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Forecasting the impact of an invasive macrophyte species in the littoral zone through aquatic insect species composition

Hugo H. L. Saulino[1] & Susana Trivinho-Strixino[2]

1. Universidade Federal de São Carlos, Programa de Pós-Graduação em Ecologia e Recursos Naturais, São Carlos, Brazil. (hugosaulino@gmail.com)
2. Universidade Federal de São Carlos, Departamento de Hidrobiologia, Laboratório de Ecologia de Insetos Aquáticos, São Carlos, Brazil. (strixino@power.ufscar.br)

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ABSTRACT. Invasive macrophytes threaten freshwater ecosystem biodiversity. We analyzed the impact of the invasive white ginger lily (*Hedychium coronarium* J. König, Zingiberaceae) on aquatic insect assemblages living in the littoral zone of a tropical reservoir. We took aquatic insect samples in the littoral zone on four main vegetal profile banks: white ginger monotypic bank, forest partially invaded, native macrophyte monotypic bank and riparian forest. At each vegetal bank, we measured abiotic variables such as dissolved oxygen, pH, water temperature and depth. We analyzed the aquatic insects through abundance, richness and Simpson diversity. We used the non-Metric Multidimensional Scaling (nMDS) analysis to analyze the spatial distribution of each assemblage, and Analysis of similarities (ANOSIM) to verify differences amongst dissimilarity distances. Additionally, we analyzed the main taxa associated with invasive macrophytes through indicator species analyses using IndVal index. We observed that the invasive macrophyte banks presented higher abundance of associated specimens, as well as lower dissimilarity of aquatic insect assemblages. Additionally, invasive macrophytes shifted the water pH and littoral depth of reservoir banks. The IndVal index indicated eight aquatic insects as indicator species. *Labrundinia unicolor* Silva, 2013, *Ablabesmyia depaulai* Neubern, 2013 and *Diastatops* Rambur, 1842 were indicator species on banks. We concluded that invasion of white ginger lily caused loss of shallow littoral habitat and altered the pH of the surrounding water probably by high decomposition rate and high production of plant biomass. We suggest the use of species of aquatic insects as indicator species to monitor white ginger lily impact in freshwater systems.

KEYWORDS. Habitat complexity, Chironomidae, freshwater conservation, macroinvertebrates, *Hedychium coronarium*.

Invasive species are considered one of the main stressors of freshwater systems, and have altered several ecosystem services, such as energy production, sailing and fishing (Dungeon, 2010). The lentic littoral zone is an important freshwater ecosystem zone which presents high diversity species, and is threatened by invasive species (Vander Zanden *et al.*, 1999). Among diverse invasive organisms, the influence of invasive macrophyte species in this freshwater zone is well recognized (Thomaz & Cunha, 2010).

Some studies report fast vegetative growth of invasive macrophyte species increasing habitat complexity, which results in the disruption of food webs (Kovalenko & Dibble, 2011). Further, the high biomass production of these plants results in the decrease of dissolved oxygen that leads to the exclusion of sensitive species (Schultz & Dibble, 2012). Additionally, invasive macrophytes can alter resource availability which shifts species assemblage (Leite-Rossi *et al.*, 2016). The ecological interaction between invasive macrophyte species and aquatic insects seems to have important implications on the impact of some ecological process, especially those involving predation (Warfe & Barmuta, 2006), herbivory (Boyero *et al.*, 2012) and decomposition (Leite-Rossi *et al.*, 2016). Because invasive macrophyte species cause changes in aquatic insect assemblages which directly impact these ecological processes, their management in freshwater systems is also of vital importance to biodiversity conservation.

Aquatic insect assemblages are recognized as good indicators of habitat alterations. Their ubiquity in freshwater systems as a consequence of their several habitat adaptations (*e.g.* respiration system, feeding habit, life cycle) enable them to be utilized in many freshwater monitoring studies (Arimoro & Ikomi, 2009). Their use as bioindicators arose from the Saprobian System approach, which was an early model that employed some aquatic insect taxa, such as, *Chironomus* Meigen, 1803 as indicators of anthropogenic disturbance (*e.g.* sewage discharge) (Rosenberg & Resh, 1993). Since then, the applicability of aquatic insect assemblages in biomonitoring studies has developed, demonstrating their importance to freshwater conservation issues such as deforestation, discontinuity in habitat and to the restoration programs (Blakely *et al.*, 2006; Navarro-Llacer *et al.*, 2010; Saulino *et al.*, 2017).

In littoral zones of lentic systems, the aquatic insect assemblages are believed to respond to habitat changes caused by invasive macrophyte species (Saulino & Trivinho-Strixino, 2017). In the present study we analyzed the effect of white ginger lily (*Hedichium coronarium* J. Köenig, Zingiberaceae) on aquatic insect assemblages dwelling in the littoral zone of a tropical reservoir. In Brazil, this invasive emergent plant species has become dominant in wetlands, riparian zones and lake banks, where it forms dense populations (De Castro *et al.*, 2016) and their impacts in the native fauna associated is still unknown. Similar to anthropogenic stressors in freshwater systems (*e.g.* erosion, sewage and deforestation), we believe that habitat alterations causing this invasive macrophyte species could lead to a decrease in diversity of aquatic insect species. In addition, specific taxa of aquatic insects associated with habitat alteration could be used as indicators of habitat disturbance, taxonomically mirroring the habitat conditions promoted by this invasive macrophyte in the littoral zone.

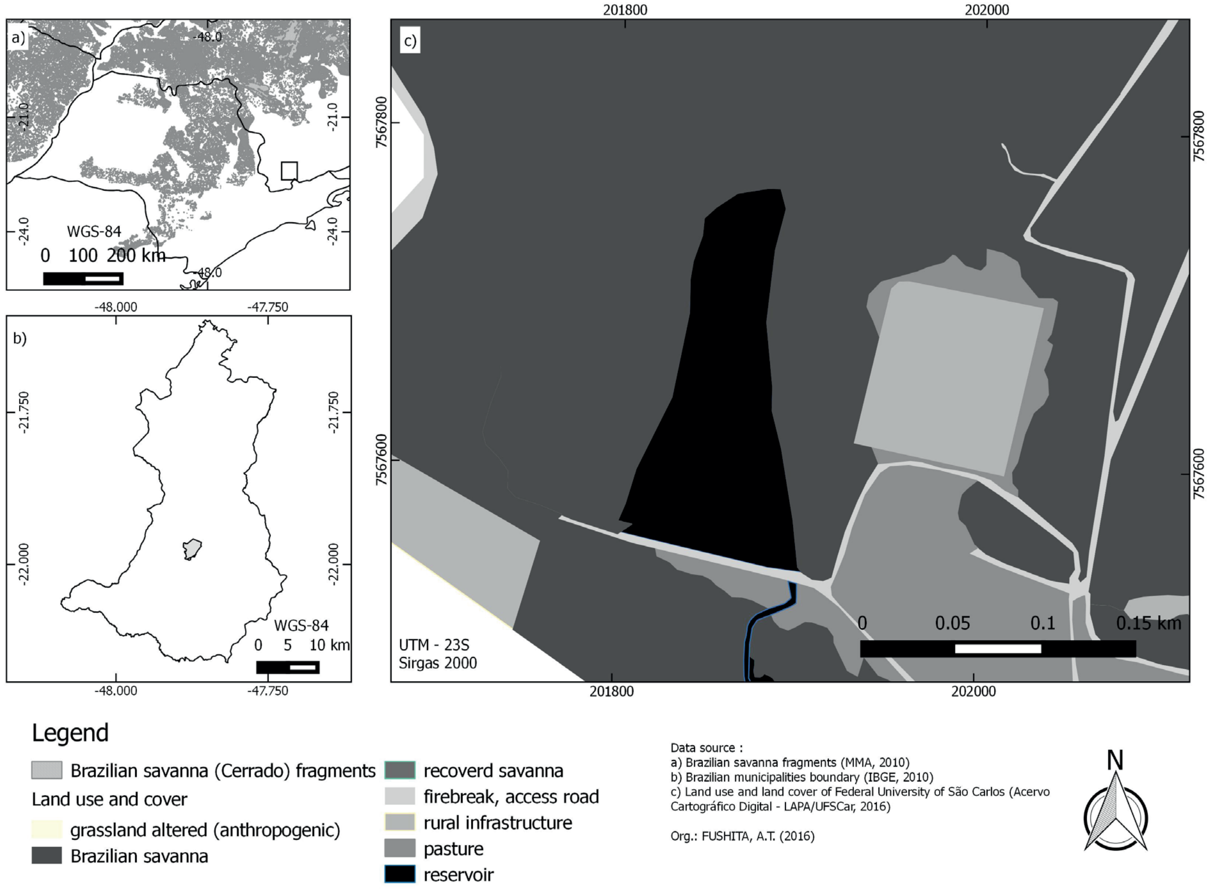
To understand this, we compared aquatic insect assemblages associated with a monotypic bank where white ginger lily was present in a tropical reservoir with other three main vegetal profiles: forest bank partially invaded by white ginger lily, monotypic bank with an amphibious macrophyte [*Eleocharis palustris* (L.) Roem. & Schult, Cyperaceae] and non-invaded riparian vegetation bank. We assumed that white ginger lily invasion promotes homogenous aquatic insect composition assemblages compared to the native vegetation profiles. In addition, we looked to identify aquatic insect taxa that could serve as indicators of disturbance associated with this invasive plant. These results could be important to conservation practices intended to monitor invasion by this macrophyte species in the lentic systems.

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 has high levels of dissolved oxygen (> 7mgL), slightly acidic pH (± 5.5) and diverse vegetation on its banks. Its total area is 11,370 m^2, 220 meters long, an average width of 51.5 m and average depth of 1.10 m and maximum 4 m. According to the Koeppen classification, this region is characterized as Cwa with hot and wet summers and dry winters, with average annual temperature ranges of 18–22°C and an average annual rainfall of approximately 1,450 mm.

The vegetation surrounding its banks consists of four main profiles. The right reservoir bank, which stretches about 80 meters is completely dominated by the (1) invasive white ginger lily (*H. coronarium*) followed by a (2) forest partially invaded by the same invasive plant. The left reservoir bank is surrounded by a (3) amphibious macrophyte *E. pallustris* and (4) native riparian forest composed of trees, shrubs and ferns.

Sampling and identification of fauna. We took samples of aquatic insects from each vegetation profile at the beginning of the dry season (May/June, 2014). Six ten-meter-long stretches of each vegetation profile bank were randomly selected, totaling 24 samples. At each stretch, we



Data source :
a) Brazilian savanna fragments (MMA, 2010)
b) Brazilian municipalities boundary (IBGE, 2010)
c) Land use and land cover of Federal University of São Carlos (Acervo Cartográfico Digital - LAPA/UFSCar, 2016)

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

took one sample from the littoral zone using dip collectors ("D" net - mesh 250 μm). In addition, we 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 taxonomic keys for aquatic insects of the Neotropical region (Dominguéz & Fernandez, 2009; Trivinho-Strixino, 2011, 2012; Oliveira *et al.*, 2013; Da Silva *et al.*, 2014; Trivinho-Strixino & Pepinelli, 2015) and with the help of Odonata specialists.

Data analyses. We compared the abiotic variables amongst vegetation profile banks through Mann-Whitney pair-wise analyses. For each aquatic insect composition assemblage, we analyzed the total abundance, richness, and Simpson diversity which we compared through Mann-Whitney pair-wise analyses. To investigate the influence of abiotic variables in these ecological aspects of aquatic insect assemblages, we used the Pearson's correlation analyses, with the coefficient correlations (r) and p-values ($p<0.05$) used as a measure to infer significant interaction strength between abiotic and assemblage variables.

We performed a non-Metric Multidimensional Scale (nMDS) analysis to verify the influence of white ginger lily invasion on the spatial distribution of aquatic insect assemblages compared to native vegetation profiles. To do this we used the total abundance of taxa present on vegetation bank profiles. The clustering among samples was determined by dissimilarity distance measured with Bray-Curtis index. In addition, we compared significant differences of dissimilarity distances in vegetation profiles in the aquatic insect assemblages using an Analysis of similarities test (ANOSIM). We used the total abundances of specimens on vegetation profile to measure the dissimilarity distances using Bray-Curtis index. The significant differences among dissimilarity distances of assemblages were analyzed through statistic tests (R) and descriptive level sampling ($p<0.05$) (Clarke, 1993).

Furthermore, to analyze the influence of white ginger lily on aquatic insect species assemblages we applied an indicator value of species analysis using the Indval index. This index measures the association between a species and a group of sites, where a statistical significance of this relationship is tested using a permutation test (nperm= 999). The IndVal index is an indicator of value species, calculated through a product of two quantities, *A* and *B*, with r as the correlation index. The quantity *A*, defined as the mean abundance of the species in the target site group divided by the sum of the mean abundance over all groups, was used. It represents the probability that the surveyed site belongs to the target site group given the fact that the species has been found. This conditional probability is called the "specificity" or "positive predictive value" of the species as indicator of the site group. The quantity *B* is defined as the relative frequency of occurrence (presence-absence) of the species inside the target group. It represents the probability of finding the species in sites belonging to the site group. This second conditional probability is called the "fidelity" or "sensitivity" of the species as indicator of the target site group (De Cáceres & Legendre, 2009; De Cáceres, 2013).

To do this, we utilized a data matrix composed of vegetation bank type in rows and aquatic insect species in columns. The IndVal indices were calculated using "indicspecies package", which is available in the R platform (R Development Core Team, 2014).

RESULTS

We observed that water near the native macrophyte banks (*E. pallustris*) presented higher dissolved oxygen than other vegetation bank profiles (white ginger lily [U= 0, p= 0.005], invaded forest [U= 0, p= 0.005], riparian vegetation [U= 4.5, p= 0.04]). The littoral zone near the white ginger lily banks was deeper than other riparian vegetation banks (U= 0.5, p= 0.006) due to its vegetative growth into open areas of the reservoir, and had a lower pH compared to other vegetal bank profiles (invaded forest [U= 5, p= 0.04], native macrophyte [U= 5, p= 0.04], riparian vegetation [U= 3, p= 0.02]) (Tab. I).

We identified 67 aquatic insect taxa (Tab. II). We observed that white ginger lily banks showed higher abundances (n= 167.5 ± 55.00) of specimens than other vegetation bank profiles (partially invaded forest, n= 74 ±24.30 [U= 2, p= 0.01], native macrophyte, n= 65.5 ±26.40 [U= 1, p= 0.008], riparian vegetation, n=56.80 ±27.71 [U= 1, p= 0.008]) (Fig. 2). We did not observed significant differences among vegetation profile banks in richness and Simpson diversity ($p>0.05$). The Pearson's correlation analyses showed that richness on the partially invaded forest bank had a strong and positive relationship to dissolved oxygen (r= 0.93, p= 0.006).

Tab. I. Abiotic variables on invasive white ginger lily bank and native vegetation bank profiles in the littoral zone of a tropical reservoir in the Brazilian Savanna (IM, invasive macrophyte; IF, invaded forest; NM, native macrophyte; RV, riparian vegetation).

Abiotic variable	IM	IF	NM	RV
dissolved oxygen (mg/L)	7.40 ±0.43	7.37 ±0.47	8.70 ±0.22 *	8.00 ±0.43
pH	5.30 ±0.24	5.55 ±0.17	5.55 ±0.16	5.77 ±0.21
depth (cm)	0.39 ±0.03 *	0.37 ±0.09	0.30 ±0.11	0.28 ±0.07
water temperature (°C)	18.70 ±0.40	18.50 ±0.41	18.50 ±0.29	18.30 ±0.27

(*) $p<0.05$

Tab. II. Aquatic insect taxa collected in different vegetation profile banks in a tropical reservoir in the Brazilian Savanna (IM, invasive macrophyte; IF, invaded forest; NM, native macrophyte; RV, riparian vegetation).

	Vegetation profile banks			
Taxa	IM	IF	NM	RV
Campsurus Walker, 1853	X	X	X	X
Caenis Stephens, 1835	X	X	X	X
Ulmeritus Traver, 1956	X	X	X	
Callibaetis Eaton, 1875			X	
Aedomyia Theobald, 1901	X	X	X	X
Dasyhelea Kieffer, 1911	X	X	X	X
Gyrinus Latreille, 1810	X	X	X	X
Desmopachria Babington, 1841	X	X	X	
Andonectes Guéorguiev, 1971	X			
Laccophilus Leach, 1815	X	X	X	X
Pronoterus Sharp, 1882	X	X		
Mesonoterus Sharp, 1882	X		X	X
Hydrocanthus Say, 1823	X			X
Scirtidae			X	X
Macronema Pictet, 1836	X	X	X	X
Cyrnellus Banks, 1913	X	X	X	X
Oecetis McLachlan, 1877	X	X	X	X
Protoneura Selys, 1857	X		X	X
Oxyagron Selys, 1876		X		
Telebasis Selys, 1865	X	X	X	X
Acanthagrion Selys, 1876	X	X	X	X
Diastatops Rambur, 1842	X	X	X	X
Miathyria Kirby, 1889	X	X	X	X
Erythrodiplax Brauer, 1842	X	X	X	X
Macrothemis Hagen, 1868		X		
Orthemis Hagen, 1861		X		
Idiataphe Cowley, 1934		X	X	
Gynothemis Calvert, 1909		X		X
Lestes Leach, 1815	X	X		
Belostoma Laitrelle, 1807			X	X
Notonecta Hungeford, 1933	X		X	X
Limnocoris Stål, 1860	X		X	X
Tenagobia Bergroth, 1899	X			
Aedokritus coffeatus Trivinho-Strixino, 1997	X		X	X
Asheum beckae Sublette & Sublette 1964	X	X	X	X
Caladomyia kapilei Trivinho-Strixino, 2012	X	X	X	X
Caladomyia riotarumensis Reiff, 2000	X	X	X	
Chironomus Meigen, 1803	X	X	X	X
Cladopelma forcipes (Rempel, 1939)	X		X	
Endotribelos bicolor Trivinho-Strixino & Pepinelli, 2015	X	X	X	X
Goeldichironomus maculatus Trivinho-Strixino & Strixino, 1991	X	X		
Polypedilum sp. 5 **cf.** Trivinho-Strixino, 2011	X	X	X	
Polypedilum (Tripodura) sp. 3 **cf.** Trivinho-Strixino, 2011		X	X	X
Polypedilum sp. 3 **cf.** Trivinho-Strixino, 2011	X	X		X
Polypedilum sp. 4 **cf**. Trivinho-Strixino, 2011				X
Stenochironomus Kieffer, 1919	X	X	X	
Ablabesmyia depaulai Neubern, 2013	X	X	X	X
Ablabesmyia laurindoi Neubern, 2013	X	X	X	X
Ablabesmyia metica Roback, 1983	X			
Ablabesmyia strixinoae Neubern, 2013	X	X	X	X
Clynotanypus Kieffer, 1913				X
Coelotanypus Kieffer, 1913	X		X	X
Labruninia carolae Silva, 2014	X	X		X
Labrundinia paulae Silva, 2014			X	X
Labrundinia sp. Fittkau, 1962	X	X	X	
Labrundinia tenata Silva, 2013	X	X		X

Tab. II. Cont.

Taxa	Vegetation profile banks			
	IM	IF	NM	RV
Labrundinia unicolor Silva, 2013	X	X	X	X
Larsia Fittkau, 1962			X	
Monopelopia Fittkau, 1962	X	X	X	X
Pentaneura Philippi, 1865			X	X
Procladius Skuse, 1889			X	X
Fissimentum desiccatum Cranston & Nolte, 1996		X		X
Fissimentum sp. 3 **cf.** Trivinho-Strixino, 2011				X
Fissimentum sp. 2 **cf.** Trivinho-Strixino, 2011			X	X
Tanytarsus sp. v. d. Wulp, 1874		X	X	X
Tanytarsus obiriciae Trivinho-Strixino & Sonoda, 2006			X	

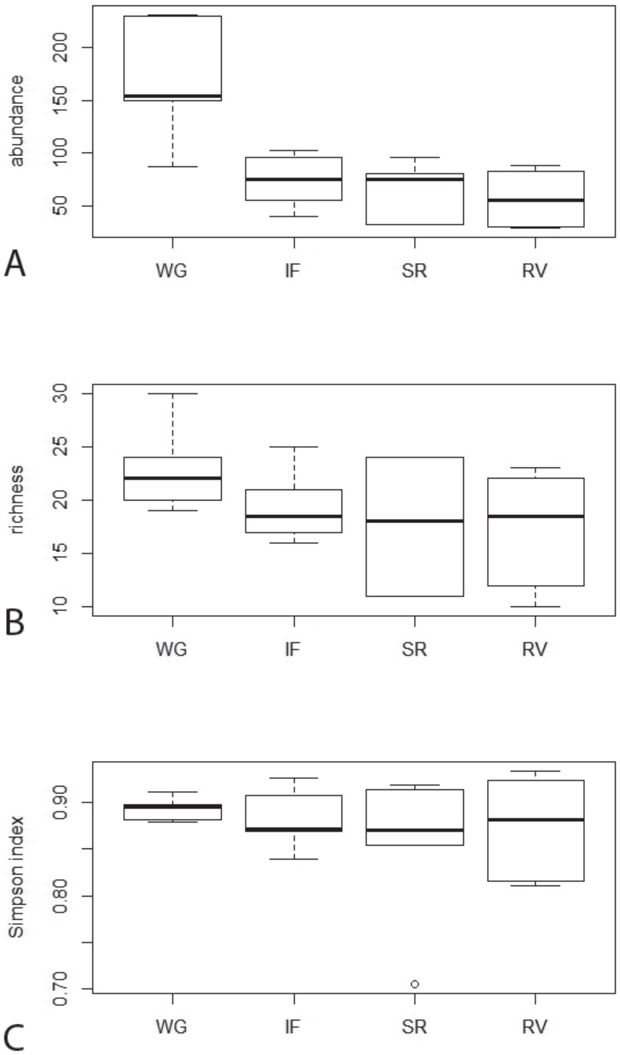

Fig. 2. Comparison between ecological variables of aquatic insect assemblages associated with invasive white ginger lily bank and other native vegetation banks in the littoral zone of a tropical reservoir in the Brazilian Savanna (A, abundance; B, richness; C, Simpson diversity; IM, invasive macrophyte; IF, invaded forest; NM, native macrophyte; RV, riparian vegetation).

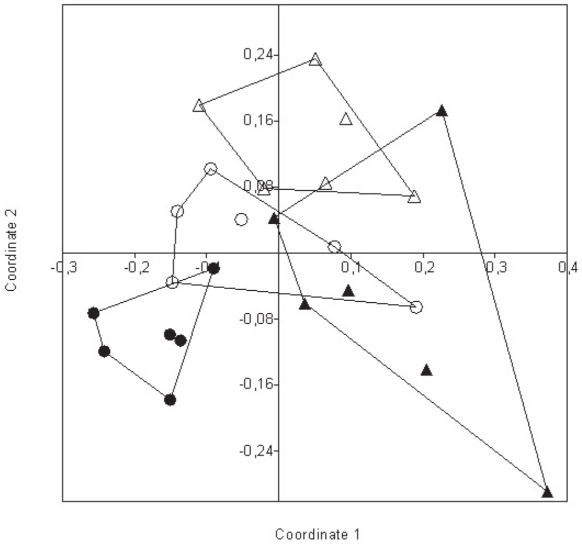

Fig. 3. Analyses of non-metric MDS of aquatic insect assemblages associated with white ginger lily banks and native vegetation profiles in the littoral zone of a tropical reservoir in the Brazilian Savanna (●, white ginger lily; ○, invaded forest; Δ, native macrohyte; ▲, riparian vegetation).

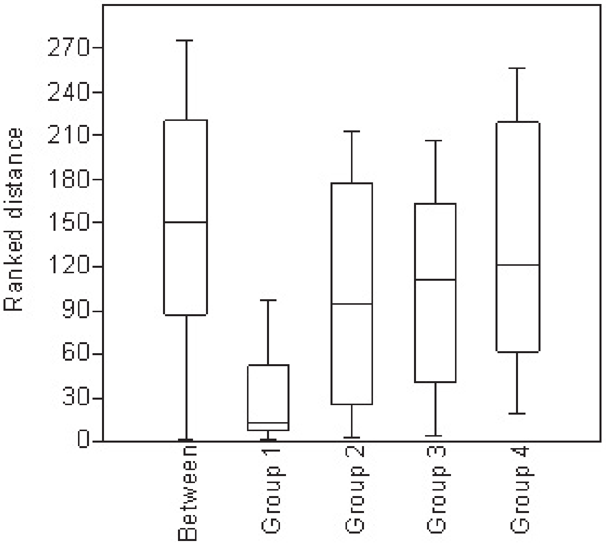

Fig. 4. Comparison among Bray-Curtis dissimilarity indices of aquatic insect assemblages associated with white ginger lily banks and native vegetation profile in the littoral zone of a tropical reservoir in the Brazilian Savanna (Group 1, white ginger lily; Group 2, invaded forest; Group 3, native macrophyte; Group 4, riparian vegetation).

Additionally, we observed this same result with abundance (r= 0.82, p=0.04), richness (r= 0.85, p= 0.03) and Simpson diversity (r= 0.94, p<0.001) on the native macrophyte bank.

The nMDS analysis showed that the aquatic insect assemblage associated with ginger lily banks differed from other vegetation profile banks. The axis1 explained to 59% (Stress = 0.22) of the clustering analyses (Fig. 3). The ANOSIM analysis showed that aquatic insect assemblages associated with invasive macrophytes exhibited a lower dissimilarity index compared with other profiles (p<0.05) (Fig. 4). The dissimilarity distances of white ginger lily bank assemblages were lower especially when compared to banks without invasion (partially invaded forest [R= 0.43, p= 0.004], native macrophyte [R= 0.83, p= 0.002], riparian vegetation [R= 0.70, p= 0.002]). These results supported the nMDS analyses.

The results of analysis of indicator species (Indval index) classified eight aquatic insect species as indicator species of vegetation profiles (Tab. III). We observed that three species presented strong association (*A*> 0.70) with white ginger lily banks (IM) (Tab. IV). *Tenagobia* sp. (Corixidae, Hemiptera) was most closely associated with white ginger lily (*A*= 1.00), but *Labrundinia unicolor* (Tanypodinae - Diptera) was the species that showed exclusive association (*B*= 1.00) with restricted distribution on this bank. Additionally, *Labrundinia paulae* (Tanypodinae - Diptera) was strongly associated with partially invaded forest banks (IF, *A*= 0.85). Similar results we observed with *Diastatops* sp. (Libellulidae – Odonata) (*A*= 0.92) and *Ablabesmyia depaulai* (Tanypodinae – Diptera) (*A*= 0.85) when we combined the invasive macrophyte areas with partially invaded forest banks (IM+IF). Regarding all vegetation profile banks on the reservoir, we observed that *Caladomyia kapilei* (Chironominae – Diptera) (*A*= 0.94, *B*= 0.94) and *Ablabesmyia strixinoae* (Tanypodinae – Diptera) (*A*= 0.91, *B*=1.00) were generally distributed in both invaded and non-invaded vegetal profile banks.

Tab. III. Analyses of IndVal index species of aquatic insect's assemblage associated with white ginger lily banks and native vegetation profile in the littoral zone of a tropical reservoir in the Brazilian Savanna (IM, invasive macrophyte; IF, invaded forest; NM, native macrophyte; RV, riparian vegetation).

Species	IM	IF	NM	RV	Index	Ttat.	P-value
Caladomyia kapilei	1	1	1	0	11	0.94	0.018
Ablabesmyia depaulai	1	1	0	0	5	0.85	0.012
Diastatops	1	1	0	0	5	0.84	0.013
Fissimentum sp. 2	0	0	0	1	4	0.87	0.005
Labrundinia paulae	0	0	1	0	3	0.77	0.009
Labrundinia unicolor	1	0	0	0	1	0.85	0.049
Labrundinia sp.	1	0	0	0	1	0.73	0.009
Tenagobia	1	0	0	0	1	0.71	0.039

Tab. IV. Analyses of relationships among aquatic insect's species indicators of ginger lily banks and native vegetation profile in the littoral zone of a tropical reservoir in the Brazilian Savanna (IM, invasive macrophyte; IF, invaded forest; NM, native macrophyte; RV, riparian vegetation).

Vegetation profile	A	B	Stat.	*P*-value
IM				
Labrundinia unicolor	0.72	1.00	0.85	0.049
Labrundinia sp.	0.80	0.67	0.73	0.009
Tenagobia	1.00	0.50	0.71	0.039
IF				
Labrundinia paulae	0.85	0.67	0.77	0.009
RV				
Fissimentum sp. 2	0.91	0.83	0.87	0.005
IM + IF				
Ablabesmyia depaulai	0.87	0.83	0.85	0.012
Diastatops	0.92	0.75	0.84	0.013
IM + IF + NM				
Caladomyia kapilei	0.94	0.94	0.94	0.018
IM + IF + RV				
Ablabesmyia strixinoae	0.91	1.00	0.95	0.019

DISCUSSION

Like many other invasive plant species (*e.g. Hydrilla verticillata* (L. f.) Royle, Hydrocharitaceae) (THEEL *et al.*, 2008) the invasion of white ginger lily shifted aquatic insect assemblage composition probably due to habitat alterations. Our results showed that white ginger lily shifted aquatic insect assemblages when compared with other native vegetation bank profiles. Furthermore, we observed that this invasive macrophyte caused changes in littoral habitat especially in littoral depth and water pH variable. These habitat changes could be caused by high plant biomass, where the faster vegetative growth of white ginger lily altered habitat by the occupation of shallow areas, as well as pH by the decomposition of its biomass.

In the littoral zones of lentic systems, the gradient depth which increases from the margins toward open water areas plays an important role in the distribution of taxa. Along this gradient, as the depth increases, reduction in heterogeneity of habitat is observed; hence, a reduction in species diversity is expected due to habitat simplification (Tolonen *et al.*, 2003; Taniguchi *et al.*, 2004). The high biomass of this invasive macrophyte can modify the chemical characteristics of water, with leaching of soluble chemical compounds during decomposition of deteriorating plant tissues altering pH characteristics (Strayer *et al.*, 2010).

Because of this, we expected to observe lower diversity of aquatic insect assemblages on white ginger lily banks. However, in our study, the richness and Simpson diversity associated with invasive macrophytes were similar to native vegetation profile banks. This similar pattern is due to the low spatial scale of the studied reservoir. The short distances among the vegetation profiles were not long enough to disrupt aquatic insect assemblages. It is well known that increasing distances between local springs and colonization places plays an important role in the structure of assemblages (Mormul *et al.*, 2011). Nevertheless, we concluded that species pools on white ginger lily banks resulted in low dissimilarity and similar diversity patterns due to higher abundance of specimens.

Aquatic insects have been considered good indicators of impacted habitats by invasive plants. Indicator species have been used especially in studies that analyzed the influence of monoculture plants such as banana and sugar cane crops (Corbi *et al.*, 2013; Corbi & Trivinho-Strixino, 2017). Although in our study the ecological variables of richness and Simpson diversity did not demonstrate differences between white ginger lily banks and native vegetation profile banks, the IndVal index provided good information about the composition of aquatic insect assemblages associated with this invasive macrophyte. As demonstrated through this index, the distribution of *Labrundinia unicolor* was restricted to white ginger lily banks (IM), and *Labrundinia paulae* was strongly associated with partially invaded forest (IF). This genus has been described as an aquatic insect commonly associated with dominant macrophyte species, especially *Salvinia* (Da Silva *et al.*, 2011). It is believed that this macrophyte with thin and ramified roots, provides shelter against predators, and the algae attached to it serves as a main food resource for macrofauna (Trivinho-Strixino *et al.*, 2000). These habitat characteristics provided by *Salvinia* provide a differential aquatic insect assemblage in lentic systems, which used host small taxa as *Labrundinia* (Peiró *et al.*, 2016).

Although the biology and ecology of *L. unicolor* and *L. paulae* is unknown, the association with monotypic banks of white ginger lily and invaded banks could be related to alteration of habitat quality caused by the vegetal invasion. With respect to habitat quality, the fast growth of white ginger lily results in banks formed by an entanglement of rhizomes, branches and leaves leading to the overlap of many branches that probably resulted in increased spatial complexity, promoting microhabitat availability. This same reason lead us to infer the strong association of *Ablabesmyia depaulai* and *Diastatops*, which were classified in our study as an indicator species, to an invasion of white ginger lily (IM+IF). Aquatic insect predators (*e.g. Labrundinia*, *Ablabesmyia* and *Diastatops*) are described as being associated with several invasive macrophyte species (*e.g. Ceratophylum demersum*) (Tóth *et al.*, 2012), whose presence in freshwater systems increase the habitat complexity and shift aquatic insect assemblages (Kuehne *et al.*, 2016). We concluded that the different composition of indicator species among invaded and partially invaded banks could be used as aquatic insect indicator species to monitor the initial stage of invasion by white ginger lily in the littoral zone of the Fazzari reservoir.

In the present study we demonstrated that invasive white ginger lily can shift aquatic insect assemblages, which identify species that can be considered indicators of changes in littoral zone habitat. Furthermore, through analyses of habitat variables, especially higher depth and lower pH in the white ginger lily bank area, we conclude that this macrophyte's invasion caused loss of shallow areas and changes in water variables. Recently, the interest in the invasion of white ginger lilies in freshwater systems in Brazil has increased and the analysis of indicator species proved to be a good tool for monitoring changes in freshwater systems caused by invasive macrophyte species. We emphasize the necessity of expanding the analysis of white ginger lily impact to other freshwater systems (*e.g.* streams), which composition of aquatic insect indicator species will contribute to the collective information about its influence on freshwater biodiversity.

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