# Exotic species of zooplankton in the Upper Paraná River floodplain, *Daphnia lumholtzi* Sars, 1885 (Crustacea: Branchiopoda)

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Received November 10, 2008 – Accepted March 4, 2009 – Distributed June 30, 2009

(With 2 figures)

## Abstract

The integrity of aquatic ecosystems is being challenged worldwide by invading species, which has been one of the frequent causes of biodiversity loss. The invader may cause extinctions of vulnerable native species through predation, grazing, competition and habitat alteration. *Daphnia lumholtzi* G. O. Sars, 1885, a native cladoceran from Australia, Southwestern Asia and North Africa, has recently been found in the Neotropical region. The *D. lumholtzi* records from the Upper Paraná River floodplain were restricted to the Pombas floodplain lake (22° 47' 55.92" S and 53° 21' 32.58" W) and Pau Véio Backwater (22° 44' 50.76" S and 53° 15' 11.16" W), in 2003 and 2008, respectively. This species can be distinguished from the other *Daphnia* species registered in Brazil by the conspicuous pointed fornix, the sizes of the tail spine and helmet, and a carapace ventral margin with strong spines. The high temperatures in the tropical region, as well as the increase in water transparency and the decrease in nutrient concentration observed in the environments of the Upper Paraná River floodplain due to the upstream retention by dams, may favor the development of *D. lumholtzi* populations. The development of populations of *D. lumholtzi* in natural environments of the Upper Paraná River floodplain may suggest that this species is establishing in the Neotropical region.

*Keywords: Daphnia lumholtzi*, exotic species, neotropical, zooplankton.

# Espécie exótica de zooplâncton na planície de inundação do Alto Rio Paraná, *Daphnia lumholtzi* Sars, 1885 (Crustacea: Branchiopoda)

## Resumo

A integridade dos ecossistemas aquáticos está sendo desafiada no mundo inteiro por espécies invasoras, as quais tem sido uma das causas freqüentes de perda de biodiversidade. Um invasor pode causar extinções de espécies nativas vulneráveis através de predação, herbivoría, competição e alteração de habitat. *Daphnia lumholtzi* G. O. Sars, 1885, cladócero nativo da Austrália, sudeste da Ásia e norte da África, recentemente tem sido registrado na região neotropoical. Os registros de *D. lumholtzi* na planície de inundação do Alto Rio Paraná foram restritos a lagoa das Pombas (22° 47' 55.92" S e 53° 21' 32.58" O) e Ressaco do Pau Véio (22° 44' 50.76" S e 53° 15' 11.16" O), em 2003 e 2008, respectivamente. Esta espécie pode ser diferenciada das demais espécies de *Daphnia* encontradas no Brasil pelos conspícuos fórnices pontiagudos, tamanho dos espinhos caudal e elmo, e margem ventral com espinhos fortes. As elevadas temperaturas na região tropical, o aumento da transparência da água e a redução das concentrações de nutrientes nos ambientes da planície de inundação do alto rio Paraná, devido aos represamentos a montante, podem estar favorecendo o desenvolvimento de populações de *D. lumholtzi.* O desenvolvimento de populações de *D. lumholtzi* em ambientes naturais da planície de inundação do alto rio Paraná pode representar o estabelecimento desta espécie na região neotropical.

*Palavras-chave: Daphnia lumholtzi*, espécie exótica, neotropical, zooplâncton.

## 1. Introduction

Species invasions represent one of the most urgent threats to the integrity of freshwater ecosystems (Havel et al., 2005a) since invaders may cause the extinction of vulnerable native species through predation, grazing, competition and habitat alteration (Mack et al., 2000). Thus, there is a growing need to understand the invasion process and to predict the success and effects of invading species (Moyle and Light, 1996) in order to

identify future invaders and predict their likely sites of invasion (Mack et al., 2000). This impact has been frequently reported in the Neotropical region, where freshwater ecosystems are threatened by the introduction and dispersion of exotic species, resulting in environmental, social and economical damage, such as the invertebrate *Limnoperna fortunei* (Mollusca) (Karatayev et al., 2007; Sylvester et al., 2007).

Zooplankton fauna from temperate and tropical regions present a clear difference in size, with a predominance of larger species in the temperate region (Fernando, 1994). This difference can be explained by some hypotheses, such as size-selective predation: predation selectivity may exclude large zooplankton species from the environment (Brooks and Dodson, 1965). Recently, *Daphnia lumholtzi* G. O. Sars, 1885 (Crustacea: Branchiopoda), a native species cladoceran from Australia, Southwestern Asia and North Africa (Dumont, 1994) that has body proportions that are on average larger than those of tropical cladocerans was recorded in Brazil, in the Três Irmãos Reservoir, São Paulo State (Zanata et al., 2003). Since the first record of its presence in North America (Sorenson and Sterner, 1992), this species has displayed rapid dispersion in reservoirs across the United States (Havel and Medley, 2006). The impact of this species on the native fauna remains to be determined; experimental studies are necessary to evaluate its real impact on Brazilian aquatic ecosystems. Taking into account the size-efficiency feeding hypothesis (which proposes that larger species are more efficient at feeding on small particles) (Dodson, 1974), the establishment of *D. lumholtzi* populations may affect the native zooplankton biodiversity in Brazilian aquatic environments.

In the Neotropical region, 190 cladoceran species were recorded in different freshwater environments, and 98 species are endemics (Forró et al., 2008). In Brazil, approximately 140 species have already been recorded (Elmoor-Loureiro, 1997; 2007; Paggi and Rocha, 1999; Santos-Wisniewski, et al., 2001; Lopes et al., 2006; Sousa et al., 2008; Lansac-Tôha et al., 2009), although a large area of the territory, with various types of biotopes, has not yet been studied.

Cladocerans are an important group for the energy metabolism of aquatic ecosystems due to their intermediate position in the food chain, allowing them to be influenced by both top-down as well as bottom-up processes (Lampert, 1997). The *Daphnia* genus presents higher species numbers in temperate regions (Sendacz, 1993; Dumont, 1994). In Brazil, four species have already been recorded: *Daphnia gessneri* H. Herbst 1967*, Daphnia leavis* E. A. Birge 1878*, Daphnia ambigua* D. J. Scourfield 1947 and *Daphnia lumholtzi* G. O. Sars 1885. The first species has a wide geographic distribution in Brazil and is endemic to the South American region (Matsumura-Tundisi, 1984).

The cladoceran community from the Paraná River floodplain has been studied in the Argentine stretch since the 1970's (Paggi, 1995; Paggi and José de Paggi, 1990; 1974; José de Paggi, 1978), and in the Brazilian stretch since the 1980s (Lansac-Tôha et al., 1992; 1993; 1997; 2004; 2009; Sendacz, 1997; Serafim Jr. et al., 2003).

Biotic and abiotic aspects of rivers, floodplain lakes, channels and backwaters from the Upper Paraná River floodplain have been regularly monitored through Long Term Ecological Research (LTER/PELD-CNPq-site 6) started in 2000. Since then, about 70 cladoceran taxa have been registered, and *Daphnia* species (*D. gessneri* and *D. leavis*) occur in the study area (Lansac-Tôha et al., 2004). In addition to other cladocerans, these species have been an important food resource for fish larvae (Makrakis et al., 2008).

The distribution of *D. lumholtzi* in freshwater environments has been of great ecological interest since modeling their occurrence has contributed to an understanding of range expansion, the potential mechanisms of dispersal, and the effects of biological invasion, coexistence, competition and predation among zooplanktonic organisms (Dzialowski et al., 2000; Johnson and Havel, 2001; Lienesch and Gophen, 2001; Havel et al., 2002; Havel et al., 2005b; Havel and Medley, 2006). Thus, for a strategy of environmental conservation that will prevent future problems, it is important to characterize the occurrence and distribution of exotic species as well as the environmental conditions where they have been observed.

The present study sought to record the occurrence of *D. lumholtzi,* an exotic cladoceran species, in natural environments in the Upper Paraná River floodplain. We aimed to provide information about population size and the environmental conditions where they have been recorded, as well as some taxonomical characteristics.

## 2. Materials and Methods

The Upper Paraná River floodplain (Figure 1) (22° 30'-22° 00' S and 53° 00'-53° 30' W) occupies an area superior to 802,150 km$^2$ in Brazilian territory (Souza-Filho and Stevaux, 2004). In this floodplain, the diversity of aquatic biotopes comprises rivers, secondary channels, backwaters, tributaries with semi-lentic characteristics and temporary and permanent floodplain lakes (Agostinho et al., 2004).

Since 2000, cladocerans have been sampled in many different environments (rivers, connected and isolated floodplain lakes, secondary channels and backwaters) located in the three principal systems of this floodplain (Baía, Paraná and Ivinheima systems). Samplings were carried out every three months, at the subsurface, in the pelagic region of each environment, using a motorized pump and plankton net (68 μm), filtering 600 L of water per sample. The samples were preserved in formaldehyde (4%) solution, buffered with calcium carbonate. The specimens are deposited in the collection of the Zooplankton Laboratory (Nupélia/UEM).

Thirty *D. lumholtzi* individuals were collected to measure the total length, body length (base of tail spine to the superior portion of the eye), tail spine length and helmet (superior portion of the eye until the end of the

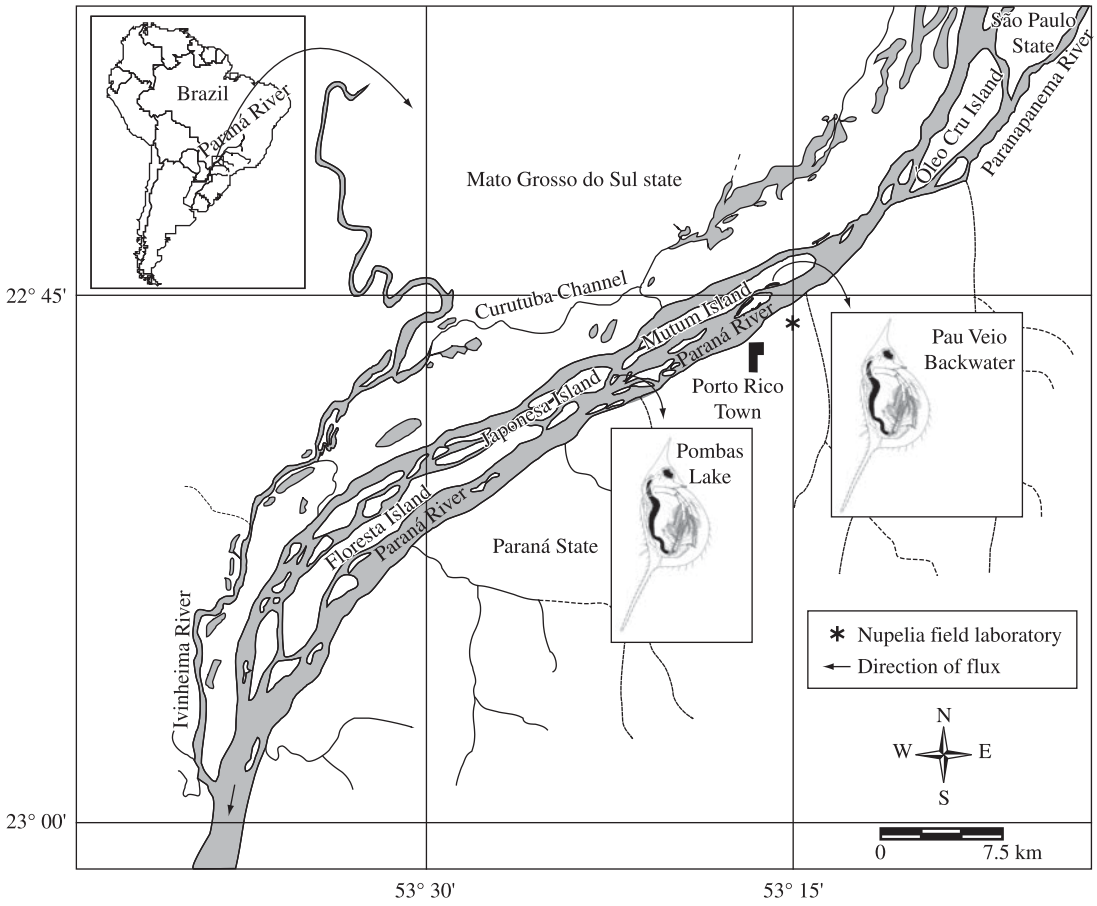


**Figure 1.** Upper Paraná River floodplain and site occurrence of *Daphnia lumholtzi*.

helmet). The measurements were taken at 125× magnification, using an optical binocular microscope fitted with an eyepiece micrometer.

Limnological data were furnished by Limnology Laboratory (Nupélia/UEM). The description of limnological factors in the Upper Paraná River floodplain and their temporal tendencies can be found in Roberto et al. (2009). We assessed the temporal tendencies of physical and chemical factors (2000-2008) in environments (Pau Véio Backwater) where quantitative samples of *D. lumholtzi* were obtained. These tendencies were measured by performing a Pearson correlation test and the significance level adopted was $p < 0.05$.

## 3. Results

### DAPHNIIDAE Straus, 1820

*Daphnia* Muller, 1795

*Daphnia lumholtzi* Sars, 1885 (Figure 2)

Sars, 1885: 18, pl. 1, figs. 1-10; pl. 3-4; Nayar, 1971: 509, figs. 1-5; Nasar, 1977: 33, fig. 9; Fernando, 1980: 110; Smirnov and Timms, 1983: 93, fig. 108; Benzie, 1988: 113-122, figs. 15-20; Havel and Hebert, 1993: 1824; Korinek, 2002: 77; Zanata et al., 2003: 717, fig. 2.

**Diagnosis:** Cephalic fornix laterally projected (Figure 2a, b). Ventral margin of carapace displayed strong spines (Figure 2a). Medium and distal region of dorsal margin and tail spine covered by spines (Figure 2a). Antennular mounds are well-developed and close to the rostrum. Claws with three pectens: a strong proximal pecten (Figure 2c), with the second and third decreasing distally. Second abdominal process is 1/3 of the first, and the third one is 1/2 of the second (in adult individuals) (Figure 2d). A detailed description of this species can be found in Benzie (1988).

Measurements (present study): Mean body width, 513 µm (±151), ranging from 250 to 840 µm. Mean body length, 842 µm (±197), ranging from 510 to 1160 µm. Tail spine ranged from 400 to 1,130 µm, with a ratio of body length/tail length ranging from 1.4 to 1.1. In this case, the length of the tail spine can be equivalent to body length. Pronounced helmets pointed and slightly projected toward the front, ranging from 200 to 420 µm.

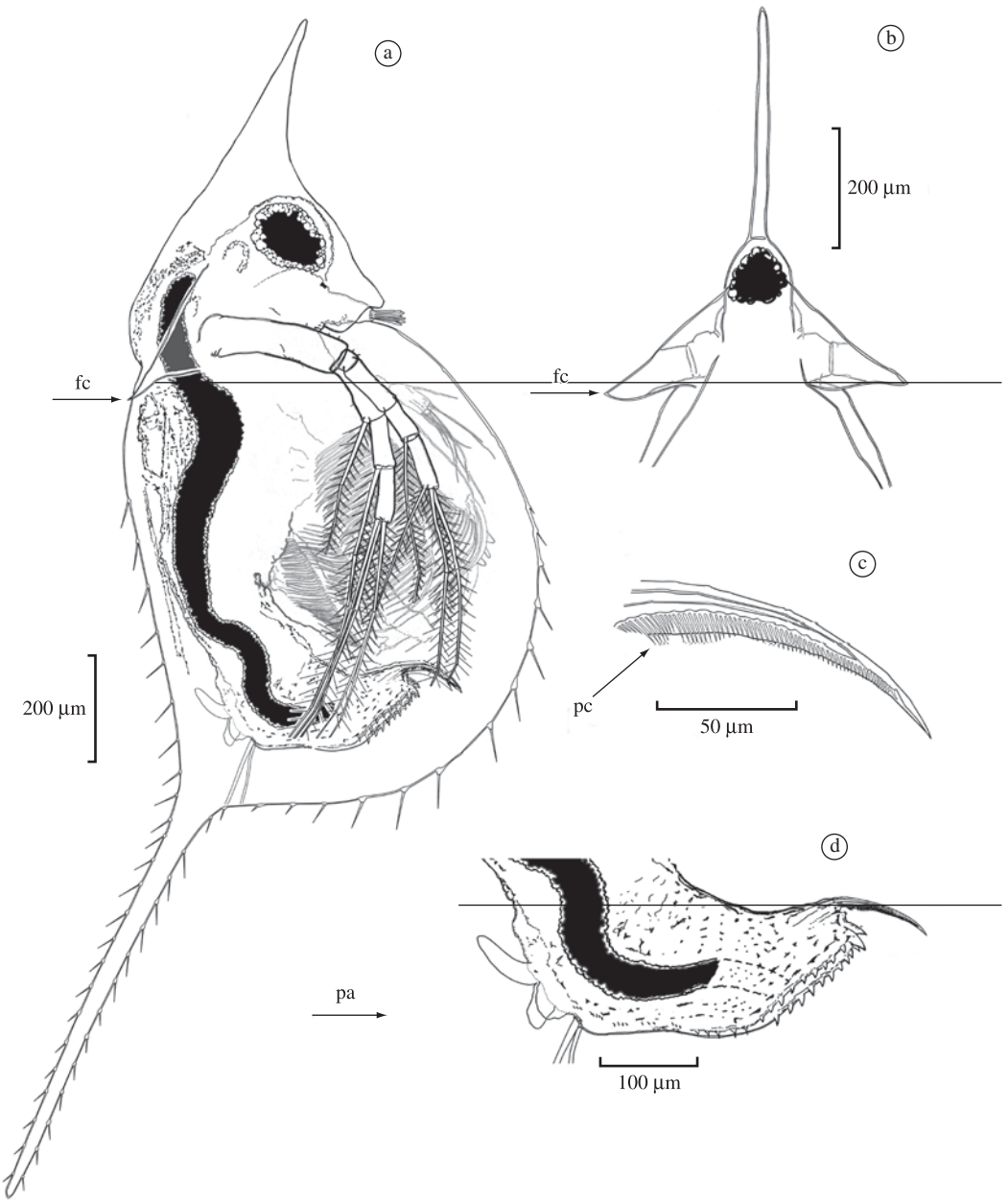


**Figure 2.** *Daphnia lumholtzi* collected in March/2008 in Pau Véio Backwater, Upper Paraná River Floodplain. a) General view; b) Front view of head; c) Claw; d) postabdomen. fc – fornix laterally projected; pa – abdominal process; pc – pectens.

The sum of body, helmet and tail spine lengths from *D. lumholtzi* specimens ranged from 1,130 to 2,710 µm.

Comments: Although the zooplankton community has been regularly sampled in different environments from the Upper Paraná River floodplain since 2000, *D. lumholtzi* was recorded, so far, in only two environments. The first record of this species was observed in qualitative samples from Pombas Lake (22° 47' 55.92" S and 53° 21' 32.58" W) in 2003, during the potamophase period (Robertson, 2004); the other record occurred in 2008, in quantitative samples from the Pau Véio backwater (22° 44' 50.76" S and 53° 15' 11.16" W) during the potamophase period, when we registered this species with a density of 442 ind.m$^{-3}$ (1.5% of the total cladoceran abundance).

Environmental conditions in the Pau Véio Backwater: the physical and chemical characteristics of the water displayed high variation throughout the period studied (Table 1). Among the variables presented in the literature as important for distribution of *D. lumholtzi*, Secchi

**Table 1.** Summary of limnological features in the Pau Véio Backwater from 2000 to 2008. *Significant positive correlation with time; **Significant negative correlation with time.

| | Minimum | Maximum | Mean | March/2008 |
|---|---|---|---|---|
| Water temperature (°C) | 17.30 | 31.30 | 25.19 | 27.0 |
| Dissolved oxygen (mg.L$^{-1}$) | 0.97 | 8.65 | 5.28 | 3.3 |
| pH | 5.87 | 7.40 | 6.58 | 6.71 |
| Electric conductivity (µS.cm$^{-1}$) | 47.00 | 69.70 | 56.95 | 67.2 |
| Total alkalinity (mEq.L$^{-1}$) | 44.10 | 775.30 | 351.74 | 370.7 |
| *Secchi disc (m) | 0.75 | 3.50 | 1.87 | 2.25 |
| Turbidity (NTU) | 0.30 | 18.60 | 4.40 | 5.46 |
| Total solids suspended (mg.L$^{-1}$) | 0.50 | 4.00 | 1.82 | 2.2 |
| **Chlorophyll-*a* (µg.L$^{-1}$) | 0.27 | 22.70 | 4.68 | 4.1 |
| *Total nitrogen (µg.L$^{-1}$) | 85.68 | 975.20 | 371.86 | 922.3 |
| Nitrite (µg.L$^{-1}$) | 0.00 | 163.20 | 72.06 | 82.9 |
| Total phosphorus (µg.L$^{-1}$) | 8.43 | 48.78 | 17.41 | 21.3 |
| Phosphate (µg.L$^{-1}$) | 0.00 | 13.12 | 4.37 | 8.8 |

disc, chlorophyll-*a* and total nitrogen showed significant changes with time: water transparency and total nitrogen increased, while chlorophyll *a* content diminished. These trends reflect changes in physical and chemical conditions of the water, which may be favoring the development of *D. lumholtzi* populations.

## 4. Discussion

*Daphnia lumholtzi* can be distinguished from the other *Daphnia* species registered in Brazil (Matsumura-Tundisi, 1984) by the conspicuous pointed fornix, size of the tail spine and helmet, ventral margin of carapace with strong spines and subrectangular postabdomen with a terminal claw that is slightly curved with three pectens. When compared to the body length of *D. gessneri* (1,170 µm, Castilho-Noll and Arcifa, 2007), *D. lumholtzi* presents similar values for body size. However, its helmet, tail spine and lateral projection are larger than those observed for *D. gessneri.*

In the Neotropical region, *D. lumholtzi* was first recorded in 2000, at Três Irmãos Reservoir (São Paulo, Brazil), with density varying from 55 ind.m$^{-3}$ in the transition region to 100 ind.m$^{-3}$ in the lacustrine region (Zanata et al., 2003). In the Upper Paraná River floodplain, *D. lumholtzi* was registered in 2003 (Pombas floodplain lake) (Roberston, 2004); only after five years (2008) was it recorded in Pau Véio backwater, with the highest density observed in the Neotropical region (442 ind.m$^{-3}$). Both environments are shallower, with mean depth of 3.3 m (Pombas floodplain lake) and 1.8 m (Pau Véio backwater).

In the native area, *D. lumholtzi* inhabits several aquatic biotopes: lakes, floodplains, and dams (Benzie, 1988). The first records in North America (United States of America) were obtained from reservoirs; then the species showed an effective dispersal (colonization) to natural environments in the same basin, such as large rivers, swamps, and natural lakes (Havel and Medley, 2006). Thus, the reservoirs act as stepping-stones for the dispersal of *D. lumholtzi* across landscapes that promoted the invasion process due to their physiochemical properties, greater connectivity, and higher levels of disturbance (Havel et al., 2005a). The same situation currently seems to be occurring in South America.

In Brazil, *D. lumholtzi* has been recorded in different environments associated with the Paraná River (reservoir, floodplain lake and backwater), suggesting that the river serves as a passive vector for dispersal of this species. Other regions in Brazil should be studied regularly to increase the knowledge of this dispersal pattern since *D. lumholtzi* uses rivers as corridors for migration into downstream reservoirs and river floodplains (Havel and Medley, 2006).

The Paraná River Basin has 26 reservoirs (of more than 100 km$^2$ each) built upstream from the floodplain (Agostinho et al., 2008); the last one built was the Porto Primavera Dam in 1998 (30 km upstream of the study area). This reservoir improved control of the previous discharge regime of the Paraná River which, in turn, impacts the limnological conditions of the environments downstream, including the Upper Paraná River floodplain. The dam obstructed suspended sediment transport, increasing river transparency and reducing nitrogen and phosphorus concentrations (Thomaz et al., 2004; Roberto et al., 2009). Thus, the river water quality in the connected environments of the floodplain has been changed, likely due to the upstream cascade of reservoirs (Roberto et al., 2009).

*D. lumholtzi* exhibits tolerance to a wide range of environmental conditions, allowing the species to reach new habitats (Dzialowski et al., 2000; Acharya et al., 2006). However, *D. lumholtzi* obtained greatest colonization success under high temperatures, great transparency, and

low levels of nitrogen and phosphorus (Work and Gophen 1999a, b; Dzialowski et al., 2000; Lennon et al., 2001; Havel et al., 2005b). These limnological conditions were observed in the environments connected to the Paraná River which have been invaded by *D. lumholtzi*.

These records and increased population size demonstrate the establishment of this species in the Neotropical region. High temperatures in the tropical region, especially during the summer, in combination with increased water transparency and decreased nutrient concentration in the Upper Paraná River floodplain, may favor *D. lumholtzi* development. The success of other exotic species in this floodplain, such as the fish *Cichla kelberi* (Abujamra, 2007) and the aquatic macrophyte *Hydrilla verticillata* (Thomaz et al., 2009), has been associated with the increase in water transparency in floodplain environments.

The morphological features of *D. lumholtzi* may also have contributed to population size increases. This species has long spines and projections in its head that are peculiar because they reduce the vulnerability to predation by planktivorous fishes and invertebrates, furnishing an advantage over other *Daphnia* species (Lagergren et al., 2007). However, Johnson and Havel (2001) observed that *D. lumholtzi* may coexist with other daphniids, in temperate regions due to little seasonal overlap with native daphniids. These authors verified that higher densities, biomass and birth rates among *D. lumholtzi* occur only during the summer when there is a decrease in the density of other daphniids that are not adapted to high temperatures. Similar results were also found by Lienesch and Gophen (2001), who stated high abundances of *D. lumholtzi* during the summer when the density of native organisms was low; such conditions favored certain zooplanktivorous fishes through the increase in foraging opportunities during a period with low prey availability. According to Acharya et al. (2006), such life history may be linked to the tropical/subtropical origin of *D. lumholtzi*, including adaptations to survival in dry conditions.

*D. lumholtzi* invasion in Brazil was observed in artificial and natural environments in the Paraná River Basin; however, *D. lumholtzi* dispersal and the consequent distribution pattern were not clear because records were not obtained frequently. This species seems to have achieved the abiotic requirements necessary to survive, but has struggled to remain in the water column (indicating the transposition of biogeographical and physiological filters, Espindola and Julio Jr., 2007) in the Neotropical region. Meanwhile, its success is determined by interactions with local species, through competition and predation (biotic filter). Once the species is successful in establishing its presence, significant changes may occur in the structure of local aquatic communities, although these changes are unpredictable.

*Acknowledgements* — We thank the Limnology Laboratory of Nupelia for providing us with limnological data. We also wish to express our gratitude to CNPq (PELD-site 6) and Nupélia for financial and logistical support, and to CNPq for scholarship funds.

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