Habitat architecture influencing microcrustaceans composition: a case study on freshwater Cladocera (Crustacea Branchiopoda)

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(With 4 figures)

Abstract

Environmental complexity is considered a key factor for diversity enhancement in aquatic ecosystems. Macrophyte stands are a major contributor for this complexity due to their differential architectures. Nevertheless, the influence of distinct aquatic habitat architectures (with different types of macrophytes or without them) on microcrustaceans’ taxa composition, usually found in macrophyte colonized water bodies, is underexplored in limnological studies. The main objective of this study was to analyze this influence by comparing the Cladocera composition among four habitat architectures: (1) fluctuant macrophytes, (2) rooted emergent macrophytes, (3) submerged macrophytes and (4) the limnetic zone of oxbow lakes associated to a large subtropical reservoir. Wide compositional variation was observed. Fluctuant macrophytes exhibited the richest Cladocera assemblage, dominated by Chydoridae. Submerged and rooted emergent macrophytes had the most similar assemblages between them. The most distinctive fauna was found in the limnetic zone, dominated by Bosminidae. Probable differences in resource availability in each sampled habitat architecture are considered as the driving factor for the Cladocera composition variation. We concluded that for a complete inventory of a given local fauna, it is imperative to take into account the aquatic habitat architecture, including macrophyte stands, in the data sampling design.

Keywords: Cladocera, composition, macrophytes, subtropical reservoir.

Arquitetura do habitat influenciando a composição taxonômica de microcrustáceos: um estudo de caso sobre Cladocera de águas continentais (Crustacea Branchiopoda)

Resumo

A complexidade ambiental é considerada um fator chave para o aumento na diversidade de ambientes aquáticos. A presença de bancos de macrófitas é um dos principais contribuintes para tal complexidade devido às suas arquiteturas diferenciadas. Entretanto, a influência de diferentes arquiteturas de habitat (com diferentes macrófitas ou sem elas) sobre a composição taxonômica de microcrustáceos, comumente encontrados em ambientes colonizados por macrófitas, é pouco explorada em estudos limnológicos. O objetivo desse estudo foi avaliar esta influência através da comparação da composição das associações de Cladocera entre quatro arquiteturas de habitat: (1) macrófitas flutuantes, (2) macrófitas enraizadas emersas, (3) macrófitas submersas e (4) a zona limnética em lagos laterais associadas a um grande reservatório subtropical. Ampla variação composicional foi observada. Macrófitas flutuantes apresentaram as mais ricas assembléias de Cladocera, dominadas por Chydoridae. Macrófitas submersas e emersas enraizadas apresentaram as associações mais similares. A fauna mais distinta foi a da zona limnética, dominada por Bosminidae. Prováveis diferenças na disponibilidade de recursos entre as arquiteturas de habitat amostradas foram consideradas o fator mais relevante levando à variação composicional dos microcrustáceos. Concluímos que para um inventário completo de uma determinada fauna local é imperativo que seja considerada a arquitetura dos habitats aquáticos, incluindo os bancos de macrófitas, no desenho amostral.

Palavras-chave: Cladocera, composição, macrófitas, reservatório subtropical.
1. Introduction

Macrophytes can support a high associated biodiversity in the Neotropics, as observed in many regional case studies (e.g.: Meschiatti et al., 2000; Elmoor-Loureiro, 2007; Maia-Barbosa et al., 2008; Guntzel et al., 2010; Panarelli et al., 2008, 2010; Ferrareze and Nogueira, 2011). The spatial complexity generated by the aquatic plants, and the consequent increase in microhabitat availability, is a major contributing factor for its biodiversity (Nogueira et al., 2003; McAbendroth et al., 2005; Thomaz et al., 2008; Thomaz and Cunha, 2010; Ferreiro et al., 2011), especially when compared to the relatively homogeneous limnetic zones (e.g.: Maia-Barbosa et al., 2008, found increased richness in littoralvegetated habitats compared to the limnetic zone). Nevertheless, this theoretical complexity is variable according to the habitat architecture provided by the different macrophyte species or their absence.

Ferreiro et al. (2011) proposed that smaller organisms would be benefitted by higher microhabitat complexity due to a relative wider area for occupation, inaccessible for larger taxa and Grenouillet and Pont (2001) discussed that both architecture and size of plants determine the fauna species composition in macrophyte stands.

Based on the previous considerations it is expected that each physiognomic group of macrophytes and the limnetic zone exhibit a unique or at least diverse fauna composition due to differential habitat architecture.

Most investigations regarding fauna-macrophyte associations (related to habitat architecture and complexity) focus on macroinvertebrates (e.g.: Fulan and Henry, 2006; Tarkowska-Kukuryk and Kornijów, 2008; Thomaz et al., 2008) or fish assemblages (e.g.: Grenouillet and Pont, 2001). Studies that evaluate microscopic fauna composition are scarce and usually do not consider species identity (e.g.: Balcombe et al., 2007). In order to investigate the species level association between fauna and habitat architecture provided by macrophytes or their absence, Cladocera was chosen as a zoological group model. These microcrustaceans have plastic life habit, with many planktonic species as well as benthic and phytophilous ones. The last type can be found associated with macrophytes in the littoral zones, but also in fluctuating stands in the limnetic zone of lentic and lotic habitats (e.g.: Gazulha et al., 2011). The size variation of these organisms is from ~400 µm to a maximum of ~2000 µm in the studied region (the Jurumirim Reservoir upstream lake system) (Nogueira, 2001; Panarelli et al., 2003). Tremel et al. (2000) have already observed Cladocera composition variation between different habitat architectures in a Canadian lake, but only one macrophyte physiognomy was considered. Duigan and Kovach (1994) showed that the macrophyte diversity index was significantly correlated with the Cladocera fauna composition in Scotland, but samples were integrated among macrophytes to represent the lakes, not particular plant architectures.

Therefore, this zoological group can be a good proxy for this investigation, being this study the first to research multiple habitat architectures, considering the presence of different macrophytes and their absence, influencing on Cladocera species composition.

2. Material and Methods

Samplings were carried out in the end of spring 2013 (November) in lateral oxbow lakes of the upstream stretch of Jurumirim Reservoir (Figure 1), a large hydropower reservoir in the Paranapanema River (São Paulo State, Brazil), where it is observed the presence of all physiognomic macrophyte groups (Costa and Henry, 2010). For practical purposes we named the different habitat architecture by the physiognomic group of the present macrophyte or limnetic zone when plants were absent. Four habitat architectures: (1) floating macrophytes, (2) rooted emergent macrophytes, (3) submerged macrophytes and (4) the limnetic zone were sampled with a specific method, as follows (Figure 2).

- **Floating macrophyte (Salvinia auriculata Aublet):**
  - This macrophyte has a complex spatial arrangement, mostly formed by the intricate set of filamentous roots where sediments are accumulated. To sample the habitat architecture provided by these plants a plankton net (68µm) was positioned bellow the stand and raised to isolate a circular area. The macrophytes were then washed inside this area, discarded, and the remaining water filtered through the net (Figure 2a).

- **Rooted emergent macrophyte (Echinochloa polystachya (H.B.K.) Hitch):**
  - The spatial structure of these macrophytes is simple, a main stem from which long leafs grow. The sampling of this habitat architecture was performed by isolating a section of the stem with an acrylic tube, which was closed in both ends after cutting off the stem. The plant was washed inside the tube, discarded, and the water entrapped filtered through plankton net (68µm) (Figure 2b).

- **Submerged macrophyte (Myriophyllum aquaticum (Vellozo) Verdcourt):**
  - These macrophytes have a considerably complex leaf system, with several empty spaces between them. The sampling of this habitat architecture was performed with an underwater hand net (68µm) through multidirectional sweeping (Figure 2c).

- **Limnetic zone:**
  - The limnetic zone can be considered the most spatially homogeneous habitat among the ones sampled. For this architecture 5m horizontal hauls with a 68µm plankton net just beneath the surface were performed (Figure 2d).
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Macrophyte stands were mono-specific and considerably isolated (some meters at least) from other macrophyte species to prevent contamination. The limnetic zone chosen was free of macrophytes on more than a 5m radius and in the surface to at least visible depth.

For each habitat architecture three samples were collected, all fixed in 4% formalin. Samples were analyzed under optical microscopy (Zeiss V6 stereomicroscope and Zeiss Standard 25 microscope). Individuals were identified to the species level through specialized literature (Korovchinsky, 1992; Smirnov, 1992, 1996; Elmoor-Loureiro, 1997; Dumont et al., 2002; Orlova-Bienkowskaja, 1998; Kořínek, 2002; Kotov and Stifter, 2006; Sinev and Elmoor-Loureiro, 2010; Van Damme and Dumont, 2008; Van Damme et al., 2010, 2011; Elmoor-Loureiro et al., 2013). No counting was performed once the different methods have no similar area/volume metrics. In this sense, only compositional data could be considered to compare the influence of habitat

Figure 1. Geographical location and map of Jurumirim Reservoir with indication of the studied region.

Figure 2. Illustration of the methods applied for sampling the different habitat architectures. (a) fluctuant macrophytes; (b) rooted emerged macrophytes; (c) submerged macrophytes; (d): limnetic zone.
architecture. Data was arranged for compositional similarity analysis through Jaccard index. A species list was produced with indication of the habitat in which the species was found. Richness obtained for the different architectures was compared through ANOVA and posterior Tukey test.

3. Results

A total of 29 species were identified in this study. A list of the species in each habitat architecture is presented (Table 1).

Table 1. Species list from habitat architectures analyzed in the upstream zone of the Jurumirim Reservoir. + means presence and – absence.

| Family                        | Limnetic | Emergent | Submerged | Fluctuant |
|-------------------------------|----------|----------|-----------|-----------|
| **Chydoridae Stebbing, 1902** |           |          |           |           |
| Aloninae Frey, 1967           |           |          |           |           |
| Acroperus tupinamba Sinev and Elmoor-Loureiro, 2010 | + | - | - | - |
| Alona cf. glabra Sars, 1901   | -        | +        | -         | -         |
| Alona dentifera (Sars, 1901)  | -        | -        | -         | +         |
| Alona ossiani Sinev, 1998     | -        | -        | -         | +         |
| Camptocercus australis Sars, 1896 | - | + | + | + |
| Karualona muelleri (Richard, 1897) | - | - | - | + |
| Leydigiosis ornata Daday, 1905 | - | - | - | + |
| Notoaalona sculpa (Sars, 1901) | -        | -        | -         | +         |
| Oxyurella ciliata Bergamin, 1939 | - | - | - | + |
| **Chydrinae Stebbing, 1902**  |           |          |           |           |
| Chydorus eurynotus Sars, 1901 | -        | -        | -         | +         |
| Chydorus nitidulus (Sars, 1901) | - | - | - | + |
| Chydorus pubescens Sars, 1901 | -        | -        | -         | +         |
| Ephemeropturus hybridus (Daday, 1905) | - | - | - | + |
| Pseudochydorus cf. globosus (Baird, 1850) | - | - | - | + |
| **Bosminidae Sars, 1885**     |           |          |           |           |
| Bosmina freyi Melo and Hebert, 1994 | + | - | - | - |
| Bosmina hagmanni Stingelin, 1904 | + | - | - | - |
| Bosmina tubicen Brehm, 1953   | +        | -        | -         | -         |
| Bosminopsis deitersi Richard, 1895 | + | - | - | + |
| **Daphniidae Straus, 1820**   |           |          |           |           |
| Ceriodaphnia cornuta Sars, 1885 | + | + | + | + |
| Ceriodaphnia silvestrii Daday, 1902 | + | - | - | + |
| Simocephalus serrulatus (Koch, 1841) | + | + | + | + |
| **Ilyocryptidae Smirnov, 1992** |           |          |           |           |
| Ilyocryptus spinifer Herrick, 1882 | - | + | - | - |
| **Macrothricidae Norman and Brandy, 1867** |           |          |           |           |
| Macrothrix elegans Sars, 1901 | +        | +        | +         | -         |
| Macrothrix squamosa Sars, 1901 | -        | +        | -         | -         |
| **Moinidae Goulden, 1968**    |           |          |           |           |
| Moina minuta Hansen, 1899     | +        | -        | -         | +         |
| **Sididae Baird, 1850**       |           |          |           |           |
| Diaphanosoma brevireme Sars, 1901 | - | - | + | + |
| Diaphanosoma fluviatile Hansen, 1899 | + | - | - | - |
| Latonopsis australis Sars, 1888 | - | + | + | + |
| Sarsilatona serricauda (Sars, 1901) | - | - | - | + |

Most species (21) were found in the fluctuant macrophytes, with assemblage dominated by small benthic detritivorous and phytophilous species of the Chydoridae family, most of them (11 species) found exclusively in this habitat. Rooted emergent and submerged macrophyte habitat architectures had the most similar species assemblage (Figure 3), with species as *Latonopsis australis* and *Simocephalus serrulatus* that can reach large body size. *Alona cf. glabra* was the only species exclusive to the rooted emergent habitat architecture (Table 1). No exclusive...
Habitat architecture influence on Cladocera species was found for the submerged macrophyte habitat architecture.

The limnetic zone habitat architecture was characterized by higher richness of true planktonic Bosminidae (3 exclusive species of this family, Table 1) and was the most divergent from all sampled habitat architectures in composition (Figure 3). Six from the 11 species found in this habitat architecture were exclusive (Table 1).

Richness calculated to the sampled habitat architectures are represented in Figure 4. Only fluctuant macrophyte habitat architecture associated richness was statistically higher from other habitat architectures. The limnetic zone did not showed lower richness as expected when compared to the rooted emergent and submerged macrophyte habitat architectures.

4. Discussion

Spatial complexity in water bodies is considered a driving factor for diversity enhancement (McAbendroth et al., 2005; Thomaz et al., 2008). For some species, the complexity represents a spatially larger habitat to be colonized due to micro-habitat availability (Ferreiro et al., 2011). Additionally, complex sites (e.g.: macrophyte stands) are also involved with refuge, feeding and nursery (Grenouillet and Pont, 2001; Meerhoff et al., 2007). Nevertheless, there are cases when complex sites are detrimental or a sign of danger to some species (Meerhoff et al., 2006).

Although generally enhancing complexity and, in consequence, richness and diversity, macrophytes have variable influence given their density of occupation and architecture (Tarkowska-Kukuryk and Kornijow, 2008; Hinojosa-Garro et al., 2010). In the present study the different habitat architectures provided by the macrophytes and their absence (limnetic zone) had distinct fauna composition, but only the fluctuant macrophyte habitat architecture showed significant higher species richness.

The fluctuant macrophytes habitat architecture was considered more spatially complex than the other ones due to the intricate root structure of these macrophytes. In the samples from this habitat architecture a high amount of organic matter (periphyton and detritus) was observed, being this conspicuous of this type of root system. As most of Chydroridae are substrate dwellers, feeding in periphyton and detritus (Fryer, 1968), the higher richness found in floating macrophytes and almost total exclusion from the other architectures are probably linked to this high amount of organic matter. Species capable of reaching large body size were also recorded in this habitat architecture, but no measures were made to investigate size class variation of the same species between architectures. This size class variation should be addressed in future studies to provide a further understanding of the architecture influence on cladoceran composition.

Hinojosa-Garro et al. (2010) demonstrated the influence of land use and trophic status in the development of periphyton on substrata with different structural complexity, showing that the degree of eutrophication is important for algae development in simpler habitat structures. The reservoir investigated in the present study is oligotrophic (Nogueira et al., 1999), but the area sampled in this study is considered as being more eutrophic than the rest of the reservoir and in need of a management plan for maintenance of water quality (Henry and Nogueira, 2007) and, consequently, the relationships observed between habitat architectures.

The rooted emergent and submerged macrophyte habitat architectures were similar in fauna composition and richness. Although they could be considered as different in spatial complexity (due to the differences in plant structure, but complexity was not measured) these differences were probably not enough to lead to a stronger fauna response. The available space for the organisms in these two habitat architectures, as proposed by Ferreiro et al. (2011), is probably from the same magnitude, thus leading to similar fauna. In the other hand, the absence of Chydroridae is linked to the probable lack of food resources, as discussed above. Although speculative, ontogenetic size variation can be
related to the habitat occupation and, thus, the species common to the macrophyte habitat architectures could present differences in age classes between macrophytes. As discussed above this subject should be addressed in future researches.

The limnetic zone had a most divergent cladoceran assemblage, with high richness of planktonic Bosminidae. The genus *Bosmina* was found only in the limnetic habitat. The species of this family are common widespread planktonic filter feeders (e.g. Melo and Hebert, 1994; Elmoor-Loureiro, 2013) and registers for the studied reservoir has already been provided (Panarelli et al., 2008, 2010; Sartori et al., 2009). This habitat architecture is the optimal habitat for planktonic taxa, thus the increased and exclusive number of planktonic species. Nevertheless, the richness of this habitat architecture was similar to the ones from submerged and rooted emergent macrophytes, although compositionally divergent. This indicates that the considered low complexity of this architecture (due to less spatial heterogeneity) is not numerically reflected by the Cladocera fauna richness in this system. This finding support the need for habitat architecture consideration in the design of studies on Cladocera, once similar richness results could be found for compositionally divergent fauna.

The expected variation of Cladocera composition was confirmed, but only the habitat architecture provided by fluctuant macrophytes was statistically different regarding richness. The assumption that the limnetic zone would have lower richness was not corroborated. The main differences observed were linked to the probable resources (food availability or optimal habitat for true planktonic taxa) associated to the habitat architectures. Numerical similarities in the richness of compositionally divergent habitats were observed, providing the evidence that for realistic assessment of local fauna diversity all habitat architectures must be properly sampled to avoid misleading interpretations. Given this scenario, future studies must take into account the habitat architecture for data sampling design.

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