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Colonization by Chironomidae larvae in decomposition of *Eichhornia azurea* (Swartz) Kunth in an Amazonian lake in Brazil

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ABSTRACT. Few studies have investigated the colonization of macroinvertebrates during macrophyte decomposition. The goal of this work was to study the colonization process of Chironomidae larvae during the decomposition of *Eichhornia azurea* in a lake in the southern state of Amazonas, Brazil from August to October 2012. Multiple regression analysis identified a significant loss of macrophyte biomass during the 72 days of the experiment. Six genera were identified: *Ablabesmyia, Chironomus, Goeldichironomus, Labrundinia, Polypedilum,* and *Tanytarsus*. The Canonical Correspondence Analysis conducted between the densities of Chironomidae larvae and biotic and environmental factors showed that *Chironomus* and *Goeldichironomus* larvae tolerated the temperature, dissolved oxygen concentration, and macrophyte biomass of the lake. *Chironomus* and *Goeldichironomus* were the densest genera, especially in the last days of the experiment. We conclude that the tolerance of some Chironomidae genera, such as *Chironomus*, may have contributed to their success in colonization because macrophyte decomposition significantly changes the chemical composition of water. In addition, we identified a significant increase in the *E. azurea* decomposition rate in Lake Paraíso compared to other lakes at greater latitudes, suggesting a direct effect between the temperature and the macrophyte decomposition rate.

Keywords: aquatic insects, diptera, macrophyte, tropical region.

Colonização por larvas de Chironomidae em decomposição de *Eichhornia azurea* (Swartz) Kunth na lagoa Paraíso, sul do Amazonas

RESUMO. Poucos trabalhos investigaram a colonização de macroinvertebrados durante a decomposição de macrófitas. O objetivo desse trabalho foi estudar no período de agosto a outubro de 2012 o processo de colonização de larvas de Chironomidae durante a decomposição de *Eichhornia azurea* em uma lagoa no sul do Estado do Amazonas. A análise de regressão múltipla identificou uma perda significativa na biomassa da macrófita durante os 72 dias do experimento. Seis gêneros foram identificados: *Ablabesmyia*, *Chironomus*, *Goeldichironomus*, *Labrundinia*, *Polypedilum* e *Tanytarsus*. A Análise de Correspondência Canônica, realizada entre as densidades das larvas de Chironomidae e fatores bióticos e ambientais, mostrou uma tolerância das larvas de *Chironomus* e *Goeldichironomus* à temperatura, ao oxigênio dissolvido e à biomassa da macrófita. *Chironomus* e *Goeldichironomus* também foram os gêneros com as maiores densidades, principalmente nos últimos dias do experimento. Concluímos que a tolerância de alguns gêneros de Chironomidade como *Chironomus* pode ter contribuído para o seu sucesso na colonização, pois a decomposição da macrófita altera significativamente a composição química da água. Além disso, identificamos aumento significativo na velocidade de decomposição de *E. azurea* na lagoa Paraíso em comparação a outra lagoa com latitude maior, sugerindo efeito direto entre a temperatura e a velocidade de decomposição da macrófita.

Palavras-chave: insetos aquáticos, diptera, macrófita, região tropical.

Introduction

Eichhornia azurea (the anchored water hyacinth) is a native of the Pontederiaceae plant family of Central and South America and is characterized by its large leaves and stolons, which can reach up to 10 meters long (BARRETO et al., 2000). Its reproduction is extremely fast and efficient; up to 5000 seeds are formed per individual (ZETTLER; FREEMAN, 1972) and one plant may produce up to 1200 individual offspring by vegetative propagation. Due to this high capacity to spread and be present at high densities, *E. azurea* can strongly deplete the oxygen concentration of water during decomposition (CUNHA-SANTINO et al., 2010);

however, the decomposition of *E. azurea* is followed by macroinvertebrate colonization that takes advantage of the reduction of unpalatable compounds, such as polyphenols, to seek new habitats (STRIPARI; HENRY, 2002, MORMUL et al., 2006). Among these macroinvertebrates, Chironomidae larvae showed a significant increase in density during the decomposition process of *E. azurea* in a lake located at latitude 21°46′68″S, Brazil (SILVEIRA et al., 2013). In addition, the authors found a higher density of Chironomidae larvae in the final stage of the decomposition process. The presence of Chironomidae is often recorded in work on macrophyte decomposition (GONÇALVES et al., 2004; SILVEIRA et al., 2013), and the presence of Chironomidae larvae during macrophyte decomposition suggests that they actively participate in decomposition and may also increase the rate of decomposition of these plants (CALLISTO et al., 2007). In addition to the participation of invertebrates, macrophyte decomposition may also be affected by environmental factors, such as temperature.

The macrophytes decomposition is directly affected by the temperature, i.e., a higher temperature increases the speed of its decomposition process (WEBSTER; BENFIELD, 1986). The northern region of Brazil is located near the equator and stands out among the regions of Brazil since it has the highest annual temperatures (VILANI et al., 2006). Are the rates of decomposition in lakes at higher latitudes different from those in lakes at lower latitudes (with lower and higher temperatures, respectively)?

In this context, we analyzed the Chironomidae colonization process in Lake Paraíso (latitude 7º30'35" S, northern region of Brazil) to identify any direct relationships between density and E. azurea decomposition and compare these results with those of similar studies conducted at other latitudes (SILVEIRA et al., 2013, STRIPARI; HENRY, 2002).

Material and methods

The Paraíso Lake (7º30'35"S and 62º53'12"W) is located in the municipality of Humaitá, Amazonas State, Brazil (Figure 1). This lake is one of the most common lakes types in Brazil: oxbow lakes (SPERLING, 1999). This work was carried out from August to October 2012. The methodology used was described by Stripari and Henry (2002). We used 42 litter bags with 2 mm mesh size and dimensions of 15 x 20cm (length x width). In each litter bag were added 15 grams of dry weight of *E. azurea* (leaf + petiole) previously sampled in the study area and dried at 60°C in an oven to constant weight. The litter bags were carefully tied one by one in the largest *E. azurea* stands in the study area. Six litter bags each time (three for the decomposition and three for colonization) were removed at random, respectively in the 1^{st}, 3^{rd}, 7^{th}, 14^{th}, 28^{th}, 56^{th} and 72^{nd} day of the experiment. The organic material was fixed in 70% ethanol and subsequently identified with specific references (TRIVINHO-STRIXINO; STRIXINO, 1995, TRIVINHO-STRIXINO, 2011). After identification, the density of Chironomidae larvae was calculated as the number of individuals per gram of dry weight of macrophyte. Biological specimens were deposited in the Limnology Laboratory of the Federal University of Amazonas in Humaitá, AM, Brazil. The temperature and dissolved oxygen were measured with a multiparameter probe (HI9146-10, Hanna, Woonsocket, USA) in the *E. azurea* stands when the litter bags were removed.

Figure 1. Paraíso Lake (7º30'35"S and 62º53'12"W), Humaitá, Amazonas State, Brazil.

A Canonical Correspondence Analysis (CCA) between the densities of Chironomidae larvae and biological and environmental variables (macrophyte dry weight, water temperature and dissolved oxygen) was performed using the CANOCO program for Windows, v. 4.5 (TER BRAAK; SMILAUER, 2002) for the purpose of investigating the effects of these variables on the density of Chironomidae larvae.

The decomposition (k) was determined by the equation $B_1 = B_0.e^{-kt}$, where B_0 and B_1 are the dry weight at time $t_0 = 0$ and $t_1 = 1, 3, 7, 14, 28, 56, 72$ days and t = interval time (in days between B_0 and B_1). The period for decomposition of 50 and

95% of initial dry weight (15 g) was calculated. A multiple regression analysis was performed with Statistica v. 6.0 software between the number of days of the experiment and the loss of dry weight of *E. azurea* to verify if the loss of dry weight was significant.

Results and discussion

Results

Chironomidae represented 64 % of total 6562 sampled macroinvertebrates. The most significant groups were Ephemeroptera (3%), Odonata (5%) and Oligochaeta (24%). Six genera of Chironomidae were identified throughout the experiment (Table 1). A high reduction in the average dry weight of *E. azurea* occurred on the first day of the experiment (28.67% of the initial dry weight). The highest average temperature of the surface water (33°C) was recorded on the 7th day. There was a progressive increase in Chironomidae density from day 1 to 72 days, except on the 28th day, where there was a slight reduction in its density (Figure 2). The variation in the concentration of dissolved oxygen in the Paraíso Lake was low.

Table 1. Taxonomic composition and average density (± standard deviation) of Chironomid larvae by dry weight macrophyte (Ind g DW^{-1})] of the three repetitions of Chironomid larvae recorded during the colonization experiment with *Eichhornia azurea* in the Paraíso Lake (Amazonas, Brazil).

Taxa	1st	3rd	7th	14th	28th	56th	72nd
Ablabesmyia Johannsen,1905	0±0	1±1	3±3	2±1	18±28	15±24	15±13
Chironomus Meigen, 1803	3±0	2±1	2±2	3±1	2±2	10±13	16±10
Goeldichironomus Fittkau,1965	5±5	11±16	15±18	26±26	16±20	37±63	62±54
Labrundinia Fittkau, 1962	2±3	5±4	10±12	15±10	3±3	7±10	9±12
Polypedilum Kieffer, 1912	4±1	1±1	1±1	6±4	3±5	9±10	7±6
Tanytarsus Van der Wup, 1874	2±2	0±1	4±4	4±3	7±4	3±6	10±8

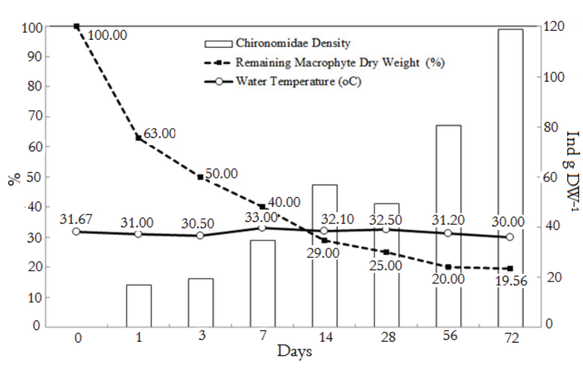

Figure 2. Average density Chironomidae larvae (Ind g DW^{-1}), remaining dry weight of *Eichhornia azurea* (%) and water temperature (ºC) measured in Paraíso Lake, Amazonas State, Brazil.

Only *E. azurea* dry weight (r = 0.85) showed a significant correlation with Chironomidae density (p < 0.05) showed Canonical Correspondence Analysis (CCA). *Ablabesmyia* density (r = -0.86) showed a negative correlation with *E. azurea* dry weight. However, *Labrundinia* (r = 0.60) and *Polypedilum* (r = 0.93) densities showed a positive correlation with *E. azurea* dry weight. The *Chironomus* and *Goeldichironomus* densities exhibited a high tolerance to biological and environmental variables measured throughout the experiment according CCA (Figure 3).

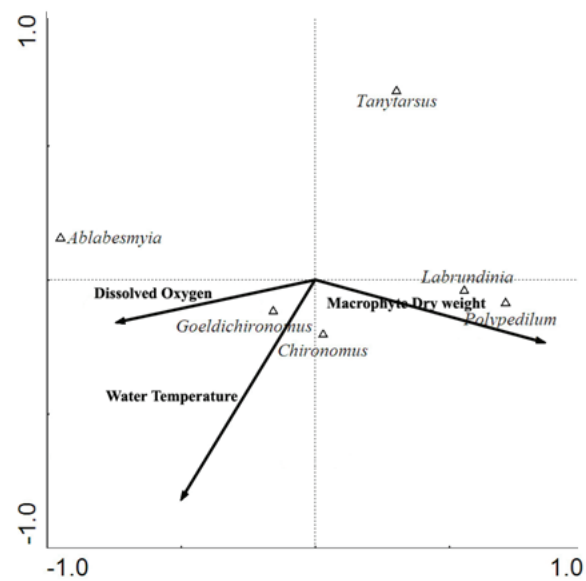

Figure 3. Canonical Correspondence Analysis (CCA) between the densities of Chironomidae larvae and biological and environmental variables (macrophyte dry weight, water temperature and dissolved oxygen) in Paraíso Lake, Amazonas State, Brazil.

Multiple regression analysis between the days the experiment and the loss of *E. azurea* dry weight was significant (F = 93.38, p < 0.001). The decomposition (k) identified in the experiment was 0.0289 day^{-1}. The time required for degradation of 50 % of the initial dry weight was calculated at 24 days. For the decomposition of 95 % of the dry weight, the estimated time was 104 days.

Discussion

Olson (1963) noted that macrophyte decomposition occurs in two phases: an initial phase characterized by a rapid loss of biomass and a reduction of soluble organic compounds, such as polyphenols, and a final stage where pioneer organisms, such as bacteria and fungi, increase the availability of nutrients, favoring the colonization of invertebrates. The two phases were clearly identified in Lake Paraíso. Multiple regression analysis revealed that the macrophyte biomass significantly decreased (29%) within 24 hours; this high loss rate had been previously observed (PAGIORO; THOMAZ 1998, STRIPARI; HENRY, 2002, SILVEIRA et al., 2013). After 24 hours, macrophyte biomass gradually decreased and the invertebrate colonization process of *Chironomus* and *Goeldichironomus* started.

Chironomus and *Goeldichironomus* were the densest genera on the last day of the experiment and were, according to the CCA, tolerant of the temperature and the depleted dissolved oxygen concentration. *Chironomus* was denser in the final phase of macrophyte decomposition in a lentic ecosystem in southeastern Brazil (SILVEIRA et al., 2013). *Chironomus* was also recorded in other colonization works in a lotic ecosystem and sediment (CAÑEDO-ARGUELLES; RIERADEVALL, 2011). The presence of *Chironomus* in different substrates (macrophytes and sediment) in different ecosystems (lentic and lotic) suggests that they are important in the new habitat colonization process. In the case of macrophyte decomposition, the success of *Chironomus* colonization could be related to its tolerance to changes in the physical and chemical characteristics of water, such as temperature and oxygen, which are common in decomposition processes (BERVOETS et al., 1996, CUNHA-SANTINO; BIANCHINI, 2006).

The effect of temperature on macrophyte decomposition has already been reported by several authors (CARPENTER; ADAMS, 1979, CARVALHO et al., 2005); an increase in temperature of 10°C can triple the biological reactions rates and greatly reduce macrophyte decomposition time, even in submerged macrophytes (CARPENTER; ADAMS, 1979, CARVALHO et al., 2005). No direct relationship between water temperature and plant decomposition rate, as measured by biomass reducation, was observed in the experiment carried out in Lake Paraíso. This lack of a direct relationship between temperature and macrophyte decomposition rate may be due to the low amplitude of variation of the water temperature, 3°C, for all 72 days of the experiment.

Lake Paraíso, latitude 7°30'35" S, is close to the equator and, like other lakes close to the equator, features slight variations in mean annual temperature (VILANI et al., 2006). When we compare the speed of decomposition of the same species of macrophyte in Lake Paraíso with that in pools of other latitudes, like Lake Cavalos, latitude 23°29'02" S, the effect of temperature on the decomposition rate was evident. The times required for the decomposition of 50 and 95% of the initial dry weight in Lake Paraíso were 24 and 104 days, respectively; Stripari and Henry (2002) estimated a loss of 50 and 95% of initial dry weight at 51 and 221 days, respectively, in Lake Cavalos. Therefore, the 50 and 95% decomposition rates of the same species of macrophyte at a lower latitude, in Lake Paraíso, was 200% faster than in the higher latitudes, such as Lake Cavalos, indicating a clear positive effect of the increased temperature on the speed of decomposition. Macrophyte decomposition also affects the concentration of dissolved oxygen (CUNHA-SANTINO; BIANCHINI, 2006).

Oxygen is consumed during the metabolic activity of decomposer organisms, such as bacteria and fungi (CARVALHO et al., 2005). Therefore, it is expected that during the decomposition a reduction in available oxygen occurred. In the experiment in Lake Paraíso, there was a maximum variation in the concentration of dissolved oxygen throughout the experiment of only 0.6 mg L^{-1}; the low variation in the oxygen concentration may be related to the presence of many other macrophytes in the study area. Aquatic plants are the primary producers in aquatic ecosystems and produce a lot of organic matter, releasing oxygen as a product that can be incorporated in the diffusion of water (ESTEVES, 2011). The experiment was set in place next to other weeds that may have affected the outcome of the experiment. The average dissolved oxygen recorded in Lake Paraíso throughout the experiment was 6.19 mg L^{-1}, higher than in other works on decomposition with the same macrophyte species, such as Silveira et al. (2013), who recorded 5.55 mg L^{-1}, and Azevedo et al. (2008), who recorded 3.25 mg L^{-1}; the higher oxygen values in our study suggest that the presence of other nearby aquatic plants may have affected the amount of oxygen in the experiment. Additionally, the densities of Chironomidae larvae identified in Lake Paraíso showed no sensitivity to oxygen; however, oxygen plays a very important role in the survival of Chironomidae because oxygen concentrations of less than 8% saturation result in the death of Chironomidae (CONNOLLY et al., 2004). The high density and presence of *Chironomus* larvae that were resistant to variations in oxygen, as discussed in previous paragraphs, were possibly responsible for the low observed sensitivity to that gas.

Conclusion

We conclude that the tolerance of some Chironomidae genera, such as *Chironomus*, may have contributed to their success in colonization because macrophyte decomposition significantly changes the chemical composition of water. In addition, we identified a significant increase in the E. azurea decomposition rate in Lake Paraíso compared to other lakes at greater latitudes, suggesting a direct effect between the temperature and the macrophyte decomposition rate.

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