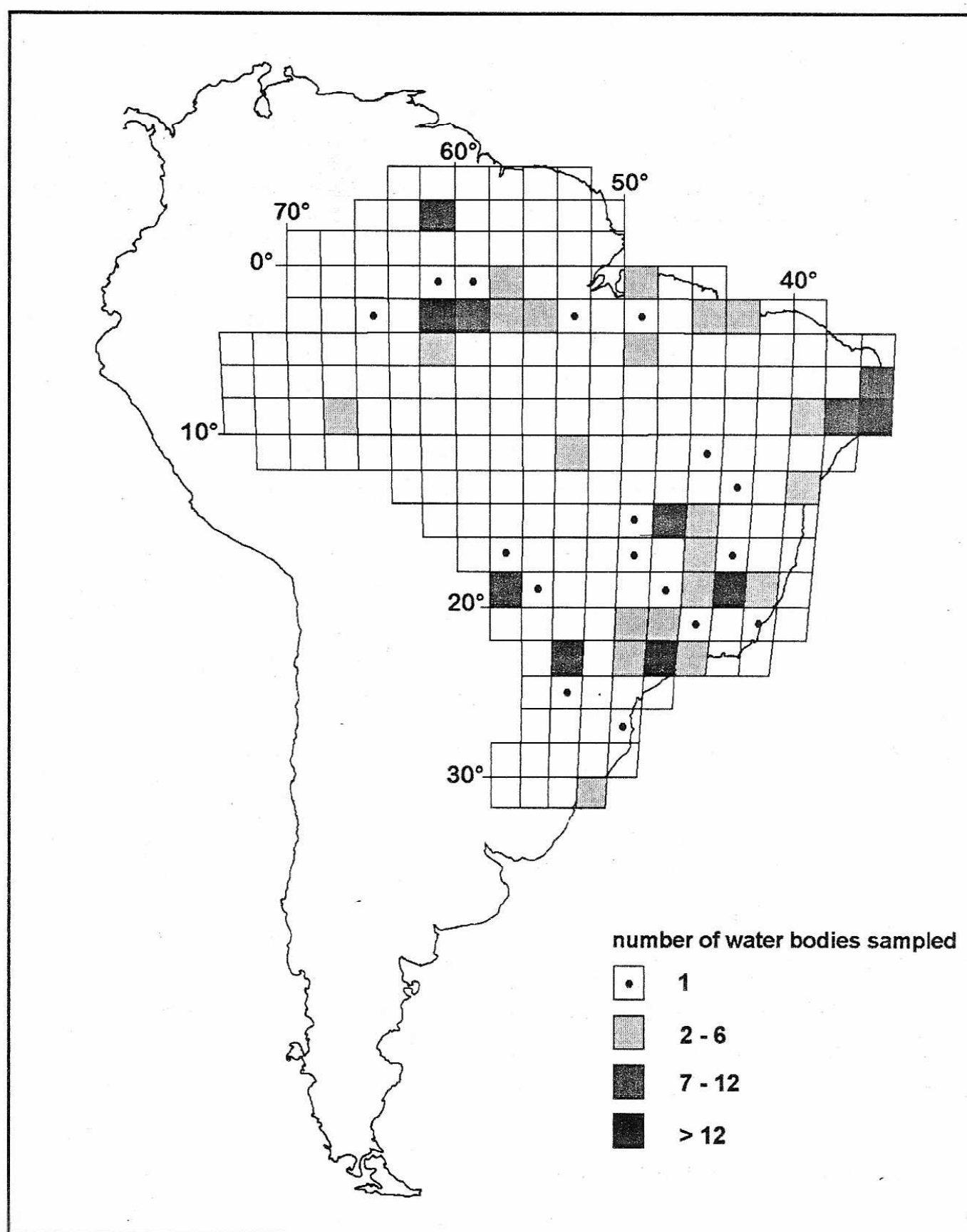


Figure 3: Density of collecting localities for cladocerans in Brazil, indicated by the number of water bodies sampled in each two degree quadrilaterals. Quadrilaterals in blank indicate no samples collected.

Discussion

Ihering's pioneer study (1895) began the history of the publications on freshwater cladocerans in Brazil. The nature of publications differs in different periods. The first half of the 20th century was characterized by species descriptions and occurrence reports (herein termed taxonomic publications). The second quarter is remarkable for the number of publications (Fig. 1), when a series of papers on northeastern cladocerans (Brehm, 1937, 1938; Brehm and Thomsen, 1936) and on cladocerans of the city of São Paulo (Bergamin, 1931, 1935, 1939a-c, 1940a-b, 1941) were published.

Most species were first recorded before 1950 (Fig. 2), resulting from the predominantly taxonomic character of the studies in that period. Sars' paper (1901) is particularly important, because of the great number of species recorded and its influence on identifications made by subsequent researchers.

From the 1970s onwards, Brazilian limnology made great strides forward, especially after the creation of postgraduate courses in ecology (Esteves, 1988). This led to the pronounced increase in cladoceran publications in the last quarter of the 20th century, and to the change in the nature of these articles (Fig. 1). This expansion allowed more extensive sampling of the national territory, but, on the other hand, complicated the picture in regard to identification and distribution. Because of the lack of taxonomic specialists and Brazilian catalogues for these animals, the limnologists based their identifications on catalogues of North American fauna (Brooks, 1959; Pennak, 1978) and other major compilations (Smirnov, 1974, 1976). For less experienced researchers, the use of this literature – which concerns a diverse fauna and is based on the concept of cladoceran cosmopolitanism (a controversial concept, as will be discussed later) – can lead to errors. For this reason, the identifications made in this period must be considered with caution.

Recent revisions (for example: Korovchinsky, 1992; Smirnov, 1992, 1996; Elmoor-Loureiro, 1997; Orlova-Bienkowskaja, 1998) have offered more adequate support for cladoceran species identification. However, it is still too early to evaluate the consequence of improved taxonomic resources for knowledge of the local cladoceran species.

Although there are cladoceran records from the majority of Brazilian states (Appendix 1), this does not mean that the country has been adequately surveyed. On the contrary, there are wide areas still unstudied, with only a few regions relatively well known (Fig. 3).

Superimposing the species list for Brazilian states (Appendix 1) on the map of distribution of water bodies studied (Fig. 3), one perceives that the regions which have a greater number of species are exactly those where greater sampling effort has been made and where there is a longer tradition of limnological studies (São Paulo, Rio Grande do Sul, Amazonia, Mato Grosso do Sul and Pernambuco). This correlation between the number of known species and sampling effort suggests that poor knowledge of the cladoceran fauna in other regions underestimates the species richness of the Brazilian fauna.

This impression of inadequate knowledge is also supported by the effect of the inclusion of few samples on the number of species (Appendix 1). Consider, for example, the case of Bahia, where the inclusion of 1 sampling area quadrupled the number of known species (from 2 to 8). The same is seen for Mato Grosso (where the addition of only 1 sample added 6 species to the previous list) and Minas Gerais (an increase of 10 species from 4 new samples).

Consider also the effect of sampling method on knowledge of species distribution. In limnological studies it is common to restrict cladoceran sampling to the zooplankton community, which results in the exclusion of three families from the samples (including the Chydoridae, the largest in species number). It seems that this procedure has not reduced the relative number of species per family in Brazil, compared to the worldwide fauna (Table II). However, such sampling constraints can be significant in the evaluation species distribution, especially in those regions where few studies have been carried out. For example in the state of Acre, the only study available (Sendacz and Melo Costa, 1991) concerned only planktonic species and therefore did not result in collections of species of Chydoridae, Macrothricidae, and Ilyocryptidae (Appendix 1), which very probably occur there.

However, the emphasis on zooplankton sampling suggests that we can place more confidence in species data for the plankton community than in that for the others. Thus, the lower ratio observed for Daphniidae and the higher ratios observed for Bosminidae and Ctenopoda for the Brazilian fauna in comparison with the world fauna (Table II) should not be considered a mere sampling artifact, but an actual distribution pattern. It is well known that species of *Daphnia* (Daphniidae) are rare in tropical lakes, perhaps because of their large size and the intense predation pressure from visual plankton-feeders in these regions (Fernando *et al.*, 1987). It may be possible that the niche left vacant by *Daphnia* species is being filled by smaller or less visible species, such as the members of the Bosminidae and many Sididae.

Cladoceran researchers have changed their attitude toward the concept of cosmopolitanism (Frey, 1995). Following the uncritical belief in the existence of cosmopolitan species that was generally held until the 1970s, it has been shown that many of these taxa are in fact species-complexes. Endemism is more prevalent than previously supposed, especially in the Chydoridae and other non-planktonic families (Frey, 1982, 1987a-b, 1993; Paggi, 1992; Korovchinsky, 1996; Dumont, 1997; Silva-Briano *et al.*, 1999). Several authors have advocated the necessity for revision of the so-called cosmopolitan species (Frey, 1995; Korovchinsky, 1996; Dumont, 1997).

Judging from this new perspective, the fragility of the data on the identification and distribution of the cladoceran species presented here is evident. Half the species recorded in Brazil are considered "cosmopolitan", two-thirds are non-planktonic species, and one-third are both non-planktonic and "cosmopolitan" (Table III). We must keep in mind that most species were first recorded before 1950 (Fig. 2). Those determinations were therefore influenced by the idea of species cosmopolitanism, and continue to influence later generations of researchers (as in the case of Sars' classic paper). Moreover, a great part of the identifications and records made in the second half of the century was made by non-taxonomists in limnological studies (Fig. 1). There is the final factor of sampling problems, already discussed. The resulting scenario is full of uncertainties, suggesting that the available species list is still preliminary, and that we are at a new starting point for future research.

This scenario indicates some urgent necessities for development of knowledge on cladoceran occurrence and distribution in Brazil: (1) to increase the sampling by exploring either new geographical areas, or different habitats in water bodies; (2) to take great care in species identification; and (3) to revise the so-called "cosmopolitan" species presently recorded from this country.

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