



Structure community of aquatic insects associated with different macrophytes in ornamental lakes in a savanna region, Southeastern Brazil

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Abstract Aquatic macrophyte communities in lentic systems provide many ecological niches, which contribute to the wealth of aquatic biodiversity. This study analyzed the community structure of aquatic insects associated with different macrophytes in ornamental lakes in a Savanna area in the state of São Paulo, Southeastern Brazil. We identified 39 genus distributed into 18 families, 656 specimens in total. Chironomidae was the richest and most abundant family, representing 69% of the collected insects. Other collected aquatic insects showed small relative participation (<5%) in the phytophilous community. Our results revealed that different habits of macrophytes in ornamental lakes can harbor different insect structure communities. Variations on the abundance of insects, observed especially in submersed macrophytes, may have occurred due to aspects such as fluctuation of water level in the ornamental lakes. Other important aspects are the morphological structure of the macrophytes. Some macrophytes are more complex with intricate leaves and roots, sheltering a slightly more abundant and rich community. Functional traits of macrophytes are important factors influencing the spatial distribution of aquatic insect communities in ornamental lakes.

Key Words: Community ecology, aquatic entomofauna, hydrophytes, phytophilous fauna.

Resumo: Estrutura da comunidade de insetos aquáticos associados à diferentes macrófitas em lagos ornamentais em uma região de Cerrado, Sudeste do Brasil. Comunidades de macrófitas aquáticas em sistemas lênticos fornecem muitos nichos ecológicos, que contribuem para o aumento da biodiversidade aquática. Este estudo analisou a estrutura da comunidade de insetos aquáticos associados a diferentes macrófitas em lagos ornamentais, em uma área de Cerrado, no Estado de São Paulo, Sudeste do Brasil. Nós identificamos 39 gêneros de insetos, distribuídos em 18 famílias, 656 exemplares no total. Chironomidae foi a família mais rica e abundante, representando 69% dos insetos coletados. Outros insetos aquáticos coletados mostraram pequena participação relativa (<5%) da comunidade fitófila. Nossos resultados revelaram que diferentes hábitos de macrófitas em lagos ornamentais podem abrigar diferente estrutura da comunidade de insetos. Variações na abundância de insetos, observadas especialmente em macrófitas submersas, pode ter ocorrido devido a aspectos como a flutuação do nível das águas nos lagos ornamentais. Outros aspectos importantes são as estruturas morfológicas das macrófitas. Algumas macrófitas são mais complexas com folhas e raízes intrincadas, abrigando uma comunidade ligeiramente mais abundante e rica. As características funcionais das macrófitas são fatores importantes que influenciam na distribuição espacial da comunidade de insetos aquáticos em lagos ornamentais.

Palavras-chave: Ecologia de comunidades, entomofauna aquática, hidrófitas, fauna fitófila.

Introduction

The littoral region of lentic environments is considered an ecotone between terrestrial and aquatic ecosystems. This is because of the constant influence of one on the other, also expressed by the exchange of energy and matter (Odum, 1988). Ornamental lakes can act as artificial freshwater systems supporting high productivity and biodiversity (Hill & Wood, 2014). The presence of macrophytes and aquatic invertebrates in these places enhances the local species richness (Williams *et al.*, 2008). In addition, hydrophytes provide a considerable number of ecological niches and sustain food chains (McAbendroth *et al.*, 2005). Aquatic invertebrates are also an important part in these chains (Covic *et al.*, 1999).

There are many autotrophic organisms in littoral regions, ranging from unicellular algae to angiosperms (Esteves, 1998). Among aquatic macrophytes, there is a classification in different functional types, considering their biological adaptations and lifestyle. The functional classification of these plants is: emerged, submerged rooted, free submerged, floating and with floating leaves. In theory, their distribution in lentic systems occurs in organized zones. Starting from the edge with emerged plants, followed by plants with floating leaves until we found rooted submerged species. However, abiotic factors (i.e. depth, water temperature, light incidence, input of nutrients, and interspecific competition) may facilitate heterogeneous distribution (Middelboe & Markager, 1997; Freitas & Thomaz, 2011).

In some shallow lakes, hydrophytes are the major source of organic matter in the system (Christensen *et al.*, 2009). These plants also act as filters retaining organic matter, allowing macrobiotic colonization, reflecting on the abundance and richness on the invertebrate community (Komínková *et al.*, 2000; Cronin *et al.*, 2006).

Diversity and abundance of invertebrates in lentic ecosystems, as mentioned, are often influenced by the presence of aquatic macrophytes (Thomaz & Cunha, 2010). The associated fauna on plants varies, because they provide different food sources, create substrate with favorable conditions for surviving, provide refuge against predators and a place to lay eggs (Trivinho-Strixino & Strixino, 1993; Elger *et al.*, 2007; Kovalenko *et al.*, 2010; Kovalenko & Dibble, 2011).

Aquatic insects are among the most important components of freshwater ecosystems' biota. These animals have a direct influence on primary productivity and decomposition on aquatic environments, and they are an important food source for fish (Batzler & Wissinger, 1996; Resende, 2000). Aquatic entomofauna shows morphological,

physiological and behavioral differences related to where they live. They can be specialists or generalists in relation to their distribution (Poff *et al.*, 2006; Tomanova *et al.*, 2012). This fauna consists of nymphs and imagos of Trichoptera, Odonata, Ephemeroptera, Coleoptera, Hemiptera, and especially larvae of Diptera. Among Diptera, the Chironomidae family is predominant in abundance and diversity, occupying different trophic levels (Roque *et al.*, 2003; Correia & Trivinho-Strixino, 2005; Leite-Rossi & Trivinho-Strixino, 2012).

Some studies on aquatic insects associated with macrophytes have already been developed, especially in South America by: Trivinho-Strixino & Strixino; 1993; Dornfeld & Fonseca-Gessner, 2005; Strixino & Trivinho-Strixino, 2006; Peiró & Alves, 2004; Peiró & Alves, 2006; Peiró & Gorni, 2010; Nascimento *et al.*, 2011; Peiró *et al.*, 2013). However, some points remain unaddressed such as those considered in the present study. This study aimed to analyze ecological aspects such as community structure (at the generic level of taxonomic identification) of aquatic insect communities in different macrophyte species in ornamental lakes. Thus, adding understanding as to how some aquatic communities interplay in tropical lentic ecosystems. In order to follow our aims, we formulated the following question: Do richness, diversity and functional feeding groups of aquatic insects show significant differences in different macrophyte species?

Materials and methods

Study area: Ornamental lakes are located adjacent to a dam in Américo Brasiliense City, State of São Paulo, Brazil (21°42'18" S and 048°01'31"W) - in a savanna area (called Cerrado Biome in Brazil), which has human influence (such as roads, river course deviation, constructions and dam) (Fig. 1). The ornamental lakes are placed near each other and have similar characteristics such as average depth (<1m), type of sediment (sandy), clean and well-oxygenated water. The lakes are surrounded by undergrowth and scrub vegetation. On their shores and bottom, there are diverse groups of macrophytes (i.e. Pontederiaceae, Nymphaeaceae, Hydrocharitaceae, Ceratophyllaceae and Salviniaceae).

Collections: Macrophyte species were chosen due to their abundance in these lakes. They were determined in the laboratory by an identification guide (Pott & Pott, 2000): *Egeria najas* Planch (M1) rooted submerged, *Utricularia* sp. (M2) rooted submerged, *Salvinia* sp. (M3) floating, and *Ceratophyllum* sp. free submerged (M4). All species are distributed in the littoral zone of three sampled ornamental lakes (Fig. 2).

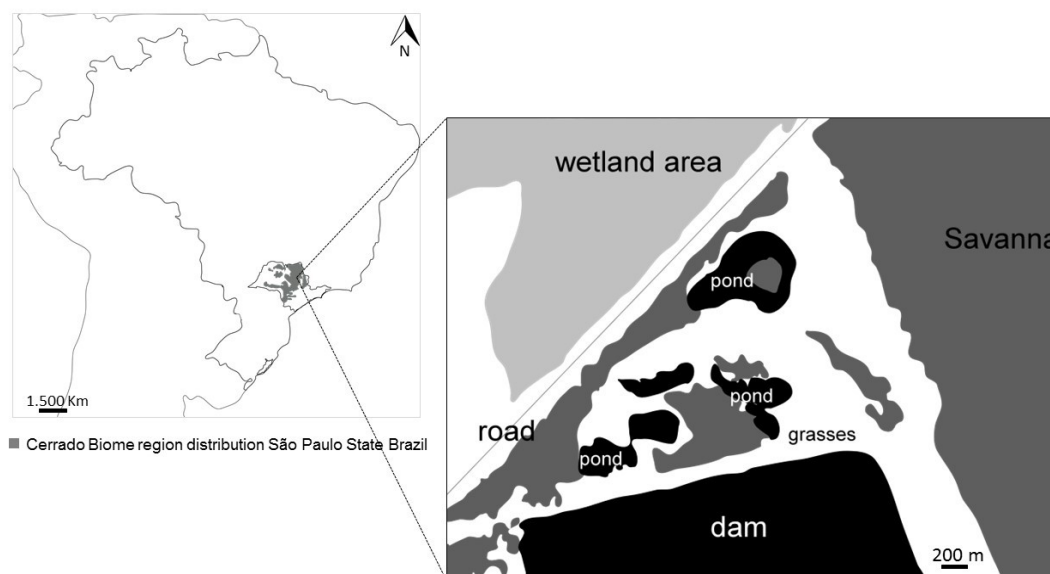


Figure 1. Study area: ornamental lakes in a savanna area (Cerrado Biome), Southeastern Brazil. Figure adapted from WWF/ *Ecoregiões do mundo* and GoogleEarth images.

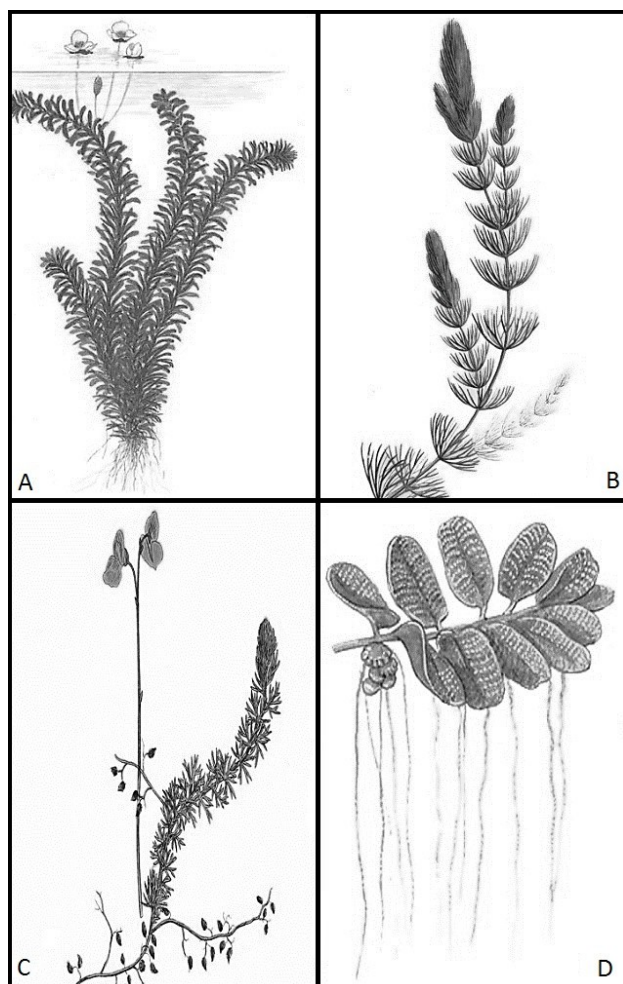


Figure 2. Illustrations of aquatic macrophytes collected in ornamental lakes in a savanna area, Southeastern Brazil. (A) *Egeria najas*, (B) *Ceratophyllum* sp., (C) *Utricularia* sp. and (D) *Salvinia* sp. Modified and adapted from Martin (2002-2007).

Plants and associated fauna were collected carefully with a hand sieve (0.21 mm mesh size). In the field, 100 g of biomass (wet weight) was taken from each plant (measured using a field scale) in three replicates. The samples were stored individually in plastic gallons containing water from the respective pond, then transported to the laboratory (Peiró & Alves, 2006). We carried out four collections, which were grouped into two seasonal periods for better analysis: the dry season (August 2013 and April 2014) and rainy season (December 2013 and March 2014).

In the laboratory, plants were washed in a sieve of 0.21 mm mesh size. Afterwards, aquatic insects were separated on a transilluminated white plastic tray, and then preserved with 70% ETOH in labeled recipients (Peiró *et al.*, 2013). Determination (identification) of aquatic insects was made at the lowest taxonomic level (mostly at generic level) using identification guides (Dominguez & Fernandez, 2009; Trivinho-Strixino, 2011). All identified taxon were classified according to their functional feeding group: collector, predator, filterer, scrapers or shredder, according to studies for Neotropical aquatic insects, and/or Chironomidae family diet (Cummins *et al.*, 2005, Galizzi *et al.*, 2012; Leite-Rossi & Trivinho-Strixino, 2012).

Community structure and diversity of aquatic insects: The associated fauna was compared among the different aquatic macrophytes and seasonal period by: abundance of specimens, species richness and the Shannon diversity index (bits/specimens). To verify the significant differences ($p < 0.05$) in each

community, the variable analysis of variance (ANOVA Mann-Whitney pairwise) was used as the data did not present normality in its distributions among macrophyte species and seasonal periods. The community distribution (abundance of insects among plants and seasonal periods) was analyzed by Non-Metric Multidimensional Scaling (NMDS) using the Morisita dissimilarity index. A perMANOVA, posteriori analysis, was performed so as to observe significant differences in dissimilarities ($p < 0.05$) among aquatic insect communities associated with macrophyte species, using total abundance taxa in each macrophyte, by Morisita index distance. According to Wolda (1981), adopting this index is feasible as it disregards the relationship between the effects of the sampling effort and community diversity.

Functional feeding groups and dominance of aquatic insects: Aquatic insect functional feeding groups were analyzed for their relative participation and total species richness in each macrophyte and seasonal period. To observe significant differences in the species richness in each feeding group among different macrophytes, an analysis of variance (ANOVA Mann-Whitney pairwise) was carried out.

Voucher specimens were deposited in the Biological Collection of the Laboratory of Aquatic Biology-Crustaceans. All analyses were performed using the Paleontological Statistical Package software (PAST version 2:17) (Hammer *et al.*, 2001).

Results

Community structure and diversity of aquatic insects. We identified 39 genus distributed into 18 families, 656 specimens in total (Table I). Chironomidae was the richest and most abundant family, representing 69% from collected insects. *Tanytarsus* sp. (17.7%), *Polypedilum* sp. (13.7%), *Labrundinia* sp. (11.4%), *Ablabesmyia* sp. (7.3%) and *Larsia* sp. (6.1%) were the most representative Chironomidae insects associated with aquatic plants. *Culicoides* sp. (5.8% - Diptera Ceratopogonidae), and *Caenis* sp. (5.2% - Ephemeroptera Caenidae) also contributed with significant relative participations. Other collected aquatic insects showed small relative participation (<5%) in the phytophilous community (Table I).

No significant differences between the average community variables of insects associated with different macrophytes species and seasonal periods were found: species richness, abundance,

Shannon diversity index ($p > 0.05$) (Fig. 3). However, the highest values of species richness and the Shannon diversity index was observed in the *Egeria najas* and *Salvinia* sp. macrophytes. The latter also showed greater abundance of specimens. The submerged macrophyte species presented variations in abundance among the seasonal periods, while *Salvinia* sp. (floating) was stable (Fig. 3).

The Non-metric multidimensional scaling (NMDS) analysis indicated (Fig. 4) that *Salvinia* sp. presented a lower distance in structure communities of the macrophyte species analyzed. This was corroborated by perMANOVA analysis indicating that *Salvinia* sp. has a different structure of entomofauna community ($p < 0.001$, $F = 3.76$).

Functional feeding groups and dominance of aquatic insects: Collector and predator functional feeding groups showed a higher relative abundance (Table II) and species richness among macrophytes and seasonal periods (Fig. 5). Concerning relative abundance (Table II), the collectors had more representative participation associated with *Egeria najas* (M1), *Utricularia* sp. (M2), and *Ceratophyllum* sp. (M4) in both seasonal periods. Only in *Salvinia* sp. (M3), predators were the most representative group, in both seasonal periods. ANOVA did not show significant differences in richness of species in each feeding groups among macrophyte species ($p > 0.05$).

Discussion

Our results revealed different habits of macrophytes in ornamental lakes can harbor different insect structure communities. The geomorphological and abiotic characteristics of lentic systems are important physic variables, which contribute to the biodiversity and distribution of aquatic insect communities (Takamura *et al.*, 2009; Heino, 2000; Sychra *et al.*, 2010). Therefore, the regional pool of aquatic insects species is an important characteristic that can also explain the low variability in some aspects, as the distance between lakes and macrophytes in the study area are very close (Heino, 2001; Mormul *et al.*, 2011; Hamerlík *et al.*, 2014).

Abundance variations of insects, observed especially in submersed macrophytes, throughout the seasonal periods (dry and rainy) may have occurred due to aspects such as water level fluctuation in the ornamental lakes. The input of water flow, as a result of the different seasonal periods, could interfere in sediment/organic matter

Table I. Abundance of aquatic insects associated with different macrophytes in ornamental lakes in a savanna area, Southeastern Brazil. FFG = functional feeding group: co = collector, pr = predator, sc = scraper, sh = shredder, fil = filter, M1 = *Egeria najas*. M2 = *Utricularia* sp. M3 = *Salvinia* sp. M4 = *Ceratophyllum* sp. NI = genus not determined.

Taxa	Dry period					Rainy period				Total
	FFG	M1	M2	M3	M4	M1	M2	M3	M4	
Diptera										
<i>Tanytarsus</i> sp.	co	11	4	42	9	19	9	13	9	116
<i>Polypedilum</i> sp.	co	9	9	9	10	7	31	4	11	90
<i>Labrundinia</i> sp.	pr	1	-	34	-	3	8	29	-	75
<i>Ablabesmyia</i> sp.	pr	5	-	1	2	28	1	2	9	48
<i>Larsia</i> sp.	pr	4	1	1	11	9	-	3	11	40
<i>Culicoides</i> sp.	pr	2	7	8	-	1	12	8	-	38
<i>Chironomus</i> sp.	co	8	5	1	-	8	5	1	3	31
<i>Aedeomyia</i> sp.	fil	1	-	8	-	1	-	13	-	23
<i>Monopelopia</i> sp.	pr	-	-	7	-	-	-	9	-	16
<i>Asheum</i> sp.	co	1	-	-	-	8	-	-	-	9
<i>Caladomyia</i> sp.	co	3	-	-	-	2	-	-	-	5
<i>Pelomus</i> sp.	co	-	-	-	2	-	-	-	2	4
<i>Thienemannia</i> sp.	co	-	-	2	-	-	-	2	-	4
<i>Cricotopus</i> sp.	co	-	3	-	-	-	-	-	-	3
<i>Endotribelos</i> sp.	sh	-	-	-	-	-	3	-	-	3
<i>Rhiethia</i> sp.	co	1	-	-	-	1	-	-	-	2
<i>Clinotanytus</i> sp.	pr	-	-	-	-	2	-	-	-	2
<i>Nilotanyus</i> sp.	pr	-	-	-	1	-	-	-	1	2
<i>Pentaneura</i> sp.	pr	1	-	-	-	-	-	-	-	1
<i>Rheotanytarsus</i> sp.	co	-	-	-	-	1	-	-	-	1
Ephemeroptera										
<i>Caenis</i> sp.	co	5	4	2	5	8	4	3	5	36
<i>Callibaetis</i> sp.	co	2	1	-	-	1	7	-	-	11
<i>Baetodes</i> sp.	co	-	-	1	-	-	1	1	-	3
Hemiptera										
<i>Paraplea</i> sp.	pr	1	-	1	-	-	1	2	-	5
<i>Tenagobia</i> sp.	sc	1	-	1	-	-	1	1	-	4
<i>Corixini</i> sp.	sc	-	-	1	-	-	-	1	-	2
<i>Gelastocoris</i> sp.	pr	-	-	1	-	-	-	1	-	2
<i>Telmatometra</i> sp.	pr	-	-	1	-	-	-	1	-	2
Veliidae (NI ⁶)	pr	-	-	1	-	-	-	1	-	2
Coleoptera										
<i>Suphisellus</i> sp.	pr	-	-	-	3	-	-	-	3	6
Curculionidae (NI)	sh	-	-	-	-	2	-	-	-	2
Scirtidae (NI)	sc	-	-	1	-	-	-	1	-	2
<i>Stegoelmis</i>	sc	-	-	1	-	-	-	1	-	2
<i>Hydrocanthus</i> sp.	pr	1	-	-	-	-	-	-	-	1
<i>Andogyrus</i> sp.	pr	-	-	-	-	-	-	1	-	1
Odonata										
<i>Libellula</i> sp.	pr	1	-	2	-	5	-	12	3	23
<i>Heliocharis</i> sp.	pr	3	2	6	1	4	6	8	1	31
<i>Epipleoneura</i> sp.	pr	-	-	-	-	-	2	-	-	2
<i>Idioneura</i> sp.	pr	-	-	-	-	1	-	-	-	1
Total		61	36	133	44	113	91	119	59	656

(resources for insects) accumulation in submersed macrophytes. In the dry period, low inputs and higher trapping of organic particles are expected, providing more availability of resources then attracting higher numbers of insects (Wharton *et al.*, 2006; Gathman & Burton, 2011).

Other important aspects are the morphological structure of the macrophytes. *Egeria najas* and

Salvinia sp. are more complex because they have intricate leaves and roots, sheltering a slightly more abundant community and considerably rich when compared to the other studied macrophytes. This occurs because of the interstitial spaces among leaves, stems or roots promoting greater structural complexity, and therefore benefiting the abundance of invertebrate fauna (Cheruvelil *et al.*, 2000;

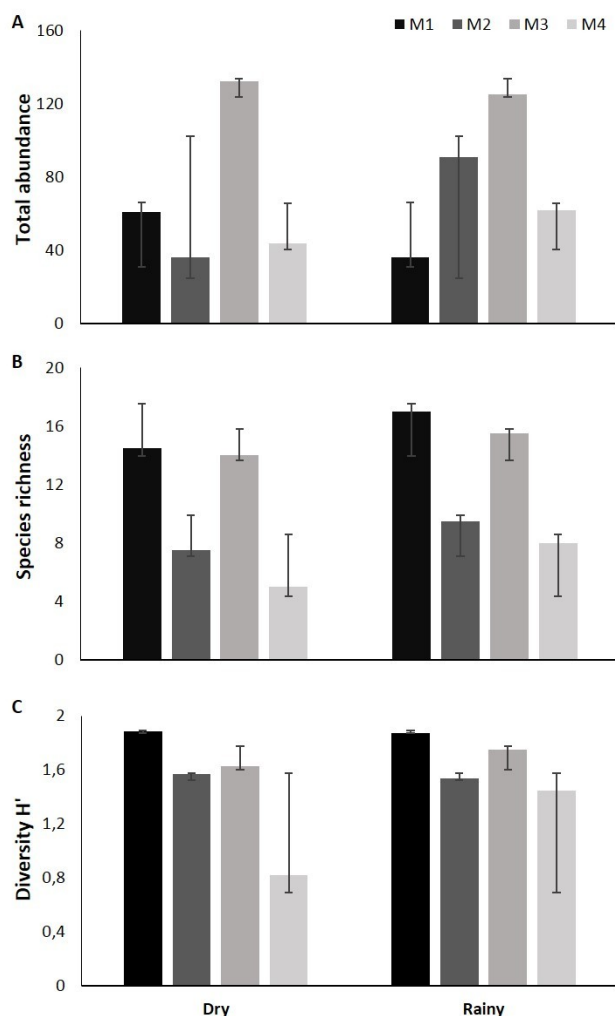


Figure 3. Community parameters of aquatic insects associated with different macrophytes in ornamental lakes in a savanna area, Southeastern Brazil. M1 = *Egeria najas*, M2 = *Utricularia* sp., M3 = *Salvinia* sp., M4 = *Ceratophyllum* sp. (A) Total abundance of specimens, (B) Species richness, (C) Shannon diversity index.

Thomaz & Cunha, 2010). However, sometimes a more complex structure does not support higher richness than less complex plants.

Generally, only smaller body size invertebrates are able to colonize interstitial spaces available in some macrophytes, and consequently differences in

richness among the plants are not always observed (McAbendroth *et al.*, 2005).

In this study, Chironomidae was the richest and most abundant family. Many specimens of this group were also observed in similar studies (Trivinho-Strixino & Strixino, 1993; Peiró & Alves, 2004; Peiró & Alves, 2006; Peiró & Gorni, 2010), where the abundance was about 80% of all aquatic insects associated with macrophytes.

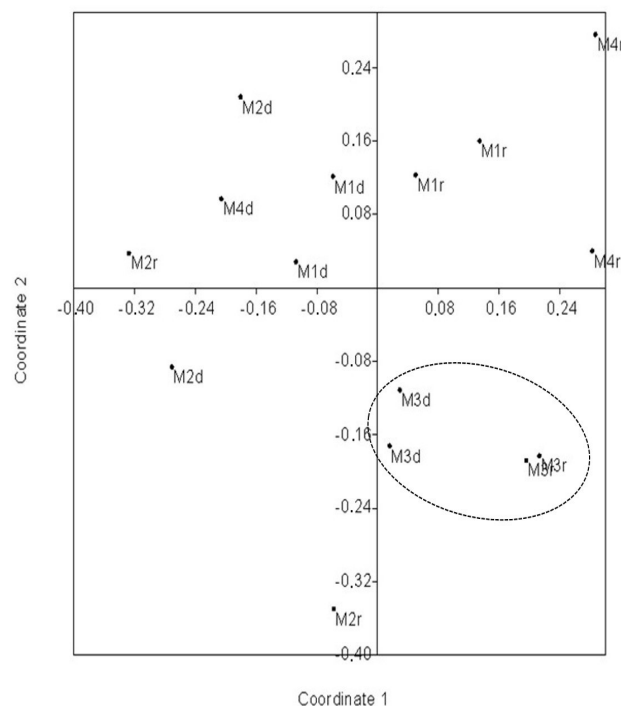


Figure 4. Aquatic insect structure community analysis NMDS associated with different macrophytes species in ornamental lakes in a savanna area, Southeastern Brazil. M1 = *Egeria najas*, M2 = *Utricularia* sp., M3 = *Salvinia* sp., M4 = *Ceratophyllum* sp., d = dry period, r = rainy period.

This family is generally observed in many freshwaters systems, reaching high abundance due to the high adaptability to different substrates, its diverse diet and the capacity to support multiple abiotic conditions in aquatic ecosystems (Batzer & Wissinger, 1996; Prellvitz & Albertoni, 2004).

Table II. Relative abundance of aquatic insect functional feeding groups associated with different macrophytes in ornamental lakes, Southeastern Brazil. FFG = functional feeding group: co = collector, pr = predator, sc = scraper, sh = shredder, fil = filter. M1 = *Egeria najas*. M2 = *Utricularia* sp. M3 = *Salvinia* sp. M4 = *Ceratophyllum* sp.

FFG %	Dry period				Rainy period			
	M1	M2	M3	M4	M1	M2	M3	M4
Co	65.6	72.2	43.2	59.1	49.5	62.6	20.3	51.7
Pr	31.1	27.8	47.7	40.9	47.7	33.0	65.3	48.3
Sc	1.6	0.0	3.0	0.0	0.0	1.1	3.4	0.0
Sh	0.0	0.0	0.0	0.0	1.8	3.3	0.0	0.0
Filt	1.6	0.0	6.1	0.0	0.9	0.0	11.0	0.0
Total	100	100	100	100	100	100	100	100

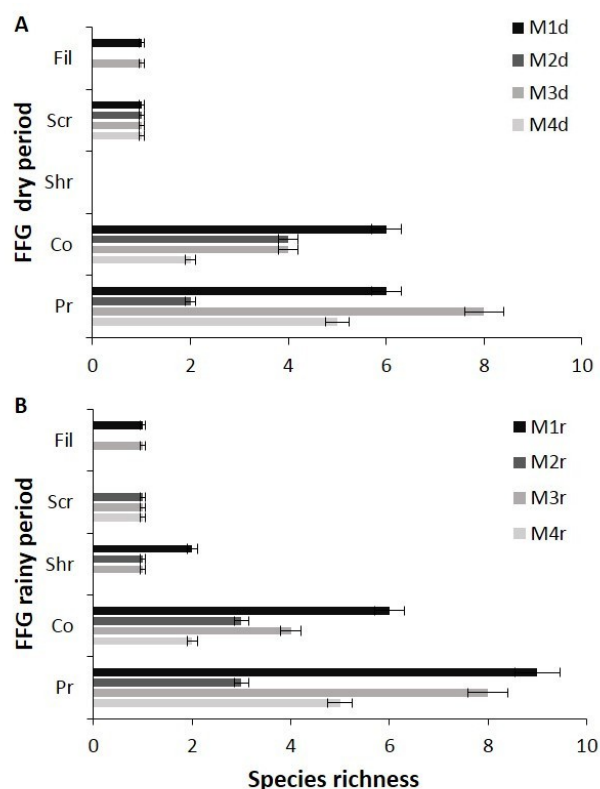


Figure 5. Aquatic insect functional feeding groups' (FFG) species richness associated with different macrophytes in ornamental lakes in a savanna area, Southeastern Brazil. (A) Dry Period, (B) Rainy Period. M1 = *Egeria najas*, M2 = *Utricularia* sp., M3 = *Salvinia* sp., M4 = *Ceratophyllum* sp., d = dry period, r = rainy period.

The community structure associated with the floating *Salvinia* sp. was influenced by high relative *Labrundinia* sp. participation. This Chironomidae genus has been reported associated with these macrophytes in different freshwater systems (Trivinho-Strixino *et al.*, 2000; Dornfeld & Fonseca-Gessner, 2005). The reason for this association could be explained by the availability of space in *Salvinia* sp., which has small gaps between roots. Considering the *Labrundinia* trophic position, as a predator, it has benefits using the macrophyte as a sheltered environment and a place to feed. As *Salvinia* sp. is a free and floating macrophyte widely distributed in aquatic ecosystems, it presents a greater local dispersion over submerged plants (*Egeria najas* and *Ceratophyllum* sp.) and *Utricularia* sp. (rooted emerged). Its morphological structures enable them to float on the surface water, supporting a different community from other macrophytes (submerged and rooted emerged), which are directly in touch with the substrate deposited on the bottoms.

Submerged rooted macrophytes can have long and tangled roots, and very thin sheets with partitions. These structures may accumulate debris, and may thus promote the presence of collectors. The collectors in this study show macrophytes as important components of ecosystems acting as a filter retainer of organic matter. In addition, these plants may contribute to structuring other communities associated with them (Warfe & Bermuta, 2006).

The predominance of insects classified as collectors and predators generally contributes to significant participation in tropical freshwater studies (Oliveira & Nessimian, 2010; Galizzi *et al.*, 2012, Tomanova, 2012). Probably the presence of collectors in macrophytes occurs because of the availability of fine particulate organic matter (FPOM) resource in the senescence stage. The use of live plant tissue as a food resource is common in shredders as *Endotribelos* (Leite-Rossi & Trivinho-Strixino, 2012) and Curculionidae (Reeves *et al.*, 2009); this feeding type presents a low participation in tropical freshwater ecosystems. Many authors have suggested that the availability of coarse particulate organic matter (CPOM) used by shredder feeders are scarce in freshwater systems (Correia & Trivinho-Strixino, 2005; Oliveira & Nessimian, 2010; Tomanova *et al.*, 2012). The presence of shredders probably influence the presence of secondary consumers such as collectors, filters and predators, enhancing the richness in the community associated to macrophytes. Furthermore, some abiotic characteristics in freshwater such as high temperatures and rapid colonization by microorganisms increase the availability of FPOM in the aquatic systems (Graça *et al.*, 2015), influencing invertebrates' gathering-collectors.

This study demonstrated that the habits of macrophytes are important factors influencing the aquatic insect community distribution in lentic systems. Although the results did not show significant differences in richness and diversity, the FFG composition of the aquatic insect community was an important factor that presented a different distribution inhabiting macrophytes with different habits (i.e. *Salvinia* sp.). Further studies adopting an ecological approach between insects and aquatic plants in freshwater systems are needed, as the knowledge of ecological aspects on tropical lakes is still scarce. Artificial aquatic systems are increasing in numbers worldwide. These kinds of systems may become important water reservoirs and biodiversity refuges in modified landscapes, and therefore

knowledge about their ecology is relevant.

Acknowledgments

We would like to thank CNPq (the National Council of Technological and Scientific Development, Brazil) for the grant awarded to DFP: 462715/2014-0, MCTI/CNPQ/Universal; and the fellowship granted to GFA: IC/PIBIC/UNIARA (during the study period). We are also thankful to Teresa Kazuko Muraoka, the Department of Biological Sciences and Health and the University center at Araraquara-UNIARA. Our thanks also extend to all members from the Laboratory of Aquatic Biology-Crustaceans for their support in the field and the laboratory work; and to Jane Coury for the English revision..

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Received: August 2015

Accepted: November 2015

Published: January 2016