Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v39i1.31899

Population structure of fishes from an urban stream

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ABSTRACT. The aim of this study was to identify the population structure of the ichthyofauna in an urban stream within an environmental protection area in southern Brazil. Quarterly samplings were conducted between October 2009 and August 2010. *Poecilia reticulata* was the most abundant species, followed by *Hypostomus ancistroides* and *Rhamdia quelen*. It was found a higher proportion of adults instead of juveniles from *P. reticulata* and *R. quelen* populations, while the opposite was recorded for *H. ancistroides*. Sex ratio of 1:1 was found for *H. ancistroides,* but differed significantly for *P. reticulata* and *R. quelen*. Females of *P. reticulata* and *R. quelen* reached higher length than males in the smaller and higher length-classes, while *H. ancistroides* females were only longer in initial length-classes. It was recorded higher occurrence of mature and maturing individuals. Mature individuals of *H. ancistroides* were sampled in October, and *P. reticulata* and *R. quelen* throughout the sampling period. Despite adverse environmental conditions, the occurrence of juveniles indicates reproductive activity for these species. Population structure studies in degraded systems are urgent, since life-history features of species may suffer changes due to anthropic impacts. Providing such information contributes to decision making and management of degraded systems.

Keywords: sex ratio, reproduction, population attributes.

Estrutura populacional de peixes em riacho urbano

RESUMO. O presente estudo teve por objetivo identificar a estrutura populacional de espécies de peixes em um riacho urbano inserido em uma área de proteção ambiental no sul do Brasil. As amostragens trimestrais ocorreram entre outubro de 2009 e agosto de 2010. *Poecilia reticulata* foi a espécie mais abundante, seguida de *Hypostomus ancistroides* e *Rhamdia quelen*. *Poecilia reticulata* e *R. quelen* tiveram maior proporção de adultos em relação aos juvenis e o oposto foi observado para *H. ancistroides*. A proporção sexual de 1:1 foi encontrada para *H. ancistroides*, enquanto diferiu significativamente para *P. reticulata* e *R. quelen*. As fêmeas de *P. reticulata* e *R. quelen* alcançaram comprimentos superiores aos machos nas classes de comprimento iniciais e finais, enquanto para *H. ancistroides* somente nas classes finais. Os estágios reprodutivos registrados com maior frequência foram de maduros e em maturação. Os exemplares maduros de *H. ancistroides* foram amostrados em outubro, e de *P. reticulata* e *R. quelen* em todo o período de coleta. As características populacionais das espécies estudadas indicam que, a despeito das condições ambientais adversas presentes neste ambiente, a ocorrência de juvenis reflete atividade reprodutiva para estas espécies. Estudos de estrutura populacional em ambientes degradados são cada vez mais urgentes, uma vez que características da história de vida das espécies podem sofrer modificações frente aos impactos antrópicos. A disponibilização dessas informações contribui para tomada de decisões e manejo de ambientes impactados.

Palavras-chave: proporção sexual, reprodução, atributos populacionais.

Introduction

Streams are small sized water bodies, of first to third order (Allan & Castillo, 2007), heterogeneous environments spatially limited and vulnerable in relation to their biological balance (Braga, Gomiero & Souza, 2009). Physical and temporal variability in these environments can influence the biotic patterns and processes, such as the life history of fish (Winemiller, Flecker, & Hoeinghaus, 2010). In general, species living in streams have small size and present a major contribution to the Neotropical biodiversity (Lowe-McConnell, 1999). However, the majority of the Brazilian streams, mainly the urban, are neglected (Magalhães, Casatti, & Vitule, 2011). In these environments, fish diversity tends to decrease, given the sensitivity of these organisms to

environmental disturbances, such as changes in water quality or the hydrological regime, typical of impacted streams (Cunico, Agostinho, & Latini, 2006). Urban streams are characterized by frequent and strong spates, which ultimately contribute to the homogenization of the stream bottom due to the carrying of structures such as branches and leaves (Ramirez, Pringle, & Wantzen, 2008).

Population structure of tropical stream fishes is diverse, revealing high interspecific variation (Winemiller, Agostinho, & Caramaschi, 2008). In spite, some parameters used in population structure studies shown established patterns for fish, like the sex ratio of 1:1 (Vazzoler, 1996), higher number of juveniles than adults (Nakatani et al., 2001), and females reaching greater lengths in relation to males, due to higher investment in reproductive strategies (Meffe, 1989), and it is expected that stream fishes may present diversified population structure features. Additionally, while considering the growing alterations imposed to urban streams that lead to instability of these environments (Cunico et al., 2006), it should be investigated and characterized the population structure of species that inhabit urban streams to provide a diagnosis of species biology under human interference.

The goal was to investigate the population structure for the resident fish fauna in an urban stream along a year period. It was conducted the evaluation of species abundance to provide estimates of their presence in the stream. It is expected higher proportion of juveniles than adults, higher proportion of females than males and small-length individuals due to the necessity of populations to cope with the highly variable urban stream dynamics.

Material and methods

Study area

The Mandacaru Stream (Figure 1) is part of the Pirapó River basin (Paraná River basin). It is a first order stream (Strahler, 1957), with approximately 7 km length and arises out in the urban area of Maringá city, Northern of Paraná State, Brazil. Most of the stream length presents scarce riparian vegetation or even the absence of it, with only a short stretch of 500 meters that drains an urban park (Cinquentenário Park). This urban park, despite being classified as an environmental protection area, presents discontinuities in vegetation, invasive plants and constant entry of people. The major impact is the accumulation of urban waste, which alters and affects negatively the microhabitats along the stream.

Limnological characterization of the urban streams showed good oxygen concentration (Table 1), possibly associated with the mechanical oxygenation provided by water velocity. On the other hand, high conductivity values provide evidence of anthropogenic particle and nutrients inputs to the system (Table 1). In a parallel study, conducted on the same location, Pera, Zanatta, Sacramento, Cionek, and Benedito (2013) showed, through a Principal Component Analysis, that no specific abiotic variable could significantly differentiate sampling sites features.

Table 1. Abiotic description of the Mandacaru Stream, Maringá, PR, Brazil. Dep. = depth; Veloc. = water velocity; DO = dissolved oxygen; Cond. = water conductivity; T water = water temperature.

Description	Abiotic variables (mean±SD)
Steep banks higher than 2.5 m, with bamboo groves, grass and sparse trees near the channel. Rocky substrate and straight channel, with small waterfalls, and backwaters areas - with high concentration of urban waste.	Dep. = 0.44±0.32 m Veloc. = 0.37±0.17 m s^{-1} DO = 7.46±0.65 mg L^{-1} Cond. = 241±44 μS cm^{-1} T water = 21.2±2.4°C

Samplings

Quarterly samples were taken between October 2009 and August 2010, at four sampling sites along the longitudinal gradient (Table I). At each sampling period and site analyzed, the following abiotic variables were taken: dissolved oxygen concentration (mg L^{-1}), electrical conductivity (μS cm^{-1}) and water temperature (°C) with a portable digital oximeter (YSI® 550A), portable digital potentiometer (Digimed®) and analogical thermometer, respectively. For physical characterization, depth of the sites was determined with a measuring tape and water velocity with a flowmeter (General Oceanics®).

The ichthyofauna were sampled during the daytime using electrofishing (Penczak, Agostinho, & Okada, 1981), a method that uses electrical discharges in water through submerged electrodes, and dip-net (0.5 mm mesh) coupled to a metal ring (Uieda & Castro, 1999; for more details about the apparatus see Alves, Tófoli, Novakowski, & Hahn, 2011). Both extremes of the sampling stretch were delimited with blocking nets (2.5 mm) to prevent fishes from escaping. Sampling was carried out in downstream to upstream direction with three consecutive efforts (Mazzoni & Lobón-Cerviá, 2000). The fish were anesthetized in 5% benzocaine and fixed in 10% formaldehyde, according to Animal Ethics Committee protocol (CEEA – UEM). Species were identified according to Graça & Pavanelli (2007). Vouchers were deposited in the Ichthyological Collection of NUPELIA (NUP 10580, NUP 10582 and NUP 10581). In the laboratory, each specimen was analyzed for total weight (Wt, g), standard length (Ls, mm), sex and gonadal development, based on the terminology proposed by Vazzoler (1996): immature, rest, maturation, mature and depleted.

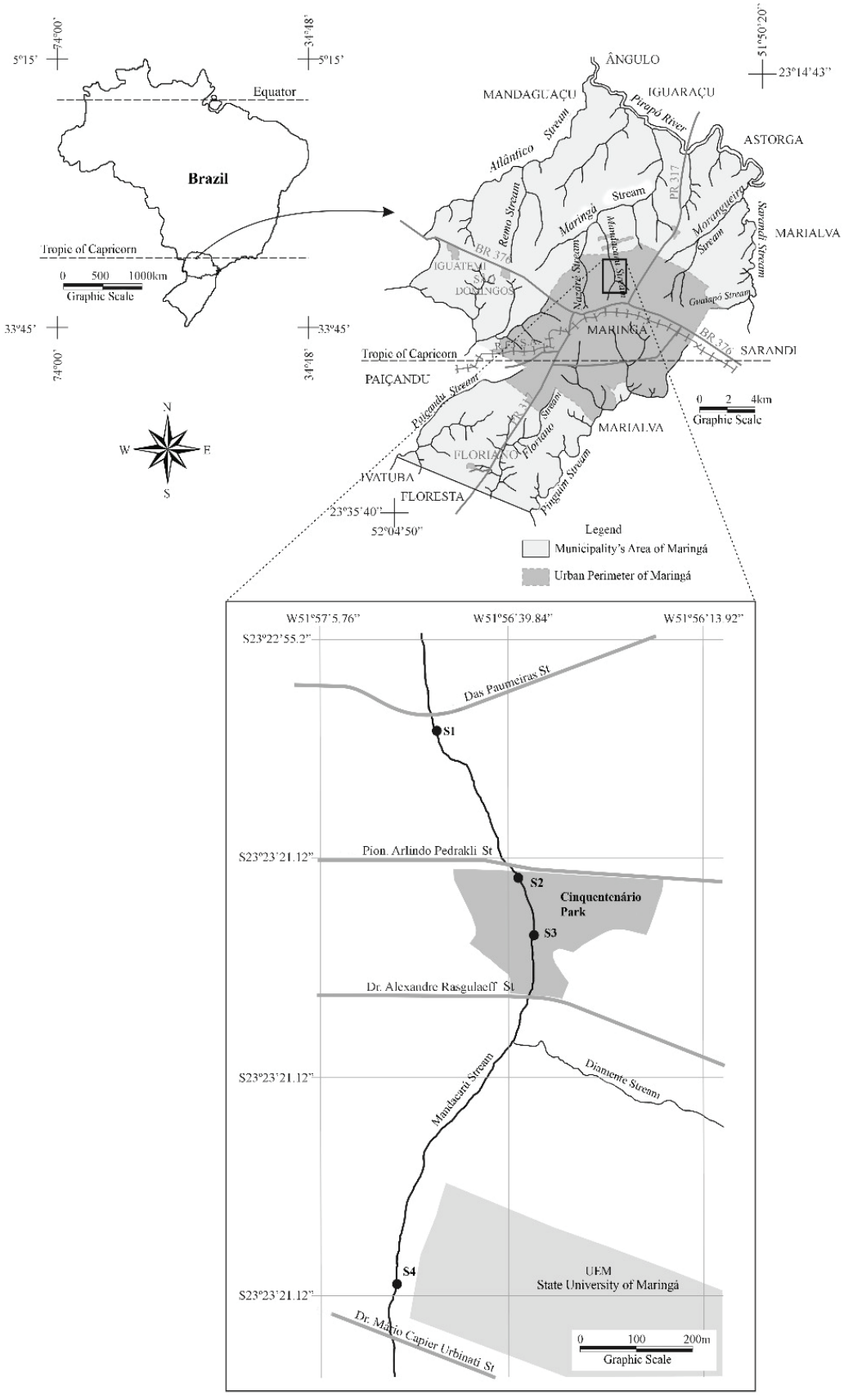

Figure 1. Sampled stretches along the Mandacaru Stream.

Data analysis

Species abundance was determined by absolute frequency, the total number of individuals, considering the standardized sampling effort. Juveniles and adults proportion was determined by identifying and quantifying the individuals of each species by sampling period.

Sex ratio was obtained by percentage between males and females, to detect significant differences from the expected proportion for fish of 1:1 (Vazzoler, 1996). For both analyses of proportion (juveniles-adults and sex ratio), significant differences were tested by G test (Zar, 1996).

The length structure of populations was analyzed for males and females separately by frequency distribution of individuals of each species into classes. The minimum length in which all the population (Cp_{100}) of a species is able to reproduce was determined by the frequency distribution of adults into standard length classes. These values were compared with the length of the smaller individual in reproduction (Ls minimum of adults), for each species analyzed (Vazzoler, 1996). Analyses were run per season to identify fluctuations in the population parameters along the reproductive cycle. The specimens with immature gonads were considered as juveniles, while the others gonadal stages were considered as adults (Vazzoler, 1996). The reproductive period was determined by analysis of the distribution of gonadal stages. The distribution of mature individuals was analyzed by sampling period.

All statistical analyses were carried out using Statistica 7.0®.

Results

Poecilia reticulata (Peters, 1859) was the most abundant species among the 3777 individuals caught, comprising about 90% of sampled specimens (3396 individuals), followed by *Hypostomus ancistroides* (Ihenring, 1911) (264 individuals or 7%) and *Rhamdia quelen* (Quoy & Gaimard, 1824) (117 individuals or 3%).

Juveniles of *H. ancistroides* were abundant in January 2010, and the adults in April 10 and August 10 (Table 2). For *R. quelen*, as well as for *P. reticulata*, the proportion of adults was higher than that of juveniles throughout the sampling period (Table 2). In April 10, it was recorded a higher frequency of females for all species (Table 2). In general, the expected sex ratio was 1:1 for *H. ancistroides* during the whole study period (Table 2). For *P. reticulata*, it was found significant differences in the sex ratio, in all sampling months, with a predominance of females (Table 2). For *R. quelen*, the males predominated in October 09, August 10 and January 10 (Table 2).

Table 2. Sex ratio and proportion of juveniles and adults of the species caught in the Mandacaru Stream, Maringá, Paraná, Brazil, between October 2009 and August 2010. G = G test for significant differences in relation to sex and age. ⋆ Significant at 0.05.

Species	Male		Female		G	Juvenile		Adult		G
	N	%	N	%		N	%	N	%	
October 09										
H. ancistroides	12	54.5	10	45.5	1.9	22	50.0	22	50.0	0.0
P. reticulata	313	47.9	341	52.1	28.6⋆	5	0.8	630	99.2	863.4⋆
R. quelen	20	74.1	7	25.9	9.2⋆	1	3.6	27	96.4	35.5⋆
January 10										
H. ancistroides	43	48.3	46	51.7	3.1	102	72.3	39	27.7	46.2⋆
P. reticulata	613	58.6	433	41.4	163.5⋆	32	4.2	737	95.8	959.0⋆
R. quelen	10	62.5	6	37.5	3.5	7	30.4	16	69.6	10.6⋆
April 10										
H. ancistroides	17	43.6	22	56.4	5.3⋆	8	19.5	33	80.5	31.4⋆
P. reticulata	392	42.2	537	57.8	155.8⋆	15	1.7	867	98.3	1172.2⋆
R. quelen	17	43.6	22	56.4	6.2⋆	7	18.4	31	81.6	30.4⋆
August 10										
H. ancistroides	1	33.3	2	66.7	1.2	1	4.0	24	96.0	4.2⋆
P. reticulata	438	45.7	520	54.3	85.4⋆	6	0.6	934	99.4	1282.8⋆
R. quelen	20	83.3	4	16.7	8.8⋆	1	4.0	24	96.0	31.3⋆

There was a higher incidence of *H. ancistroides* females in the smaller standard length classes, while in the larger classes males prevailed (Figure 2A). For *P. reticulata,* males prevailed in the inicial length classes, while females were more abundant in the intermediary classes (Figure 2B). There was a higher incidence of *R. quelen* females in the inicial and final classes, while males were abundant in the intermediary classes (Figure 2C).

Regarding the maturation stages, it was reported a higher prevalence of immature (juveniles) and maturing individuals for *H. ancistroides* (90%), while *P. reticulata* showed the highest percentage of specimens in the stages of mature and in maturation (97%). The higher occurrence of *R. quelen* individuals was in maturation (55%), mature (30%) and immature (15%) (Figure 3). All the mature individuals of *H. ancistroides* were caught in October, while for *P. reticulata* and *R. quelen* it was observed occurrence of mature individuals in the entire sampling period, with higher frequency in August and April (Figure 3).

Discussion

The high abundance of *P. reticulata* can be attributed to the reproductive strategies assumed by the species, as internal fertilization and development (Bisazza, Novarini, & Pilastro, 1996). These characteristics of the family Poecilidae increase the offspring viability, since it is protected of environmental oscillations and predators, providing better survival conditions (Mendonça & Andreata, 2001; Cunico, Ferreira, Agostinho, Beaumord &, Fernandes, 2012).

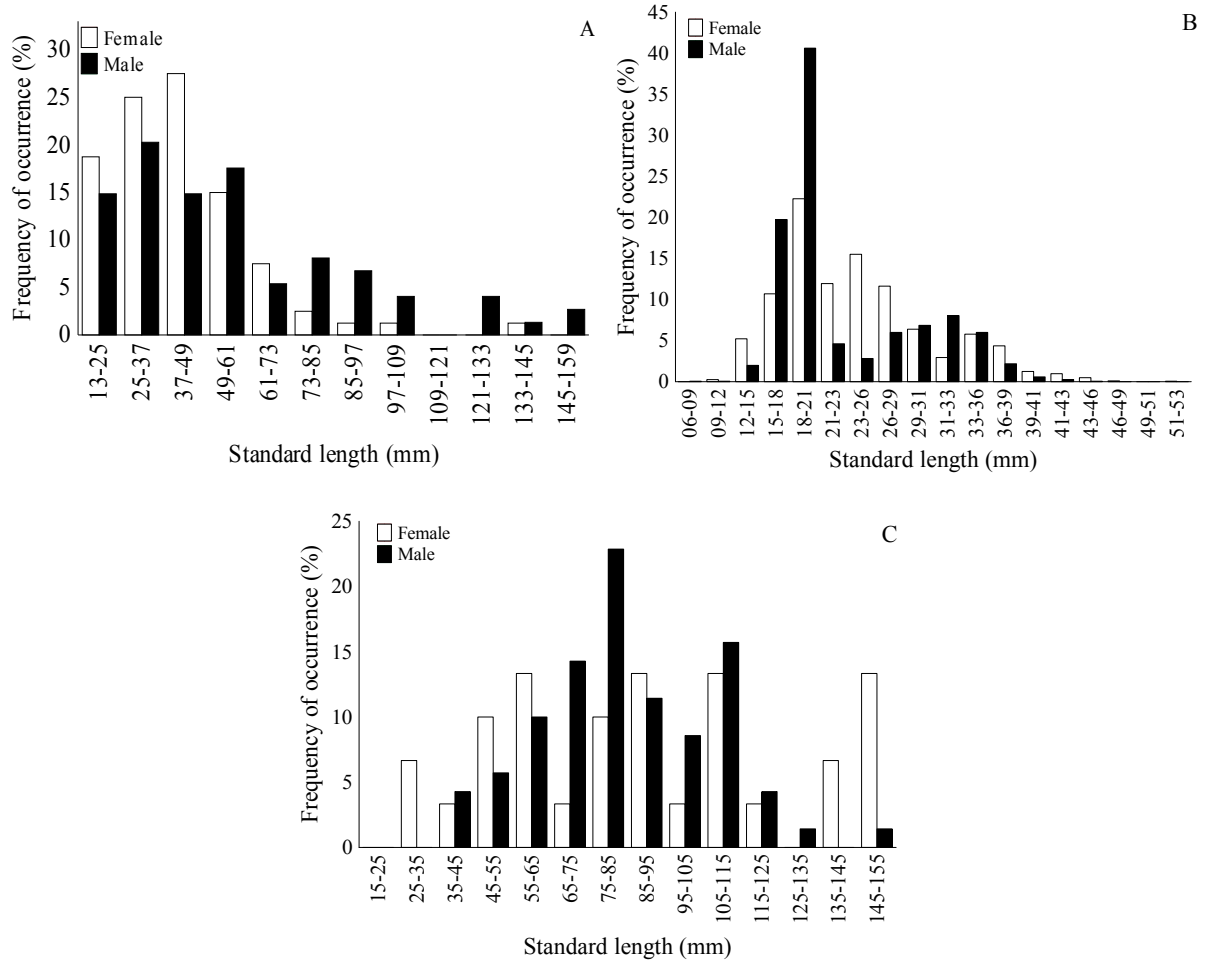

Figure 2. Percentage of individuals of *Hypostomus ancistroides* (A), *Poecilia reticulata* (B) and *Rhamdia quelen* (C) per standard length class and sex in the Mandacaru Stream, Maringá, PR, Brazil.

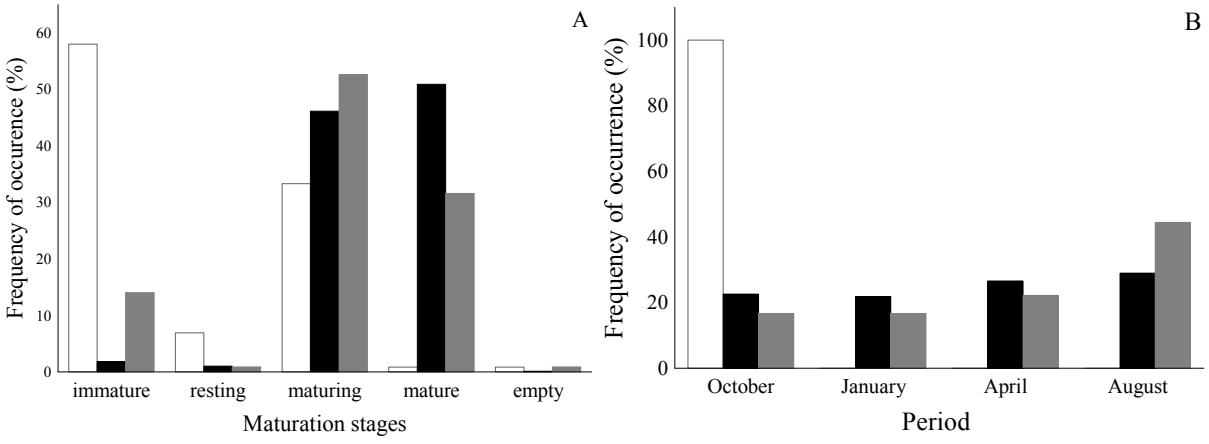

Figure 3. Frequency of occurrence of *Hypostomus ancistroides, Poecilia reticulata* and *Rhamdia quelen* per gonadal maturation stage (A), and frequency of occurrence of adults per period (reproductive activity) (B), in the Mandacaru Stream, Maringá, PR, Brazil. (white bars: *H. ancistroides*, gray bars: *P. reticulata*, black bars: *R. quelen*).

Species of *Poecilia* genus are considered tolerant, and usually present high abundance in impacted environments (Araújo, Peixoto, Pinto, & Teixeira, 2009). One of the adaptive feature *Poecilia* species presents is the consumption of a variety of food items, such as algae (Lawal, Edokpayi, & Osibona,

2012), detritus (Oliveira & Bennemann, 2005), organic matter and insect fragments (Rolla, Esteves, & Ávila-Da-Silva, 2009), which may represent an increase in fitness for the species, since it can rely on a great number of alimentary resources. The Mandacaru Stream is subjected to strong human interference that affects directly the fish populations, as verified by the abundance of *P. reticulata* (Cunico et al., 2012). According to Felipe & Súarez (2010), the increase in environmental disturbances reduces the number of sensitive species, which, in turn, alters the organization and dynamic of aquatic communities. Moreover, the success of *P. reticulata* in the Mandacaru Stream may be associated with its generalist habit, opportunism and tolerance to pollution and degraded environments (Pagotto, Veríssimo, Goulart, & Mise, 2012).

The adults were more abundant than the juveniles, distinct from the expected. The low representativeness of juveniles (with exception of *H. ancistroides*) can be associated with the ecological demands of this stage (Kipper, Bialetzki, & Santin, 2011), with more specific requirements regarding the habitat, feeding and behavior (Nakatani et al., 2001). Moreover, this result reflects the influence of stream deterioration on the populations, regarding the high mortality of juveniles that do not find a favorable environment for their development.

In the current study, *H. ancistroides* showed a sex ratio of 1:1 in almost all sampling periods, as also observed by Viana et al., (2008). For the other two species, in almost all samples, sex ratios were significantly different from 1:1, with higher abundance of females for *P. reticulata* and males for *R. quelen*. The predominance of females for *P. reticulata* can be attributed to habitat use (Banet, Svendsen, Eng, & Reznick, 2016). Almost all individuals of this species were mature and in maturation. According to Banet et al. (2016) the pregnancy in *P. reticulata* reduces the locomotion performance, which could affect the scape of predators. However, the same authors showed that in places with low-predation, females with high reproduction allocation would prefer habitats with the lowest water velocity. In this study, water velocity was fast, especially in the main channel (range: 0.19 - 0.50 cm s^{-1}), while backwater areas were also frequent and possibly sufficient to attain *P. reticulata* needs.

The sex ratio for *R. quelen* seems to be associated with the reproductive cycle, with males predominant in the second cycle (Reidel, Boscolo, Feiden, & Romagosa, 2010). It is noteworthy that the studied stream showed high accumulation of urban waste, and although the abiotic features presented acceptable values for the survival of aquatic organisms, local population reported the ongoing illegal dumping of domestic and industrial effluents, which represents a punctual and negative impact, not detected by the sampling, and causes increased chemical contamination (Yu et al. 2014), imbalance in reproductive functions (Tetreault, Bennett, Cheng, Servos, & McMaster, 2012) and external variations in limnological and hydrological conditions (Walsh, et al., 2005). Females showed higher standard lengths than males of *P. reticulata* and *R. quelen*, which characterizes the sexual dimorphism (Araujo & Garutti, 2002), described in the literature both for *P. reticulata* (Araújo et al., 2009) and for *R. quelen* (Gomiero & Braga, 2007). Although the Siluriformes species show females frequently larger than males (Gomiero & Braga, 2007), this characteristic was not registered for *H. ancistroides* in this study.

The studied species showed reproductive activity earlier when compared to other locations (Gomes, Golombieski, Gomes, & Baldisserotto, 2000; Gomiero, Souza, & Braga, 2007; Montag, Freitas, Raiol, & Silva, 2011). The limnological variables of the stream can have influenced the onset of the first sexual maturity of analyzed species. In natural environments with unstable hydrology, such as streams (Abilhoa, 2007), the premature length of first maturity can be a strategy to maximize the reproductive success (Mazzoni & Silva, 2006), since under adverse conditions (natural or anthropogenic) it is better to invest in reproduction than in somatic growth (Kusano, 1982). Then, strategies and tactics that ensure the survival and reproduction allow the permanence of the species in the environment (Zanatta, Cionek, & Benedito, 2013).

Mature individuals of *H. ancistroides* were verified only in October, which is consistent with the reproductive period (between October and January) characterized for the species (Viana et al., 2008). For *P. reticulata* and *R. quelen,* individuals in reproductive stages (in maturation and mature) were registered during the entire sampling period, which suggests prolonged reproductive activity for this species, as also evidenced by Gomiero et al. (2007) and Montag et al. (2011). As the Mandacaru Stream is characterized as a degraded environment subjected to high organic matter input, it is possible to infer that the biological characteristics of the three studied species indicate tolerance to environmental impacts (Cunico et al., 2006), thus, favoring the survival and reproduction due to the strategies of life adopted by the species.

Conclusion

The urban stream fish populations presented high abundance, prevalence of adults and females, and early reproductive activity, most probably related to the irregular dynamic of degraded systems. Studies on population biology in degraded environments are essential to promote a better understanding of population structure in response to human alterations, besides helping in decision-making and management of impacted environments. Conservation measures should be adopted in the surroundings of urban streams, for example: environmental education about the land and water use, prohibition of waste discharge inside the stream and reforestation of the riparian vegetation with native species.

Acknowledgements

To Nupélia for logistical support; to the colleagues of laboratories of Nupélia and especially those of Energetic Ecology; to Celso, Valdir, Francisco and Valdecir for the sampling support; to Dr. Claúdio Zawadzki for the equipment loan for field sampling.

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Received on May 12, 2016.
Accepted on October 3, 2016.