# Influence of fish abundance and macrophyte cover on microcrustacean density in temporary lagoons of the Northern Pantanal-Brazil

## Influência da abundância de peixe e da cobertura de macrófitas sobre a densidade de microcrustáceos em lagoas temporárias do Pantanal Norte-Brasil

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**Abstract:** The purpose of this work was to analyze the influence of the abundance of *Serrapinnus calliurus* (Boulenger, 1900) and the macrophyte cover on the total density of microcrustaceans, their groups (Cladocera and Copepoda) and the phases of development in temporary lagoons of northern Pantanal, in the municipality of Nossa Senhora do Livramento, MT, Brazil. Specimens were collected during the ebbing phase in 10 temporary lagoons. A station was selected in each lagoon where microcrustacean and fish specimens were collected and the macrophyte cover was estimated. We found that *S. calliurus* abundance and the aquatic macrophyte cover exerted a negative effect on the total microcrustacean density ($r^2 = 0.62$; $p = 0.03$) and the nauplius ($r^2 = 0.62$; $p = 0.03$), copepodite ($r^2 = 0.68$; $p = 0.01$) and adult ($r^2 = 0.71$; $p = 0.01$) phases of copepods. However, no significantly negative effect was found on the Cladocera ($r^2 = 0.26$; $p = 0.34$) and Copepoda ($r^2 = 0.52$; $p = 0.07$) groups. Our findings suggest that the low concentrations of dissolved oxygen in areas with large macrophyte cover, allied to the high risk of predation by *Serrapinnus calliurus*, are the possible reasons why microcrustaceans avoid areas with macrophytes. Therefore, the density of microcrustaceans in the northern Pantanal is the result of their ecological interactions with predators and the habitat structure.

**Keywords:** zooplankton, *Serrapinnus calliurus*, spatial distribution, refuge effect, floodplain.

**Resumo:** Este trabalho teve como objetivo analisar a influência da abundância de *Serrapinnus calliurus* (Boulenger, 1900) e da cobertura de macrófitas sobre a densidade total de microcrustáceos, seus grupos (Cladocera e Copepoda) e as fases de desenvolvimento em lagoas temporárias do Pantanal Norte, município de Nossa Senhora do Livramento, MT-Brasil. As coletas foram realizadas no período hidrológico de vazante em 10 lagoas temporárias. Em cada lagoa foi sorteado uma estação onde foram tomadas amostras de microcrustáceos, peixes e estimada a cobertura de macrófitas aquáticas. Foi constatado que a abundância de *Serrapinnus calliurus* e a cobertura de macrófitas aquáticas afetaram negativamente a densidade total de microcrustáceo ($r^2 = 0.62$; $p = 0,03$) e as fases de náuplio ($r^2 = 0,62$; $p = 0,03$), copepodito ($r^2 = 0,68$; $p = 0,01$) e adulto ($r^2 = 0,71$; $p=0,01$), entre os copépodes. Porém não se constatou efeito significativo sobre os grupos Cladocera ($r^2 = 0,26$; $p = 0,34$) e Copepoda ($r^2 = 0,52$; $p = 0,07$). Os resultados sugerem que as baixas concentrações de oxigênio dissolvido em área com alta cobertura de macrófitas, bem como o alto risco de predação por *Serrapinnus calliurus*, são as possíveis causas pelas quais os microcrustáceos evitam as áreas com macrófitas. Assim, a densidade de microcrustáceos em lagoas temporárias do Pantanal Norte é resultado interações ecológicas com seus predadores e o hábitat.

**Palavras-chave:** zooplâncton, *Serrapinnus calliurus*, distribuição espacial, efeito refúgio, planície de inundação.

## 1. Introduction

One of the main goals of ecology is to understand the variations in species distribution and abundance patterns. In a broad sense, species distribution and abundance are affected by dispersion, habitat selection, interrelations with other organisms, and physicochemical factors (Krebs, 2001). The relative importance of these factors in determining these patterns varies according to the spatial scale of the analysis, with some factors showing greater importance on some scales than on others.

Innumerable studies have shown that the spatial distribution of zooplankton organisms in lagoons is influenced by the aquatic macrophyte cover and by fish predation pressure (Scheffer, 1998). This distribution depends on the effectiveness of the use of macrophytes as refuge, which results from the equilibrium between predation pressure and macrophyte density (Schriver et al., 1995; Jeppesen et al., 1998; Perrow et al., 1999). Thus, the preference of zooplankton for open waters or vegetated littoral is related to predation risk (Burks et al., 2002). The predator's presence therefore induces zooplankton to develop responses toward spatially opposite directions to those of its predator in order to reduce the risk of being preyed upon (Relyea, 2003).

In short, the macrophyte cover and predation by fish are possible factors that play an important role in the structuring of the density of microcrustaceans. However, little is known about the effective action of these factors in the spatial regulation of the density of microcrustaceans in northern Pantanal lagoons. This study therefore aimed to assess the effect of macrophyte cover and the abundance of fish in the inter-lagoon variation of microcrustacean density. Specifically, we sought answers to the following questions: i) do *Serrapinnus calliurus* (Boulenger, 1900) abundance and macrophyte cover influence the inter-lagoon variation in total microcrustacean density or in microcrustacean groups (Cladocera and Copepoda)?; and ii) do *S. calliurus* abundance and macrophyte cover affect copepod density in the development phases?

## 2. Material and Methods

### *2.1. Study site*

The temporary lagoons are located in the northern part of the Pantanal, in the municipality of Nossa Senhora do Livramento (MT, Brazil). During the period of flooding and high waters (December to April), this region is influenced directly by the flooding of the Piraim River, which is connected to the Cuiabá River, one of the main rivers that make up the Northern Pantanal (Loverde-Oliveira, 2005; Figure 1). During the ebbing period (April to July), the floodplain loses its connection to the river and several temporary lagoons of varying sizes and shapes are formed.

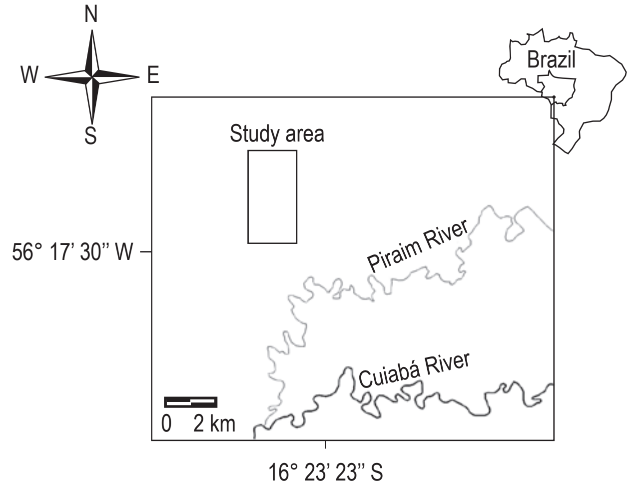


**Figure 1.** Location of the study area in the northern Pantanal.

These lagoons generate a large quantity of habitat, offering a wide availability of food and refuge for many organisms.

Complementary studies carried out in temporary lagoons of the region have revealed ichthyofauna composed of 31 species, among which *Serrapinnus calliurus* (Characidae, Cheirodontinae) is the most abundant, contributing on average to 70% of the total abundance of fishes in this system. The most frequent macrophytes with the highest cover were *Nymphoides grayana*, *Eichhornia azurea*, *Cabomba furcata Marsilea deflexa* (unpublished data).

### *2.2. Sampling*

The study, which involved ten of these lagoons, was carried out on June 5 and 6, 2006, during the ebbing phase of the region's hydrological cycle. In each lagoon, we measured the collection depth, maximum depth, area, perimeter, and water volume. The perimeter was measured by ascertaining the coordinated using GPS (Garmim 76) around the lagoons. Each coordinate was plotted with the AutoCAD (2007) program, which calculated the perimeter and area of each lagoon. The volumes (V) of the lagoons were estimated considering the volume of a hypothetical cone as the basal area of the lagoon's area (A), with height equal to its maximum depth (h) ($V = 1/3\ A*h$).

Using a sketch of the lagoons, one coordinate per lagoon was selected where the area of coverage of aquatic macrophytes, microcrustacean density, and *S. calliurus* abundance were estimated. The macrophyte cover was estimated using a wooden square (1 $m^2$) divided with steel wire into 100 quadrats (0.01 $m^2$). To estimate the total area of cover of the selected station, a count was made of the number of quadrats containing macrophytes. The values were expressed in percentage of cover. To estimate the microcrustacean density (Cladocera and Copepoda), 50 L of water were collected from the subsurface, using a 5 L bucket. The water was filtered through a plankton net

(45 µm mesh) and the specimens were stored in 100 mL flasks with 4% formalin. The microcrustacean density was determined by counting subsamples (3 mL) in Sedgewick-Rafter chambers removed with a conventional pipette. The final density was calculated in individuals per cubic meter. The fish were collected using a rectangular 80 x 120 cm fishing net made of mosquito netting with 2 mm mesh openings. Three standard casts with the net were made close to the selected station to estimate the fish abundance. The collected fish were fixed in 10% formaldehyde and preserved in 70% ethanol for future identification and counting of the species *Serrapinnus calliurus*.

An assessment was made of the effect of the environmental variables on the microcrustacean density by multiple linear regression, using as explanatory variables the *S. calliurus* abundance and the percentage of macrophyte cover and as response variable the microcrustacean density. The assumptions of the regression analysis (linearity and normality) and the correlation between the explanatory variables were checked to verify their colinearity.

## 3. Results

The lagoons of this study were round or elongated, with size and volume varying from 390 $m^2$ to 4,380 $m^2$ and 61 $m^3$ to 1,298 $m^3$, respectively, and were shallow (≤2.00 m; Table 1). The stations chosen in each lagoon varied little in terms of the percentage of macrophyte cover, but this variation can be considered high when one considers the number of *Serrapinnus calliurus* individuals captured (Figure 2).

Total microcrustacean density and fish abundance showed high spatial variability, with densities of zero to 328,000 ind.$m^{-3}$. In the two groups, Cladocera density varied from 2,000 to 96,000 ind.$m^{-3}$ and Copepoda density from 2,000 to 282,000 ind.$m^{-3}$ (Figure 3). As for the mean density of the groups, the contribution of the copepods was higher (75%) than that of the cladocerans (25%).

Considering the copepod development phases, nauplii were more abundant, contributing on average with 83% of the total copepod density, followed by copepodites, with 13% and adults with 3% (Figure 4).

The joint effect of *S. calliurus* abundance and aquatic macrophyte cover on microcrustacean density was significant ($F_{2,7}$ = 5.73; $r^2$ = 0.62; p = 0.034). *Serrapinnus calliurus* abundance (b = –291.21; p = 0.023; Figure 5a) and macrophyte cover (b = –1597.42; p = 0.029; Figure 5b) showed a similarly significant effect on the density of microcrustaceans. Thus, lagoons with lower abundance of *S. calliurus* and aquatic macrophyte cover showed higher densities of microcrustaceans.

Considering the microcrustacean groups separately, we found that the abundance of *S. calliurus* and the macrophyte cover did not exert a significant effect on the cladocerans ($F_{2,7}$ = 1.24; $r^2$ = 0.26; p = 0.34) or on the copepods ($F_{2,7}$ = 3.87; $r^2$ = 0.52; p = 0.07). However, these variables were found to affect the density of development phases of copepods, i.e. nauplii ($F_{2,7}$ = 5.62; $r^2$ = 0.62; p = 0.03), copepodites ($F_{2,7}$ = 7.58; $r^2$ = 0.68; p = 0.01) and adults ($F_{2,7}$ = 8.89; $r^2$ = 0.71; p = 0.01). An increase was identified in the coefficient of determination ($r^2$) with the copepod

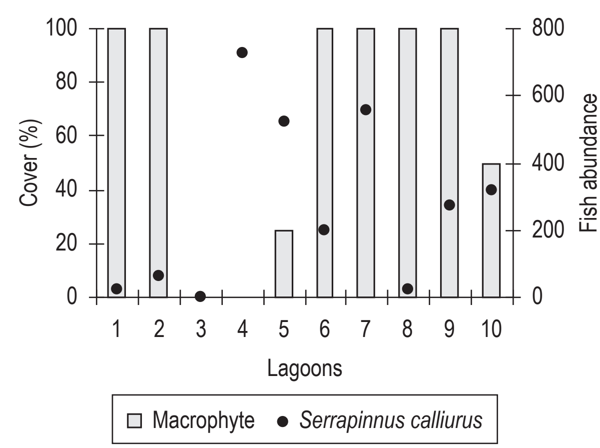


**Figure 2.** Spatial variation of the percentage of macrophyte cover and abundance of *Serrapinnus calliurus* in temporary lagoons of the northern Pantanal.

**Table 1.** Location coordinates and morphometric characteristics of the temporary lagoons of the northern Pantanal.

| Lagoons | Coordinates | | Sampling depth (m) | Maximum depth (m) | Area ($m^2$) | Volume ($m^3$) | Form |
|---|---|---|---|---|---|---|---|
| 1 | 573943 | 8192059 | 0.27 | 0.37 | 2724 | 336 | rectangular |
| 2 | 573356 | 8193472 | 0.27 | 0.34 | 538 | 61 | elongated |
| 3 | 573278 | 8193357 | 0.72 | 2.00 | 1947 | 1298 | round |
| 4 | 573263 | 8193664 | 0.50 | 0.50 | 390 | 65 | round |
| 5 | 573838 | 8195175 | 0.30 | 1.40 | 1395 | 651 | elongated |
| 6 | 572626 | 8190603 | 0.70 | 1.50 | 630 | 315 | round |
| 7 | 572513 | 8190203 | 0.38 | 0.45 | 4380 | 657 | elongated |
| 8 | 572429 | 8190003 | 0.70 | 1.05 | 754 | 264 | round |
| 9 | 572379 | 8189978 | 0.53 | 0.70 | 990 | 231 | elongated |
| 10 | 572348 | 8189813 | 1.20 | 1.70 | 2172 | 1231 | round |

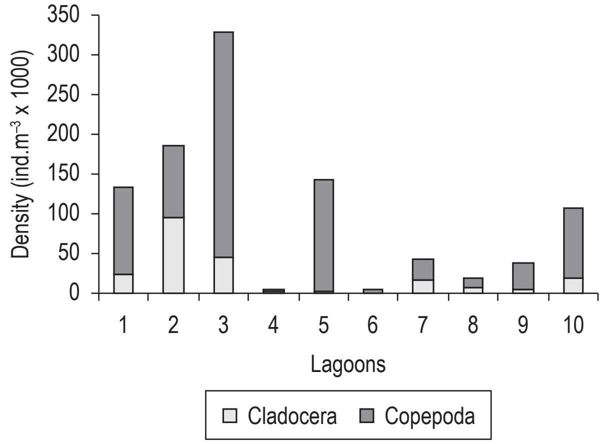


**Figure 3.** Spatial variation of the microcrustacean density, with the contribution of each group (Cladocera and Copepoda).

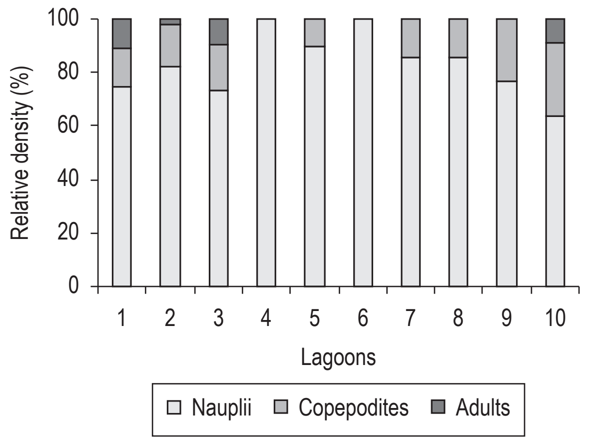


**Figure 4.** Relative contribution of the copepod development phases.

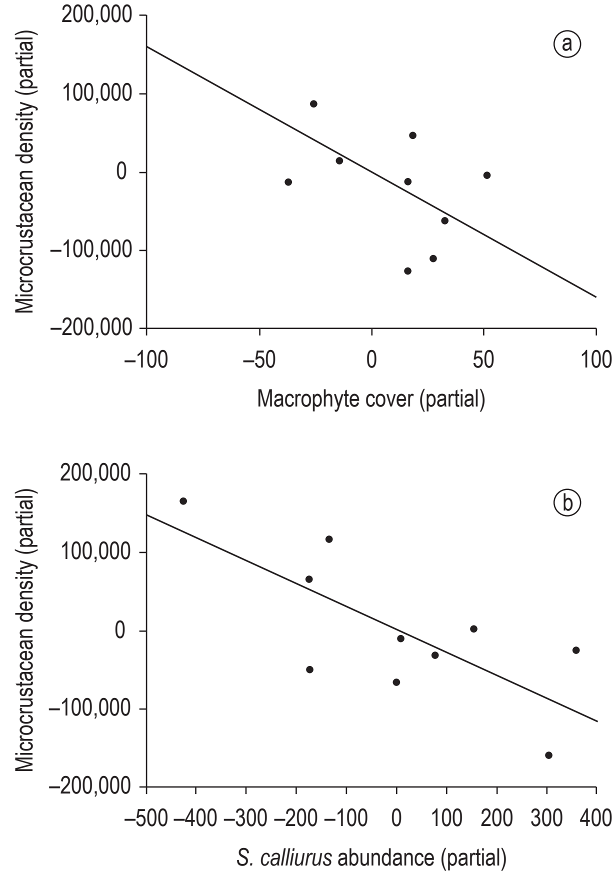


**Figure 5.** Partial results of the Multiple Regression: a) Influence of the macrophyte cover on microcrustacean density; b) Influence of *Serrapinnus calliurus* abundance on microcrustacean density in temporary lagoons of the northern Pantanal.

development phases, suggesting that *S. calliurus* abundance and macrophyte cover act more strongly upon adult copepods than they do on the naupliar phase.

## 4. Discussion

Microcrustacean structure and dynamics in floodplains are the outcome of interactions of the plankton community with the environmental conditions and with other live organisms, resulting in relationships specific to each microhabitat (Wetzel, 1983). In the present study, the magnitude of the variation in microcrustacean density was congruous with the densities reported by Morini (1999) and Fantin-Cruz (2006) in lagoons in this region during the same hydrological phase. With regard to the contribution of the microcrustacean groups in this region, it is common to find higher proportions of copepods than of cladocerans during the entire hydrological cycle (Espíndola et al., 1996; Morini, 1999; Neves et al., 2003; Fantin-Cruz, 2006).

In aquatic environments, the richness and abundance of aquatic macrophytes are two of the primary factors linked to habitat structuring (Wetzel, 1983), providing sites for refuge from predation for microcrustaceans and favoring their diversity and density (Stansfield et al., 1997; Jeppesen et al., 1998; Perrow et al., 1999; Lansac-Tôha et al., 2003). However, the negative effect of macrophytes on the density of microcrustaceans found in this study leads to the supposition that high percentages of macrophyte cover could alter the expected relationship and affect the refuge effect, food availability and limnological characteristics of this environment, as was found by Schriver et al. (1995), where the refuge effect only exists in low macrophyte densities (15-20% of cover) and depends on the density of fishes. Moreover, areas with dense macrophyte cover increase the velocity of nutrient cycling, reducing the availability of oxygen in the environment (Miranda et al., 2000; Thomaz et al., 2003).

Robertson and Hardy (1984) claim that low oxygen concentrations are one of the causes for the diminished density of zooplankton organisms. Hence, it would be reasonable to assume that the low oxygen concentration indicated by the high macrophyte cover was a limiting factor of this relation. Loverde-Oliveira (2005) and Fantin-Cruz

(2006) also observed lower densities of microcrustaceans and dissolved oxygen in the littoral region next to macrophytes than in the limnetic region of the Coqueiro lagoon (Pantanal). This pattern remained unaltered throughout the period of the study.

The negative influence of *Serrapinnus calliurus* abundance on the microcrustacean density can be explained by two mechanisms. First, the mere presence of fish may have led the microcrustaceans to stay away from the site. In experiments, Lauridsen and Lodge (1996) found that, in the absence of fish or of their chemical signs, the population of *Daphnia magma* avoided the littoral region, while in the presence of fish or signs thereof, this cladoceran displayed a tendency to avoid open areas. Secondly, there is the possibility of direct predation, a frequently cited mechanism, whereby fishes may influence lacustrine ecosystems, reducing the abundance and body size of the populations of their prey (Ortaz et al., 2006; Russo and Hahn, 2006). Besides affecting the abundance and size, predation may also select less agile organisms, since they are more easy prey (Fernando, 1994).

The spatial variation of predation risk is explained by the density gradient of microcrustaceans, whose distribution depends on the abundance and location of their predator. In temperate lagoons, zooplankton agglomerates around macrophytes to avoid predation (Scheffer, 1998). This does not occur in tropical and subtropical lagoons due to the large numbers of small and juvenile fishes living in association with macrophyte banks, where the zooplankton distribution pattern is the opposite of that observed in temperate lagoons (Meerhoff et al., 2003; Agostinho et al., 2003; Lansac-Thôa, 2004).

In our study, the dominance of copepods over cladocerans is probably due to the greater motile efficiency of copepods, which facilitates their escape (Zaret, 1980). In fish exclusion experiments in the northern Pantanal, Paiva (2007) found that this exclusion led to a significant increase in the density of cladocerans, indicating that the top-down effect is the main factor in the structuring of the zooplankton community.

Thus, the low microcrustacean density in high macrophyte cover may be ascribed to the high predation pressure by fish in these areas, contradicting the idea that macrophytes provide refuge for zooplankton against fish predators in temperate lagoons (Jeppesen et al., 1998; Burks et al., 2002). In fact, the biomass of periphyton and phytoplankton in Brazil's floodplains probably does not exert any influence on the macrophyte-microcrustacean association because it is a more abundant resource in vegetated areas than in open water (Loverde-Oliveira, 2005; Taniguchi et al., 2005).

Therefore, our findings indicate that the spatial distribution of microcrustaceans is influenced negatively by *S. calliurus* abundance and macrophyte cover, due to the low concentrations of dissolved oxygen in areas with high macrophyte cover, allied to the high risk of predation by *Serrapinnus calliurus*. Due to these factors, macrophytes do not act as a refuge for microcrustaceans against fish predation.

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