The influence of river flooding regime on food web and community structure of stream benthic invertebrates

A influência do regime de cheias sobre a estrutura de teias alimentares e da comunidade de invertebrados bentônicos

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ABSTRACT

Benthic invertebrates are a key link between primary producers and higher trophic levels in aquatic systems. Feeding interactions between species in food webs may provide information about biodiversity and the organization of aquatic ecosystems in different seasonal periods. We evaluated the influence of seasonal variation on the structure of food webs in the *Rio Claro* Mallet, *Paraná*, Southern Brazil. Two samplings were performed in the dry (October and November 2010) and wet (December 2010 and February 2011) seasons in three sites along the river. We conducted food web modeling and also calculated measures of benthic community structure regarding seasonal periods. Our results suggest that the invertebrate community changes depending on flooding. However, particular trophic groups may be more resilient after disturbances.

Key words: Benthic macroinvertebrates. Food webs. Lotic ecosystems. Resilience.

RESUMO

Os invertebrados bentônicos representam um elo entre os produtores primários e os níveis tróficos superiores, que é constituído por intrínsecas relações

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alimentares nos sistemas aquáticos. A compreensão dessas interações entre as espécies nas teias tróficas é de extrema importância, pois as elas podem fornecer informações sobre a biodiversidade e a organização dos ecossistemas hídricos em diferentes períodos sazonais. O objetivo deste estudo foi avaliar a influência da escala temporal na estrutura das teias tróficas do Rio Claro (Mallet, Paraná, Brasil). Duas amostragens foram realizadas no período seco (outubro de 2010 e novembro de 2010) e no período chuvoso (dezembro de 2010 e Fevereiro de 2011) em três pontos amostrais ao longo do gradiente longitudinal do Rio Claro. A modelagem da teia trófica e os atributos da comunidade bentônica foram avaliados entre os períodos sazonais. Os resultados sugerem que o Rio Claro sofre alteração na fauna de invertebrados durante os períodos de cheia, entretanto particulares grupos tróficos podem demonstrar o mecanismo de resiliência quando sujeitos a perturbações.

Palavras-chave: *Macroinvertebrados bentônicos. Teia trófica. Ecossistemas lóticos. Resiliência.*

INTRODUCTION

Benthic invertebrate communities are a key element to understand the structure and function of freshwater ecosystems, since they are a link between insects, fish, and insectivorous birds in trophic chains. Furthermore, benthic invertebrates may favor the colonization of other organisms, since they reduce the particle size of allochthonous and autochthonous organic matter (Merrit & Cummins, 1996a, Carvalho & Uieda, 2004). Macroinvertebrates are widely distributed in aquatic systems. Their distribution is influenced by resource availability, morphometric, physical, and chemical conditions of the habitat (Abilio *et al.*, 2007).They are usually classified into four functional feeding groups depending on the mechanism of food acquisition Cummins (1992): (i) collectors, which feed on small particles of organic matter from the surface, water column, and sediment (Fine Particulate Organic Matter - FPOM); (ii) shredders, which encompass detritivore organisms feeding on Coarse Particulate Organic Matter (CPOM) (allochthonous material, such as leaves and woody detritus); (iii) scrapers, which feed on autochthonous detritus and periphyton by means of adapted mouthparts, and (iv) predators, those that feed on live prey or its corporal fluids.

Previous studies pointed out that this classification is advantageous for ecological assessments in lotic ecosystems. For example, by (i) minimizing the dualism of the niche concept, since species may be classified according to both their function in communities and the environmental conditions that allow their coexistence, (ii) providing an approach independent of their taxonomic relationship, and (iii) allowing the realization of comparative studies in aquatic communities using the guild concept, since the assessment of all interactions among species is often not feasible (Root, 1967).

However, ecological studies also need to consider natural disturbances, such as flooding, which may alter aquatic trophic chains. The main water chemistry variables associated with those events are temperature and hydric flow, which influence the establishment, physiology, and behavior of organisms (Lampert & Sommer, 2007). Thus, changes on benthic communities associated with natural events along the river may be a result of physical and chemical alterations, including food availability in the water column or in the sediment (Vannote *et al.*, 1980). Therefore, we evaluated the influence of seasonal variations in aquatic food webs on a stretch of the *Rio Claro,* Mallet, *Paraná*, Southern Brazil.

MATERIAL AND METHODS

Study sites

This study was conducted in a stretch of the *Rio Claro*, Mallet, Southern *Paraná*, Southern Brazil (Figura 1) (Maack, 1981). The river rises in the *Serra* *da Esperança*, which is covered by secondary forest. We sampled benthic invertebrates in three transects along the river: i) site 1 (PT1) (25° 55' 00.70" S, and 50° 52' 16.20" W; 808 a.s.l.) is upstream from the other sites, surrounded by crops and secondary forest, ii) site 2 (PT2) (25° 55' 28.62" S and 50° 51' 15.32" W; 801 a.s.l.), surrounded by urban area, and iii) site 3 (PT3) (25° 58' 02.53" S and 50° 49' 07.36" W; 806 a.s.l.), is downstream from the other sites, surrounded by preserved forest. The geographic distance between PT1 and PT2 is 5.21km, while the PT2 and PT3 is 11.24km distant from each other. Distance from PT1 to PT3 is about 15km.

Water chemistry

Water temperature was measured with a thermometer and discharge was calculated according to the floating methodology, based on current velocity and depth variables (Palhares *et al.*, 2007), both during the two sampling periods.

Sampling design

Macroinvertebrates were sampled from the substrate in rapids using a Surber sampler (250µm mesh; 900cm²). Samples were taken on the left, right, and center of the sampling site, with a minimum distance of 1m between samples, during the dry (October and November 2010) and wet season (December 2010 and February 2011). Samples were fixed with 80% ethanol in the field. Specimens were identified under a stereomicroscope and optical microscope to the family level and further separated into trophic species; except for chironomids, which were identified to the subfamily level (Trivinho-Strixino & Strixino, 1995; Merrit & Cummins, 1996a;1996b; Costa *et al.*, 2004; Mugnai *et al.*, 2010).

Data analysis

Trophic species were classified into six functional feeding groups Merrit & Cummins (1996a; b): (i) biofilm of microorganisms; (ii) scrapers that are feed on algae and periphyton on the substrate; (iii) shredders that feed on CPOM; (iv) filter-collectors that feed on FPOM suspended in the water column; (v) gather-collectors that feed on FPOM from the sediment; and (vi) predators, which feed on other macroinvertebrates. It is noteworthy that we assigned functional feeding groups to trophic species, not biological species.

Those feeding groups were used to represent food webs from the two sampling periods by using a binary matrix, in which the columns are food resources and rows are consumers. The matrix was built with the software Pajek®, version 1.28 (Batagelj & Mrvar, 1998).

The two food webs were compared using nine descriptors Calado (2011): proportion of basal species, proportion of intermediate species, proportion of top species, density of links, connectance, proportion of omnivorous, maximum length of the web, minimum length of web, and number of trophic compartments.

Figure 1. Study area in the *Rio Claro*, *Paraná*, Southern Brazil. PT1 = site 1 (25° 55' 00.70" S, and 50° 52' 16.20" W), PT2 = site 2 (25° 55' 28.62" S and 50° 51' 15.32" W), and PT3 = site 3 (25° 58' 02.53" S and 50° 49' 07.36" W), where PT1 and PT2 are upper reaches from and PT3 is a lower reach from in *Rio Claro*.

Fonte: Own authorship.

Descriptors of the macroinvertebrate community structure were calculated, namely: trophic species richness (S); Margalef's richness index (d), which is given by S - 1/ ln N, where N is the total number of organisms; Shannon-Wiener diversity index (H), which was calculated based on community biomass in relation to taxonomic richness; Pielou equitability (J'), and Dominance (Dm) (Begon *et al.*, 2007). An Analysis of Variance (Anova) was performed to test for differences in these indexes between the two sampling periods, as well as the variability among abiotic factors (Gotelli & Ellison, 2004). Data were tested for normality and homogeneity of variance using Shapiro-Wilk's test prior to analysis. Analyzes were conducted in the software Past®, version 2.17 (Hammer *et al.*, 2007).

RESULTS

Water temperature varied from 18°C to 21°C throughout the sampling period, but this difference was not significant (F=0.41; DF=5.97; *p*=0.67). Discharge increased along sampling periods, varying from 1.44l/s to 5.01l/s in the dry seaon, while in the wet period it varied from 8.23l/s to 21.21l/s. Variation in discharge between sampling periods was not significant (F=0.58; DF=5.73; *p*=0.59).

We found 1,818 specimens from 27 taxa, belonging to six trophic groups. From this, 1,684 specimens were sampled in the dry season and 134 in the wet season. The most abundant taxa throughout the study were: Chironomidae (Insecta: Diptera) (68.4%), Simuliidae (Insecta: Diptera) (30.1%), Elmidae (Insecta: Coleoptera) (21.6%), and Hydropsychidae (Insecta: Trichoptera) (14.2%).

Filter-collector (n=671) was the most abundant trophic group in the dry season, due to the occurrence of Hydropsichidae (Insecta: Trichoptera) and Simuliidae (Insecta: Diptera). Collectors comprised 571 specimens, from Baetidae (Insecta: Ephemeroptera), Chironominae (Insecta: Diptera: Chironomidae), Hydrophilidae (Insecta: Coleoptera), Leptophlebiidae (Insecta: Ephemeroptera), and Orthocladiinae (Insecta: Diptera: Chironominae) during the dry season. Collectors (n=67) were the most abundant trophic group during the wet season, which was represented by Baetidae, Chironominae, Hydrophilidae, Leptophlebiidae, and Orthocladiinae. Elmidae (n=22) was the only gather-collector found in the wet season (Figure 2). The occurrence of others trophic groups also varied between seasons (Table 1).

There was no significant difference in the descriptors of community structure between seasons (F=0.10; DF=11.06; *p*=0.99). PT1 was the most diverse site in the dry season (Table 2), although there was no significant difference among descriptors of community structure for sites in this period (F=0.04; DF=5.85; *p*=0.96). PT3 was the most diverse and equitable site in the wet season, while PT2 was the less diverse (Table 2). There was no difference among sampling sites in the wet season (F=0.09; DF=5.62; *p*=0.91).

The food web from the dry season had higher trophic species richness (dry season=1.679; wet season=132), which contributed to its higher number of links among individuals (dry season=7.126; wet season=2.116) (Figure 3A and Figure 3B). Such result may be explained by the increased discharge due to high precipitation in the wet season. This favors the carrying of organisms and reduces their establishment.

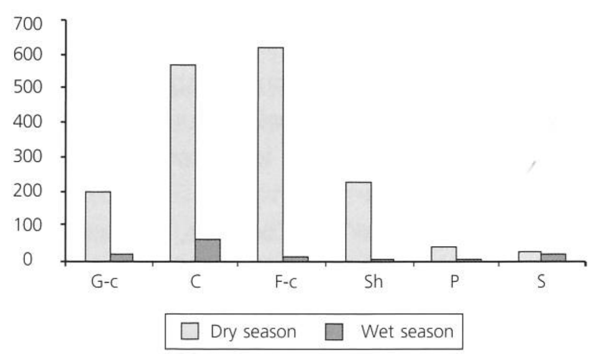

Figure 2. The most abundant trophic groups during the dry (October/2010 and November/2010) and wet (December/2010 and February/2011) seasons in the *Rio Claro, Paraná*, Southern Brazil.

Note: G-c: Gather-collector, C: Collector; F-c: Filter-collector; Sh: Shredder; P: Predator; S: Scraper.

Connectance and density of links in the dry season (0.002 and 5.955 respectively) were lower than in the wet season (0.122 and 16.030 respectively). Thus, the season with higher density of links was not the same with higher trophic species richness. Conversely, the number of trophic levels, maximum and minimum lengths of the web were the same for the two sampling periods.

DISCUSSION

Our results showed the influence of seasonality on the community and food web structures of aquatic macroinvertebrates. For example, a higher abundance of macroinvertebrates was found in the dry season, which may be related to lower water volume, providing resources and opportunities for colonization of individuals along the river. Conversely, the increased water volume and current velocity in the wet season may have detached organisms from the substrate.

The occurrence of specific trophic species in both sampling periods was a key component of the interaction dynamics of the food web. This can be explained by the fact that some macroinvertebrates show particular adaptations to resist environmental fluctuations (Vannote *et al.*, 1980). This factor could have been relevant in both seasonal periods in our study, since food webs had similar number of trophic levels and length, which can be the result of the plasticity to natural disturbances of organisms.

Despite the apparent high tolerance to disturbances, some food web descriptors differed between seasons. For example, trophic species richness was lower, but connectance was higher during the wet season. Thus, the wet season food web was unstable, since if one organism gone extinct, that can drive the exclusion of other individuals dependent on this interaction (Motta & Uieda, 2005;

Table 1. Total abundance of trophic groups in three sampling sites during the dry and wet seasons in the *Rio Claro*, *Paraná*, Southern Brazil.

Trophic groups	Dry season				Wet season			
	PT1	PT2	PT3	Total	PT1	PT2	PT3	**Total**
Gather-collectors	32	133	34	199	2	4	16	22
Collectors	74	398	99	571	26	17	24	67
Filter-collectors	28	285	304	617	6	2	2	10
Shredders	27	158	41	226	1	1	5	7
Predators	5	30	2	37	2	4	2	8
Scrapers	1	3	25	29	3	1	14	18

Note: (Dry season: October/2010 and November/2010; Wet season: December/2010 and February/2011).

Table 2. Macroinvertebrate community diversity metrics in the three sampling sites during the dry and wet seasons in the *Rio Claro*, *Paraná*, Southern Brazil.

Community's attributes	Dry season			Wet season		
	PT1	PT2	PT3	PT1	PT2	PT3
S	20	19	12	11	9	13
Dm	0.16	0.17	0.19	0.32	0.31	0.18
H	2.23	2.03	1.73	1.66	1.58	1.98
J'	0.74	0.69	0.69	0.69	0.72	0.77
d	3.70	2.60	1.76	2.71	2.37	2.87

Note: S: Species richness; Dm: Dominance; H: Shannon-Wiener diversity; J': Pielou equitability; d: Margalef's richness index. Dry season: October/2010 and November/2010; Wet season: December/2010 and February/2011.

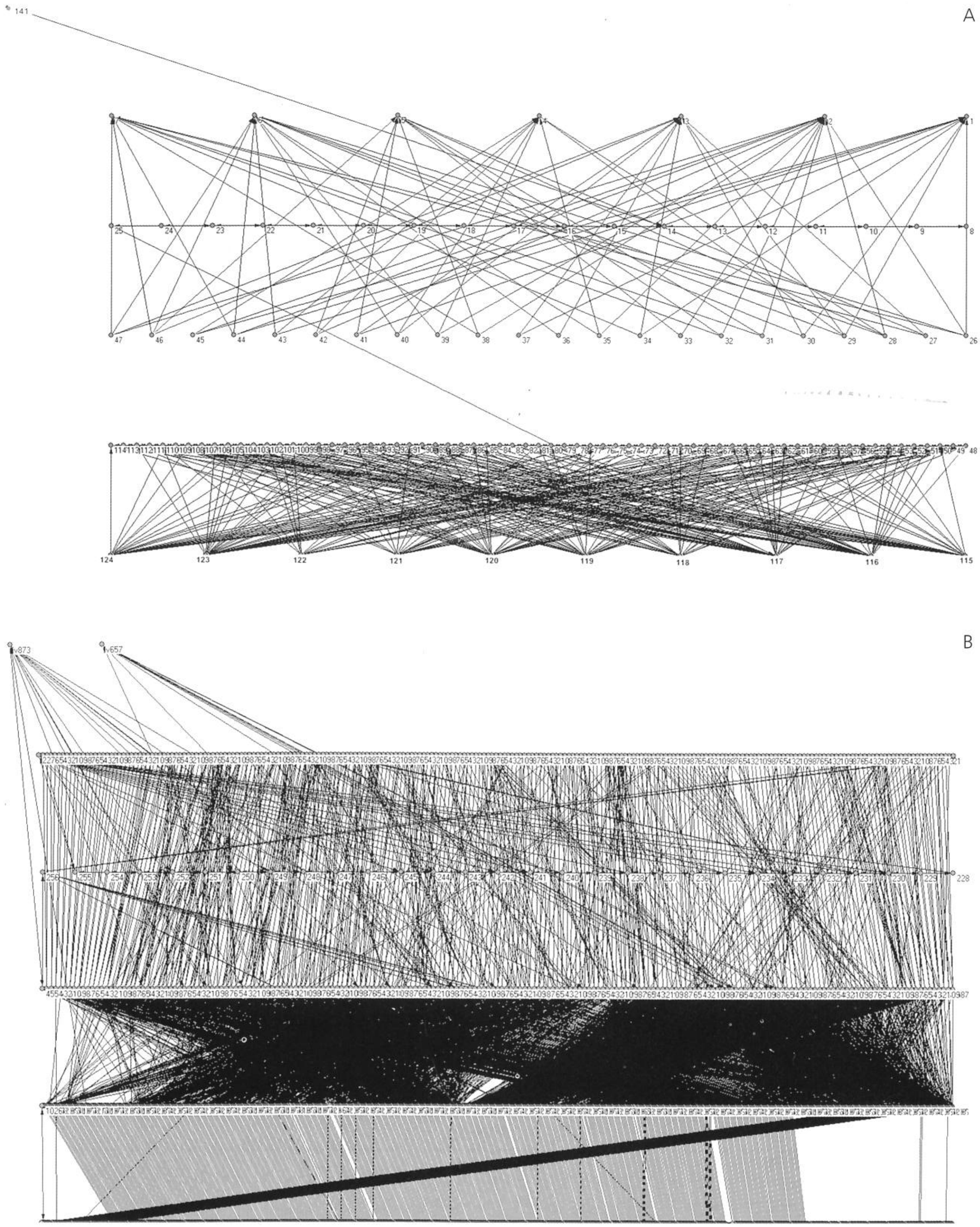

Figure 3. Food webs for both dry (a) and wet (b) seasons in *Rio Claro*, *Paraná*, Brazil (Dry season: October/2010 and November/2010; Wet season: December/2010 and February/2011).

Source: Own authorship.

Rezende *et al.*, 2008). Therefore, higher connectance can be associated with lower complexity in food webs as a result of low trophic species richness.

The difference between seasonal periods in composition of trophic groups may also be related to two factors: i) the structure of aquatic communities is a result of biotic interactions, which is associated with environmental variations in spatial and temporal scales (Uieda & Motta, 2007), and ii) the community may be comprised of opportunistic species, which may survive and increase their populations when conditions are favorable between catastrophic floods and droughts. The River Continuum Concept also corroborates this idea, showing that communities can be placed between those two extremes involving deterministic and stochastic processes.

Although the occurrence of many organisms can be reduced during the wet season, it may also facilitate the exchange of nutrients to floodplains, and consequently increase their biomass (Junk *et al.*, 1989). Those mechanisms could compensate the deficit of habitat and stable conditions available for organismal establishment caused by natural disturbance during wet periods (Junk *et al.*, 1989; Effenberger *et al.*, 2008). Therefore, we suggest that some relevant properties of the food web of the *Rio Claro* are resilient to flooding events, since conditions and resources are likely to be provided to the establishment of biota during the increase of the hydric flow.

In conclusion, studies have pointed out that the biological integrity of aquatic systems is related to functional redundancy and environmental factors, such as magnitude and intensity of disturbances (Silva-Filho, 2004).

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