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Article

Diversity and microhabitat use of benthic invertebrates in an urban forest stream (Southeastern Brazil)

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ABSTRACT. This work aimed to assess the diversity and microhabitat use of benthic invertebrates in an urban forest stream in southeastern Brazilian region. The invertebrates were sampled in a headwater stream, located at the Tijuca Forest, Rio de Janeiro. Three types of microhabitats were sampled (litter, sand and stone) using a Surber sampler. Specimens were identified to the family-level and rarefaction curves were constructed for the total sampling and for each type of microhabitat. Community structure indices (abundance, taxonomic richness, diversity, and dominance) were calculated for each microhabitat. Differences among indices were tested through a repeated measure ANOVA, and differences among microhabitats' composition through a PerMANOVA. A total of 9,800 specimens were registered in which Chironomidae was the most abundant. The rarefaction curves did not reach the asymptote. Community structure indices exhibited differences (RM ANOVA; $p < 0.001$), as well as microhabitats' composition (PerMANOVA; $p < 0.001$). Abundance and taxonomic richness were the highest in litter, diversity was higher both in litter and stone, and sand had the highest dominance. Results highlighted that the variety of microhabitats may enhance local diversity and that the differences in resources availability of each type of microhabitat determine the distribution of these invertebrates.

KEYWORDS. Atlantic Forest, macroinvertebrates, Neotropical region, substrates.

RESUMO. Diversidade e uso de microhabitat de invertebrados bentônicos de um riacho de floresta urbana (Sudeste do Brasil). Este trabalho teve como objetivo avaliar a diversidade e o uso de microhabitat de invertebrados bentônicos em um riacho de floresta urbana na região do sudeste brasileiro. Os invertebrados foram coletados em um riacho de cabeceira, localizado na Floresta da Tijuca, Rio de Janeiro. Três tipos de microhabitats foram amostrados (folhiço, areia e pedra) usando um amostrador Surber. Os espécimes foram identificados em nível de família e curvas de rarefação foram construídas para a amostragem total e para cada tipo de microhabitat. Índices de estrutura de comunidade (abundância, riqueza taxonômica, diversidade e dominância) foram calculados para cada microhabitat. Diferenças entre os índices foram testados através de uma ANOVA de medidas repetidas, e diferenças entre a composição dos microhabitats através de uma PerMANOVA. Um total de 9,800 espécimes foram registrados em que Chironomidae foi mais abundante. As curvas de rarefação não atingiram a assíntota. Os índices de estrutura de comunidades apresentam diferenças (RM ANOVA; $p < 0.001$), bem como a composição dos microhabitats (PerMANOVA; $p < 0.001$). Abundância e riqueza taxonômica foram maiores em folhiço, diversidade foi maior em folhiço e pedra, e areia teve a maior dominância. Os resultados expostos destacaram que a variedade de microhabitats pode aumentar a diversidade local, e que as diferenças na disponibilidade de recursos de cada tipo de microhabitat determina a distribuição desses invertebrados.

PALAVRAS-CHAVE. Mata Atlântica, macroinvertebrados, Região Neotropical, substratos.

Freshwater ecosystems harbor high biodiversity and provide many services for the population, such as water provision for domestic, agriculture and industrial use, power generation and recreation (Aylward *et al.*, 2005). Nevertheless, they are among the most threatened ecosystems in the world (Harrison *et al.*, 2016). Most of the endangered freshwater ecosystems are headwater streams, which comprise around 80% of hydrographic basin's total drainage area, contributing with organic nutrients to downstream reaches due to their forested location areas (MacDonald & Coe, 2007). This contribution to the dynamic and transport of nutrients in a basin makes headwater streams a priority to conservation, especially in the context of increasing human expansion within the last decades (Callisto *et al.*, 2012).

Among all anthropogenic activities, the replacement of riparian vegetation by agriculture, pasture, or urban areas is one of the major disturbances affecting headwater streams and their biodiversity (Hepp *et al.*, 2010; Melo *et al.*, 2020). The riparian vegetation stabilizes the stream bank, preventing erosion and sedimentation, acts as watershed protection against organic pollution, and regulates the in-stream temperature and primary production (Allan, 2004; Riis *et al.*, 2020). Additionally, this vegetation subsidizes the aquatic food web with resources in animal and vegetal organic matter, providing a wide variety of ecological niches (Recalde *et al.*, 2016). Therefore, it is expected that headwater streams with conserved riparian vegetation support higher biodiversity than streams within deforested areas (Hepp & Santos, 2009; Hepp *et al.*, 2010; Costa *et al.*, 2020).

The benthic invertebrates are among the most diverse groups inhabiting headwater streams (Clarke *et al.*, 2008) and one with the fastest responses to local environmental disturbances due to their low mobility and high abundance (Rosenberg & Resh, 1993). Their distribution in these ecosystems is mainly shaped by local physical factors, such as water flow and substrate type (Allan & Castillo, 2007). Hydrodynamics determines substrate availability and consequently the microhabitat heterogeneity within the stream (Allan & Castillo, 2007). There are different types of microhabitat patches that are formed on the streambed that present distinct resource availability. For example, litter microhabitats (patches composed mainly of accumulated higher plant debris) present higher abundance of food and shelter in relation to others, such as fine sediments, and thus are expected to harbor a higher number of organisms (Kikuchi & Uieda, 2005). Different types of microhabitats also harbor different taxa depending on their morphological and physiological adaptations, such as their mechanisms to obtain food, *i.e.* functional feeding groups (FFGs) (Buss *et al.*, 2004; Oliveira & Nessimian, 2010). These invertebrates hold critical ecological roles in food webs, from primary consumers to predators (Motta & Uieda, 2004; Carvalho & Uieda, 2009; Silveira-Manzotti *et al.*, 2016). Due to these characteristics and importance, benthic invertebrates are frequently used as environmental monitoring tools (Callisto *et al.*, 2001; Oliveira & Callisto, 2010; Silva *et al.*, 2017).

There are many advantages in conserving urban forests since these ecosystems promote local air filtration, microclimate regulation, and carbon dioxide reduction, among other provision services (Solomou *et al.*, 2019). The Tijuca Forest is the largest urban forest in southeastern Brazil. Its small headwater streams act as a local water reservoir for the city of Rio de Janeiro, supplying around 17,000 resident people (CEDAE, 2019). The Tijuca Forest has already undergone intense land use, such as sugarcane, coffee plantations and pasturelands, which interrupted the water supply for the local population (Freitas *et al.*, 2006). In 1961, the local conservation unit area, the Parque Nacional da Tijuca (ICMBio, 2008), was established to protect this water reservoir (Freitas *et al.*, 2006). Since its establishment, studies concerning its freshwater ecosystems are incipient.

Therefore, considering the importance of this urban forest and its freshwater ecosystems, we assessed the diversity and microhabitat use of benthic invertebrate in a second-order stream stretch of the Tijuca River. These invertebrates are highly dependent on their microhabitats for food and shelter and different taxa may inhabit different types of microhabitats depending on their FFG. Thus, we expect to find differences in assemblage composition among types of microhabitats and that the higher resource availability of litter patches will increase diversity in relation to the others. Additionally, the variety of microhabitat types on the Tijuca River streambed may enhance environmental heterogeneity and local diversity.

MATERIAL AND METHODS

Study area. This study was conducted at two second-order stretches of the Tijuca River (22°57’36”S, 43°16’31”W), located at the Parque Nacional da Tijuca, Rio de Janeiro, Brazil. The stretches presented well-preserved riparian forest (Figs 1-3). The park receives nearly 3 million visitors per year that engage in multiple activities, such as tracking and bathing. The sampled stretches of the Tijuca River are prohibited for bathing. The Tijuca Forest is one of the largest protected urban forests worldwide, with a perimeter encompassing nearly 25 km and surrounded by 4,000 hectares of Atlantic Forest. The forest is located in the mountains of Rio de Janeiro at 350 meters of altitude and going up to 1,020 meters in its highest peak. The southeastern Atlantic Forest has an unstable climate with rainfall occurring throughout the year (Buss *et al.*, 2004). In the Tijuca Forest, the temperature varies between 18°C and 26°C and precipitation can reach 1,200 mmyear^{-1} (ICMBio, 2008).

Data sampling. Sampling was carried out in September 2016, December 2017, and July 2018. Rainfall did not exhibit significant variation in the month before the sampling expedition (INMET, 2020): September 2016 ranged from 2 to 32 mm (mean ± SD: 15 ± 30); December 2017 ranged from 1 to 45 mm (15 ± 44); and July 2018 ranged from 3 to 30 mm (13 ± 27). The expeditions were carried out at two stretches of 40 meters each of the Tijuca River. Using a Surber sampler (0.09 m², mesh size 250 µm), litter, sand and stone microhabitats were sampled. The 2016 expedition was carried out at only one of the stretches, only litter and sand microhabitats were sampled, and there was no measurement of physical variables. Although the 2016 expedition is limited, it was chosen to use the data to represent as maximum diversity as possible. Microhabitat replicates were taken in riffle and pool areas, totaling 55 sample units, consisting of 20 litter samples, 20 sand samples and 15 stone samples. Litter samples consisted predominantly of allochthonous organic debris, such as leaves and branches, sand samples are fine inorganic sediment, and stones samples are the periphyton material brushed from submersed stones. The samples were taken as far as possible from each other, and these microhabitats were selected because they were the most representative within the stream. The samples were fixed and conserved in 70% alcohol in the field.

Physical variables were measured every 5 meters of each stretch: (i) stream width, measured using a surveyor’s tape; (ii) stream depth, measured using a graduated ruler perpendicularly fixed to the ground; and (iii) streamflow, estimated by recording the time a floating object cover a predetermined distance. The stream width ranged from 1.9 to 7.3 m, stream depth ranged from 0.02 to 0.5 m, and streamflow ranged from 0 to 0.52 ms^{-1}. Sampling was authorized by *Instituto Chico Mendes de Conservação da Biodiversidade* (ICMBio; license number: 53551).

Figs 1-3. Sampled stretches of the Tijuca River, Tijuca Forest, Rio de Janeiro, Brazil: Figs 1, 2, first stretch located at 380 meters of altitude; and Fig. 3, second stretch located at 420 meters of altitude.

Sampled specimens were counted and identified under a stereomicroscope. Specimens were identified to the family-level whenever possible using specialized literature (Mugnai *et al.*, 2010; Hamada *et al.*, 2014). Family-level identification was already shown to be adequate to detect ecological patterns of aquatic invertebrates due to high ecological similarities within the family-level (Céréghino *et al.*, 2018). Then, the taxa were classified into seven Functional Feeding Groups (FFGs): brushers (Bs), collector-filterers (CF), collector-gatherers (CG), scrapers (Sc), shredders (Sh), pierces (Pi) and predators (Pr), using published data (Merritt & Cummins, 1996; Cummins *et al.*, 2005; Tomanova *et al.*, 2008; Domínguez & Fernández, 2009; Shimano *et al.*, 2012; Thorp & Rogers, 2015).

Data analysis. For the data analysis the dataset of the three years of sampling (n = 55) were pooled. First, sampling sufficiency was assessed by constructing rarefaction curves based on the abundance data matrix for both the total sampling and each microhabitat type. Rarefaction was performed utilizing the Hill number of order q = 0, which is analogous to taxonomic richness (Chao *et al.*, 2014). The extrapolation (prediction of what would happen if we sample the double of the actual sample size) and 95% confidence intervals were calculated for each curve. Rarefaction curves were constructed in the iNEXT package (Hsieh *et al.*, 2016) in R (R Core Team, 2019).

In order to describe the local diversity of each type of microhabitat (litter, sand, and stone), the following community structure descriptors were calculated: (i) log-transformed abundance; (ii) log-transformed richness; (iii) Shannon's diversity; and (iv) Simpson's dominance. The differences in community structure among microhabitat types were analyzed by applying the one-way repeated measure Analysis of Variance (RM ANOVA) and the Tukey post hoc test for each descriptor. The Permutational Multivariate Analysis of Variance (PerMANOVA) was applied to test differences in community composition among microhabitat types. Analyses were performed using the square-root abundance data matrix, the Bray-Curtis dissimilarity coefficient, and 1,000 permutations. Variation in community composition among microhabitat types was visualized with a Non-metric multidimensional scaling (NMDS). Finally, we quantified the contribution of each taxon to the observed differences among microhabitats by using the Similarity Percentages analysis (SIMPER). These analyses were performed in the *vegan* package (Oksanen *et al.*, 2020) in R (R Core Team, 2019). Our dataset is available at Figshare: 10.6084/m9.figshare.13377311.

RESULTS

A total of 9,800 specimens were sampled, distributed in Chelicerata, Crustacea, Entognatha and Insecta (Tab. I). The rarefaction curves of the total sampling and for each type of microhabitat did not reach the asymptote (Fig. 4). However, the curves of each type of microhabitat exhibited distinct patterns. Litter did not reach the asymptote with the actual sample size as well as with the extrapolation. Stone exhibited the highest tendency of increase in taxonomic richness, which is expected once we had less sampling units of this microhabitat. Sand did not reach the asymptote with the actual sample size, but, apparently, it may reach it with a little more sampling effort as shown with the extrapolation.

Tab. I. Abundance (n) and relative abundance (%) of benthic invertebrates of Tijuca River, located at the Tijuca Forest, Rio de Janeiro, Brazil (FFG = functional feeding group; Bs = brushers; CF = collector-filterers; CG = collector-gatherers; Sc = scrapers; Sh = shredders; Pi = pierces; Pr = predators).

Taxa	FFG	Litter		Sand		Stone	
		n	%	n	%	n	%
Acari							
not identified	Pi	54	0.80	54	2.47	55	6.43
Decapoda							
not identified	Sh	8	0.12	–	–	3	0.35
Collembola							
not identified	CG	4	0.06	2	0.09	2	0.23
Coleoptera							
Elmidae (larvae)	CG/Sc	412	6.09	90	4.12	202	23.60
Elmidae (adult)	CG/Sh	26	0.38	4	0.18	14	1.64
Noteridae	Pr	1	0.01	–	–	–	–
Psephenidae	Sc	3	0.04	2	0.09	–	–
Diptera							
Ceratopogonidae	Pr	61	0.90	26	1.19	58	6.78
Chironomidae	CG	4313	63.78	1832	83.96	347	40.54
Simuliidae	CF	228	3.37	1	0.05	2	0.23
Syrphidae	CF	1	0.01	–	–	–	–
Tipulidae	CG/Pr	1	0.01	–	–	–	–
Ephemeroptera							
Baetidae	CG/Sc	152	2.25	44	2.02	122	14.25
Leptophlebiidae	CG/Bs	1093	16.16	58	2.66	20	2.34
Hemiptera							
Naucoridae	Pr	1	0.01	17	0.78	3	0.35
Veliidae	Pr	26	0.38	24	1.10	6	0.70
Odonata							
Libellulidae	Pr	2	0.03	–	–	–	–
Megapodagrionidae	Pr	3	0.04	4	0.18	1	0.12
Gomphidae	Pr	10	0.15	4	0.18	2	0.23
Coenagrionidae	Pr	16	0.24	13	0.60	1	0.12
Plecoptera							
Gripopterygidae	Sh	33	0.49	–	–	1	0.12
Perlidae	Pr	34	0.50	–	–	1	0.12
Trichoptera							
Hydrobiosidae	Pr	15	0.22	1	0.05	–	–
Hydropsychidae	CF	202	2.99	3	0.14	15	1.75
Leptoceridae	Sh	63	0.93	3	0.14	1	0.12
Total		6762		2182		856	

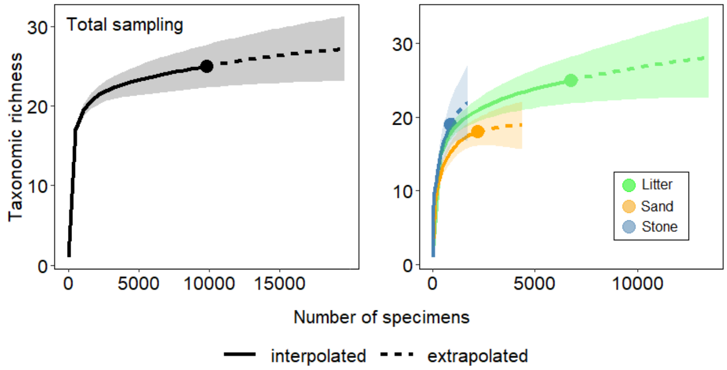

Fig. 4. Rarefaction curves with extrapolations and 95% of confidence intervals for both the total sampling and each type of microhabitat of benthic invertebrates of Tijuca River, located at the Tijuca Forest, Rio de Janeiro, Brazil.

From the total sampling, the most abundant taxa were Chironomidae (Diptera; 66.2%), Leptophlebiidae (Ephemeroptera; 11.9%), and Elmidae (Coleoptera) larvae (7.2%). We recorded Noteridae (Coleoptera), Syrphidae, and Tipulidae (both Diptera) only once. The Ephemeroptera, Plecoptera and Trichoptera (EPT) fauna encompassed nearly 19% of the total abundance, mostly ephemeropterans (15.2%). More than half of the specimens (69%) were found inhabiting litter microhabitats, followed by sand (22.3%) and then stone (8.7%) (Tab. I). Chironomidae was the most abundant in all the three types of microhabitats with its highest number in litter. Leptophlebiidae was the second most abundant in litter and sand, while Elmidae larvae was the second in stone.

Collector-gatherers were the most abundant FFG, encompassing nearly 90%, mostly because of chironomids (Tab. I). Not as abundant, but with the occurrence of many taxa, we also found collector-filterers (4.6%), predators (3.4%) and shredders (1.6%). The FFGs inhabited mainly litter microhabitats: predators (49%), scrapers (55%), collector-gatherers (68%), and almost all shredders (90%) and collector-filterers (95%). After litter, scrapers occurred mostly in stone (35.5%), collector-gatherers in sand (23.5%), and predators had nearly the same occurrence in sand and stone (both around 25.5%).

Abundance and taxonomic richness were the highest in litter microhabitat, diversity was higher both in litter and stone, while sand exhibited the highest dominance (RM ANOVA; $p < 0.001$; Fig. 5). Assemblage composition also exhibited differences among microhabitats (PerMANOVA; $F_{2, 52} = 10.3$; $p < 0.001$). The NMDS analysis visually highlighted these differentiations (Fig. 6); litter samples grouped in the left of the ordination, while sand samples grouped in the center in a narrower multivariate space, and stone samples dispersed in the right in a much wider space. Chironomidae contributed the most for the dissimilarity between all pairs of microhabitats (average dissimilarity contribution; Tab. II). Most of the five taxa with the highest contribution for the dissimilarity inhabited mostly litter microhabitats (average abundance; Tab. II), except for Baetidae that had preference for stone over litter. Comparing sand and stone, only Chironomidae had preference to inhabit sand microhabitats, while the rest of the taxa inhabit mainly stone.

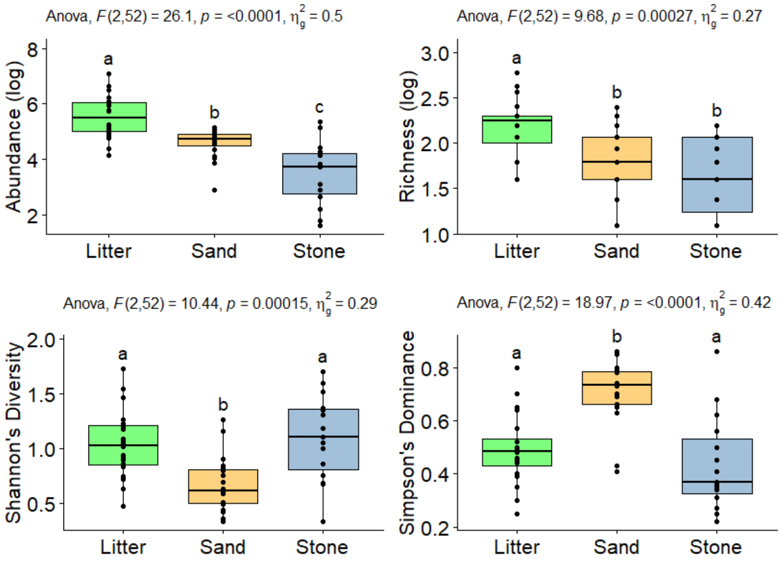

Fig. 5. Boxplot of the ecological descriptors calculated for each microhabitat type (litter, sand, and stone) with the one-way repeated measure ANOVA results and the Tukey pairwise post hoc test (letters). Different letters denote significant difference results ($p < 0.001$).

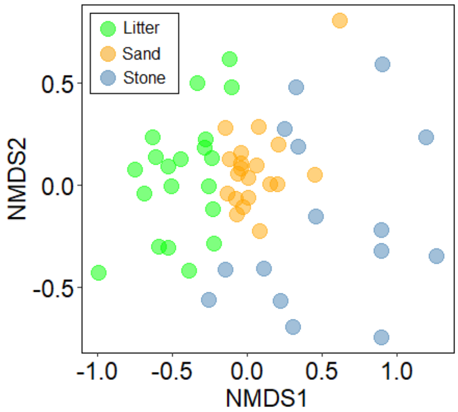

Fig. 6. NMDS ordination (stress = 0.18) of each microhabitat type (litter, sand, and stone) sampled at the Tijuca River, located at the Tijuca Forest, Rio de Janeiro, Brazil.

DISCUSSION

Our study surveyed a fraction of the diversity of benthic invertebrates of a small headwater stream within the largest urban forest of southeastern Brazil, the Tijuca Forest. Results showed that the different types of microhabitats within the Tijuca River may act as an enhancing factor of the local diversity as well as determinant to the local distribution of these invertebrates. As predicted, the assemblage composition of microhabitat types differed among each other, highlighting that each taxa may prefer to inhabitat certain microhabitats based on morphological adaptations to better take advantage of the resources available on the environment. We also corroborated our hypothesis of resource availability, with litter patches exhibiting higher diversity. Aside from litter, stone also exhibited high diversity, while sand was the poorest of the microhabitats.

Small headwater streams have narrow channel width and are highly dependent on the allochthonous subsidies provided by the riparian vegetation (Vannote *et al.*, 1980). This constant input of nutrients maintains the diversity of in-stream organic microhabitat patches, reflecting on the functional organization and distribution of macroinvertebrates (Kobayashi & Kagaya, 2004; Moraes *et al.*, 2014; Ono *et al.*, 2020). The presence of these patches along the streambed allows shredders to take advantage of this resource and keep critical ecological processes functioning, such as leaf processing (Silva-Araújo *et al.*, 2020). In the current study, nearly all the shredder organisms inhabited litter microhabitats. The vegetation surrounding the Tijuca River is preserved due to the management of the Parque Nacional da Tijuca (ICMBio, 2008). Therefore, we consider this conservation unit area critical to local diversity patterns by preserving the riparian vegetation. Indeed, protected areas are efficient in maintaining the integrity of streams and their benthic fauna in the Atlantic Forest (Oliveira & Callisto, 2010; Restello *et al.*, 2020).

Tab. II. Similarity Percentage analysis (SIMPER) showing the five taxa that contributed the most for the dissimilarity between all pairs of microhabitats (Av. diss. contribution = average dissimilarity contribution).

Taxa	Microhabitats Average abundance		Av. diss. contribution	Cumulative contribution (%)
	Litter	Sand		
Chironomidae	215.65	91.6	0.29	53.56
Leptophlebiidae	54.65	2.9	0.12	76.44
Elmidae larvae	20.6	4.5	0.02	81.71
Simuliidae	11.4	0.05	0.02	86.08
Hydropsychidae	10.1	0.15	0.02	89.87
	Litter	Stone		
Chironomidae	215.65	23.13	0.45	56.29
Leptophlebiidae	54.65	1.33	0.16	76.05
Elmidae larvae	20.6	13.46	0.05	82.52
Baetidae	7.6	8.13	0.3	86.36
Simuliidae	11.4	0.13	0.2	89.93
	Sand	Stone		
Chironomidae	91.6	23.13	0.47	67.54
Elmidae larvae	4.5	13.46	0.07	77.49
Baetidae	2.2	8.13	0.04	84.21
Acari	2.7	3.66	0.03	88.59
Ceratopogonidae	1.3	3.86	0.02	91.54

Chironomidae (Diptera) was the most common family found in Tijuca River, inhabiting mainly litter microhabitats. High diversity of chironomids genera and species is commonly observed in lotic systems around the globe (Rosemond *et al.*, 1998; Laursen *et al.*, 2015; Pio *et al.*, 2020; Monteles *et al.*, 2021) and was already reported on another low order stream within the Tijuca Forest, the Fazenda River (Henriques-Oliveira *et al.*, 2003a). The high abundance of chironomids described herein is in accordance with its known ecological traits, since many species of this family are strongly associated with waters enriched with organic matter, feeding on it and using it as a shelter (Henriques-Oliveira *et al.*, 2003b; Sanseverino & Nessimian, 2008). Also, studies indicate that most of the chironomids are the pioneers in the microhabitat colonization process (Carvalho & Uieda, 2004; Santos *et al.*, 2016) and demonstrate good resilience after disturbance events, such as spates (*e.g.* Mesa, 2012). This resilience may be related to their life history adaptations as a strategist with rapid development time and nearly continuous reproduction (Mesa, 2012). Thus, these characteristics may favor quick colonization after constant disturbance, consequently favoring their local dominance in areas subject to frequent spates (Mesa, 2012), as Atlantic Forest headwater streams.

We also found a fair amount of specimens from all the EPT group representatives, which may indicate good habitat integrity (Bagatini *et al.*, 2012). The occurrence and distribution of some species of this group can be drastically affected by physical and chemical changes in the water promoted by organic pollution (Hepp *et al.*, 2013). These taxa prefer flowing waters and can occur in a varied type of microhabitats (Bagatini *et al.*, 2012; Schmitt *et al.*, 2020). The litter accumulation on the bottom of forested Neotropical streams, such as the Tijuca River, can explain the occurrence of the EPT group, as many genera of these families take advantage of the organic matter for shelter and food (Amaral *et al.*, 2015). We found a considerable abundance of this group in litter microhabitat, primarily because of Leptophlebiidae (Ephemeroptera), known to be abundant and to inhabit different types of organic microhabitats in the lotic ecosystems of the state of Rio de Janeiro, such as bottom litter and marginal vegetation (Da-Silva *et al.*, 2010). Baetidae was the only family of this group that had preference for stone microhabitats. Genera of this family are collector-gatherers as well as scrapers (Shimano *et al.*, 2012), thus the periphyton attached to the submersed stones of the Tijuca River are a fine source of food for these organisms.

Our results showed higher taxonomic richness and abundance of macroinvertebrates in litter microhabitat, and higher diversity in both litter and stone. Different types of microhabitats exhibit different degrees of complexity (Vinson & Hawkins, 1998), an important factor determining the assemblage composition and local distribution of these organisms (Buss *et al.*, 2004; Silveira *et al.*, 2006; Oliveira & Nessimian, 2010). Sandy microhabitats are usually homogeneous and lack feeding resources. In contrast, both organic patches and stones harbor greater habitat complexity and food availability due to the presence of leaves, woody debris and periphyton (Baptista *et al.*, 2001; Kikuchi & Uieda, 2005). Because of its abundant source of food, organic patches may attract many FFG to colonize it, consequently turning into a food capture strategy for predators (Sonoda, 2010). Indeed, most of the predators found here inhabited litter microhabitats. Also, the environmental heterogeneity of lotic ecosystems can promote the taxonomic richness as well as functional diversity (Crisci-Bispo *et al.*, 2007; Gurski *et al.*, 2014; Nicacio *et al.*, 2020). The highest dominance was in sand microhabitats, mostly because of Chironomidae, which encompassed nearly 85% of the total specimens found, lowering the assemblage evenness. That said, it can be concluded that the diversity of microhabitats given by the complexity of organic patches and periphyton of submersed stones on the Tijuca River streambed may be facilitating the niche partitioning among taxa and promoting increased local diversity.

Even embedded in an urbanized matrix, urban forests may still harbor high biodiversity and endangered species; thus, efforts to conserve should not be focused only on pristine areas (Alvey, 2006). The Parque Nacional da Tijuca has been the focus of many management actions, such as reintroducing mammal species, which was proven to be effective (Cid *et al.*, 2014; Fernandez *et al.*, 2017; Monteiro & Lira, 2020). Similar efforts in local freshwater ecosystems have not been carried out. The studied stretches of the Tijuca River exhibited preserved riparian vegetation and diversity of in-stream microhabitats, which favored the high diversity of benthic aquatic invertebrate families, emphasizing the need for conservation of these ecosystems as well. The differences exhibited between the three types of microhabitat corroborated our expectations that the higher resource availability of organic microhabitat patches support higher diversity. Also, we contributed with more information about some of the microhabitat preferences of benthic aquatic invertebrates based on their functional feeding groups. However, despite these findings, we still highlight the importance of identifying at genera or species level to record the actual local diversity and better investigate these invertebrates' ecological traits, such as those microhabitat preferences.

Additionally, the Parque Nacional da Tijuca is a tourism hotspot of the city of Rio de Janeiro, with many visitors throughout the year. Aside from biodiversity conservation and scientific research, this category of conservation unit area allows the use of the space for entertainment. Thus, direct human contact may slowly compromise the integrity of these ecosystems. Therefore, it is necessary to conduct long-term monitoring of these streams to secure its importance in maintaining the local biodiversity.

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