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TÁSSIA RAYANE FERREIRA CHAGAS

MACROPHYTES AS DRIVERS OF PLEUSTONIC OSTRACODA (CRUSTACEA) IN TROPICAL FLOODPLAIN LAKES

LAVRAS – MG
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Dissertação apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ecologia Aplicada, área de concentração em Ecologia e Conservação de Recursos Naturais em Ecossistemas Fragmentados e Ecossistemas, para a obtenção do título de Mestra.

Dra. Alessandra Angélica de Pádua Bueno
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Dr. Paulo dos Santos Pompeu UFLA

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RESUMO

Comunidades de plantas aquáticas, conhecidas como macrófitas, são diversas em planícies de inundação e desempenham papel de agentes estruturadores em tais habitats, proporcionando recursos alimentares, abrigo e habitat para forrageamento para vários organismos. Muitos estudos pelo mundo abordaram macrófitas e seus efeitos de complexidade sobre a biodiversidade, entretando, a maioria deles não considera as diferenças intrínsecas das distintas formas de crescimento das plantas aquáticas. Nós usamos Modelos Lineares Generalizados Mistos, para focar em macrófitas livres flutuantes e seus efeitos nas assembleias dos ostrácodes pleustônicos. Nós testamos duas variaveis preditoras da riqueza e densidade de ostrácodes. A primeira é a espécie da macrófita livre flutuante, representando a relação interespecífica, e a segunda é o volume do sistema radicular, como uma medida da estrutura de habitat. Este estudo foi conduzido em duas lagoas da planície de inundação do Rio Pandeiros, um tributário do Rio São Francisco. A diversidade total encontrada é consideravelmente alta comparada a planícies tropicais (31 espécies – das quais pelo menos quatro espécies, e também dois gêneros, são possíveis novos registros para a ciência). Maiores valores de volume de raiz abrigaram maior riqueza, entretanto, mesmo entre as macrófitas livres flutuantes existem diferenças além da estrutura de habitat proporcionada. Para a densidade de organismos, a espécie da macrófita teve um efeito independente da estrutura de habitat. *P. stratiotes* e *Salvinia* spp. abrigaram maiores densidades de organismos que *E. crassipes*, mesmo não havendo diferença significativa entre os valores de volume das raízes entre as plantas. A baixa densidade de *E. crassipes* encontrada e o efeito negativo desta planta na densidade de ostrácodes é surpreendente. Nossos resultados revelam a existência de links tróficos em um ambiente ameaçado e situado numa ecorregião de alta prioridade de conservação. Nós chamamos atenção para biodiversidade desconhecida que habita as águas do bioma Cerrado e sugerimos futuros estudos na planície do Rio Pandeiros abordando ostrácodes e seus requerimentos específicos dos recursos e condições proporcionados pelas macrofitas.

Palavras-chave: Biodiversidade do Cerrado. Macrófitas aquáticas livres flutuantes. Estrutura de habitat. Lagoas conectadas.

ABSTRACT

Aquatic plants communities, known as macrophytes, are diverse in floodplains and play the role of structuring agents in such habitats, providing availability of food resources, shelter and foraging habitat to several communities. Worldwilde, several studies have approached macrophytes and its structure effects on biodiversity, although, most of them do not take in account macrophytes distinct ecologic groups. We used Generalized Linear Mixed Models, to focus on free-floating macrophytes and its effects on pleustonic Ostracoda assemblages. We test two variables as predictors of Ostracoda richness and density. The first is free-floating macrophytes species, representing interspecific relationship, and root system volume, as a habitat structure measure. This study was carried in two lakes in Pandeiros floodplain, a São Francisco River tributaire. Total diversity registered is considerably high compared to tropical floodplains (31 species - which at least four species and also two genera are possibly new to science). Higher roots volume values supported higher richness, however, even amongst free-floating macrophytes there are differences beyond habitat structure provided. For density, macrophytes species effect was independent of habitat structure measure. *P. stratiotes* and *Salvinia* spp. were able to host high organism densities than *E. crassipes,* even though root volumes did not differ amongst them. Low *E. crassipes* density was found and a negative effect of this macrophyte on Ostracoda density is outstanding. Our results reveal the existence of important trophic links in an endangered and high priority ecorregion. We call attention to the undiscovered biodiversity inhabiting wetlands in Cerrado biome and suggest further studies at Pandeiros floodplain targeting ostracods and their specific requirements of resources and conditions provided by macrophytes.

Keywords: Cerrado biodiversity. Free-floating aquatic macrophytes. Habitat structure. Connected lakes.

SUMÁRIO

PRIMEIRA PARTE

1 INTRODUÇÃO

Macrófitas aquáticas são vegetais que durante o processo evolutivo desenvolveram adaptações que os permitiram voltar ao ambiente aquático. Possuem uma grande heterogeneidade taxonômica e filogenética, incluindo desde macroalgas até angiospermas (Esteves, 1998). São cosmopolitas e colonizam ambientes diversos como fontes termais, lagoas, lagos, estuários e recifes de corais (Esteves, 1998), além de serem muito abundantes em planícies de inundação neotropicais (Pereto et al., 2016).

Plantas aquáticas são classificadas em grupos ecológicos, de acordo com seu biótopo. Elas apresentam um gradiente de adaptações ao ambiente aquático, onde as plantas submersas enraizadas e livres apresentam adaptações mais intensas, como cloroplastos na epiderme superior, e são consideradas totalmente aquáticas. As enraizadas emersas e enraizadas com folhas flutuantes estão num nível intermediário, seguidas pelas flutuantes livres. As principais adaptações desses vegetais são a redução do grau de lignificação e do xilema. Possuem plasticidade tão intensa, que algumas espécies são capazes de se transformar em formas terrestres em períodos de seca, apresentando acentuadas modificações anatômicas, fisiológicas e fenotípicas (Esteves, 1998).

Comunidades de macrófitas habitam a região litorânea de lagos e lagoas rasas, são a principal comunidade produtora de biomassa em tais ambientes e através da produtividade primária tornam este o compartimento mais produtivo do ecossistema (Esteves, 1998). São agentes estruturadores, pois contribuem para o aumento da complexidade do habitat através de diferentes arquiteturas e complexidade estrutural de suas raízes (Bell et al., 1991), atuam no ecossistema provendo uma série de funções ambientais como maior disponibilidade de alimento, abrigo, local de forrageio e estabelecimento de espécies (Matsuda et al., 2015a). Macrófitas têm sido estudadas como elemento estruturador para peixes (Dias et al., 2017),

macroinvertebrados (Ferreiro et al., 2014) e especialmente para organismos fitófilos (Liberto et al., 2012), que vivem associados a plantas aquáticas.

A fauna associada às raizes das plantas livres flutuantes é conhecida como pleuston (Esteves, 1998). Entre os invertebrados pleustônicos destacam-se os ostrácodes que são pequenos crustáceos caracterizados pela presença de carapaça bivalve envolvendo todo o corpo e apêndices (Horne et al., 2002) com comprimento variando entre 0,3 a 5 mm (Meisch, 2000). Alguns estudos têm demonstrado que comunidades de invertebrados associadas a macrófitas complexas apresentam comumente elevada abundância e riqueza (Higuti et al., 2007, 2010)

Ostracoda, uma das classes mais diversa entre os crustáceos, colonizam diferentes habitats como o ambiente terrestre, marinho e também de água doce (Horne et al., 2002). Na região Neotropical, ostrácodes compreendem 13.75% da diversidade global de ostrácodes viventes não marinhos, conhecida atualmente (Martens et al., 2008) e aproximadamente 260 espécies estão descritas na América do Sul (Martens, 1994).

Ostrácodes viventes de água doce podem ser bioindicadores de parâmetros físico-químicos (Ruiz et al., 2013), mas também apresentam certa tolerância a variações de destes e a parâmetros ecológicos, como presença de cobertura vegetal e predação, com diferentes respostas para espécies diferentes (Kiss, 2007). Fatores como tipo de substrato e nicho ecológico da espécie, influenciam mais a abundância e distribuição de ostrácodes do que características espaciais como variações no tipo de ambiente (Matsuda et al., 2015b).

Estes microcrustáceos apresentam uma grande variedade de interações trófifcas, podem ser carnívoros ou decopositores, mas também podem ser parasitas, hospedeiros e presas. Devido a grande diversidade de hábitos e formas de interação, ostrácodes são considerados links tróficos entre bactérias, algas, macrófitas, invetebrados e vertebrados (Rodríguez-Peréz and Baltanás, 2008). Além da importância na cadeia trófica e ampla distribuição geográfica, a

sua relação com a estrutura de habitat disponibildado pelas plantas aquáticas tem sido estudado recentemente (Higuti et al., 2010; Matsuda et al., 2015a), entretanto, não há clareza sobre o quanto dessa influência é devida a fatores bióticos como relações interespecíficas ou a estrutura de habitat que a planta proporciona (Matsuda et al., 2015a).

Os estudos com enfoque na taxonomia e ecologia sobre ostrácodes ainda são escassos no Brasil e estão concentrados na região sul do país. Na região sudeste, apenas um trabalho foi realizado nas lagoas do médio Rio Doce/MG (Miranda, 2008). Este trabalho faz parte do projeto FAPEMIG 03593/12, intitulado "Desenvolvimento de ferramenta para a priorização de descomissionamento de pequenas centrais hidrelétricas (PCH) no estado de Minas Gerais e estudo de caso para a PCH Pandeiros" e foi desenvolvido na planície de inundação do Rio Pandeiros, um tributário do Rio São Francisco, que contribui para a manutenção da flora e fauna de organismos residentes ou migratórios (Nunes et al., 2009). Vários habitats e duas unidades de conservação existem ao longo de sua planície de inundação: a Área de Preservação Ambiental do Rio Pandeiros (APA) e o Refúgio da Vida Silvestre (REVS), com uso sustentável e proteção integral, respectivamente (Pivari et al., 2013).

A biodiversidade da região é tão alta que somente no REVS existem 101 espécies de macrófitas registradas (Pivari et al., 2013). Por conta do alto endemismo de epécies, e por ser um remanescente lótico para peixes, essa região é considerada área prioritária para conservação da biodiversidade da savanna Brasileira (sensu, "bioma cerrado") (Drummond et al. 2005). Portanto, entender a interação entre ostrácodes e macrófitas no REVS do Rio Pandeiros torna-se relevante para a conservação da biodiversidade aquática do local.

REFERÊNCIAS

Bell SS, McCoy ED, Mushinsky HR. 1991. **Habitat structure: the physical arrangement of objects in space.** Chapman and Hall, New York.

Dias, R M, Silva, J C B, Gomes, L C, Agostinho, A A. 2017. **Effects of macrophyte complexity and hydrometric level on fish assemblages in a Neotropical floodplain**. *Environ Biol Fish* 100:703–716 DOI 10.1007/s10641-017-0597-y.

Duffy J. E. & Thiel M. (2007) **Evolutionary Ecology of Social and Sexual Systems. Oxford University Press.**

Drummond, G.M., C.S. Martins, A.B.M. Machado, F.A. Sebaio and Y.Antonini. 2005. **Biodiversidade em Minas Gerais: um atlas para sua conservação.** Belo Horizonte: Fundação Biodiversitas. 222 p.

Esteves, FA. 1998. **Fundamentos de Limnologia**. Rio de Janeiro (Brazil): Interciência.

Ferreiro, N., Feijoo, C., Giorgi, A., and Hinojosa-Garro, J. R. 2010. **Macroinvertebrates select complex macrophytes independently of their body size and fish predation risk in a Pampean stream.** Hydrobiologia.

Higuti, J., Velho, L. F. M. Lansac-Tôha F. A. and Martens, K. (2007). **Pleuston communities are buffered from regional flood pulses: The example of ostracods in the Parana' River floodplain, Brazil.** Freshwater Biol. 52: 1930–1943.

Higuti J., Declerck S.A.J., Lansac-Tôha F.A., Velho L.F.M., Martens K. (2010) **Variation in ostracod (Crustacea, Ostracoda) communities in the alluvial valley of the upper Parana' River (Brazil) in relation to substrate.** Hydrobiologia 644:261–278.

Horne, D. J.; Cohen, A; Martens, K. **The Ostracoda: Applications in Quaternary Research**. In: HOLMES, J; CHIVAS, A. R. (Eds) Biology, Taxonomy and Identification. Washington, DC: American Geophysical Union Techniques, 2002. p. 5-36.

Liberto, R., Mesquita-Joanes, F., César, I., 2012. **Dynamics of pleustonic ostracod populations in small ponds on the Island of Martín García (Rio de la Plata, Argentina).** *Hydrobiologia* 688, 47–61, http://dx.doi.org/10.1007/s10750-011- 0600-0.

Kiss A. (2007) **Factors affecting spatial atemporal distribution of Ostracoda assemblages in different macrophyte habitats in a shallow lake (Lake Fehe´r, Hungary).** Hydrobiologia 585:89–98.

Matsuda J. T., Lansac-Toha F. A., Martens K., Velho L. F. M., Mormul R. P. & Higuti J., 2015a. **Association of body size and behavior of freshwater ostracods (Crustacea, Ostracoda) with aquatic macrophytes.** *Aquat Ecol* **49**:321–331.

Matsuda JT, Martens K, Higuti J., 2015b. **Diversity of ostracod communities (Crustacea, Ostracoda) across hierarchical spatial levels in a tropical floodplain.** Hydrobiologia. 762:113–126.

Martens, K.; Behen. **A checklist of the non-marine ostracods (Crustacea, Ostracoda) from the inland Waters of South American and adjacent islands.** Travaux Scientifiques du Musee d' Histoire Naturelle de Luxembourg, v. 22, p. 1-81, 1994.

Martens, K., Schön, I. Meisch C. and Horne, D. J. 2008: **Global diversity of ostracods (ostracoda, Crustacea) in freshwaters.** Hydrobiologia 595: 185–193.

Meisch, C. **Freshwater Ostracoda of Western and Central Europe.** Berlin: Spektrum Akademischer Verlag, 522 p., 2000.

Miranda, F. S. 2008. **Ocorrência de Ostracoda no médio Rio Doce/mg e revisão do estado da arte do estudo desse grupo no Brasil.** Universidade Federal de Lavras, Brasil. MSc Dissertation.

Nunes Y. R. F, Azevedo I. F. P., , Neves W. V. , Veloso, M. D, Souza R. A., Fernandes G. W., (2009). **Pandeiros: o pantanal mineiro**. MG.BIOTA, Belo Horizonte, v.2, n. 2, 4–17.

Pereto SCAS, Ribas LGS, Wojciechowski J, Ceschin F, Dittrich J., Bezerra LAV, Padial AA. 2016. **Trade-off in leaf and root investment of an abundant aquatic macrophyte in a Neotropical floodplain.** Fundam. Appl. Limnol. 188(4): 309-314.Rodríguez-Peréz and Baltanás, 2008

Rodrigues P. M. S., Azevedo I. F. P., Veloso M. D. M. , R M. Santos, Menino G. C. O., Nunes Y. R. F. e Fernandes G. W., (2009). **Riqueza florística da vegetação ciliar do rio Pandeiros, norte de Minas Gerais.** MG.BIOTA, Belo Horizonte, v.2, n. 2, 18-35.

Ruiz, F., Abad, M., Bodergat, A. M., Carbonel, P., Rodrıguez Lazaro, J., Gonzàlez-Regalado,M.L., Toscano,A., Garcìa, E. X. and Prenda, J. (2013): **Freshwater ostracods as environmental tracers.** Int. J. Environ. Sci. Technol. 10(5): 1115–1128.

SEGUNDA PARTE

ARTIGO

Macrophytes as drivers of pleustonic Ostracoda (Crustacea) in tropical floodplain lakes

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Abstract:

Aquatic macrophytes are structuring agents that provide availability of food resources, shelter and foraging habitat to several communities in aquatic habitats. Although several studies have approached aquatic macrophytes and its effects on biodiversity, most of them indistinctly target different ecologic groups. Thus, using the Generalized Linear Mixed Models, we focus on free-floating macrophytes and use pleustonic Ostracoda as model organism. We test two variables as predictors of Ostracoda richness and density: free-floating macrophytes species as an interspecific relationship, and root system volume as a habitat structure measure, in two lakes of a priority area for biodiversity conservation in Cerrado domain. Total diversity is considerably high compared to tropical floodplains (31 species - which at least four are new species and also two genera are new to science). Increasing roots volume provided higher richness, although, even amongst free-floating macrophytes there are differences beyond habitat structure provided. For density, macrophytes species effect was independent of habitat structure measure. P. stratiotes and Salvinia spp. were able to host higher organism densities than E. crassipes, even though root volumes did not differ amongst them. Low occurrence of E. crassipes was observed and a negative effect of this macrophyte on ostracods density is surprisingly. Our results reveal the existence of important trophic links in an endangered and high priority ecorregion. We call attention to the undiscovered biodiversity inhabiting wetlands in Cerrado biome and suggest further studies at Pandeiros floodplain targeting ostracods and their specific requirements of resources and conditions provided by macrophytes.

Keywords: Cerrado biodiversity – free-floating aquatic macrophytes – habitat structure – connected lakes

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Introduction

In neotropical floodplains there are high diversity of ecosystems (Oslon et al., 1998) and diversity of habitat is one of the factors that maintain and enhance biodiversity (Junk, 2000). Despite conservation efforts, these environments are placed amongst the most threatened ecosystems around world (Millennium Ecosystem Assessment, 2005) by construction and functioning of dams, alteration of floodpulses, degradation of hydromorphic soil areas (known as veredas), withdrawal of riparian vegetation and deforestation (Oslon et al., 1998; Nunes et al., 2009. Junk et al., 2014). These impacts, direct or indirectly, promote habitat loss to freshwater organisms.

In the last 15 years, several studies have been conducted in freshwater environments considering influence of habitat structure, including habitat complexity and structural heterogeneity, on assemblages diversity (Taniguchi and Tokeshi, 2004; Pelicice et al., 2008; Choi et al., 2016). The 'habitat heterogeneity hypothesis' (see MacArthur and Wilson, 1967) assumes that structural complexity provides more niches and exploiting resources habitats, and therefore, more diverse communities. At local scale, refuge (Mbahinzireki et al., 1991; Warfe and Barmuta, 2004), niche overlap reduction (Vejrikova et al., 2017), availability of small spaces (Tokeshi and Arakake, 2012), particulate organic matter (Stewart, 2003) and biofilm (Balcombe and Closs, 2016) are conditions and resources that maintain biodiversity.

According Tews et al. (2004) "keystone structure" is a distinct spatial structure affording resources, shelter or ecosystem goods and functions crucial for other species. On tropical floodplains, aquatic macrophytes are very abundant (Pereto et al., 2016), they are taxonomic and filogenetic diverse plants which during evolution process returned from terrestrial to aquatic (Esteves, 1998). Thus, they are classified in ecologic groups based on their biotope and on adaptative characteristics to aquatic environment. Submerged plants have more anatomic and fisiologic adaptations compared to free-floating ones and interact distinctly with habitat, the first provide habitat to aquatic organisms with roots, stems and leaves, while the second is not attached to sediment, follow water level and host communities of organisms associated to its roots, which live in the interface water atmosphere, refeered as pleuston (see Esteves, 1998).

Macrophytes are structuring agents that provide availability of food resources, shelter and foraging habitat to several communities, including macroinvertebrates and microinvertebrates (Bell et al., 1991; Kouamé et al., 2011; Lucena-Moya and Duggan, 2011).   They act as keystone structure to fishes (Padial et al., 2009; Dias et al., 2017), macroinvertebrates (Silva and Henry, 2013; Ferreiro et al., 2014), periphyton (Hinojosa-Garro, 2010; Hao et al., 2017) and especially to organisms which live associated to aquatic plants roots (Rocha and Por, 1998; Higuti et al., 2007; Liberto et al., 2012).

The habitat structure that macrophytes provide can be measured through several characteristics, as discrete variables, e.g. number of habitat types, or continuous variables, eg. vegetation coverage (Tews et al., 2004) and it has been assessed by both approaches, by considering root cavities (Hull, 1997; Taniguchi and Tokeshi, 2004; Lucena-Moya and Duggan, 2011) or stem per square meter (Gotceitas and Colgan, 1989), and through plant complexity index of natural macrophytes (Dibble et al., 2006) or artificial ones (Warfe and Barmuta, 2006; Padial et al., 2009), fractal method (Thomaz et al., 2008; Hao et al., 2017) and entire plant dry weight (Dias et al., 2017).

In face of so many approaches to evaluate macrophyte habitat structure and its effects on biodiversity, we recognize macrophytes as keystone structure in aquatic environments, although it is important to consider that the ecological groups, or life forms, have influence in framing associated communities structure (Walker et al., 2013). For example, submerged plants have more anatomic and physiological adaptations to aquatic habitats compared to free-floating ones and interact distinctly with habitat, the first provide habitat to aquatic organisms with roots, stems and leaves, while the second is not attached to sediment and follow water level.

Here we focus on free-floating aquatic macrophytes, they host communities of organisms associated to its roots, which live in the interface water atmosphere, refeered as pleuston (see Esteves, 1998). Several taxa comprise pleustonic communities, as Insecta, Mollusca, Oligochaeta and Crustacea (Walker et al., 2013). Among crustaceans, cladocerans, copepods and mainly ostracods are present (Liberto et al., 2012; Mazzini et al., 2014; Higuti et al., 2016; Conceição et al., 2017).

Ostracods, known as "seed shrimp" or "mussel shrimp", are ubiquitous microcrustaceans protected by bivalve-like valve or "shell" comprising soft body and appendices (Meisch, 2000; Horne et al., 2002). They have a wide variety of trophic interactions as recyclers (Vannier et al., 1998), carnivorous (Ottonelo and Romano, 2010; Prokopenko et al., 2017) and parasites (Bennett et al., 1997), but also can be hosts (Abe and Horiuchi, 2000; Gustafson et al., 2016) and most commonly preys (Harding, 1962; Lancaster and Robertson, 1995; Gutierrez et al.,

2016). This diversity place them as trophic links amongst bacteria, algae, aquatic plant, invertebrates and vertebrates (Rodríguez-Peréz and Baltanás, 2008).

Besides trophic importance and ubiquitous distribution, their relationship with aquatic plants complexity has being studied only recently (Higuti et al., 2010; Matsuda et al., 2015a). Biotic factors, as macrophytes specific characteristics, and structural features are amongst variables driving variation on ostracods diversity, but is still not clear how much of this variation is accounted for each variable (Matsuda et al., 2015a). We select ostracods as model organisms due their sensibility to structural habitat changes, since the structural variable depend on model organisms used (Tews et al., 2004).

In this study, we consider that aquatic environments are three-dimensional spaces where organisms interact and thereby they require measuring methods able to represent water-substrate-organisms interaction. Therefore, we test root volume of free-floating macrophytes as a measure of habitat structure because their root system volume, specifically, represents simultaneously an index of area and a depth gradient of three-dimensional space provided as shelter for pleustonic ostracods. This selection also allow us to untangle our results from the influence of different ecological groups on biodiversity.

We aim to assess the effects of macrophytes species characteristics and habitat structure on richness and density of ostracods assemblage in lakes of a tropical floodplain, excluding sazonal effects. In order to do so, we ask two questions: (I) Does root volume affect positively richness and density of ostracods? (II) Is there an effect of macrophytes species on ostracod richness and density?

Material and Methods

Study area

Cerrado area is a global biodiversity hotspot (Strassburg et al., 2017). The second largest Brazilian biome has covered originally approximately 2 millions km^2, nowadays as little as 20% remains undisturbed and only 6.2% of its area is protected (Myers et al., 2000). In the last 30 years, land use intensification has been altered soil and water parameters (Hunke et al., 2015), and between 2002 and 2011 deforestation rates were 2.5 times higher than in the Amazon (1% per year) (Strassburg et al., 2017). Pandeiros River is a tributary situated on the left margin of the São Francisco and maintains flora and fauna of resident or migratory organisms (Nunes et al., 2009). Because of high endemism of species, especially birds, and for being a lotic remnant for endangered fishes, it is considered a

priority area for biodiversity conservation of the Brazilian Neotropical savanna (sensu, "cerrado biome"), in Minas Gerais state (Drummond et al. 2005). Pandeiros River has two conservation units: the Environmental Protection Area of the Panderios River (APA) with sustainable use and the full protection Pandeiros River Wildlife Sanctuary (REVS), which is located at Pandeiros village, Januária/Minas Gerais state, Brazil, occupying a total area of 6,102.75 ha (Pivari et al., 2013).

The floodplain (15º 40' 06'' S and 44º 38' 03'' W) is permanently inundated on wet season (Rodrigues et al., 2009), and its flooding area ranges from approximately 3,000 to 5,000 ha (Nunes et al., 2009). The average flow rate varies between 8 m³/s to 24 m³/s, during dry and wet seasons, respectively (Fonseca et al., 2008). We selected two permanently connected lakes in the Pandeiros River floodplain apart 4.57 km one from each other, Véio Juca and Torre lakes (Figure 1).

Sampling procedures

In the entire REVS there are 101 macrophytes species (Pivari et al., 2013), amongst them we selected species of the free-floating ecological group present at these lakes: the angiosperms *Eichhornia crassipes* (Mart.) Solms and *Pistia stratiotes* (L.), and the pteridophyte *Salvinia* spp. To collect pleustonic ostracods, we sampled free-floating macrophytes *E. crassipes*, *P. stratiotes* and *Salvinia* spp. in both margins of Véio Juca and Torre lakes, in March 2016 (wet season) and July 2016 (dry season) in order to represent assemblage variation in both hydrological periods. *E. crassipes* was only found in Torre lake.

We established a total of 16 sites, 8 sites in each lake. They were distributed 100 meters distance apart from each other, 4 sampling sites along each margin (Table 1, Figure 1). Key limnological factors such as pH, dissolved oxygen concentration and water temperature were measured *in situ* at each site. Macrophytes sampling units were collected according to their occurrence over the 16 sites in the lakes. Because macrophytes species were not present at all sites 11 samples of *E. crassipes*, 9 of *P. stratiotes* and 29 samples of *Salvinia* spp., 49 samples in total (Tabela 1) were colected. Macrophytes were sampled manually and placed into plastic bucket (see Higuti et al., 2007; Campos et al., 2017).

Ostracods assemblages

Macrophytes roots were separated from the leaves, washed in the bucket to remove ostracods associated with and the residuals were filtered through a zooplankton net (68 μm mesh size). We preserved the samples in 70% ethanol. Ostracods were sorted under a stereomicroscope and were identified to the higher taxonomic level possible using the specialized literature (Martens & Behen, 1994; Rossetti & Martens, 1998; Higuti & Martens, 2012a, b, 2014; Higuti et al., 2013).

Macrophytes root volume

We measured macrophytes root volume (ml) as the displacement of water observed when each root sample was submerged in a 500ml graduated becker. Then the roots were oven-dried at 60ºC for 72h and subsequently weighted to calculate density of organisms as individuals per gram of plant dry mass.

Data Analysis

Distinct estimators were used to express values of species richness, in order to evaluate whether observed species richness recorded in this study is representative of the total ostracod diversity for Pandeiros River floodplain. These estimators were Chao 1, Chao 2, first and second orders Jackknife, Bootstrap, ACE and ICE. Chao 1 and ACE estimators are based on species abundance and the other species richness estimators are based on species incidence. Due to the differences in abundance amongst the samples, rarefaction curves were used to compare species richness amongst macrophytes species.

A Principal Component Analysis (PCA) was performed to order sampling sites based on abiotic limnological variables (pH, water temperature and dissolved oxygen). The abiotic matrix was log transformed, except for pH, to minimize the effect of skewed values. Based on PCA results we treated data to following analysis. A nonparametric Kruskal-Wallis variance analysis was used to assess differences of macrophytes root volume amongst macrophytes species/seasons.

We used Generalized Linear Mixed Models (GLMM's), considering season as a random effect - which means do not take in account season effects to evaluate the effects of habitat structure measures (volume) and macrophytes species on the assemblage taxonomic richness and density of ostracods. We constructed one model considering richness as response (count data) variable and another to density (continuous data). Both models

included volume (count data) and macrophytes species (categorical data) as explanatory variables. We used negative binomial error distributions for richness analyses, since our count data showed significant overdispersion, and a Gaussian error distribution for density data as it fitted normality assumptions. Shapiro-Wilk analisys was applied to test normality of models residuals.

To test every possible combinations of the variables included in the global model we used the dredge function from the MUMIN package. Based on the Akaike Information Criterion of Second Order (AICc) we determined which of these explanatory variables have the biggest effect in potential in the assemblage species richness and density, where the lower AICc values (bellow 2.0) were assumed to indicate the best models (Burnham, Anderson & Huyvaert 2011).

Estimators and rarefaction curves were carried out using the EstimateS statistical software. Graphics were computed using the Systat Software, Inc. SigmaPlot 10.0. Paleontological Statistics Software (PAST) was used to run PCA. GLMM, Kruskal-Wallis and Shapiro-Wilk analysis were performed on R, version 3.2.5 (R Development Core Team. 2009-2017).

Results

In the three free-floating macrophytes species collected , were recorded 5,972 ostracods individuals distributed within 31 species (Table 2), which at least four species and also two genera are possible new to science. The most abundant species were *Cytheridella ilosvayi* Daday, 1905, *Diaphanocypris meridana* (Furtos, 1936), and *Strandesia lansactohai* Higuti & Martens, 2013.

Based on average richness estimations, our sampling effort has reached 89.32% of total estimated richness. Richness estimators showed values that are similar to observed richness, the estimator which best approached observed species richness were the abundance based ACE and Chao. Hence, total numbers of expected and observed species are closely convergent (Figure 2). *Salvinia* spp. presented 27 ostracods species followed by *E. crassipes* (26) and *P. stratiotes* (25). The rarefaction curves showed that there is tendency to increase richness in all macrophytes according to increase the number of individuals (Figure 3).

For the abiotic data (Table 3) the PCA first two axis explained 97.7% of observed variance (Figure 4). Axes 1 and 2 showed no clustering of seasons or lakes. Kruskal-Wallis could not detect significant differences between both lakes abiotic data ($p_{(pH)}$=0.09; $p_{(T)}$=0.91; $p_{(O2)}$=0.7; $p_{(cond)}$=0.54). Kruskal-Wallis test showed no

significant difference amongst the volumes of the three macrophytes species (p = 0.5633)(Figure 5), nevertheless, it changes significantly between seasons ($p_{(P.\ stratiotes)}$ = 0.1761; $p_{(E.\ crassipes)}$ = 0.1839; $p_{(Salvinia\ spp.)}$ = 0.05395) .

From the global model constructed to test complexity effects on richness, the best two ones were selected on the AICc bases. The first model has explained 67.7% of the richness variation and included only root volume, it means that root volume affected richness positively, independent of macrophytes species. The second best model explained 25.8% of variation and included root volume and macrophytes. Macrophytes effects were diverse, *Salvinia* spp. showed a negative effect when compared to *P. stratiotes* and *E. crassipes* (Table 5), demonstrating that despite *Salvinia* spp presented the higher total richness of ostracods, it presented lower richness throughout samples (Figure 6).

Taking in account only the best model selected on the AICc bases for density, only macrophytes species was included and explained 74% of the variation on ostracod assemblage. *E. crassipes* surprisingly exhibited a negative influence on density in relation to *Salvinia* spp. and *P. stratiotes* (Table 6). Root volume does not affect ostracod density. Residuals Based on Shapiro-Wilk analysis both models show normality of the residuals ($p_{resid.rich}$ = 0.3841 and $p_{resid.dens}$ = 0.1604).

Discussion

Human pressures have been causing biodiversity decline in freshwater ecosystems worldwide (Dudgeon et al., 2006) and our results reveal the existence of important trophic links in an endangered and high priority ecorregion. Wild life sanctuary of Pandeiros River under all threats that are inherent to Cerrado biome, as deforestation, fire, crop production and cattle grazing threats, which cause siltation and water body reduction (Nunes et al., 2009). Besides all these threats, this Conservation Unit shelter high ostracods richness, being one of the best area to biodiversity conservation in Minas Gerais state. We even found possible new species to science, all of them belong to Cyprididae, the most specious ostracod family (1,000 spp) (Martens et al., 2008). Neotropical region account for 13.75% of the known global diversity of living non-marine ostracods (Martens et al., 2008) and these data contribute to highlight the relevance of Conservation Units in Cerrado biome as effective areas to biodiversity conservation. This is the first record of pleustonic ostracods in São Francisco River basin, whose wetlands are considered endangered, regionally outstanding and with high priority for conservation at regional scale (Oslon et al., 1998).

High diversity of phytophilous ostracods (associated with aquatic macrophytes) has been recorded in tropical floodplains. For example, in the floodplain of the upper Paraná River and adjacent areas, about 48 species of ostracods were recorded in several environments (over 50), including rivers, channels, isolated and connected lakes (see Higuti et al., 2010, 2013, 2017; Matsuda et al., 2015; Campos et al., 2017), 29 species were recorded in 17 lakes of Araguaia River floodplain (Pereira et al., 2017), and 25 ostracod species were recorded in 13 lakes of Amazon River floodplain (Higuti & Martens, 2016). Thus, when we compare our findings with tropical floodplains, total richness is considerably high (31 species). There are two other studies with pleustonic ostracods around the world, which recorded 20 species from one Hungarian lake (Kiss, 2007) and 11 ostracod species from 13 sampling sites at Caffarella Valley area in Rome (Mazzini et al., 2014). Several theories have been proposed to explain high species richness latitudinal gradient, they are based on climate, area, evolution, random factors or organisms metabolic rates (Wright, 1983; Rohde, 1992; Colwell and Lees, 2000; Wiens and Donoghue, 2004; Whittaker, 2006; Hawkins et al., 2007), however they treat of terrestrial patterns, it seems to be true to aquatic environments, either.

Previous studies have been showed that architectural complexity provided by macrophytes is a driver for aquatic invertebrate richness (Thomaz et al., 2008; Lucena-Moya and Duggan, 2012; St. Pierre and Kovalenko, 2014). In aquatic environments, substrates provide three-dimensional space wherein organisms interact and are essential to enhance diversity (Tokeshi, 1999), as macrophyte stands in freshwaters or sea grasses and macroalgae in shallow coastal waters (Tokeshi and Arakaki, 2012), therefore root volume might represent a proxy of this space for free-floating macrophytes and its associated pleuston.

Similar ostracods richness values registered on each macrophytes species (*Salvinia* spp.,27; *E. crassipes,* 26 and *P. stratiotes*, 25) clearly shows that species richness was not dependent of the number of individuals sampled, since we found significant effects of macrophytes species on organisms density. Similar composition was also observed, indicating no ostracods selectivity related to free-floating macrophytes species (Table 2).

Greater root volumes provided higher richness, and this relationship is macrophytes species-independent. Species richness tends to increase with increasing area in terrestrial habitats, following species area relationship (see Preston, 1960; MacArthur and Wilson, 1967; Fattorini et al., 2017), in aquatic habitats, volume may have an equivalent effect. However, fractal method applied to measure habitat structural complexity of free-floating and submerged macrophytes, a component of habitat structure, showed that it affects both invertebrate's richness and

density (Thomaz et al., 2008), although, only ostracods richness showed positive relationship with root volume. The difference between both results might be due limitations of the complexity measure tested or due intrinsec differences of growth form, at the extent that submerged macrophytes has positive influence on organisms abundance (Walker et al., 2013).

Not only root volume but also macrophytes species was included on the second best model for richness, indicating that even amongst free-floating macrophytes habitat provided there are differences. *E. crassipes* and *P. stratiotes* showed positive effect on ostracod richness as demonstrated by Higuti et al. (2010), their results showed both macrophytes with well developed root system and indicate that size of root systems can affect ostracod assemblages on pleuston. Complexity might be species dependent (Dibble et al., 2006), in spite of that, root volume measured did not show significant differences amongst macrophytes.

For density, macrophytes species was the only variable selected from our global model by the dredge function of MuMin R package, its effect is independent of structural complexity. Although, Ferreiro et al. (2014) showed that macroinvertebrates density might be explained, in part, by a positive effect of complexity on periphyton biomass. In our study, other aspects of specifity of substrate could be determinant to ostracod densities in a greater extent than habitat structure . *P. stratiotes* and *Salvinia* spp. were able to host high organism densities than *E. crassipes*, even though root volumes did not differ amongst them, thus other predictive variables should be addressed in studies to come, as features of productivity (e.g. availability of N) or biotic interations (e.g. fish and macroinvertebrate predation). Low *E. crassipes* biomass was found in the lakes of Pandeiros floodplain, and a negative effect of this macrophyte on density is surprisingly because finding greater organisms densities associated to *E. crassipes* roots is more common (Kouame et al., 2011) than we recorded in this study. In neotropical environments *E. crassipes* is responsible to host rich pleuston communities and to be an important habitat structuring (Higuti et al., 2007), this aquatic plant usually forms dense large root mats (Mitchell, 1985) that contain muddy sediment and large amounts of autochtonous and allochtonous organic matter (Higuti et al., 2010) and this high complexity condition is known to favor high diversity of invertebrates communities (Warfe et al., 2008).

The high explanation of macrophyte on ostracod density suggests that interaction macrophyte x ostracod is a considerable driver for assemblage structuring in this habitat. Ostracods present habitat preferences shaped by food nutritional value (e.g. periphyton sticked to roots) and food supply (Mbahinzireki et al., 1991, Roca et al., 1993; Balcombe and Closs, 2016).

In this research, we have shown that habitat structure disponibility and inter specific interactions might be predictors to understand pleustonic assemblage structure. Our results indicate root volume as a practical measure of habitat structure amongst free-floating macrophytes, but it is still needed to investigate the inter specific effect of free-floating macrophytes on pleuston densities and carry out studies focusing on the other ecologic groups, because they might lead to different results, since they habit different biotopes. We call attention to the undiscovered biodiversity inhabiting Cerrado wetlands and suggest further studies at Pandeiros floodplain targeting ostracods and their specific requirements of resources and conditions provided by aquatic plants of all ecologic groups. We also reinforce the relevant role that Conservation Units play in maintaining aquatic biodiversity, especially on endangered biomes, because they are able to shelter high diversity of species.

Acknowledgments

References

Abe K, Horiuchi J. 2000. Reproductive strategy of an isopod *Onisocryptus ovalis*, parasitizing a bioluminescent myodocope ostracod *Vargula hilgendorfi. Hydrobiologia* **419**: 191–197.

Balcombe SR, Closs GP. 2016. Patchiness in food resources drives fish abundances in emergent macrophytes under field and experimental conditions. *Hydrobiologia* **781**:127–142 DOI 10.1007/s10750-016-2828-1.

Barreto R, Charudattan R, Pomella A, Hanada R. (2000) Biological control of neotropical aquatic weeds with fungi. *Crop Protection* **19**: 697–703.

Bell, SS, McCoy ED, Mushinsky, HR. 1991. Habitat structure: the physical arrangement of objects in space. *Chapman and Hall*, New York.

Bennett MB, Heupel MR, Bennett SM, Parker AR. 1997. Sheina orri (Myodocopa: Cypridinidae), an ostracod parasitic on the gills of the epaulette shark, Hemiscyllium ocellatum (Elasmobranchii: Hemiscyllidae). *Int J Parasitol* **27**:275–281.

Burnham, KP, Anderson, DR, Huyvaert, KP. 2011. AIC model selection and multimodel inference in behavioral ecology: some background, observations, and comparisons. *Behavioral Ecology and Sociobiology* **65**:23–35.

Campos R, Conceicão EO, Pinto MBO, Bertoncin APS, Higuti J, Martens K. 2017. Evaluation of quantitative sampling methods in pleuston: an example from ostracod communities. *Limnologica* **63**: 36–41.

Conceição, E.O., Higuti, J. and Martens K. 2017. Variability in ostracod communities (Crustacea, Ostracoda) in connected and isolated tropical floodplain lakes. *Ann. Limnol. - Int. J. Lim.* **53**:325–332 DOI: 10.1051/limn/2017016.

Colwell, R. K., and D. C. Lees. 2000. The mid-domain effect: geometric constraints on the geography of species richness. Trends in Ecology and Evolution 15:70–76.

Choi J, Jeong K, Kim S, Joo G. 2016. Impact of habitat heterogeneity on the biodiversity and density of the zooplankton community in shallow wetlands (Upo wetlands, South Korea). *Oceanological and Hydrobiological Studies* **45**:485-492.

Dias RM, Silva JCB, Gomes LC, Agostinho AA. 2017. Effects of macrophyte complexity and hydrometric level on fish assemblages in a Neotropical floodplain. *Environ Biol Fish* 100:703–716 DOI 10.1007/s10641-017-0597-y.

Dibble ED, Thomaz SM, Padial AA. 2006. Spatial-complexity measured at a multi-scale among three aquatic plant species. *Journal of Freshwater Ecology* **21**: 239–247.

Drummond GM, Martins CS, Machado ABM, Sebaio FA, Antonini Y. 2005. Biodiversidade em Minas Gerais: um atlas para sua conservação. Belo Horizonte*: Fundação Biodiversitas*. 222 p.

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan CA. 2006. Freshwater biodiversity: importance, threats, status and conservation chal- lenges. *Biol. Rev. Camb. Philos. Soc.* **81**:163–182. http://dx.doi.org/10.1017/ S1464793105006950.

Esteves, FA. 1998. Fundamentos de Limnologia. Rio de Janeiro (Brazil): Interciência.

Fattorini S, Borges PAV, Dapporto L, Strona G. 2017. What can the parameters of the species – area relationship (SAR) tell us? Insights from Mediterranean islands. *Journal of Biogeography* **44**, 1018–1028.

Ferreiro N, Feijoo C, Giorgi A, Hinojosa-Garro JR. 2014. Macroinvertebrates select complex macrophytes independently of their body size and fish predation risk in a Pampean stream. *Hydrobiologia* **740**:191–205 DOI 10.1007/s10750-014-1953-y

Fonseca EMB et al. 2008. Pandeiros: uma complexa interface com a gestão ambiental regional. In: *SIMPÓSIO BRASILEIRO SOBRE PEQUENAS E MÉDIAS CENTRAIS HIDRELÉTRICAS*, *Anais*.

Gotceitas V, Colgan P. 1989. Predator foraging success and habitat complexity: quantitative test of the threshold hypothesis. *Oecologia* **80**: 158-166.

Gustafson KD, Belden JB, Bolek MG. 2016. Atrazine reduces the transmission of an amphibian trematode by altering snail and ostracod host-parasite interactions. *Parasitol Res* DOI 10.1007/s00436-015-4893-1

Gutierrez MF, Andrade V, Fantón N, Gagneten M. 2016. Facing predation risk in aquatic systems: differential response of zooplankton and habituation to the false alarm. *Fundam. Appl. Limnol.* **188**(4):329–339.

Hao B. Wu H, Cao Y, Xing W, Jeppesen E, Li, W. 2017. Comparison of periphyton communities on natural and artificial macrophytes with contrasting morphological structures. *Freshwater Biology* **62**:1783–1793. DOI: 10.1111/fwb.12991.

Harding JP. 1962. *Mungava munda* and four other new species of ostracod crustaceans from fish stomachs. In: *The Natural History of Rennell Island*, British Solomon Islands 4:51–62. Danish Science Press, Copenhagen.

Hawkins, B. A., D. Montoya, M. A´ . Rodrı´guez, M. A´ . OlallaTa´ rraga, and M. A´ . Zavala. 2007. Global models for predicting woody plant richness from climate: comment. Ecology 88:255–259.

Higuti J, Velho LFM, Lansac-Tôha FA, Martens K. 2007. Pleuston communities are buffered from regional flood pulses: the example of ostracods in the Paraná River floodplain, Brazil. *Freshw. Biol.* **52:**1930–1943. http://dx.doi.org/10. 1111/j.1365-2427.2007.01821.x.

Higuti J, Declerck SAJ, Lansac-Tôha FA, Velho LFM, Martens K. 2010. Variation in ostracod (Crustacea, Ostracoda) communities in the alluvial valley of the upper Paraná River (Brazil) in relation to substrate. *Hydrobiologia* **644**:261–278. http://dx.doi.org/10.1007/s10750-010-0122-1.

Higuti J, Martens K. 2012a. On a new cypridopsine genus (Crustacea, Ostracoda, Cyprididae) from the Upper Paraná River Floodplain (Brazil). *Zootaxa* **3391**: 22–38.

Higuti J, Martens K. 2012b. Description of new genus and species of Candonopsini (Crustacea, Ostracoda, Candoninae) from the alluvial valley of the Upper Paraná River (Brazil, South America). *Eur J Taxon* **33**:1-31.

Higuti J, Schon I, Audenaert L, Martens K. 2013. On the Strandesia obtusata/elliptica lineage (Ostracoda, Cyprididae) in the alluvial valley of the upper Paraná River (Brazil), with the description of three new species. *Crus taceana* **86**: 182–211.

Higuti J, Martens K. 2014. Five new species of Candoninae (Crustacea, Ostracoda) from the alluvial valley of the Upper Paraná River (Brazil, South America). *European Journal of Taxonomy* **106**: 1–36.

Higuti J, Martens K. 2016. Invasive South American floating plants are a successful substrate for native Central African pleuston. *Biol Invasions* **18**:1191–1201 DOI 10.1007/s10530-016-1061-1

Higuti J, Conceição EO, Campos R , Ferreira VG, Rosa J, Pinto MBO, Martens K. 2017. Periphytic community structure of Ostracoda (Crustacea) in the river-floodplain system of the Upper Paraná River. *Acta Limnol. Bras*., **29**:e120. http://dx.doi.org/10.1590/s2179-975x12217.

Horne DJ, Cohen A, Martens K. 2002. Taxonomy, morphology and biology of Quaternary and living Ostracoda. Washington, DC: *American Geophysical Union, Biology, Taxonomy and Identification Techniques*; p. 5–36.

Hull SL. 1999. Intertidal ostracod (Ostracoda: Crustacea) abun- dance and assemblage structure within and between four shores in north-east England. *Journal of the Marine Biological Association of the United Kingdom* **79**: 1045–1052.

Hunke P, Mueller EN, Schröder B, Zeilhofer P. 2015. The Brazilian Cerrado: as- sessment of water and soil degradation in catchments under intensive agricultural use. *Ecohydrology* **8:**1154–1180. http://dx.doi.org/10.1002/eco.1573.

Junk, JW. 2000. Mechanisms for development and maintenance of biodiversity in neotropical floodplains. *Biodiversity in wetlands: assessment, function and conservation* **1**:119-139

Junk WJ, Piedade M T F, Lourival R. 2014. Brazilian wetlands: their definition, delineation, and classification for research, sustainable management, and protection. *Aquatic Conservation: Marine and Freshwater Ecosystems,* **24**(1): 5–22. doi: 10.1002 /aqc.2386

Kiss A. 2007: Factors affecting spatial and temporal distribution of Ostracoda assemblages in different macrophyte habitats of a shallow lake (Lake Fehér, Hungary). *Hydrobiologia* **589**: 89–98.

Kouamé MK, Dietoa MY, Edia EO, Da Costa SK, Ouattara A, Gourène G. 2011. Macroinvertebrate communities associated with macrophyte habitats in a tropical man-made lake (Lake Taabo, Côte d'Ivoire). *Knowl. Manag. Aquat. Ecosyst.* **400**, 01–18, http://dx.doi.org/10.1051/kmae/2010035.

Lancaster J, Robertson AL. 1995. Microcrustacean prey and macroinvertebrate predation in a stream food wev. *Freshwater Biology*, **34**:123-134.

Liberto R, Mesquita-Joanes F, César I. 2012. Dynamics of pleustonic ostracod populations in small ponds on the Island of Martín García (Rio de la Plata, Argentina). *Hydrobiologia* **688**, 47–61, http://dx.doi.org/10.1007/s10750-011- 0600-0.

Lucena-Moya P, Duggan IC. 2011. Macrophyte architecture affects the abundance and diversity of littoral microfauna. *Aquat Ecol* **45**:279–287.

Martens K, Behen F. 1994. A checklist of the non-marine ostracods (Crustacea, Ostracoda) from the inland Waters of South American and adjacent islands. *Travaux Scientifiques du Musee d' Histoire Naturelle de Luxembourg* **22**: 1-81.

Martens K, Schön I, Meisch C, Horne DJ. 2008: Global diversity of ostracods (ostracoda, Crustacea) in freshwaters. *Hydrobiologia* **595**: 185–193.

Matsuda JT, Lansac-Toha FA, Martens K, Velho LFM., Mormul RP, Higuti J. 2015a. Association of body size and behavior of freshwater ostracods (Crustacea, Ostracoda) with aquatic macrophytes . *Aquat Ecol* **49**:321–331.

Matsuda JT, Martens K, Higuti J., 2015b. Diversity of ostracod communities (Crustacea, Ostracoda) across hierarchical spatial levels in a tropical floodplain. *Hydrobiologia*. 762:113–126.

Mazzini I, Ceschin S, Abati S, Gliozzi E, Piccari F, Rossi A. 2014. Ostracod communities associated to aquatic macrophytes in an urban park in Rome, Italy. *Int Rev Hydrobiol* **99**:425–434.

Mbahinzireki G, Uiblein F, Winkler H. 1991. Microhabitat selection of ostracods in relation to predation and food. *Hydrobiologia*, **222**, 115–119.

Meisch CK. 2000. Freshwater ostracoda of western and central Europe. Spektrum Akademischer Verlag, *Heidelberg* p. 522

Millennium assessment, 2005. Ecosystems and Human Well-being: A Framework for Assessment.

Mitchell DS. 1985. Surface-floating aquatic macrophytes. In: *The Ecology and Management of African Wetland Vegetation (Eds P. Denny)*, 109–124.

MacArthur RH,Wilson EO. 1967. The Theory of Island Biogeography. *Princeton University Press*, Princeton.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J, 2000. Biodiversity hotspots for conservation priorities. *Nature* **403:**853–858. http://dx.doi. org/10.1038/35002501.

Nunes YRF, Azevedo IFP, Neves WV, Veloso MD, Souza RA, Fernandes GW. 2009. Pandeiros: o pantanal mineiro. *MG.BIOTA* **2:** 4–17.

Olson D, Dinerstein E, Canevari P, Davidson I, Castro G, Morisset V, Abell R, Toledo, E. 1998. Freshwater biodiversity of Latin America and the Carribean: a conservation assessment. *Biodiversity Support Program*,Washington, DC, 70 pp.

Ottonello D, Romano A. 2010. Ostracoda and Amphibia in temporary ponds: who is the prey? Unexpected trophic relation in a Mediterranean freshwater habitat. *Aquat. Ecol*., **49**(3): 321-331. DOI 10.1007/s10452-010-9323-y

Padial AA, Thomaz SM, Agostinho AA, 2009. Effects of structural heterogeneity provided by the floating macrophyte Eichhornia azurea on the predation efficiency and habitat use of the small Neotropical fish *Moenkhausia sanctaefilomenae*. *Hydrobiologia* **624**, 161–170, http://dx.doi.org/10.1007/ s10750-008-9690-8.

Pelicice FM, Thomaz SM, Agostinho AA (2008) Simple relation- ships to predict attributes of fish assemblages in patches of submerged macrophytes. *Neotrop Ichthyol* **6**:543–550

Pereira LC, Lansac-tôha FA, Martens K, Higuti J. 2017. Biodiversity of ostracod communities (Crustacea , Ostracoda) in a tropical floodplain. *Inland Waters*, **7**(3):323-332.

Pereto SCAS, Ribas LGS, Wojciechowski J, Ceschin F, Dittrich J., Bezerra LAV, Padial AA. 2016. Trade-off in leaf and root investment of an abundant aquatic macrophyte in a Neotropical floodplain. Fundam. Appl. Limnol. 188(4): 309-314.Preston, F. W., 1960. Time and Space and the Variation of Species. *Ecological Society of America,* **41**(4): 611–627.

Pinto RL, Rocha CEF, Martens K. 2004. On the genus Penthesilenula Rossetti & Martens, 1998 (Crustacea, Ostracoda, Darwinulidae) from (semi-) terrestrial habitats in São Paulo State (Brazil), with the description of a new species. *Journal of Natural History* **38**: 2567–2589.

Pivari, MOD, Viana PL, Leite FSF. 2013. List The Aquatic Macrophyte Flora of the Pandeiros River Wildlife Sanctuary , Minas Gerais , Brazil. *Check List* **9**(2): 415–424.

Prokopenko CM, Turgeon K, Fryxell JM. 2017. Evaluation of alternative prey-, predator-, and ratio-dependent functional response models in a zooplankton microcosm. *Canadian Journal of Zoology* 95(3): 177-182.

Rocha CEF, Por FD. 1998. Preliminary comparative data on the fauna of the pleuston in the southern Pantanal, Brazil, with emphasis on the microcrustaceans. Verh Int Ver Limnol 26: 2137–2140.

Rodríguez-Peréz H, Baltanás A. 2008 Ecology and production of Heterocypris exigua and Plesiocypridopsis newtoni (Crustacea, Ostracoda) in an oligohaline hypertrophic shallow lake. *Fundamental and Applied Limnology* **172**(1): 13–26.

Rodrigues PMS, Azevedo IFP, Veloso MDM, Santos RM, Menino GCO, Nunes YRF, Fernandes GW. 2009. Riqueza florística da vegetação ciliar do rio Pandeiros, norte de Minas Gerais. *MG Biota* **2**: 18–35.

Rohde, K. 1992. Latitudinal gradients in species diversity: the search for the primary cause. Oikos 65:514–527.

Rossetti G, Martens K. 1998. Taxonomic revision of the recent and Holocene representatives of the Family Darwinulidae (Crustacea, Ostracoda), with a description of three new genera. Bulletin de Institut Royal des Sciences Naturelles de Belgique. *Biologie* **68**: 55–110.

Silva CV, Henry R. 2013. Aquatic macroinvertebrates associated with Eichhornia azurea (Swartz) Kunth and relationships with abiotic factors in marginal lentic ecosystems (São Paulo, Brazil). *Braz. J. Biol* **73** (1): 149-162.

St. Pierre JI, Kovalenko KE. 2014. Effect of habitat complexity attributes on species richness. *Ecosphere* **5**:22.

Stewart TW, Shumaker TL, Radzio TA. 2003. Linear and nonlinear effects of habitat structure on composition and abundance in the macroinvertebrate community of a large river. *Am Midl Nat* **149**:293–305.

Strassburg BBN, Brooks T, Feltran-Barbieri R, Iribarrem A, Crouzeilles R, Loyola R, Latawiec AE, Oliveira Filho FJB, Scaramuzza de CAM, Scarano FR, Soares-Filho B, Balmford A. 2017. Moment of truth for the Cerrado hotspot. *Nat. Ecol. Evol*. **1**:99. http://dx.doi.org/10.1038/s41559-017-0099.

Taniguchi H, Tokeshi M. 2004. Effects of habitat complexity on benthic assemblages in a variable environment. *Freshwater Biology*, **49**, 1164–1178.

Tews J, Brose U, Grimm V, Tielborger K, Wichmann MC, Schwanger M, Jeltsch F. 2004. Animal species diversity driven by habitat heterogeneity/diversity: the impor- tance of keystone structures. *J. Biogeogr*. **31:**79–92.

Thomaz SM, Cunha ER. 2010. The role of macrophytes in habitat structuring in aquatic ecosystems: methods of measurement, causes and consequences on animal assemblages' composi- tion and biodiversity. *Acta Limnol Bras* **22**(2):218–236.

Thomaz SM, Dibble ED, Evangelista LR, Higuti J, Bini LM. 2008. Influence of aquatic macrophyte habitat complexity on invertebrate abundance and richness in tropical lagoons. *Freshw Biol* **53**:358–367.

Tokeshi M, Arakaki S. 2012. Habitat complexity in aquatic sys- tems: fractals and beyond. *Hydrobiologia* **685**:27–47.

Vannier J, Abe K, Ikuta K. 1998. Feeding in myodocope ostracods: functional morphology and laboratory obser- vations from videos. *Mar Biol* **132:**391–408.

Vejříková I, Eloranta AP, Vejřík L, Šmejkal M, Čech M, Sajdlová Z, Frouzová J, Kiljunen M, Peterka J. 2017. Macrophytes shape trophic niche variation among generalist fishes. *PLoS ONE* 12: e0177114. DOI: 10.1371/journal.pone.0177114.

Walker, PD, Wijnhovenb S, van der Veldea G. 2013. Macrophyte presence and growth form influence macroinvertebrate community structure. *Aquatic Botany* **104**: 80–87.

Warfe DM, Barmuta LA. 2006. Habitat structural complexity mediates food web dynamics in a freshwater macrophyte community. *Oecologia* **150**:141–154

Warfe DM, Barmuta LA, Wotherspoon S. 2008. Quantifying habitat structure: surface convolution and living space for species in complex environments. *Oikos* **117**:1764–1773.

Wiens, J. J., and M. J. Donoghue. 2004. Historical biogeography, ecology and species richness. Trends in Ecology and Evolution 19:639–644.

Wright, D. H. 1983. Species–energy theory: an extension of species–area theory. Oikos 41:496–506.

Whittaker, R. J., 2006. Island species–energy theory. Journal of biogeography 33(1): 11-12.

Tables

Table 1. Experimental design in the Pandeiros River floodplain.

Lake	Season	Macrophyte	Sample unit
Véio Juca	Wet	*P. stratiotes*	3
		Salvinia spp.	8
	Dry	*P. stratiotes*	2
		Salvinia spp.	8
Torre	Wet	*E. crassipes*	7
		P. stratiotes	1
		Salvinia spp.	7
	Dry	*E. crassipes*	4
		P. stratiotes	3
		Salvinia spp.	6

Table 2. Faunal inventory of Ostracoda associated with aquatic macrophytes in lakes of Pandeiros River floodplain.

	E. crassipes	*P. stratiotes*	*Salvinia* spp.
Superfamily Cypridoidea Baird, 1845	X	X	X
Family Candonidae Kaufmann, 1900	X	X	X
Candobrasilopsis brasiliensis Sars, 1901	X	X	X
Candobrasilopsis elongata Higuti & Martens, 2014	X	X	X
Physocypria spp	X		X
Family Cyprididae Baird, 1845	X	X	X
Cabelodopsis hispida Sars, 1901	X	X	X
Chlamydotheca colombiensis Roessler, 1985	X		X
Chlamydotheca deformis Farkas, 1958	X	X	X
Chlamydotheca iheringi (Sars, 1901)	X	X	X
Cypretta costata G.W.Müller, 1898	X	X	X
Cypricercus centrura (Klie, 1940)	X	X	X
"Cypridopsis" n. gen. n. sp.			X
Diaphanocypris meridana (Furtos, 1936)	X	X	X
Hemicypris sp. 1	X	X	
"Ilyodromus" n. gen. n. sp.	X	X	X
Neocypridospsis nana (Sars, 1901)	X	X	X
Potamocypris sp. 1	X	X	X
Stenocypris major (Braid, 1859)	X	X	X
Stenocypris malayica Victor & Fernando, 1981	X		X
Stenocypris sp. 1	X	X	X
Strandesia lansactohai Higuti & Martens, 2013 in Higuti et al., 2013	X	X	X
Strandesia mutica (Sars, 1901)		X	X
Strandesia tolimensis Roessler, 1990			X
Strandesia trispinosa (Pinto & Purper, 1965)	X	X	X
Strandesia cf. *trispinosa*	X	X	X
Strandesia cf. *minuta*	X	X	
Strandesia n. sp. 1	X		X
Strandesia n. sp. 2	X	X	X
Superfamily Darwinuloidea Brady & Norman, 1889	X	X	X
Family Darwinulidae Brady & Robertson, 1885	X	X	X
Alicenula serricaudata (Klie, 1935)	X	X	X
Darwinula stevensoni (Brady and Robertson, 1870)	X	X	
Penthesilenula brasiliensis (Pinto and Kotzian, 1961)		X	X
Vestalenula pagliolii (Pinto & Kotzian, 1961)	X	X	X
Superfamily Cytheroidea Baird, 1850	X	X	X
Family Limnocytheridae Klie, 1938	X	X	X
Cytheridella ilosvayi Daday, 1905	X	X	X

Table 3. Environmental characteristics in the lakes of the Pandeiros River floodplain. Water temperature (WT), hydrogen potential (pH) and dissolved oxygen (DO).

Lake	Season	Sampling sites	pH	WT (ºC)	DO (mg.L^{-1})
Véio Juca	Wet	P1	6.31	26.2	7.99
		P2	6.19	27.3	4.94
		P3	6.28	28	3.57
		P4	6.46	26.4	2.31
		P5	6.83	30.5	9.63
		P6	6.59	27.5	6.78
		P7	6.59	29.3	4.25
		P8	6.13	27.9	4.79
Torre		P9	6.34	28.1	1.36
		P10	6.32	28.2	6.16
		P11	6.55	28.8	6.7
		P12	6.66	28.8	5.3
		P13	6.82	30.9	3.35
		P14	6.98	32.7	7.24
		P15	6.75	30.2	5.02
		P16	6.36	30.2	2.98
Véio Juca	Dry	P1	6.7	28.8	4.16
		P2	6.23	27.4	4.24
		P3	6.6	25.2	3.2
		P4	6.7	26.4	3.37
		P5	6.57	27	5.64
		P6	6.2	24.2	3.33
		P7	6.14	23.9	5.63
		P8	5.92	24.9	3.03
Torre		P9	6.63	21.3	5.98
		P10	6.43	22.9	6.05
		P11	6.76	21.8	5.84
		P12	6.92	22.2	4.92
		P13	6.19	23.6	4.87
		P14	6.23	23.6	5.43
		P15	6.44	26.3	1.75
		P16	6.45	22.2	4.91

Table 4. Best Mixed Models selected on AICc bases for ostracods richness, where mcrph: macrophyte; vol: root volume.

Best Generalized Linear Mixed Models for ostracods richness			
Model	AICc	ΔAICc	Weight
mcrph + vol	249.5	0	0.677
+			
mcrph + vol	251.4	1.96	0.258
+ +			

Table 5. Best Mixed Models selected on AICc bases for ostracods density, where mcrph: macrophyte; vol: root volume.

| Best Generalized Linear Mixed Models for ostracods density			
Model	AICc	ΔAICc	Weight
mcrph + vol +	153.2	0	0.740
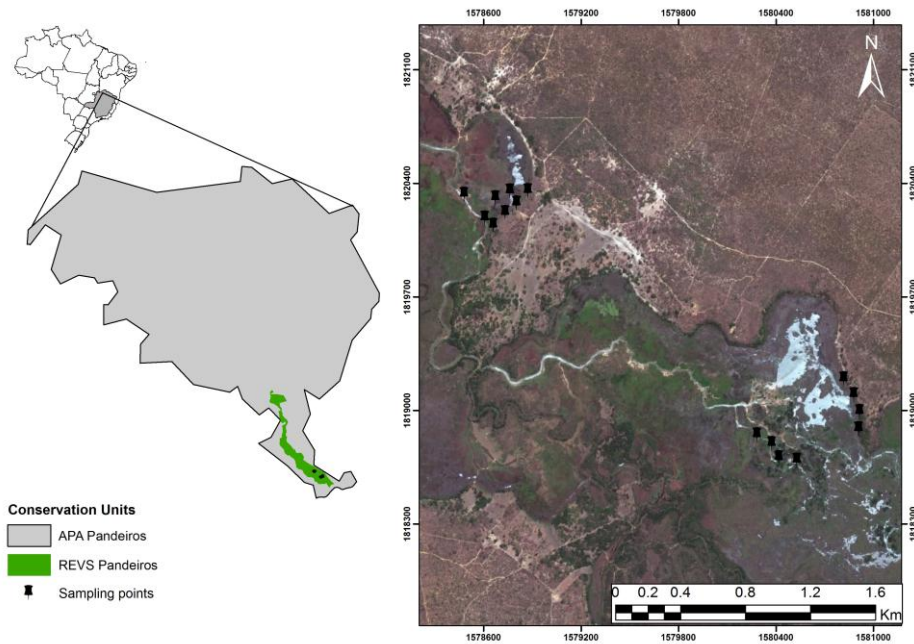
Figure 1. Location of the lakes in the Pandeiros River floodplain.
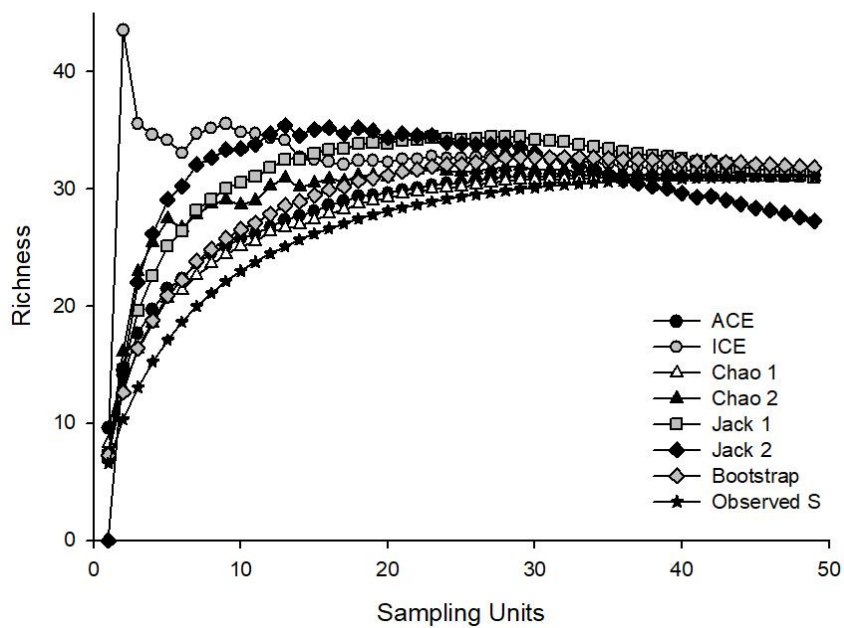
Figure 2. Species accumulation curve of ostracods resulting from different species richness estimators of the Pandeiros River floodplain.
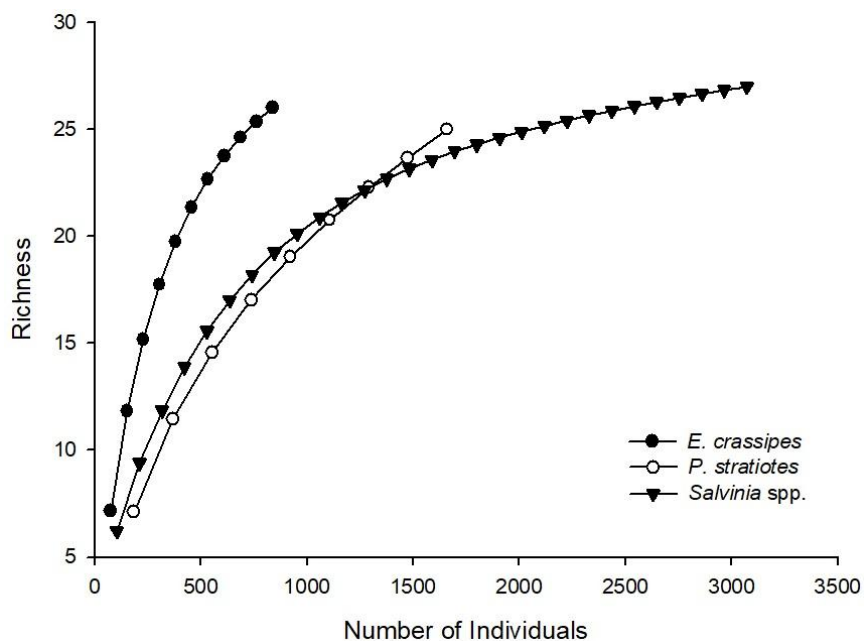
Figure 3. Rarefaction curves of ostracod assemblage associated with macrophytes in lakes of Pandeiros River floodplain.
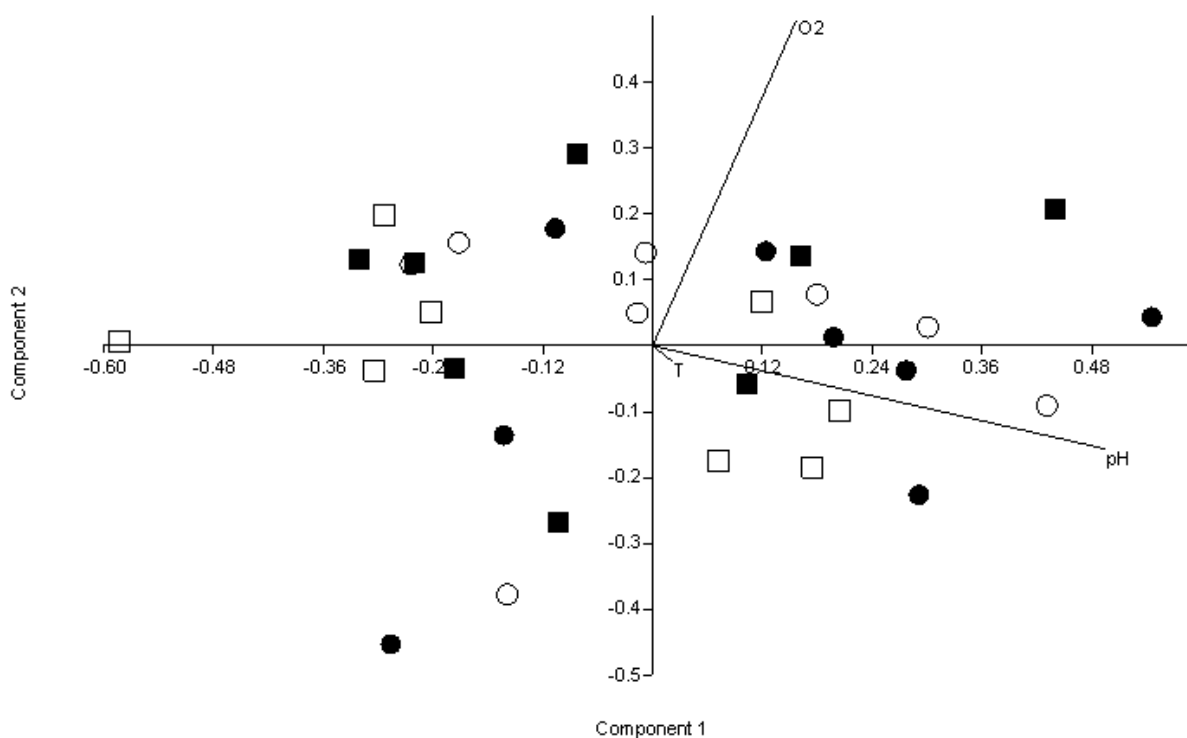
Figure 4. Results of Principal Components Analisys (PCA) abiotic data. Filled symbol: wet season, unfilled symbol: dry season, squares: Veio Juca lake, circles: Torre lake.
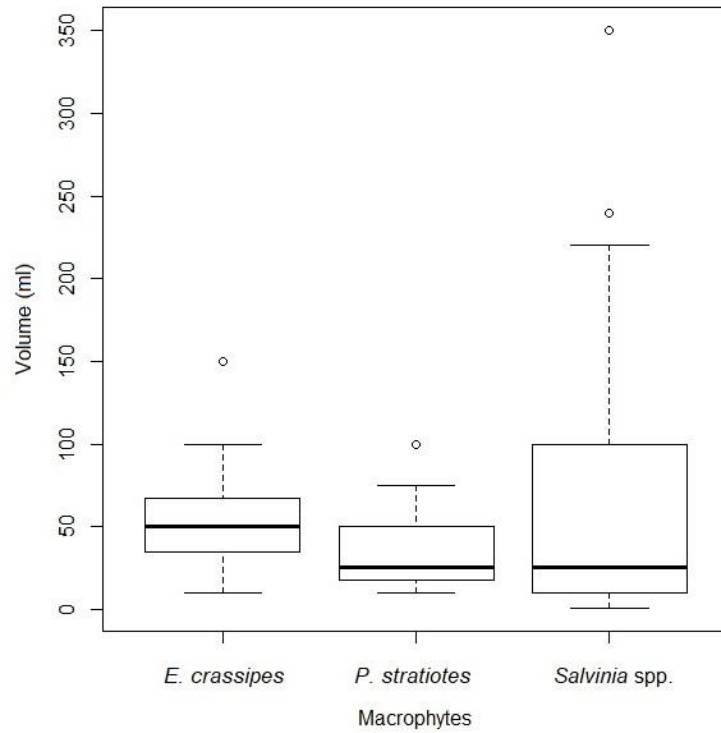
Figure 5. Boxplot of macrophytes root volume data.
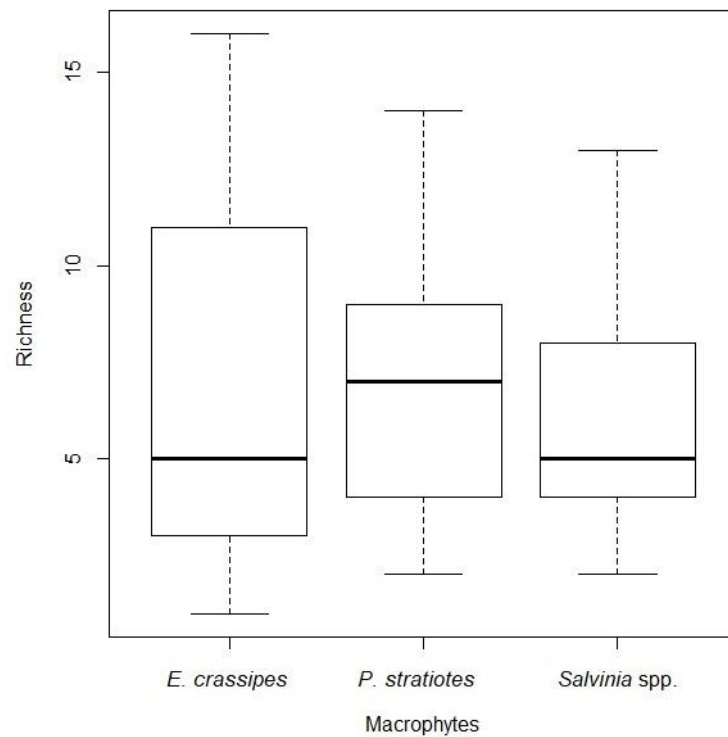
Figure 6. Boxplot of pleustonic ostracod richness along macrophytes species samples.

Figure captions

Suplementary material
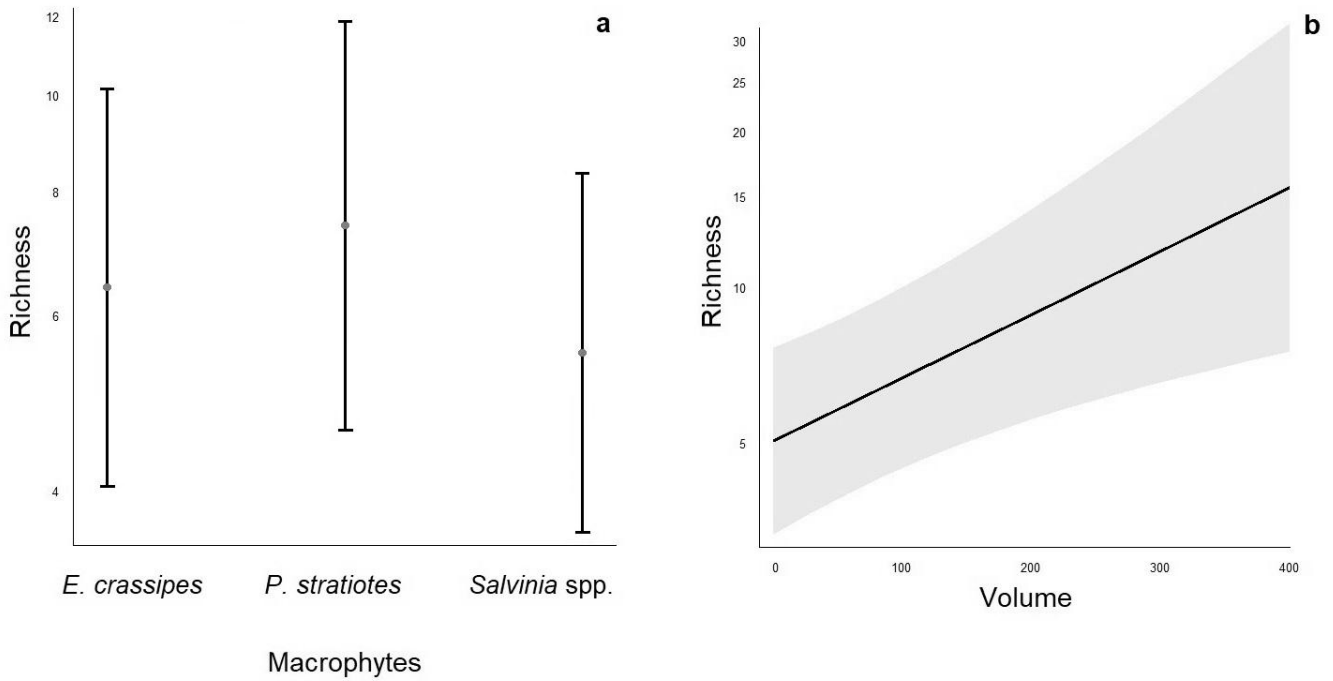
Figure S1. Effects of (A) macrophyte identity and (B) root volume on ostracods richness.
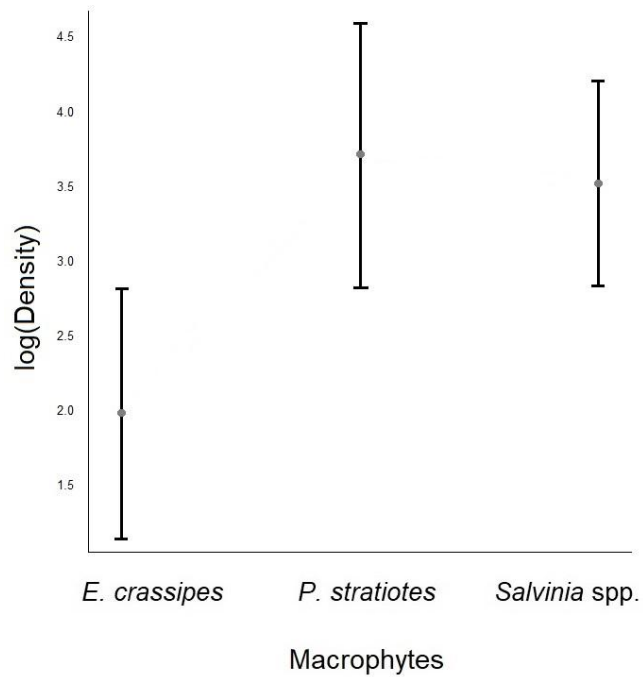
Figure S2. Effects of macrophyte identity on ostracods density.