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Diet of *Poecilia reticulata* Peters, 1959 in streams from Paraná River basin: influence of the urbanization

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ABSTRACT. This study aimed to assess the diet of *Poecilia reticulata* in rural (RS) and urban stream (US) and under seasonal influence. We hypothesized that rainfall have a strong negative impact on the diet of the species in the US, due to its abrupt effect on food resources; in RS this effect is less apparent. Both streams belong to Pirapó River sub-basin, Paraná River basin. Fishes were sampled bimonthly, between July 2007 and June 2008 in three sample sites along the longitudinal gradient of the streams, using electrofishing. According to the Feeding Index, in both streams the population consumed almost exclusively detritus associated with aquatic organisms (>95%), regardless of the hydrological period. The main taxa explored by fish were Simuliidae in RS and Chironomidae in US. The diet was significantly different between streams; however, the seasonal factor was not significant, showing that the results were partially consistent with the suggested proposal. In US stream the diet of the fish followed an ordinarily pattern found in urban environments. Thus, *P. reticulata* can be used as a tool to assess environmental conditions due to its ability to reach bioindicator organisms, such as Chironomidae species.

Keywords: benthivorous fish, feeding, macroinvertebrates, anthropic impact, Paraná River basin.

Dieta de *Poecilia reticulata* Peters, 1959 em riachos da bacia do rio Paraná: influência da urbanização

RESUMO. Este estudo objetivou investigar a dieta de *Poecilia reticulata*, em riacho rural (RR) e urbano (RU), sob influência sazonal. Foi hipotetizado que a chuva tem forte impacto negativo na dieta da espécie no RU, devido ao efeito abrupto sobre os recursos alimentares disponíveis, sendo este menos aparente em RR. Os riachos pertencem à sub-bacia hidrográfica do rio Pirapó, bacia do rio Paraná. Os peixes foram amostrados bimestralmente entre julho de 2007 e junho de 2008 em três pontos ao longo do gradiente longitudinal dos riachos, usando pesca elétrica. De acordo com o Índice alimentar, em ambos os riachos as populações consumiram quase que exclusivamente detrito associado com organismos aquáticos (>95%) independente do período hidrológico, sendo os principais: Simuliidae no RR e Chironomidae no RU. Houve diferença significativa na dieta entre os dois riachos, porém o fator sazonal não foi significativo, mostrando que os resultados foram parcialmente consistentes com a proposta sugerida. No RU a dieta mostrou um padrão comumente encontrado em ambientes urbanos. Dessa forma, *P. reticulata* pode ser usada como ferramenta para avaliar condições ambientais devido à sua habilidade em consumir organismos bioindicadores, tais como espécies de Chironomidae.

Palavras-chave: peixe bentívoro, alimentação, impacto antrópico, bacia do rio Paraná.

Introduction

The fast radial expansion of urban centers has had as consequence the habitat degradation, and it reflects upon natural resources and aquatic ecosystems (Lee, 2000; Fogaça, Gomes, & Higuti, 2013). Regarding streams in urban areas, the status of degradation is more accelerated, especially due to the small size of these water bodies, which make them more likely to sudden changes (Johnson & Arunachalam, 2012) than large rivers. A known factor that has been affecting severely these environments is the urbanization (Cunico, Ferreira, Agostinho, Beaumord, & Fernandes, 2012; Fogaça et al., 2013). This impact has as consequence an increase of the frequency and magnitude of water flows from heavy rains (Campana & Tucci, 2001; Zhou & Wang, 2007; Johnson & Arunachalam, 2012), a higher probability of erosion processes, changes in channel morphology which effects the composition of the riverbed (Wood & Armitage, 1997; Booth et al., 2004), and also an increased load of nutrients and pollutants concentration from surface leaching (Mainstone & Parr, 2002; Hatt, Fletcher, Walsh, & Taylor, 2004; Cunico et al., 2012).

The processes resulting from urbanization, even they occur isolated, are harmful to the different biological communities that inhabit streams, affecting everything from microorganisms to fishes, thereby undermining the dynamics of food webs. Considering the structure of biological communities, the urbanization causes an increase of tolerant species and a decrease of those sensitive, and leads to the dominance of a few species, culminating in less functionally diverse communities when compared with streams without an urban landscape in its surroundings (Allan, 2004; Cunico et al., 2012).

Seasonal floods are part of the natural disturbance regime of many streams, but according Coleman II, Miller and Mink (2011) the urbanization increases its frequency and magnitude. For benthivorous fish, shifts in the dynamics of the substrate (*i.e.* caused by rainfall) changes the macroinvertebrates community, affecting the diet of these species. Thus, studies regarding the trophic ecology of populations inhabiting these habitats can be an indirect way to assess impacts on aquatic environments (Tófoli, Alves, Higuti, Cunico, & Hahn, 2013).

The guppy, *Poecilia reticulata* Peters, 1859, (locally known as *guarú*) is a dominant non-native species in rural and urban streams (Oliveira & Bennemann, 2005; Cunico et al., 2012), regardless the degree of degradation and pollution (Cunico, Agostinho, & Latini, 2006). *Poecilia reticulata* is a bottom-dwelling species (especially in streams), since it feeds on algae, invertebrates and detritus (Dussalt & Kramer, 1981; Oliveira & Bennemann, 2005; Silva, Delariva, & Bonatto, 2012; Bonatto, Delariva, & Silva, 2012). The bottom of streams and the organisms associated with it are highly sensitive to changes, no matter of its origin (i.e. anthropic or seasonal). Thus, *P. reticulata* becomes an important tool for environmental assessment studies of streams, because it has ideal characteristics such as abundance, resistance and trophic dependence on benthic resources.

In this study we investigated the diet of *P. reticulata* in two streams (rural and urban) in the Pirapó River sub-basin. We hypothesized that rainfall have a strong negative impact on the diet of the species in the US, due to its abrupt effect on food resources; while in RS this effect will be less apparent. Thus, we expect that the diet of *P. reticulata* to be different temporally (rainy and dry) and spatially (rural and urban) in these streams.

Material and methods

This study was conducted in low-order streams (*sensu* Strahler, 1957), situated in two extremes: 0% urbanization (rural - RS; named Romeira - 1st order) and 100% urbanization (urban - US; named Nazaré - 2nd order). These data were obtained through high resolution satellite images (Quickbird panchromatic) using Spring 4·3.2 software (Camara, Souza, & Freitas, 1996). The streams are located in the Pirapó River sub-basin (507.60 ha in area), state of Paraná, Brazil (Figure 1), in the physiographic region termed the Terceiro Planalto Paranaense (Third Plateau of Paraná; 22°30’ - 23°30’ S and 51°15’ - 52°15’ W), with a drainage area of approximately 5.076 km^2. The regional climate assures abundant summer rains, with annual mean temperatures above 20°C (Queiroz, 2003). During the collection season, rainfall was more frequent in July, September and November/2007 (227.9 mm), while in February, April and June/2008 only 134.6 mm was recorded (Cunico et al., 2012).

Fishes were sampled bimonthly between July 2007 and June 2008 in three sample sites along of the longitudinal gradient of each stream. We used electrofishing equipment (1 KW, 220 V. 3-4 A portable AC generator) using a procedure of three successive catches with a constant unit of effort. All specimens were anesthetized (eugenol), killed, measured (standard length, cm) and weighed (total weight, g). Gastrointestinal contents were fixed in 10% formalin. Representative specimens of *P. reticulata* from each stream were deposited in the *Museu de Peixes, Nupélia, Universidade Estadual de Maringá,* Brazil (http://www.nupelia.uem.br/colecao).

Considering that this species do not have a defined stomach, the first third of the gastrointestinal tracts were opened and analyzed under stereoscopic and optical microscope. The identification of the resource and/or food item was made regarding to where the food was obtained (aquatic or terrestrial) and at lower taxonomic levels through identification keys.

To infer about the composition and quantity of the food consumed by the species, the frequency of occurrence (%F) and volume (%V) were used (Hyslop, 1980). The %F is a percentage of a food item in relation to all occurrences recorded in the gastric contents, whereas the %V represents the volume of an item in relation to the total volume of all items registered. The volume of each item was obtained in mm^3 using a graduated plate and subsequently transformed in ml.

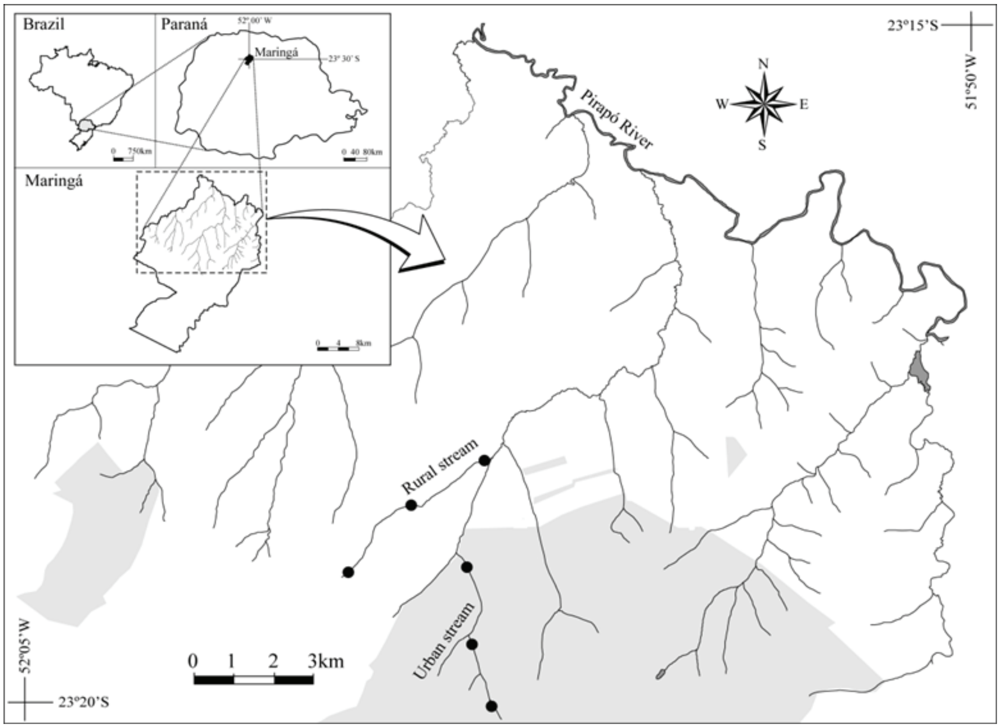

Figure 1. Study area with emphasis on the streams, rural and urban, Pirapó River sub-basin, State of Paraná, Brazil and the three samples location in each (●). Grey areas delimit urbanized areas.

Data were combined in the Feeding Index (%IAi) (Kawakami & Vazzoler, 1980), given by IAi= (F*i* x V*i*/ F*i* x V*i*) x 100, where *i* = food item; F = occurrence frequency (%) of the item *i*; V = volumetric frequency (%) of the item *i*.

In order to determine possible differences in the diet of fish between the hydrological period (rainy and dry) and the streams (rural and urban), we used the Permutational Multivariate Analysis of Variance (PERMANOVA). This is a non-parametric permutation-based analogue of analysis of variance (ANOVA) between two or more groups based on a distance measure (Anderson, 2001). The original matrix (the volume of each prey item in the stomach of each captured fish) was transformed to a dissimilarity matrix by the Bray-Curtis method. The analyses were carried out using the statistical computing software PRIMER 6 (Clarke & Gorley, 2006; Anderson, Gorley, & Clarke, 2008).

Results

We analyzed 189 *P. reticulata* gastrointestinal contents, being 84 from RS and 105 from US. In both streams the species consumed almost exclusively detritus and aquatic organisms associated with it (>95%), regardless of the hydrological period (Figure 2).

In RS the most consumed resources in the rainy period were detritus, followed by aquatic organisms, while in the dry period the population explored almost exclusively detritus. In US a similar pattern was observed in the rainy period, however aquatic organisms were most important than detritus. In the dry period, the fish consumed detritus and aquatic organisms in similar proportion. Terrestrial organisms were insignificant in the diet in US, but they were more expressive in RS (Figure 2).

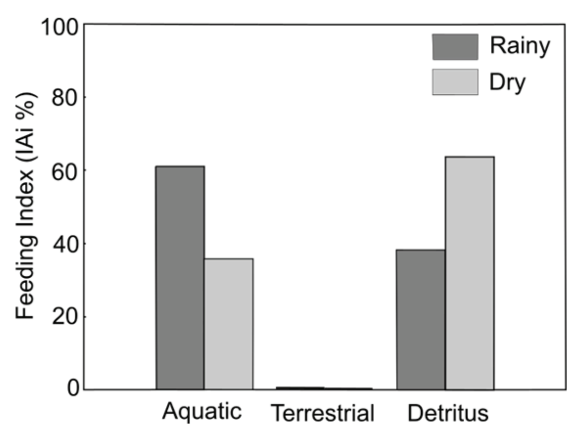

Figure 2. Food resources consumed by *Poecilia reticulata* Peters, 1859, in rural and urban streams, Pirapó River sub-basin, State of Paraná, Brazil, during the rainy and dry periods.

The most exploited organisms in the RS and US, during the rainy period were immature Dipteran (Simuliidae and Chironomidae, respectively), while in the dry period only Chironomidae had some relevance to the population of the US (Table 1). Thus, the diet was significantly different between the RS and US (Pseudo-F = 7.4014; p = 0.0002). When considering the hydrological period (*i.e.* rainy and dry), the analysis also showed significant differences (Pseudo-F = 5.8606; p = 0.0002). However, the interaction of both factors did not have significant difference, *i.e.* there is no difference between hydrological periods when considering each stream separately.

Table 1. Resources/food items consumed by *Poecilia reticulata* (values represent the Feeding Index, %IAi), in rural and urban streams, during the rainy and dry periods. L=larvae; P=pupae; Ni=nymph; A=adult; Na=naiad. Values in bold indicate predominance of the food.

Resources/items	Rural		Urban	
	Rainy	Dry	Rainy	Dry
Aquatic				
Detritus	**54.75**	**92.19**	**38.39**	**63.86**
Chironomidae (P+L)	4.58	1.96	**51.01**	**28.05**
Simuliidae (P+L)	**33.80**	3.11	0.38	0.54
Empididae (L)	0.13	0.02	0.12	0.01
Ceratopogonidae (L)	0.04	0.01		
Other Diptera (L+P)	0.15	0.10	1.72	0.29
Ephemeroptera (Na)	0.90	0.01	1.15	4.85
Coleoptera (L)		0.03	0.01	0.02
Trichoptera (L)	2.30	0.84	0.52	0.62
Odonata (Ni)			0.01	0.11
Plecoptera (L)	0.02	0.01		
Cladocera		0.01	0.13	
Copepoda	0.01	0.06		
Ostracoda	0.30	0.36		
Amphipoda	0.75	0.01		
Bacillariophyceae	0.23	0.29	5.99	1.32
Oedogoniophyceae			0.13	0.01
Chlorophyceae			0.03	0.01
Zygnemaphyceae			0.03	0.01
Fish scale	0.04	0.20	0.03	0.05
Terrestrial				
Insect remains	0.86	0.21	0.08	0.12
Trichoptera (A)	0.01	0.14		
Homoptera (A)			0.04	0.01
Hymenoptera (A)	0.75	0.01	0.01	0.05
Lepidoptera (A)			0.02	
Diptera (A)			0.06	0.06
Araneae	0.05	0.07		
Plant	0.33	0.36	0.17	0.01
No. of stomachs	84		105	

Discussion

The consumption of detritus and benthonic invertebrates reinforces the status of benthivorous fish of *P. reticulata*, such as verified by several authors (Dussalt & Kramer, 1981; Zandona et al., 2011; Silva et al., 2012; Bonatto et al., 2012). However, the presence of terrestrial organisms in the gastrointestinal contents indicates that this small fish can occasionally feed on the surface. Moreover, this species was also classified as planktivorous in polluted channels from Southwestern Nigeria (Lawal, Edokpayi, & Osibona, 2012).

The presence of distinct organisms in low quantity, and the predominance of detritus in the gastrointestinal contents in both streams during the two hydrological periods suggests that this species was little selective when foraging or that needed scour the bottom in search of food. This assumption can be supported by the study of Dussalt and Kramer (1981), in which they verified the feeding behavior of *P. reticulata* through mouth movements. The authors reported that during the foraging individuals performs "bites" very fast and the jaws are protracted to the maximum extension to cover a relatively large area of the substrate.

The high consumption of detritus, which is a resource of low nutritional value, can indicate a "compensatory feeding strategy" (Yeager, Layman, & Hammerschlag-Peyer, 2014) to *P. reticulata* in the studied streams. This strategy had been demonstrated for many taxa when environmental conditions limit the availability of high quality food resources (Taillon, Sauve, & Cote, 2006; Yeager et al., 2014). It is also possible that the species had developed mechanisms to extract the maximum quantity of nutrient present in the ingested detritus (e.g. bacteria, protozoans, particulate organic matter, etc.), once that this guppy species has already been successfully established in these environments. According to Cunico et al. (2012), *P. reticulata* was the most abundant species in rural and urban streams (in the same sub-basin of this study), representing respectively 97% to 100% of the fish fauna captured. Additionally, it is important to highlight that *Imparfinis mirini* (Haseman, 1911), a small bodied fish which also forage the substrate and were captured in the same sample sites of this study, consumed a very low proportion of detritus related to the benthonic organisms (Tófoli et al., 2013). It shows that the high quality food (i.e. benthonic macroinvertebrates) was available, and that *P. reticulata* has another strategy to acquire food. This hypothesis, however, is based on inference and as such must be further confirmed by observation of feeding behavior or carbon and nitrogen isotope analysis.

Significant variation in diet was detected only for the spatial factor, showing that these streams have different characteristics in the availability of food resources. One issue that might have contributed to this significant difference was the consumption of allochthonous food items in RS (e.g. insect remains and plants) being the insects probably catch in the drift and the plants on riverbanks. Thus, the assumption that the seasonality becomes less apparent in rural stream was not consistent with our expectations. Although impacted by agricultural activities in its surrounding areas, the RS shows a natural seasonal dynamic regarding the rainfall regime, since it is located in the countryside. It is important to mention that Simuliidae larvae were the second most consumed food item during the rainy season in RS. Moreover, it is noteworthy that immature representatives of this Diptera family live stuck on rocks or vegetation, filtering suspended particles in water (McCafferty, 1981). Thus, it is possible that *P. reticulata* has found some punctual patches containing this dipteran adhered to vegetation, which facilitated the capture, considering that these larvae were rare in the environment (Janet Higuti, unpublished data). On the other hand, Coleoptera was the most abundant organism on this stream (Tófoli et al., 2013), but not the most consumed by this population.

We did not found seasonal significant difference in the diet of fish from US. This occurs likely because the population fed on a more balanced manner, consuming detritus and Chironomidae in both hydrological periods. These results were contrary to our expectations that the US is subject to more pronounced changes during the rains, affecting food resources to fishes (Kikuchi & Uieda, 1998; Fogaça et al., 2013; Tófoli et al., 2013). The US is the most degraded as a function of receiving a large load of urban pollution, but in this environment, the species consumed a high amount of Chironomidae. Although the taxa in the gastrointestinal content identification was to family level, it is known that several Chironomidae genera and species are very resistant to hostile environment (Trivinho-Strixino & Strixino, 2005), being these genera probably the ones that colonize the US of this study. The amount of Chironomidae consumed (approximately 50% and 20% in the rainy and dry periods, respectively) coincides with its abundance in the environment in these hydrological periods (Janet Higuti, unpublished data) and it seems that the rainfall did not affect the permanence of these insects in this stream. Besides, some Chironomidae species are tolerant to poor environmental quality (Xu, Wang, & Pan, 2014). According Smith and Lamp (2008), physical and chemical changes in the environment promote reduction of less tolerant taxa and increase those more tolerant to pollution, which can be observed in the US in this study.

Conclusion

In short, the diet of *P. reticulata* was significantly different between streams, but the seasonality did not interfered on diet, as previously proposed. In US stream the diet was composed mainly by detritus and tolerant immature insects adapted to extreme conditions (*i.e.* Chironomidae), followed an ordinarily pattern found in urban environments. Thus, *P. reticulata* could be used as a tool to assess environmental conditions due to its ability to reach bioindicator organisms. Other studies should be conducted in order to add knowledge about the biology of this species, since it is an introduced species and has been dominating the fish fauna of many streams in South America.

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