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Predation by *Erythemis* nymphs (Odonata) on Chironomidae (Diptera) and Elmidae (Coleoptera) in different conditions of habitat complexity

Predação de ninfas de *Erythemis* (Odonata) sobre Crironomidae (Diptera) e Elmidae (Coleoptera) em diferentes condições de complexidade do habitat

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Abstract: Aim: The goal of this study was to analyze the effects of predation by nymphs of *Erythemis* Hagen, 1861 on Elmidae and Chironomidae and to check if the presence and the architecture of aquatic macrophytes may mediate this interaction. **Methods:** All prey as well as nymphs were captured near macrophytes in a small lagoon alongside a highway near Humaitá, Amazonas, Brazil. Twelve buckets were used in three different treatments: with *Pistia stratiotes* Linnaeus, 1753, with *Salvinia auriculata* Aublet and without macrophytes. **Results:** We found a mortality rate of 100% of Chironomidae and Elmidae larvae in the treatment without macrophytes. There was a greater survival of Elmidae compared to Chironomidae in the treatments with *P. stratiotes* and *S. auriculata;* however, there was a greater survival of both preys on treatment with *P. stratiotes*. **Conclusions:** We conclude that the presence of macrophytes decreased the efficiency of predation of *Erythemis* nymphs under experimental conditions. The architecture of macrophytes affected predation as macrophytes with longer roots and with greater habitat complexity promoted a greater survival of prey.

Keywords: dragonflies; lake; macrophyte.

Resumo: Objetivo: Os objetivos deste trabalho foram analisar os efeitos da predação de ninfas de *Erythemis* Hagen, 1861 sobre Elmidae e Chironomidae, e verificar se a presença e a arquitetura de macrófitas podem mediar essa interação. Métodos: Todas as presas bem como as ninfas foram capturadas em uma pequena lagoa lateral a rodovia BR319 que passa pelo município de Humaitá, Amazonas. Doze baldes foram utilizados nos três diferentes tratamentos: *Pistia stratiotes* Linnaeus, 1753, *Salvinia auriculata* Aublet e sem macrófitas. Dez larvas de Coleoptera, dez larvas de Chironomidae e duas ninfas de *Erythemis* foram utilizadas em cada tratamento. **Resultados:** Houve mortalidade de 100% das larvas de Chironomidae e Elmidae no tratamento sem macrófitas. Houve maior sobrevivência de Elmidae em comparação a Chironomidae nos tratamentos com *P. stratiotes* e *S. auriculata*, porém houve sobrevivência maior de ambas as presas no tratamento com *P. stratiotes*. **Conclusões:** A presença de macrófitas diminuiu a eficiência de predação das ninfas de *Erythemis* em condições experimentais. A arquitetura da macrófita afetou a predação, sendo que raízes mais longas e com maior complexidade do habitat propiciaram uma maior sobrevivência das presas.

Palavras-chave: libélulas; lago; macrófita.

1. Introduction

The choice of habitat by the prey is directly related to the risk of predation (Hossie & Murray, 2010; Figueiredo et al. 2015). More complex habitats as macrophytes have a lower predation risk, and therefore, near these plants there is high densities of small fish and other macroinvertebrates (Webster & Hart, 2004; Pelicice et al., 2005; Pelicice & Agostinho, 2006; Cunha et al. 2012; Figueiredo et al., 2013). This positive relationship between associated fauna and high density due to the higher habitat complexity was observed by several authors (Jeffries 1993; Pelicice & Agostinho 2006).

In Brazil there is high species diversity of macrophytes, including submerged rooted, rooted floating and floating forms (Esteves, 2011). Among the floating plants, two stand out because of their high incidence: *Pistia stratiotes* Linnaeus, 1753 and *Salvinia auriculata* Aublet. Although both are floating plants, they differ in the length and diameter of roots, being larger and wider in *P. stratiotes* compared to *S. auriculata* (Joly, 1987). A typical *P. stratiotes* has a root length around 15-20 cm, while *S. auriculata* around 2-10 cm (Joly, 1987). Nymphs of Odonata are recorded frequently in *P. startiotes* and *S. auriculata* (Escher & Lounibos, 1993; Fulan et al., 2011)

The nymphs of Odonata are known to be one of the major predators in aquatic ecosystems, feeding on any prey compatible with their size (Corbet, 1999). According to Soares et al. (2003), Odonata nymphs can feed even on post-larval fish like American catfish *Ictalurus punctatus* (Rafinesque, 1818), Tilápia *Oreochromis niloticus* (Linnaeus, 1758) and Curimba *Prochilodus lineatus* (Valenciennes, 1847). However, the preys recorded more often in the stomach contents of the nymphs are macroinvertebrates, mainly Chironomid larvae (Hamada & Oliveira, 2003) and Coleoptera larvae (Thompson, 1978); in this case when the Odonata are already in their final instar.

Chironomid larvae are the most abundant macroinvertebrate in the sediment and on macrophytes (Nessimian & Carvalho, 1998). They are herbivores and/or detritivorous and generally benthic and sedentary, but may also exhibit a swimmer behavior (Takagi et al., 2005). This swimmer behavior was observed in *Chironomus* both in the first instar (Oliver, 1971) and the last instar (Moon, 1940; Berg, 1950). Elmidae larvae (Coleoptera), in contrast to Chironomidae, do not show a swimmer behavior at any stage of their cycle life (White, 1983). Their larvae live crawling on consolidated sediments as well as on small rocks or even macrophytes from lotic environments (most species), but may even occur in small ponds with stagnant water (Mccafferty, 1983; Stehr, 1991).

This difference in architecture is important for their colonization by macroinvertebrates. A comparative study of *P. stratiotes* and *Salvinia* showed that the abundance of associated macroinvertebrates was higher in *P. stratiotes* compared to *Salvinia* and that this difference was caused by greater habitat complexity observed in *P. stratiotes* (Torretta et al., 2006).

In this context, the aim of this study was to investigate the effects of habitat complexity provided by the roots of *P. stratiotes* and *S. auriculata* on predation of Chironomidae (Diptera) and Elmidae (Coleoptera) by *Erythemis* nymphs (Odonata).

2. Material and Methods

All Diptera and Coleoptera, the nymphs of *Erythemis* and macrophytes (*P. stratiotes* and *S. auriculata*) were sampled on a side lagoon BR319 (7°37’54” S and 63°04’47” W) near the city of Humaita, Amazonas State, Brazil. The experiment was conducted in the Limnology Laboratory of the Federal University of Amazonas. Twelve buckets with 20 liters of water each were used in the experiment. Treatments were performed with the macrophyte *P. stratiotes*, *S. auriculata* and without macrophytes. Four replications were carried out for each treatment. The macrophytes were washed before the experiment to completely remove all associated macroinvertebrates. A 50% surface area cover of water was ensured in the buckets where the floating macrophytes were placed. The standardized length of the roots of *P. stratiotes* and *S. auriculata* were 15 and 5 cm, respectively.

Ten Chironomid larvae and ten of Coleoptera were placed in each bucket 24 hours before the start of the experiment for enable adaptation. The *Erythemis* nymphs were maintained for 24 hours without food and after this period two individuals were placed in each bucket.

The laboratory temperature was maintained between 26 and 32 °C. The experiment was started at 10:00 am on 15 January 2013 and ended at 10:00 am on 17 January 2013. The macroinvertebrates were obtained from the Limnology Laboratory of the Institute of Education, Agriculture and Environment. A Chi-square test was performed to investigate if the frequency of predation differed among treatments.

3. Results and Discussion

All Chironomidae and Elmidae were preyed in the treatment without macrophytes in all four replicates (Figure 1). A Chi-square test revealed significant difference in the frequency of predation of *Erythemis* on Elmidae (X^2=541.81; *p*= 0.05; *df*=2; Table 1) and Chironomid (X^2=61.80; *p*= 0.05; *df*=2; Table 2) between the treatments. Tables 1 and 2 show that macrophytes are important refuges for macroinvertebrates against their predators as observed by other researchers (Padial et al., 2009; Cunha et al., 2012; Kovalenko et al., 2012). In addition, in the laboratory experiment it was registered a significant difference in survival of Elmidae and Chironomidae according to the species of macrophyte. There was a higher survival of Elmidae and Chironomidae in the treatment with *P. stratiots* compared to *S. auriculata*. This higher survival on the treatment with *P. stratiotes* likely occurred due to difference in the plant architecture that modifies its complexity habitat. Kovalenko et al. (2012) argued that habitat complexity is one of the most important factors in structuring biotic assemblages and affects predator-prey interactions, despite the lack of knowledge about mechanism. According to the authors, it is also very difficult to compare different macrophytes species as *P. stratiots* and *S. auriculata*.

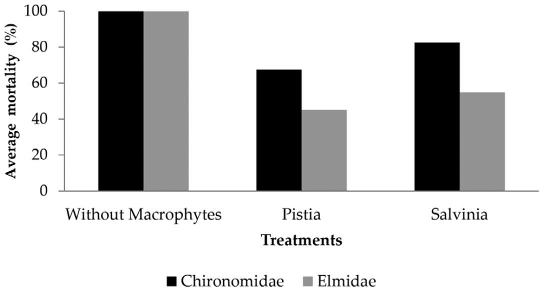

Figure 1. Average predation rate of Chironomidae and Elmidae in the presence of *Erythemis* nymphs in treatments with *P. stratiotes*, *S. auriculata* and without aquatic macrophytes.

Table 1. Predation on Elmidae in the differents treatments.

Treatment	Preyed	Non-preyed	TOTAL
Control	40	0	40
P. stratiotes	22	18	40
S. auriculata	18	22	40
TOTAL	80	40	120

Table 2. Predation on Chironomid in the differents treatments.

Treatment	Preyed	Non-preyed	TOTAL
Control	40	0	40
P. stratiotes	13	27	40
S. auriculata	7	33	40
TOTAL	60	60	120

P. stratiotes exhibits a distinct architecture when compared with *S. auriculata*, especially regarding its roots (Joly, 1987). Whereas *S. auriculata* shows a horizontal rhizome formed by a colony of branches, a pair of floating sheets and modified leaves that have similar function to a small root (Croxdale, 1978, 1979, 1981; Room, 1983), *P. stratiotes* shows floating leaves in the form of rosette, which can be alone and extensive adventitious root system (Langeland & Burks, 1998). This difference in architecture, especially with regard to the length and diameter of the *S. auriculata* and *P. stratiotes* root, can affect the availability of refuges. Torretta et al. (2006) observed a greater abundance of macroinvertebrates along the roots of *P. stratiotes* compared to *S. auriculata,* mainly due to the greater habitat complexity provided by *P. stratiotes*. Padial et al. (2009) also reported that the increase in complexity of the habitat due to plant architecture decreased benthic predation by other predators such as fish, similar to that observed in this work.

Our analysis clearly suggests that the shelters provided by the roots of macrophytes increased the survival of prey, because while in the treatments with macrophytes some larvae of Chironomidae and Elmidae survived, in the treatment without macrophytes all prey were consumed, without exception and in all replicates. These results are in line with the findings of Parsons & Matthews (1995) that macrophyte roots form important refuges for macroinvertebrates. The survival of Chironomidae and Elmidae in the treatments with macrophytes likely occurred because their roots provided refuges for the prey, which decreased the efficiency of detection of the prey by the Odonata nymphs. According to Corbet (1999), normally larvae of Odonata detect preys by their movement and caught then alive. However, there was a higher predation rate on the treatments with *S. auriculata* when compared to *P. stratiotes*.

We conclude that the presence of floating aquatic macrophytes decreased the predation efficiency of *Erythemis* nymphs in artificial conditions. The macrophyte architecture affected the predation, and longer roots and more habitat complexity provided a greater survival of prey.

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