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The invasive white ginger lily (*Hedichium coronarium*) simplifies the trait composition of an insect assemblage in the littoral zone of a Savanna reservoir



Hugo Henrique Lanzi Saulino^{a,*}, Susana Trivinho-Strixino^b

^a Universidade Federal de São Carlos, Programa de Pós-Graduação em Ecologia e Recursos Naturais, São Carlos, SP, Brazil

^b Universidade Federal de São Carlos, Departamento de Hidrobiologia, Laboratório de Ecologia de Insetos Aquáticos, São Carlos, SP, Brazil

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ABSTRACT

The invasive white ginger lily (*Hedichium coronarium* – J. Köenig, 1783) simplifies the trait composition of an insect assemblage in the littoral zone of a Savanna reservoir. Invasive plants are believed to shift the trait composition of aquatic insects dwelling in banks of lentic ecosystems. In this study, we analyzed the relationship between the presence of the invasive white ginger lily (*H. coronarium*) and the functional trait indices of the aquatic insect assemblage in the littoral zone of a tropical reservoir. We sampled aquatic insects on the invaded and non-invaded banks of the reservoir and then analyzed the insect trait indices by estimating the Functional Dispersion (FD_{is}), Functional Evenness (FE_{ve}) and the Functional Divergence (FD_{iv}), as well as the Community level Weight-Mean traits (CWM). Finally, we compared these indices between invaded and non-invaded banks as well as their relationship with the abiotic variables, such as dissolved oxygen, pH, depth and water temperature. The result confirmed that the invaded banks had lower values of functional indices as well as dissolved oxygen. However, this abiotic variable was found to have no effect on the functional indices. In addition, the white ginger lily bank presented higher contribution of collector-gathering to predator-piercer groups. We suggest that the invasion of white ginger lily promotes low heterogeneity habitat resulting in simplification on functional traits of aquatic insect assemblage.

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Introduction

The littoral zone of lentic system contains highly diversified community (Heino, 2000, 2008); this biodiversity of this ecosystem have been seriously disturbed and threatened by human activities and is on the verge of losing its characteristic features (e.g. nutrient storage, water supply, recreation) (Brauns et al., 2007; McGoff et al., 2013). The invasive species plants are among the main stressors agents that shift the diversity and structure of many assemblages in freshwater systems (Kelly and Hawes, 2005), especially of the aquatic insects (Kovalenko et al., 2010). With respect to this, it research has shown that alteration of structure of aquatic insect assemblage by invasive plants has important implications to their diversity maintenance. This is justified by the ecological relationships observed between these representative communities,

especially those involving the changes caused by decomposition and habitat structure (Vannote et al., 1980; Graça, 2001).

For instance, the growth of macrophytes in the littoral zones provides habitat (Cheruvilil et al., 2000; Becerra-Muñoz and Schramm, 2007) and food resource that promote high diversity of aquatic insects (Cronin et al., 1998; Clapcott and Bunn, 2003; Stenberg and Stenberg, 2012). Nevertheless, the consumption of invasive macrophyte plants such as Eurasian watermill foil (*Myriophyllum spicatum*), which contains high concentrations of secondary compounds (e.g., polyphenols), can interfere with the growth rate of some aquatic insect species (Choi et al., 2002). This could results to changes of the structural assemblage due to the removal of some functional feeding group especially shredders (Boyero et al., 2012) this change would have a negative impact in the bioconversion of Coarse Particulate Organic Matter CPOM to Fine Particulate Organic Matter (FPOM) which is the major food resource to collector-gather and filtering-feeders groups. Another important aspect is related to changes in habitat structure, the change in the habitat structure is to verify the absence of which invasive macrophyte species have caused the changes in the freshwater systems. In respect to this,

* Corresponding author.

E-mail: hugosaulino@gmail.com (H.H. Saulino).

invasive submerged macrophyte species such as *Hydrilla* (*Hydrilla verticillata*) and Eurasian watermilfoil (*M. spicatum*) with high morphological complexity host great abundance of aquatic insects, especially those that present high vulnerability to fish predators (e.g. Odonata) (Theel et al., 2008; Kovalenko and Dibble, 2011). This occurs because macrophytes with higher morphological complexity impair to predators identify their preys, which present adaptive ability to blend with their intrinsic spaces. The dominance of these invasive macrophytes have been reported as the major factor that disrupts food webs through decoupling of predator-prey interactions due to the homogenization of habitat (Kovalenko and Dibble, 2011).

Considering the role of ecological processes previously mentioned and the biological invasions causing the decrease biodiversity (Dundgeon, 2010), our aim in this study was to investigate the influence of the invasive plant, white ginger lily (*Hedychium coronarium* – J. Koenig, 1783) in the aquatic insect assemblage's traits composition in the littoral zone of a tropical reservoir. In Brazil, this invasive plant is widely distributed with high predominance in marshy areas, mainly in coastal regions, as well as in transition regions between the Atlantic Forest and the Cerrado (Zenni and Ziller, 2011). These invasive emergent plants species (e.g. *Urocloa* sp.), the white ginger lily presents strong competitive strategies such as fast growth and rapid dispersal that enable them to become dominant in wetlands, riparian zones, lake banks, where it forms dense populations (De Castro et al., 2016). Additional information regarding the influence of these invasive plants species in aquatic insects assemblages have been attempted to explain the change in the functional feeding group's (FFG) and the claim about whether invasive macrophyte species can alter other aquatic insect's functional structures such as body length and habit, which are directly related to habitat modification. Here, we explored the Functional

Diversity (FD) using a multimetric dissimilarity index approach, which we explored as aquatic insect's combination traits (FFG, body length, strategy feed and habitat) to analyze the influence of invasive plant in the aquatic insect trait assemblage composition. To do this, we utilized three FD indices, which explore different ecological traits aspect of niche assemblages: (i) Functional dispersion (FDis) – which measure how composition traits differ among species within assemblages; (ii) Functional evenness (FEve) – which measure how niche space is occupy by traits composition assemblages, and (iii) Functional divergence (FDiv) – which measure the level of niche differentiation by functional traits within the assemblages.

It was expected that the dominance of the invasive white ginger lily would modify some of the environmental conditions such as abiotic variables and the habitat structure of this invaded bank and consequently would lead to a simplification of the trait composition of the aquatic insect assemblage resulting to a decrease of the FD indices. This resultant would be a niche constrain of aquatic insect assemblages, once specified the aquatic species traits selection would mirror the habitat and the resource food modification caused by the invasive dominance of macrophyte.

Material and methods

Study area

This study was performed in a tropical reservoir located in a preserved area of Brazilian Savanna vegetation (Cerrado Biome) in the central region of São Paulo State (Brazil) (Fig. 1). The Fazzari reservoir presents chemical characteristics such as high levels of dissolved oxygen, slightly acidic pH, low ammonium and nitrite concentrations (Table 1), and diverse vegetation on its banks. Its total area is 11,370 m², 220 meters long, an average width of 51.5 m

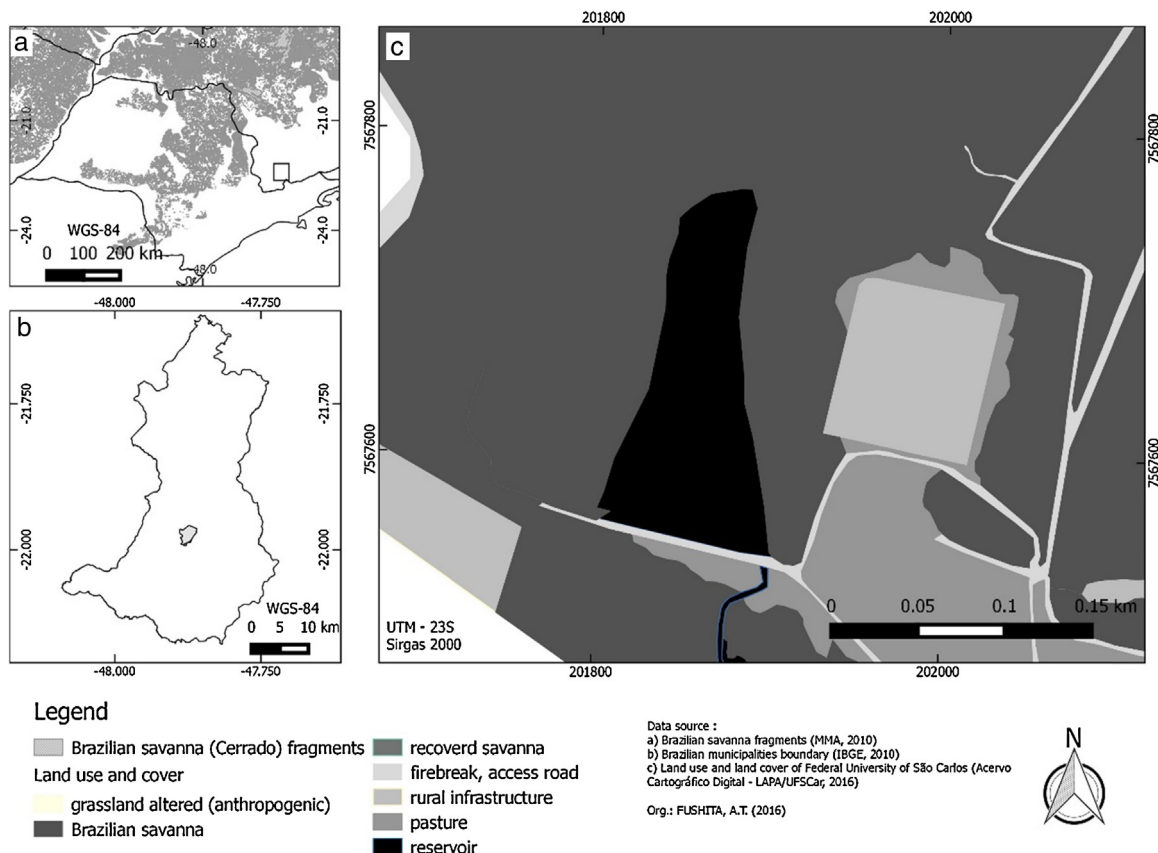


Fig. 1. Location and characterization of plant composition banks of Fazzari reservoir in the Brazilian Savanna (Cerrado Biome, Brazil).

Table 1
Abiotic characterization of Fazzari reservoir localized in the Brazilian Savanna (Cerrado Biome) area.

Abiotic variable	Reservoir banks	
	Invaded bank	Non-invaded
Dissolved oxygen (mg/L)	7.67 ± 0.61	8.29 ± 0.26 ^a
pH	5.42 ± 0.51	5.71 ± 0.26
Water temperature (°C)	19.25 ± 1.54	18.60 ± 0.51
Littoral depth (cm)	0.42 ± 0.13	0.37 ± 0.14

^a $p < 0.05$.

and average depth of 1.10 m and maximum 4 m. According to the Koeppen classification, this region is characterized with hot and wet summers and dry winters (Cwa), with average annual temperatures ranges of 18–22°C and an average annual rainfall of approximately 1450 mm.

The vegetation surrounding its banks consists of two main profiles. The right reservoir bank, which stretch about 80 m is completely dominated by the invasive white ginger lily (*H. coronarium*) followed by a forest partially invaded by the same invasive plant. The left reservoir bank is surrounded by a native riparian forest (trees, shrubs and ferns) and with amphibian macrophyte *Eleocharis* R. Brown.

Sampling and identification of fauna

The aquatic insect from the invaded bank and non-invaded reservoir bank were sampled at the beginning of the dry season (May/June, 2014). Twelve stretches with 10 m distance long were randomly sorted in each vegetation bank, totaling 48 samples. At each stretch, we took one sample from the littoral zone using two collectors: the kick sampling method (“D” net – mesh 250 µm) was used in the 10 m long stretches in areas nearer to the reservoir bank, and Ekman grab was used at 1.5 m away from the reservoir bank. In addition, we also measured the abiotic variables such as the dissolved oxygen, pH, and water temperature using a multisensory probe (HORIBA U010), the depth was obtained using a measuring tape.

The specimens were sorted live on transilluminated trays and conserved in 80% ethanol. We carried out the specimen identification to the lowest possible taxonomic level using identification taxonomic keys of aquatic insects of the Neotropical region (Dominguez and Fernandez, 2009; Trivinho-Strixino, 2011, 2012; Oliveira et al., 2013; Silva et al., 2014; Trivinho-Strixino and Pepinelli, 2015) and with the help of specialists for Odonata.

Functional classification of aquatic insects

In order to obtain the FD indices, we attributed qualitative scores according to the classification trait as follow.

- (i) Functional feeding groups (FFG): scrapers, shredders, collectors and predators. For these biological traits, we classified the FFG according to studies of the Neotropical region (see Table 2) and scored the values according to the Anderson and Cummins (1979) ranking of the organic material potentially available to aquatic insects on an increasing nutritive gradient as: (1) scrapers that consume the microbiota associated with senescence leaves and stems plants. (2) shredders that consume wood and leaf litter and live leaf tissue; (3) collectors that consume decomposing vascular plant and FPOM; (4) predators that usually consume animal tissues.
- (ii) Feeding strategy – detritivore, filtering-feeder, gatherer, herbivore, engulfer and piercer. For this biological trait, we scored the aspects according to the organic particle size that are used

by larvae: (1) detritivore (detritus), (2) filter-feeder (FPOM), (3) gatherer (medium detrital particles) and (4) herbivore (CPOM), (5) engulfer (planktonic and benthic algae) and piercer (generally invertebrates with high biomass).

- (iii) Body length – (1) short (about 10 mm long), (2) mid (between 10 mm and 30 mm long) and (3) long (higher than 30 mm long).
 - (iv) Habit – (1) sprawler, (2) swimmers, (3) planktonic, (4) diver, (5) climber/clinger, (6) silk tube builder, (7) miner, (8) burrower.
- The classification of functional feeding groups of each taxon followed the diet studies of aquatic insects in the Neotropical regions (Table 2). In the cases, where we lacked the knowledge about feeding strategy and habit of some taxa, we utilized the information available in Merritt and Cummins (1996).

FD analyses and fauna composition

The FD indexes were calculated by combining a matrix containing the abundances and trait classification of each taxon as cited above. The FD index is represented by the distance measured based on trait values, where the distance between the taxa is calculated using a PCoA matrix. The distances of aquatic insect’s assemblage traits were calculated using the Gower dissimilarity distance “in a trait space”, separating species with a cluster analysis based on their proximity in a trait distance matrix. To do so, we used the “FD-package” (Laliberté et al., 2014), which is available on the R platform (R Development Core Team, 2014).

In order to analyze the trait composition of aquatic insect assemblages, the following FD indices were considered: 1) Functional Dispersion (FDis) – it measures the mean weight mean distance of the individual species to their weight centroid, where the weights are their relative abundances. FDis has been considered as a functional index of biodiversity (Anderson et al., 2006; Laliberté and Legendre, 2010); 2) Functional Evenness (FEve) – it measures the niche space occupied by the community. This index analyses the effective use of all resource bands that are available for the community; 3) Functional divergence (FDiv) – it measures the level of niche differentiation occupied by the community (Manson et al., 2005); 4) Community-level Weight Means (CWM) – it measures the relevance of the traits found in the community. This measure of diversity is directly related to the hypothesis of Grime’s mass ratio, which considers that the more abundant traits of the species determine the ecosystem processes (Lavorel et al., 2008).

Data analysis

We compared the estimated values of FDis, FEve, FDiv and CWM-traits between the invaded and non-invaded banks, as well as the abiotic variables, with a permutation test for independent samples ($n=999$), which is analogous to a nonparametric t-test. In addition, we analyzed whether there were some influence of abiotic variables in the FD indices. To do this, we used a multiple linear regression model, in which we modeled only the FD indices (dependent variable) and abiotic variables (independent variable) that presented significant differences between the invaded and non-invaded banks.

We complemented our study by comparing the assemblage composition throughout the analysis of the similarity percentage (SIMPER) using the abundances of FFG as well as aquatic insect taxa. It verifies the contribution of each FFG and taxon to the observed similarity between the vegetation banks. In addition, this analysis enables us to identify the FFG that are most important in creating the observed pattern of structural assemblage. The Bray-Curtis index was used to calculate the aquatic insect assemblage’s FFG and the taxa dissimilarity on the invaded and non-invaded banks and

Table 2

Score and classification of aquatic insect's functional traits associated with an invaded and non-invaded bank in littoral zone of Fazzari reservoir – Brazilian Savanna (Cerrado Biome).

Taxa	Functional trait scores				Bank	References
	Body	FFG	Feed	Habit		
<i>Campsurus</i> Walker, 1853	2	3	2	8	I N	Molineri and Emmerich (2010), Brasil et al. (2014)
<i>Caenis</i> Stephens, 1835	1	1	4	1	I N	Edmunds and Waltz (1996), Molineri and Malzacher (2007)
<i>Ulmeritus</i> Traver, 1956	1	3	3	2	I N	Cummins et al. (2005), Salles and Domínguez (2012).
<i>Callibaetis</i> Eaton, 1875	1	1	4	2	– N	Salles et al. (2004), Da-Silva and Salles (2012), Tomanova et al. (2006)
<i>Aedomyia</i> Theobald, 1901	1	3	2	3	I N	Merritt and Cumins (1996)
<i>Dasyhelea</i> Kieffer, 1911	1	3	3	1	I N	Ferreira-Kepler et al. (2014)
<i>Gyrinus</i> Latreille, 1810	2	4	5	2	I N	Archengelsky et al. (2009)
<i>Desmopachria</i> Babington, 1841	1	4	6	4	I N	Braga and Ferreira-Jr (2014)
<i>Andonectes</i> Guéorguiev, 1971	1	4	6	4	I –	Archengelsky et al. (2009)
<i>Laccophilus</i> Leach, 1815	1	4	6	4	I N	Archengelsky et al. (2009)
<i>Pronoterus</i> Sharp, 1882	1	4	5	2	I –	Archengelsky et al. (2009)
<i>Mesonoterus</i> Sharp, 1882	1	4	5	2	I N	Archengelsky et al. (2009)
<i>Hydrocanthus</i> Say, 1823	1	4	5	2	I N	Archengelsky et al. (2009)
Scirtidae	1	1	4	5	– N	Merritt and Cumins (1996)
<i>Macronema</i> Pictet, 1836	2	3	2	5	I N	Flint and Bueno-Soria (1982)
<i>Cyrnellus</i> Banks, 1913	1	3	2	5	I N	Pes et al. (2014)
<i>Oecetis</i> McLachlan, 1877	1	4	5	5	I N	Dominguez and Fernandez (2009)
<i>Protoneura</i> Selys, 1857	2	4	5	5	I N	Costa et al. (2004)
<i>Oxyagrion</i> Selys, 1876	2	4	5	5	I –	Costa et al. (2004)
<i>Telebasis</i> Selys, 1865	2	4	5	5	I N	Costa et al. (2004)
<i>Acanthagrion</i> Selys, 1876	3	4	5	5	I N	Costa et al. (2004)
<i>Diastatops</i> Rambur, 1842	2	4	5	1	I N	Costa et al. (2004)
<i>Miathyria</i> Kirby, 1889	3	4	5	1	I N	Costa et al. (2004)
<i>Erythrodiplax</i> Brauer, 1842	3	4	5	1	I N	Costa et al. (2004)
<i>Macrothemis</i> Hagen, 1868	2	4	5	1	I –	Costa et al. (2004)
<i>Orthemis</i> Hagen, 1861	2	4	5	1	I –	Costa et al. (2004)
<i>Idiataphe</i> Cowley, 1934	2	4	5	1	I N	Costa et al. (2004)
<i>Gynothemis</i> Calvert, 1909	2	2	1	4	I N	Costa et al. (2004)
<i>Lestes</i> Leach, 1815	3	4	5	5	I –	Costa et al. (2004)
<i>Belostoma</i> Laitreille, 1807	3	4	5	5	– N	Nieser and Melo (1997)
<i>Notonecta</i> Hungford, 1933	1	4	5	5	I N	Nieser and Melo (1997)
<i>Limnocois</i> Stål, 1860	1	4	5	5	I N	Nieser and Melo (1997)
<i>Tenagobia</i> Bergroth, 1899	1	1	4	2	I –	Nieser and Melo (1997)
<i>Aedokritus coffeatus</i> Trivinho-Strixino, 1997	1	3	3	8	I N	Butakka et al. (2014)
<i>Asheum beckae</i> Sublette & Sublette 1964	1	3	3	8	I N	Butakka et al. (2014)
<i>Caladomyia kapilei</i> Trivinho-Strixino, 2012	1	3	3	5	I N	Butakka et al. (2014)
<i>Caladomyia riotarumensis</i> Reiff, 2000	1	3	3	5	I N	Butakka et al. (2014)
<i>Chironomus</i> Meigen	1	3	3	8	I N	Sanseverino and Nessimian (2008), Butakka et al. (2014)
<i>Cladopelma forcipes</i> (Rempel, 1939)	1	3	3	8	N	Merritt and Cumins (1996)
<i>Endotribelos bicolor</i> Trivinho-Strixino & Pepinelli, 2015	1	2	2	8	I N	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)
<i>Goeldichironomus maculatus</i> Trivinho-Strixino & Strixino, 1991	1	3	3	8	I –	Merritt and Cumins (1996)
<i>Polypedilum</i> sp5 cf Trivinho-Strixino, 2011	1	3	3	2	I N	Sanseverino and Nessimian (2008), Butakka et al. (2014)
<i>Polypedilum (Tripodura)</i> sp3 cf Trivinho-Strixino, 2011	1	3	3	2	I N	Sanseverino and Nessimian (2008), Butakka et al. (2014)
<i>Polypedilum</i> sp3 cf Trivinho-Strixino, 2011	1	3	3	2	I N	Sanseverino and Nessimian (2008), Butakka et al. (2014)
<i>Polypedilum</i> sp4 cf Trivinho-Strixino, 2011	1	3	3	2	– N	Sanseverino and Nessimian (2008), Butakka et al. (2014)
<i>Stenochironomus</i> Kieffer, 1919	1	2	4	7	I N	Sanseverino and Nessimian (2008), Butakka et al. (2014)
<i>Ablabesmyia depaulai</i> Neubern, 2013	1	4	5	1	I N	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)
<i>Ablabesmyia laurindoi</i> Neubern, 2013	1	4	5	1	I N	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)
<i>Ablabesmyia metica</i> Roback, 1983	1	4	5	1	I N	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)
<i>Ablabesmyia strixinoae</i> Neubern, 2013	1	4	5	1	I –	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)
<i>Clynotanytus</i> Kieffer, 1913	2	4	5	1	– N	Butakka et al. (2014)
<i>Coelotanytus</i> Kieffer, 1913	2	4	5	1	I N	Butakka et al. (2014)
<i>Labruminia carolae</i> Silva, 2014	1	4	5	1	I N	Butakka et al. (2014)
<i>Labrundinia paulae</i> Silva, 2014	1	4	5	1	– N	Butakka et al. (2014)
<i>Labrundinia</i> sp Fittkau, 1962	1	4	5	1	I N	Butakka et al. (2014)
<i>Labrundinia tenata</i> Silva, 2013	1	4	5	1	I N	Butakka et al. (2014)
<i>Labrundinia unicolor</i> Silva, 2013	1	4	5	1	I N	Butakka et al. (2014)
<i>Larsia</i> Fittkau, 1962	1	4	5	1	– N	Henriques-Oliveira et al. (2003)
<i>Monopelopia</i> Fittkau, 1962	1	4	5	1	I N	Butakka et al. (2014)
<i>Pentaneura</i> Philippi, 1865	1	4	5	1	– N	Henriques-Oliveira et al. (2003), Butakka et al. (2014)
<i>Procladius</i> Skuse, 1889	1	4	5	1	– N	Henriques-Oliveira et al. (2003), Butakka et al. (2014)
<i>Fissimentum desiccatum</i> Cranston & Nolte, 1996	1	3	3	1	I N	Butakka et al. (2014)
<i>Fissimentum</i> sp 3 cf Trivinho-Strixino, 2011	1	3	3	1	– N	Butakka et al. (2014)
<i>Fissimentum</i> sp 2 cf Trivinho-Strixino, 2011	1	3	3	1	– N	Butakka et al. (2014)
<i>Tanytarsus</i> sp v. d. Wulp, 1874	1	3	2	6	I N	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)
<i>Tanytarsus obiriciae</i> Trivinho-Strixino & Sonoda, 2006	1	3	2	6	I N	Henriques-Oliveira et al. (2003), Sanseverino and Nessimian (2008)

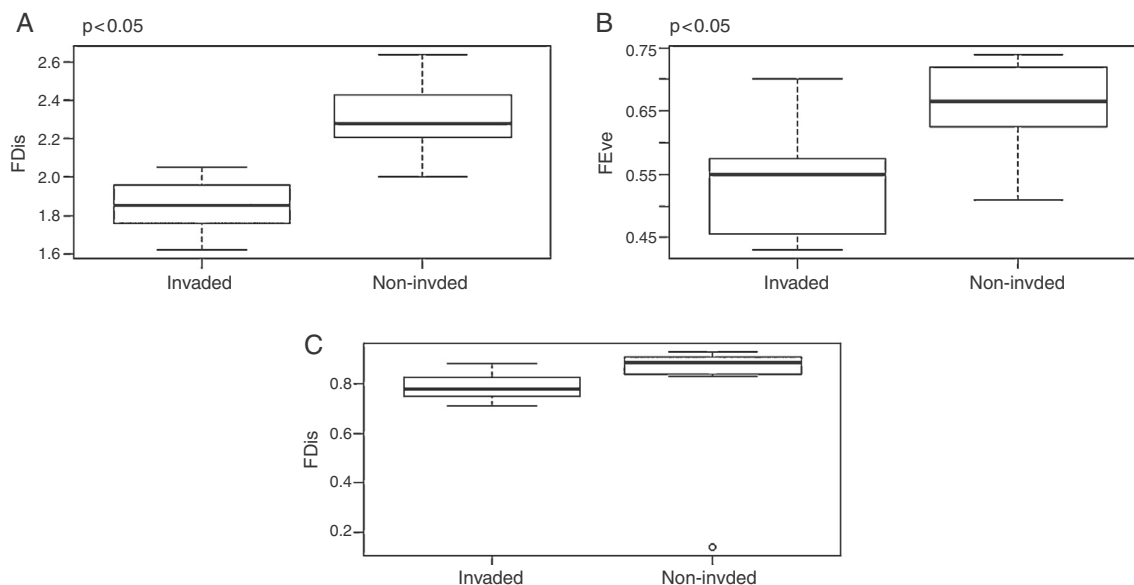


Fig. 2. The average values of FD indices of aquatic insect assemblages in invaded and non-invaded bank by white ginger lily of a reservoir in Brazilian Savanna (Cerrado Biome). A – FDIs, B – FEve, C – FDiv. FD, Functional Diversity; FDIs, Functional Dispersion; FEve, Functional Evenness; FDiv, Functional Divergence.

the relative participation of the taxon to deduce the influence in the trait composition of aquatic insect assemblage.

Results

2067 specimens were collected and analyzed for the trait composition of 66 taxa (Table 2). The observed lower averages were FDIs ($t = -6.08$, $p < 0.0001$), FEve ($t = -4.03$, $p < 0.001$) of aquatic insect assemblages in the invaded bank (Fig. 2). CWM-trait of functional feeding groups ($t = 2.76$, $p = 0.01$) presented the same results, however the CWM-trait of strategic feed ($t = 4.06$, $p < 0.001$) was higher in the invaded bank (Fig. 3). For the abiotic variables, the observed lower dissolved oxygen was ($t = -3.24$, $p = 0.004$) in the invaded bank (Table 1).

With respect to the influence of the abiotic variables in the FD indices, we observed that the dissolved oxygen had no influence on the FDIs ($b = -0.05$, $p = 0.53$, $R^2 = 0.22$), FEve ($b = -0.03$, $p = 0.34$, $R^2 = 0.08$), CWM-trait of functional feeding groups ($b = 0.05$, $p = 0.46$,

$R^2 = 0.21$) or CWM-trait of strategy feeding ($b = -0.04$, $p = 0.81$, $R^2 = 0.22$).

The SIMPER analyses indicated an overall average dissimilarity of 45% between the functional feeding groups of aquatic insect assemblages. The collector-gathers contributed more than 30% of the assemblages, followed by predators-piercers (>20%) (Table 3). *Chironomus* (8%), *Asheum beckae* (8%), *Caladomyia kapilei* (5%) and *Ablabesmyia strixinoae* (7%), contributed the highest participation in the overall trait composition, as well as higher average abundance in the invaded bank. The other two groups, collector-filterers (>15%) and predator-engulfers (>10%) also contributed a high participation in the composition traits of aquatic insect assemblages. *Aedomyia* (9%) and *Telebasis* (5%) contributed higher participation in the composition assemblages, as well as a higher average abundance in the invaded bank. In contrast, the non-invaded bank presented higher average abundance of the scrapers group, that presented low relative participation in the overall composition assemblage (<5%) (Table 4).

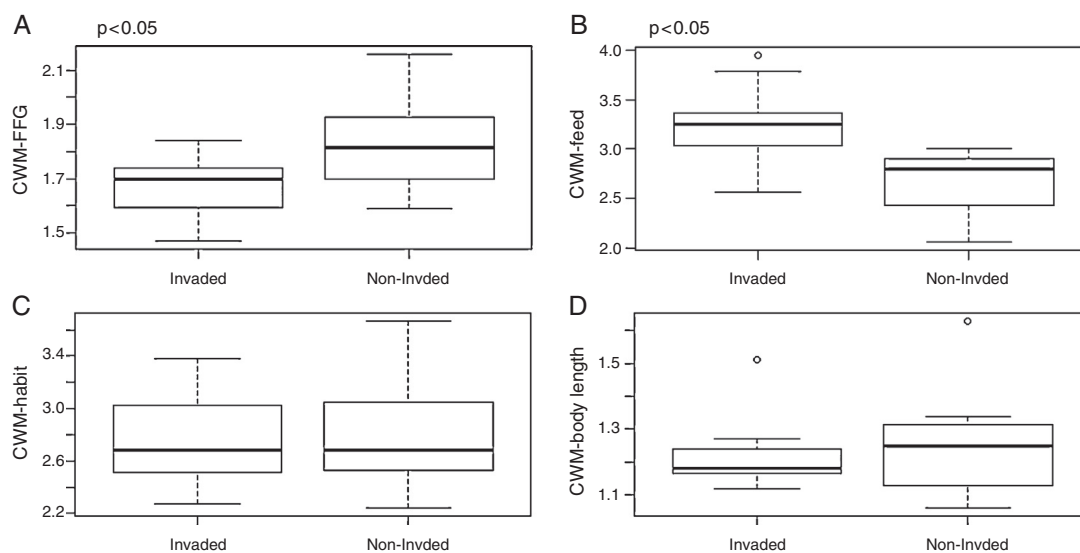


Fig. 3. The average values of CWM-trait values of aquatic insect assemblages in invaded and non-invaded banks by white ginger lily of a reservoir in Brazilian Savanna (Cerrado Biome). A – CWM-FFG, B – CWM-feed, C – CWM-habit, D – CWM body length. CWM, Community level Weight-Mean.

Table 3

Average dissimilarity and relative participation of aquatic insects' functional feeding groups in assemblages of invaded and non-invaded bank by white ginger lily of a reservoir in Brazilian Savanna (Cerrado Biome).

FFG/strategy feeding	Average dissimilarity	Contribution (%)	Cumulative (%)	Reservoir bank	
				Invaded (average abundance)	Non-invaded (average abundance)
Collector-gatherer	14.06	31.38	31.38	41.20	15.30
Predator-piercer	10.60	23.67	55.05	26.80	9.33
Collector-filterer	7.82	17.45	72.50	26.50	17.70
Predator-engulfer	6.47	14.45	86.95	21.10	9.58
Scrapers	3.33	7.42	94.37	2.75	6.25
Predator-sucker	1.38	3.10	97.46	0.42	2.50
Shredder-leaf litter	0.76	1.71	99.17	1.58	0.25
Shredder-minner wood	0.37	0.83	100.00	0.50	0.25

Discussion

As we expected, the invasive white ginger lily shifted the composition traits of the aquatic insect assemblage in the littoral zone especially by the decreasing especially the dissimilarity distance (FD_{is}) and niche space occupation (FE_{ve}). The abundance distribution of the Functional Feeding Groups (FFG) seemed to be the main variable that influenced the trait composition of the assemblages.

It could be inferred throughout result that the presence of the monotypic banks formed by the white ginger lily, is likely to result into low habitat spatial heterogeneity in comparison to native vegetation banks. Some studies have already showed that the presence of riparian vegetation which is composed of different species plants, promotes higher diversity of aquatic insects associated (Voelz and McArthur, 2000; Nessimian et al., 2008) with monotypic plant species banks (Kovalenko et al., 2010). This occurs because high diversity species plants can provide high substrate heterogeneity, interstitial space habitat and food resource (CPOM and FPOM) (Merritt and Cumins, 1996; Heino, 2000), which promote variety types of niche to aquatic insect species (Townsend and Hildrew, 1994). Throughout FFG composition, we observed that native vegetation banks, consisting of especially trunks, leaf litter increased the participation of aquatic insects groups such as scrapers and shredders, leading to the increase of functional traits diversity. On the other hand, the dominance of the invasive species plants which generally formed the monotypic banks seemed to host low diversity of aquatic insect species due to low spatial heterogeneity habitat and resource. This probably occurs due to the rapid vegetative growth of invasive species plants that lead to reduction of substrate heterogeneity, interstitial space and food resource on freshwater ecosystem (Theel et al., 2008; Hlyladz et al., 2011; McNeish et al., 2012).

Generally, the rapid vegetative growth of invasive species plants promotes high biomass and it is reported as the main cause of habitat alteration by changing abiotic variables such as oxygen concentration that exclude sensitive species of aquatic insects such as Ephemeroptera nymphs (Samways et al., 2011; Stiers et al., 2011; Coetze et al., 2014). Although this variable had no effect on the functional trait composition on the aquatic insect. The main cause of the disrupting structural assemblage occurred through the higher participation of chironomids. In fact, some chironomids larvae can tolerate very low level of dissolved oxygen (Whatley et al., 2014), however, they have been reported to have higher participation in aquatic insects dwelling and invade banks by invasive macrophytes species (Theel et al., 2008). As observed in such studies, the high participation of the larvae of this family probably is due to the habitat quality and high availability of food resource (FPOM), which corroborate with our inferences about the negative impact of white ginger in the littoral zone. In respect to habitat heterogeneity, the fast growth of white ginger lily results in banks formed by an entanglement of rhizomes, branches and leaves

leading to the overlapping of many branches that probably reduced habitat spatial heterogeneity. Therefore, based on the results we suggested that the invasion by white ginger lily probably promoted low spatial heterogeneity habitat especially when we observed it in a narrow niche band occupation resulting in lower FE_{ve} and lower dissimilarity composition traits (FD_{is}). In additional, we also could consider that the availability of resource was the main factor that selected specific traits especially CWM-FFG composition, with the higher abundance of chironomid collector-gathering groups seemed strongly influence by the lower FD indices.

According to Wellnitz and Poff (2001), the increase in the assemblage similarity traits is one of the main causes of extinctions of diversity functions. In addition, the availability of resource acts as filter that selects species trait determining the width of the ranges of niche occupation of assemblages on ecosystems (Southwood, 1977; Korfiatis and Stamou, 1999). In this respect, the invasion by white ginger lily in the littoral zone had important implication for the conservation of the biodiversity (Samways et al., 2011; McNeish et al., 2012). The decrease of habitat heterogeneity and low availability resource display important role in the maintenance of aquatic insect's composition trait leading to simplification of structure assemblages. Furthermore, the resource availability could be considered an important variable that would influence the composition of FFG assemblage, once the low resource heterogeneity decreases the participation of scrapers. The low participation of this functional feeding group in the assemblage composition traits was an indication that the white ginger lily invasion along time could lead to homogenization of aquatic insect's structure assemblage in the reservoir banks.

Finally, we highlighted that the predominance of these invasive plant species in the littoral zone as we expected it shifted the functional structure of aquatic insect assemblages, acting as a selective filter that benefits only few species, whose functional feeding groups reflect the low variety of resources used by the aquatic insect assemblages. This finding has important implications for the maintenance of ecological processes such as exchange of energy flow in the system, as well as for the biological diversity of aquatic insect assemblages in the littoral zones. Similar to other diverse stressor agents found in freshwater environments (e.g. eutrophication, agriculture and urbanization expansion), the invasion of white ginger lily has a negative impact on the aquatic insects assemblage composition traits resulting in the loss of the functional diversity. Similar to other invasive species, the occupation of this plant in surrounding freshwater ecosystems resulted in the loss of the functional traits structures of the native assemblages (Olden et al., 2004). Considering that due to the wide propagation of white ginger lily in many Brazilian biomes, interest related to aspects of its invasion has increased (Zenni and Ziller, 2011; Sampaio and Schmidt, 2013). We highlight the importance of the role of control of invasive plant species, as they contribute to decreasing the aquatic biodiversity and ecosystem services in the Neotropical region.

Table 4
Average dissimilarity and relative participation of aquatic insect taxa in assemblages of invaded and non-invaded bank by white ginger lily of a reservoir in Brazilian Savanna (Cerrado Biome).

Taxon	Average dissimilarity	Contribution (%)	Cumulative (%)	Reservoir bank	
				Invaded mean abundance	Non-invaded mean abundance
<i>Aedomyia</i>	6.40	9.10	9.10	19.30	10.50
<i>Chironomus</i>	5.72	8.13	17.23	13.60	3.50
<i>Asheum beckae</i>	5.59	7.94	25.17	11.80	2.25
<i>Ablabesmyia strixinoae</i>	5.29	7.53	32.70	12.30	3.33
<i>Caladomyia kapilei</i>	3.74	5.31	38.02	8.75	2.25
<i>Campsurus</i>	3.25	4.62	42.64	3.25	5.33
<i>Telebasis</i>	3.14	4.47	47.11	5.33	0.83
<i>Caenis</i>	2.90	4.12	51.23	1.92	5.25
<i>Ablabesmyia laurindoi</i>	2.24	3.19	54.42	5.00	1.25
<i>Diastatops</i>	2.00	2.86	57.29	5.67	0.25
<i>Ablabesmyia depaulai</i>	1.70	2.40	59.70	3.42	0.50
<i>Dasyhelea</i>	1.60	2.29	61.99	1.08	2.50
<i>Labrundinia unicolor</i>	1.49	2.11	64.00	3.17	0.67
<i>Protoneura</i>	1.41	2.01	66.11	2.58	0.42
<i>Fissimentum</i> sp2	1.34	1.91	68.00	0.00	1.92
<i>Erythrodiplax</i>	1.33	1.82	70.00	1.92	1.67
<i>Acanthagrion</i>	1.32	1.88	71.80	0.50	2.17
<i>Miathyria</i>	1.03	1.46	73.26	1.25	0.83
<i>Polypedilum</i> sp5	1.00	1.45	74.70	1.50	0.42
<i>Cymellus</i>	0.98	1.39	76.10	1.67	0.92
<i>Polypedilum</i> sp3	0.94	1.34	77.44	1.58	0.25
<i>Notonecta</i>	0.91	1.29	78.22	0.33	1.58
<i>Labrundinia paulae</i>	0.89	1.27	80.00	0.00	1.58
<i>Macronema</i>	0.81	1.16	81.15	1.25	0.50
<i>Endotribelos bicolor</i>	0.76	1.09	84.24	1.58	0.25
<i>Tanytarsus obiriciae</i>	0.69	0.99	83.23	1.00	0.00
<i>Oecetis</i>	0.64	0.90	84.13	0.42	0.92
<i>Monopelopia</i>	0.62	0.88	85.00	0.92	0.50
<i>Polypedilum</i> (Tripodura) sp3	0.61	0.87	85.90	0.25	0.92
<i>Gyrinus</i>	0.61	0.86	86.74	1.17	0.33
<i>Pentaneura</i>	0.52	0.74	87.48	0.00	1.00
<i>Aedokritus coffeatus</i>	0.48	0.69	88.17	0.83	0.08
<i>Labrundinia carolae</i>	0.44	0.62	88.79	0.92	0.08
<i>Caladomyia riotarumensis</i>	0.42	0.59	89.39	0.67	0.17
<i>Labrundinia</i> sp	0.39	0.56	89.94	0.75	0.08
Scirtidae	0.38	0.54	90.49	0.00	0.67
<i>Stenochironomus</i>	0.37	0.53	91.02	0.50	0.25
<i>Orthemis</i>	0.35	0.50	91.52	0.50	0.00
<i>Tenagobia</i>	0.34	0.48	92.00	0.83	0.00
<i>Mesonotus</i>	0.33	0.48	92.48	0.08	0.50
<i>Coelotanyppus</i>	0.33	0.47	92.95	0.08	0.50
<i>Pronotus</i>	0.30	0.42	93.38	0.42	0.00
<i>Limnocoris</i>	0.29	0.42	93.80	0.08	0.50
<i>Labrundinia tenata</i>	0.28	0.39	94.19	0.58	0.08
<i>Laccophilus</i>	0.27	0.38	94.58	0.42	0.17
<i>Ulmeritus</i>	0.26	0.37	94.95	0.42	0.08
<i>Tanytarsus</i> sp	0.26	0.37	95.33	0.08	0.42
<i>Desmopachria</i>	0.26	0.37	95.70	0.42	0.08
<i>Belostoma</i>	0.24	0.34	96.04	0.00	0.42
<i>Ablabesmyia metica</i>	0.22	0.31	96.36	0.58	0.00
<i>Cladopelma forcipes</i>	0.22	0.31	96.67	0.08	0.33
<i>Goeldichironomus maculatus</i>	0.21	0.30	96.97	0.50	0.00
<i>Macrothemis</i>	0.21	0.29	97.27	0.33	0.00
<i>Idiataphe</i>	0.19	0.27	97.54	0.17	0.08
<i>Fissimentum desiccatum</i>	0.19	0.27	97.81	0.17	0.17
<i>Lestes</i>	0.19	0.26	98.07	0.33	0.00
<i>Polypedilum</i> sp4	0.18	0.25	98.32	0.00	0.33
<i>Gynothemis</i>	0.17	0.24	98.56	0.08	0.25
<i>Callibaetis</i>	0.16	0.23	98.80	0.00	0.33
<i>Oxyagron</i>	0.16	0.23	99.03	0.25	0.00
<i>Hydrocanthus</i>	0.16	0.22	99.25	0.17	0.17
<i>Clynotanyppus</i>	0.13	0.19	99.44	0.00	0.25
<i>Procladius</i>	0.13	0.19	99.63	0.00	0.25
<i>Fissimentum</i> sp3	0.11	0.19	99.79	0.00	0.17
<i>Larsia</i>	0.08	0.13	99.92	0.00	0.17
<i>Andonectes</i>	0.06	0.08	100	0.17	0.00

Conflicts of interest

The authors declare no conflicts of interest.

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