Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v35i4.16592

Does a small forested area contribute to enhance species richness and diversity of fish assemblage at an urban stream?

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ABSTRACT. Conservation Units (CU) aim to contribute to the balance between human and environmental demand, by protecting natural resources and biological communities. In this study we examined the differences in the attributes of the fish community in four stretches of an urban stream, two inside and two outside the CU, without vegetation cover, and tested the hypothesis that the presence of riparian vegetation is positively reflected in the attributes of fish fauna. Five species were caught, distributed into four orders and five families. Attributes like richness, abundance, dominance, Shannon-Wiener diversity, and evenness were estimated and significant differences were detected for continuous stretches considering stream flow direction. The first stretches (URBI and UCI) presented a lower diversity that increased gradually until the last stretch, and an inverse result was found for dominance. These changes occurred regardless the location of the stretch, in- or outside the CU. The importance of Conservation Units within urban areas is severely affected by the lack of continuity of forested areas, especially riparian vegetation. Therefore, we suggest the effective recovery of permanent preservation areas and of riparian vegetation in order to mitigate the impacts of human activities.

Keywords: fish fauna, conservation units, neotropical streams, pollution, urbanization.

Uma pequena área florestada contribui para aumentar a riqueza de espécies e diversidade da assembleia de peixes de um riacho urbano?

RESUMO. Unidades de Conservação (UC) contribuem para o equilíbrio entre demanda humana e ambiental, protegendo recursos naturais e as comunidades biológicas. Neste contexto, o presente estudo investigou a existência de diferenças nos atributos da comunidade Ictiíca em quatro trechos de um riacho urbano, dois localizados no interior de uma UC e dois externos a ela, sem cobertura vegetal, testando a hipótese de que áreas vegetadas aumentam a diversidade e riqueza de espécies e diminuem a dominância em assembleias de peixes. Foram capturadas cinco espécies, distribuídas em quatro ordens e cinco famílias. Atributos como riqueza, abundância, dominância, diversidade de Shannon-Wiener e equitabilidade foram calculados e diferenças estatísticas encontradas para trechos contínuos considerando o fluxo do riacho. Os primeiros trechos (URBI e UCI) apresentaram menor diversidade, que foi gradualmente aumentando até o último trecho. Resultado inverso observado para a dominância. Estas mudanças ocorreram independentemente da localização do trecho, interno ou externo à UC. Concluiu-se que a efetividade de Unidades de Conservação em áreas urbanas é seriamente prejudicada quando da ausência de continuidade de áreas florestadas, em especial da vegetação ciliar. Sugere-se, portanto, a efetiva restauração das áreas de preservação permanente e da vegetação ciliar a fim de minimizar os impactos da ação antrópica.

Palavras-chave: ictiofauna, unidades de conservação, riachos neotropicais, poluição, urbanização.

Introduction

Riparian zones consist of areas with natural vegetation cover (KLEPKA, 2011) responsible for protecting the water bodies from siltation, leaching, and soil erosion (BAXTER et al., 2004). They represent sites with continuous exchange between aquatic and terrestrial ecosystems (GREGORY et al., 1991) contributing to diversity and function of streams. The vegetation in these zones plays important roles (RODRIGUES; FILHO, 2001), both as the main source of energy to riverine food webs (HALL-JR. et al., 2000; HALL et al., 2001; MEYER; EDWARDS, 1990; VANNOTE et al., 1980), and in controlling the input of energy, organic and inorganic material into the aquatic ecosystem (PUSEY; ARTHINGTON, 2003). In this way, changes in these areas are prone to influence, direct or indirectly, the biological communities (GREGORY et al., 1991; TEIVE et al., 2008).

Ecosystems are rarely closed systems, and thus there is a flow of matter and energy that subsidizes and governs the functioning of another ecosystem (LAMBERTI; CHALONER, 2010), such as the biological relationships at the terrestrial-aquatic interface (BAXTER et al., 2004). The permanence of a Conservation Unit within a predominantly urban area may contribute to the balance between human and environmental demand (CAMPHORA, 2009) aiming to protect and preserve the regional biodiversity, working as a maintainer of environmental patterns close to the natural (MORALES et al., 2009), perpetuating thus the dynamics and minimizing the human impacts.

Importantly, the urbanization triggers several changes with direct and indirect consequences to aquatic environments. Among them, stands out the change on the hydrology of streams, in which the natural channel are replaced by concrete ones (GROFFMAN et al., 2003); the modification in the settlement of soil layers, caused by erosion and sedimentation processes in the catchment area; chemical changes in the water quality; alterations in the channel morphology (width and depth) and consequent modification in the composition of biological assemblages (WALSH et al., 2005).

The fish assemblage is compounded by some species sensitive to disturbances and others more adapted to environmental changes (PIET; JENNINGS, 2005), thus being suitable to infer about the local environmental situation. Other reasons to use fish as environmental bioindicators are the multiple trophic guilds within this group, relative easiness to identify, presence in all aquatic environments, including the most polluted ones, and the public can easily identify high fish mortality or morphological changes in their living area.

Thus, researches that bring together abiotic and biotic factors over spatial scales may produce more accurate results about the fluctuations in the richness of populations (LIMA et al., 2000), and detect changes in the complex structure of the communities (PIET; JENNINGS, 2005). This study aimed to analyze if the attributes of fish community are different between stretches of an urban stream with and without vegetation cover, in order to investigate the punctual effect of a conservation unit within an urban area, and propose measures to improve its function. For this, we hypothesized that vegetated areas increase diversity and species richness and decrease dominance of fish assemblages.

Material and methods

Study area

The Mandacarú Stream is a first order stream (STRAHLER, 1957), with approximately 7 km in length. It drains the urban area of the municipality of Maringá, Northern Paraná State, and flows about 500 meters inside the Cinqüentenário Park Conservation Unit (CU) (coordinates 23°23’30.7’’S to 51°56’34.4’’W and 23°23’25.3’’S to 51°56’36.7’’W). This CU has 18-ha area.

On the limits of the Park there are two high barriers made up by the construction of two urban streets (personal observation). It is believed that these barriers may isolate the stretches that drain the interior of the Park.

This stream is located on the Northern slope of the Pirapó river basin. Part of the studied stretch is channeled, but there are backwater areas alternated with rapids and small waterfalls, with turbulent waters.

Samplings were undertaken in the stretches upstream (URB I) and downstream (URB II) outside the CU, and in the stretches UC I and UC II, inside the CU (Figure 1). The approximate distance between the stretches URBI and UCI is 1,150 m, between UC I and UCII, 250 m, between UC II and URB II, 670 m.

Each stretch was categorized based on physical aspects like substrate characterization, banks, riparian and aquatic vegetation and presence of human activity (visual inspection), by assigning percentage values in relation to the sampled stretch. Also, we measured the width and length (m) using a measuring tape, depth, using graduated poles (cm), and area (m^2), by multiplying width by length. The flow velocity ($m\ s^{-1}$) was measured with a flow meter (General Oceanics), the water temperature (ºC) and dissolved oxygen with a digital portable oximeter (YSI), and conductivity and pH, with digital portable potentiometers (Digimed, model DM-3 and DM-2, respectively). The water level of the stream was determined by obtaining the volume in m^3 in each sampled stretch.

The stretch URB I (23º24’00.1”S and 51º56’51.0”W) refers to the first urban stretch upstream of CU. There is bamboo, grass, trees adjacent to the channel that has steep banks with height above 2.5 m. The channel presents rocky substrate and its width at the beginning of this stretch is narrow, straight and made up by small waterfalls. The lower section of this stretch has a backwater about 5-fold larger than the rest of the sampled stretch. The upper section has rapid and turbulent flow, and the lower section, slow flow and greater depth. The average water velocity is 0.19 $m\ s^{-1}$.

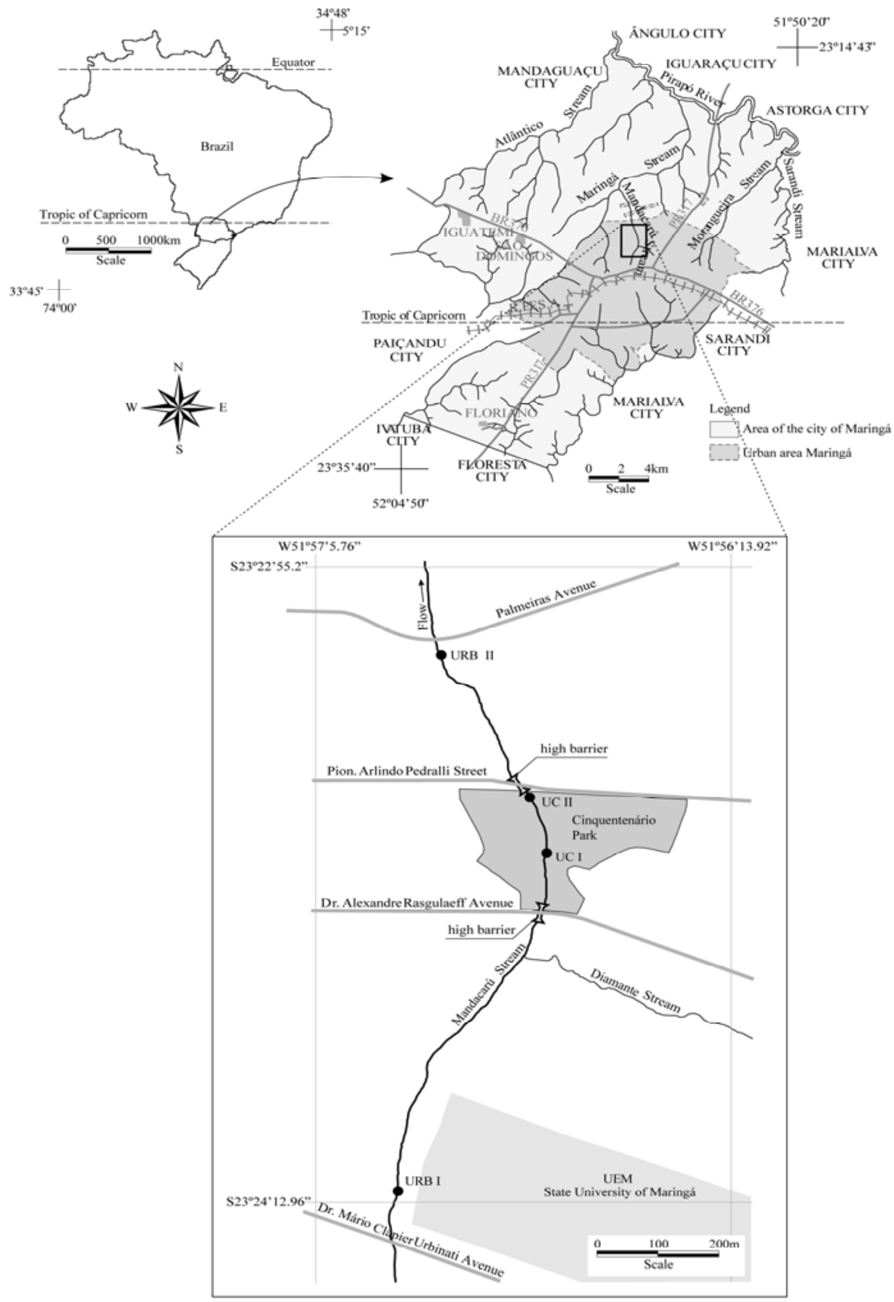

Figure 1. Location of the sampled stretches on Mandacarú Stream. Two of them drain areas outer of the Cinquentenário Park – URB I and URB II, and two drain inner areas UC I and UC II, in Maringá-Paraná State.

The stretch UC I (23°23'25.3"S and 51°56'36.7"W) is inside the CU, has abundant riparian vegetation, mainly consisting of shrub and grass alternately, and somewhat spaced in relation to the channel. The banks slope is obtuse and the substrate has a large proportion of gravel and boulders. The non-meandering channel is wide, and the average water velocity is 0.50 m s^{-1}.

Also inside the CU is the stretch UC II (23°23'30.7"S and 51°56'34.4"W). At this site, there are trees and shrubs sparsely distributed, and abundant grass, 1 m distant from the channel, on average. This is a little meandering and narrow stretch, with 38cm depth. The flow is slower (0.40 m s^{-1}) than in stretch UC I. Highlights the abundant waste in this stretch, reaching areas above 3m due to heavy rainfall episodes.

The stretch URB II (23°23'04.2"S and 51°56'47.6"W) is the lower section of the stream. The vegetation is compounded by shrub and grass adjacent to the channel, which has low-steep banks easy to access. There is a rocky-bottom backwater, with little meandering course. The average water velocity is 0.42 m s^{-1}.

Samplings

Samplings were performed every three months, between October 2009 and August 2010. Fish were sampled using electrofishing (PENCZAK et al., 1981), and dip nets (0.5 mm mesh size) with three consecutive efforts, by the morning. The voltage was adjusted according to the water conductivity, in order to maximize the capture efficiency and minimize the mortality of aquatic organisms (KIMMEL; ARGENT, 2006).

The fish were anesthetized with benzocaine 5% and then fixed in 10% formaldehyde, obeying the protocol submitted to the Animal Ethics Committee (CEEA - UEM). The animals were placed in plastic bags, properly labeled with information such as local, effort and collection date. Samples were taken to the Laboratory of Energetic Ecology of the Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura (Nupélia) of the State University of Maringá, where they had been systematically identified according to Graça and Pavanelli (2007). Voucher specimens were deposited in the Ichthyological Collection of Nupélia (Table 1).

Table 1. Fish species sampled in the Mandacarú Stream, Maringá, Paraná State, description author, catalog number, absolute abundance, and relative percentage per stretch.

Classificação	Nº Tombo	URB I		UC I		UC II		URB II		Total
Cyprinodontiformes		N	%	N	%	N	%	N	%	
Poeciliidae										
Poecilia reticulata Peters, 1859	NUP 10580	1700	50.1	1201	35.4	37	1.1	457	13.5	3395
Siluriformes										
Heptapteridae										
Rhamdia quelen (Quoy & Gaimard, 1824)	NUP 10582	51	45.9	17	15.3	2	1.8	41	36.9	111
Loricariidae										
Hypostomus ancistroides (Ihenring, 1911)	NUP 10581	11	4.2	71	26.8	38	14.3	145	54.7	265
Synbranchiformes										
Synbranchidae										
Synbranchus marmoratus Bloch, 1975	NUP 10583	0	0.0	0	0.0	1	50.0	1	50.0	2
Gymnotiformes										
Gymnotidae										
Gymnotus inaequilabiatus (Valenciennes, 1839)	NUP 10593	0	0.0	1	50.0	0	0,0	1	50.0	2
Total		1762	46.7	1290	34.2	78	2.1	645	17.1	3775

Data analysis

The data of the consecutive efforts were pooled for the statistical analyses. To test possible differences in community attributes (richness, dominance, Shannon-Wiener diversity and evenness) between the sampled stretches, a one-way ANOVA was performed.

The richness was considered as the number of species in the sampling unit. Shannon-Wiener diversity was obtained by the expression: H'= - ∑ (pi) (log pi), where H' = Shannon-Wiener diversity index; pi = proportion of individuals found in a given species, and log pi = base 10 logarithm of pi (MAGURRAN, 2004).

The dominance corresponded to the numerical superiority of one or two species in relation to the others (RYAN et al., 1995), calculated through the formula:

$$D = \sum (n\,i / n)^2$$

where:

n_i is the number of individuals of the taxon *i*.

In turn, the evenness (E) is the ratio between the diversity index and the maximum expected. Thus: $E = H'/H'_{Max}$.

Aiming to summarize the physical and limnological variables in the four sampled stretches, seeking to distinguish the environmental conditions between the different stretches, a principal component analysis (PCA) was employed. These analyses were performed using the software Statistica 7.0®.

Results

Five species were identified among the 3,775 sampled individuals (Table 1). The stretches with higher abundance were URBI and UCI, respectively, due to the expressive dominance of *Poecilia reticulata* (Table 1).

Significant differences were detected for the values of Shannon-Wiener diversity ($F = 31.70$; $p < 0.0100$) between the stretches URB I/UC I and UC II/URB II, with the highest values observed in the stretches UC II and URB II. In relation to the dominance, the stretches URB I/UC I and UC II/URB II were statistically different ($F = 24.10$; $p = 0.0000$), being the greatest dominances verified for URB I and UC I (Figure 2A and B). Still, the stretches were also significantly distinct as for the evenness ($F = 4.85$; $p = 0.0240$). Differences between the fish fauna attributes were found between continuous stretches, that is, the first two (considering the flow direction) had higher dominance, whereas the last two, higher diversity and evenness (Figure 2).

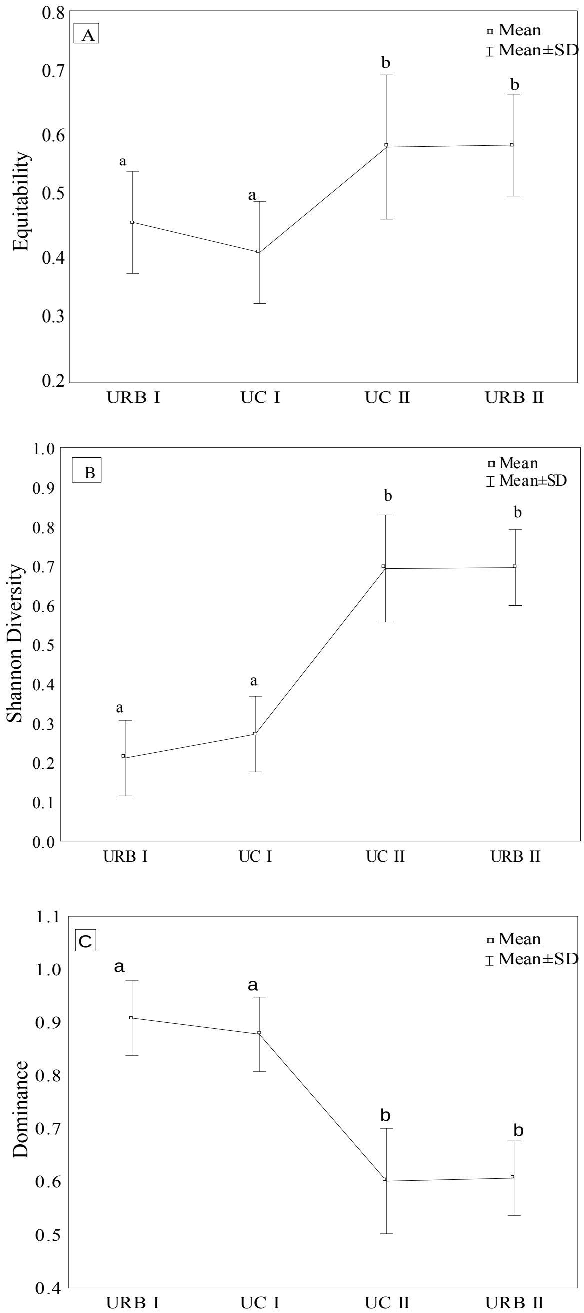

Figure 2. Mean values and Standard Deviation (SD) of (A) Evenness, (B) Shannon diversity and (C) Dominance per sampled stretch.

The Principal Component Analysis (PCA) explained 80% of total data variability, retaining the first three axes. However, no-clear distinction could be observed among the abiotic factors in the stretches in- and outside the Park. Although with slight distinction, in relation to the axis 1, the factors relative to area and volume had negative influence, while rapids and canopy cover had positive influence on this axis. The variables volume and area have influenced positively and negatively the axis 2, respectively. For the axis 3, area and conductivity were the variables positive- and negatively related with this axis, respectively.

The arrangement of the axes 2 and 3 in the Figure 3 evidenced a slight separation between the stretches in- and outside the CU, with the inner stretches more associated with the area, and the outer, with the volume.

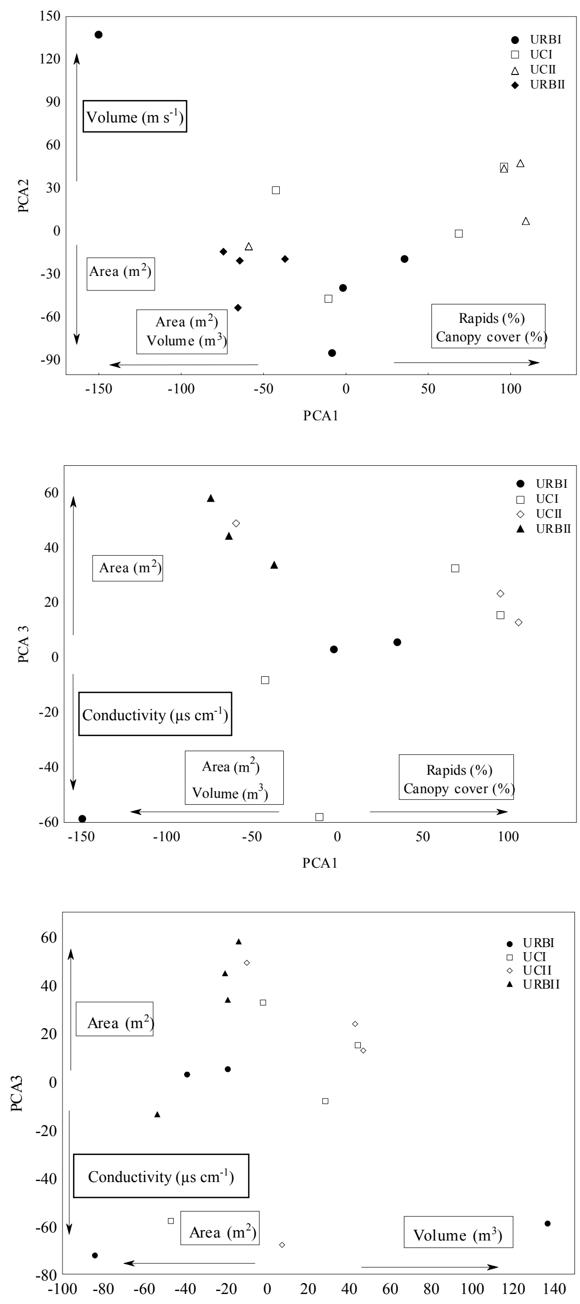

Figure 3. Principal Component Analysis performed with abiotic data of the stretches of Mandacarú Stream during the study period.

Discussion

Fragmentation of natural habitats derives from the human activity such as the developing of urban centers, forming isolated vegetated patches within an non-forested landscape, especially those located on the banks of streams that drain these areas (SIVIERO; SETZ, 2011). The frequent constructions throughout these areas reduce the infiltration rate of the soil and increase the discharge of waste and sewage in the streams (KLEPKA, 2011). The urbanization affects negatively the environmental conditions of the streams and leads to changes in their functioning (WALSH et al., 2005). Researches point out the consequences of these changes, such as the increased water flow, increased level of nutrients and contaminants, change in morphology and stability of the channel, reduced biotic richness with enhanced dominance of tolerant species (MEYER et al., 2005; PAUL; MEYER, 2001; WALSH et al., 2001, 2005).

The maintenance of forested areas amidst urban landscapes is a necessary alternative to environmental conservation, aiming to mitigate negative human impacts on animal and plant species (SANTIAGO et al., 2007). For streams, the buffering effect displayed by riparian vegetation is essential, considering its role on the maintenance of banks structure, filtration of pollutants, and energy supply to the environment (CASATTI et al., 2001; KRUPEK; FELSKI, 2006; VIGIAK et al., 2007).

The stream studied has about 7 km length, of which only 500 meters are inside the CU, where the riparian vegetation has a width above 30 meters on both sides. In the other stretches, this vegetation does not reach 20 meters width on the banks, evidencing the neglect of maintenance of the vegetation at these places. The lack of significant differences in fish fauna attributes, and in the abiotic variables, evidenced by the PCA, in the stretches in- and outside the CU, was possibly due to the low buffering provided by the small forested area in large adjacent deforested areas, and therefore leading to discard the tested hypothesis. Moreover, we should also consider that the Mandacarú Stream is directly contaminated by sewage treatment and carry materials (plastic, paper, and waste in general) which can be observed throughout its course (KLEPKA, 2011).

The differences along the longitudinal gradient may be possibly influenced by the addition of two individuals of *Synbranchus marmoratus* and two *Gymnotus inaequilabiatus* in the last stretches, responsible for the increased diversity and evenness, even with a low number of individuals. Along with this addition, the number of exemplars of *P. reticulata* had reduced on the last two stretches, which directly affected the increase in evenness and diversity at these locations.

Importantly, *Poecilia reticulata*, an opportunistic species, is able to survive in contaminated water (ARAÚJO et al., 2009; OLIVEIRA; BENNEMANN, 2005), and was dominant in all sampled stretches. Besides that, it has greater tolerance to environmental conditions and its occurrence is associated with environmental degradation (CASATTI et al., 2006). Studies in water bodies that drain urban areas have identified the numerical predominance of species tolerant to altered environmental conditions (CUNICO et al., 2006), such as the accumulation of plastics, clothes, and waste in general (NEVES; TUCCI, 2008), evidences of erosion on the banks of the water bodies (LUCAS; CUNHA, 2007) and disruption of the water natural flow (DORNELLAS; CAMPOS, 2008).

Conclusion

Regarding the changes to the ecosystem balance, and especially to fish community, we concluded that the effectiveness of Conservation Units in urban areas is severely impaired given the lack of continuity of forested areas, mainly of riparian vegetation. Small forested areas are not enough to minimize the impacts of urban areas along the catchment area of streams. Therefore it is suggested the effective recovery of permanent preservation areas and of riparian vegetation throughout the extension of the water body in order to keep the environmental integrity through ongoing biomonitoring of the patterns of water quality and of biological communities.

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Received on March 30, 2012.
Accepted on November 28, 2012.