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Environmental assessment in tropical streams by using abundance-biomass curves and W index in fish assemblages

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ABSTRACT. We investigated the fish fauna response to different environmental conditions of urban (three) and rural (seven) streams through biomass/abundance curves and W index of environmental stress. Negative values of W indicate some level of stress, while positive values suggest environments with lower stress. Dissolved oxygen, marginal erosion (both left and right margins), mesohabitat diversity, and percentage of canopy cover were measured to characterize the 10 streams analysed around Maringá city, Southern Brazil. Fish were sampled by electrofishing, then identified and weighed. Results showed negative values of W to the urban streams and positive to the rural. Urban streams showed a tendency to have assemblages of fish with lower biomass and greater abundance (*r*-strategists).

KEYWORDS. Neotropical region, biotic indices, stream ecology, biodiversity.

RESUMO. Avaliação ambiental em riachos tropicais utilizando curvas de biomassa-abundância e índice W em assembleias de peixes. A resposta da fauna de peixes a diferentes condições ambientais foi verificada em riachos urbanos (três) e rurais (sete), por meio de curvas de abundância/biomassa e o índice W de estresse ambiental. Valores negativos de W indicam níveis consideráveis de estresse, enquanto valores positivos sugerem ambientes com menos estresse. Para caracterizar os 10 riachos no sudeste do Brasil foram medidos oxigênio dissolvido, erosão das margens (direita e esquerda), diversidade de mesohabitats, e porcentagem de dossel. Os peixes foram amostrados por meio de pesca elétrica, identificados e pesados. Os resultados mostraram valores negativos de W para os riachos urbanos e positivos para os rurais. Os riachos urbanos mostraram uma tendência a ter assembléias de peixes com menor biomassa e maior abundância (*r*-estrategistas).

PALAVRAS-CHAVE. Região Neotropical, índices bióticos, ecologia de riachos, biodiversidade.

Despite its ecological and socioeconomic relevance, tropical streams have been very impacted by human activities. These impacts have modified physical, chemical and biotic characteristics of these aquatic ecosystems, which affect the species' abundance and composition in these environments (Malmqvist & Rundle, 2002; Englert *et al.*, 2015) and commonly result from both urban and rural practices. In a general classification, studies have separated streams in urban and rural, according to the kinds of impacts, and activities in areas surrounding the water bodies (Kühl *et al.*, 2010; Cunico *et al.*, 2012). Urban streams are often reported as affected by increasing impermeable surface, which boost the frequency and magnitude of floods (Campana & Tucci, 2001), as well as by industrial and domestic sewage, that changes the water quality (Pinto *et al.*, 2006; Cunico *et al.*, 2006; Fialho *et al.*, 2008). Whereas the rural streams are commonly affected by deforestation, agricultural wastes (including pesticides and fertilizers), and pasture (Casatti *et al.*, 2006; Kühl *et al.*, 2010; Casatti *et al.*, 2012; Teresa *et al.*, 2015). When compared with one another, urban streams are generally more impacted than rural.

All anthropic impacts mentioned above can affect not only species abundance and composition, but also trophic structure (food webs), functional structure and vulnerability to introduced species (Cunico *et al.*, 2011; Casatti *et al.*, 2015; Ceneviva-Bastos *et al.*, 2017), causing therefore disturbance to the ecosystems. Understanding the changes in stream communities caused by humans is a key role to mitigate negative impacts and increase the management efficiency and to prevent biodiversity loss. Biological indices have been used to assess the environmental quality of tropical streams. Some indices range from biological entities as taxonomic diversity (*e.g.* Shannon index), functional diversity (*e.g.* trophic positions of species and ecomorphological aspects), species composition (*e.g.* native vs nonnative species), biomass, proportion of tolerant species and a set of physical and chemical variables (Bozzetti & Schulz, 2004; Terra *et al.*, 2013). In streams, fish and invertebrates are the most used organism in indices of environmental quality, such as the biotic integrity index, and the EPT, respectively (Kerans & Karr, 1994; Bozzeti & Schulz, 2004).

In a range of methods, the abundance-biomass curves (ABC) comprise a widely used method to assess the response of the organism to environmental alterations (Warwick, 1986). Initially proposed for invertebrates, studies have used this method to assess response of fish assemblages to environmental stressors (Pinto *et al*., 2006; Sá-Oliveira *et al*., 2014; Santos *et al*., 2015). Based on K-dominance curves, the ABC method compares the percentage of cumulative curves of abundance and biomass of each assemblage in a scatterplot (Magurran, 2004). This method assumes that in assemblages under non-significant impacts, the *K*-strategist species establish over time, and contribute with a major part of the biomass. On the other hand, in assemblages under significant impacts, there is a tendency for selection of *r*-strategist species that presents rapid development and lower biomass.

The quantitative representation of the ABC curve is the W index (Warwick & Clarke, 1994) which values vary from −1 to 1. Negative values represent abundance curve overlapped with biomass curve, and positive values indicate the biomass curve above abundance curve. Thus, negative W suggests stressed condition and saturation by lower biomass species, while positive W indicates a lower environmental stress and species with larger biomass (Warwick & Clarke, 1994).

In this context, the abundance-biomass curves were used here to investigate the fish assemblage response to urban and rural impacts on tropical streams. We expected urban streams to be more impacted than rural and thus present negatives values of the W index, *i.e.*, a more environmentally stressed fish fauna.

MATERIAL AND METHODS

The fieldworks were conducted in ten streams (second to third order) from the Pirapó River basin (22°30'S/ 51°15'W; 23°30'S/ 52°15'W), in the Maringá City, Paraná state, Brazil (Fig. 1). Urban streams were Mandacaru, Miosótis and Maringá Stream. Rural streams were: Queçaba, Lombo, Remo, Granada, Romeira, Roseira and Zaúna. The classification of rural and urban followed Kühl *et al*. (2010) and Cunico *et al.* (2012), which used satellite images (Landsat 5 TM). Urban streams presented more than 10% of impermeable surface, calculated using software ArcGIS 9.3 and ENVI 4.5 (Cunico *et al.*, 2012). Unfortunately, reference sites could not be used because all water bodies in the region are under impact from urban or rural influence, as addressed by Kühl *et al*. (2010).

Fish were sampled in May 2011 by electrofishing (AC portable generator 1KW, 220V, 3-4A), that was carried out along 50 m stretch in each stream. The specimens were fixed in 4% formalin and preserved in 70% alcohol, then identified (following Graça & Pavanelli, 2007), measured, and weighed.

Measurements at five transects (10 meters of distance) along the sampled stretches were performed to the environmental characterization of each stream. Oxygen saturation (percentage of dissolved oxygen) and conductivity (µm/L) were obtained using Yellow Springs Inc. equipment

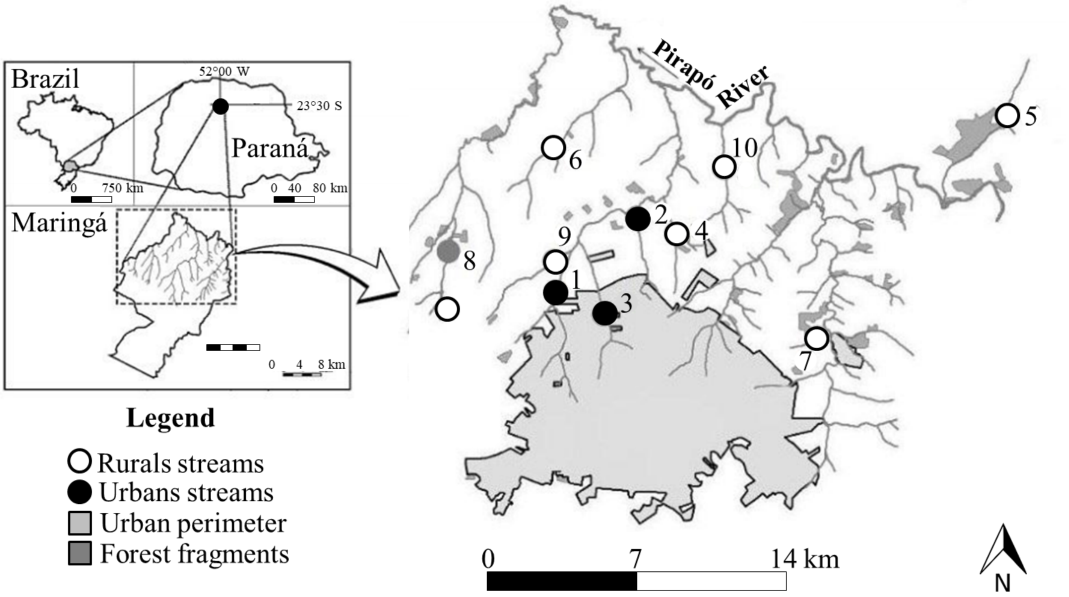

Fig. 1. Streams sampled in Maringá (PR), South Brazil: 1, Ribeirão Maringá (51°58'8.00"W/ 23°22'28.09"S); 2, Miosótis (51°55'52.29"W/23°20'39.82"S); 3, Mandacaru (51°56'49.16"W/ 23°23'5.01"S); 4, Roseira (51°54'50.45"W/ 23°21'2.26"S); 5, Granada (51°45'39.95"W/ 23°18'5.26"S); 6, Lombo (51°58'7.07"W/ 23°18'49.53"S); 7, Zaúna (51°50'55.11"W/ 23°23'41.99"S); 8, Remo (52°1'0.75"W/ 23°21'27.09"S); 9, Romeira (51°58'9.55"W/ 23°21'40.40"S); 10, Água Queçaba (51°53'28.78"W/ 23°19'22.24"S). White circles represent rural streams; black circles represent urban streams; gray area is the urban perimeter; and dark gray are forest fragments.

(models 95 and 30). Percentage of canopy cover and margin erosion (right and left) were estimated by visual inspections. Flooded vegetation was quantified by the number of filled 25 cm^2 quadrants in a 1 m^2 plastic square. Lastly, we defined pools, rapids, and riffles as categories of mesohabitat, then we quantified the diversity of mesohabitats in 1, 2, and 3 levels by the number of mesohabitat's categories present in each transect by visual inspection. With exception of mesohabitat diversity, an average of the parameters was performed to characterize each stream.

Using these environmental variables, a Principal Coordinate Analysis (PCoA) was performed on normalized data to show the environmental dissimilarities among the streams. The PCoA was conducted using a dissimilarity matrix calculated by the Gower distance, which can handle with data from different natures (Pavoine *et al.*, 2009), considering that mesohabitat diversity was an ordinal variable, and the others were quantitative. The environmental variables more associated with each PCoA ordination axis were identified by examining the correlation (Spearman rank correlation). The axes 1 and 2 from this environmental PCoA were Spearman rank correlated with species abundance (Orsi *et al.*, 2018) and biomass to investigate their association with the environmental characteristics of the streams.

The abundance and biomass were used to quantify the environmental stress according to the ABC method and the W stress index (Warwick & Clarke, 1994). The efficiency of W in describe the environmental stress was analyzed through a Spearman correlation between W and the scores from PCoA 1.

All the statistical analyses, the ABC curves drawing, and the W calculation were performed in the PRIMER-E software (Clarke & Gorley, 2006), and the PCoA was performed using the R software (R Core Team, 2008).

RESULTS

We captured a total of 890 individuals of 28 species, belonging to six orders and ten families (Tab. I). In urban streams, we collected 413 individuals of 11 species and in rural streams, 587 individuals of 27 species. The urban streams Mandacaru and Miosótis presented lower fish species richness, with five species (but another urban stream, Maringá, had 11 species) (Tab. I). On the rural streams, Queçaba presented the higher number of species (16). Granada, and Zaúna showed 15 and 10 species, respectively. Roseira, Lombo, and Remo streams had nine fish species each one.

The two first axes of the PCoA explained 72.9% of environmental variability among the streams and showed a clear separation regarding environmental distinctiveness between urban and rural streams (Fig. 2). Mesohabitat diversity and percentage of canopy covering were more negatively correlated with PCoA1, which was more positively correlated with marginal erosion of the left margin. On the other hand, PCoA2 was more negatively correlated with Mesohabitat

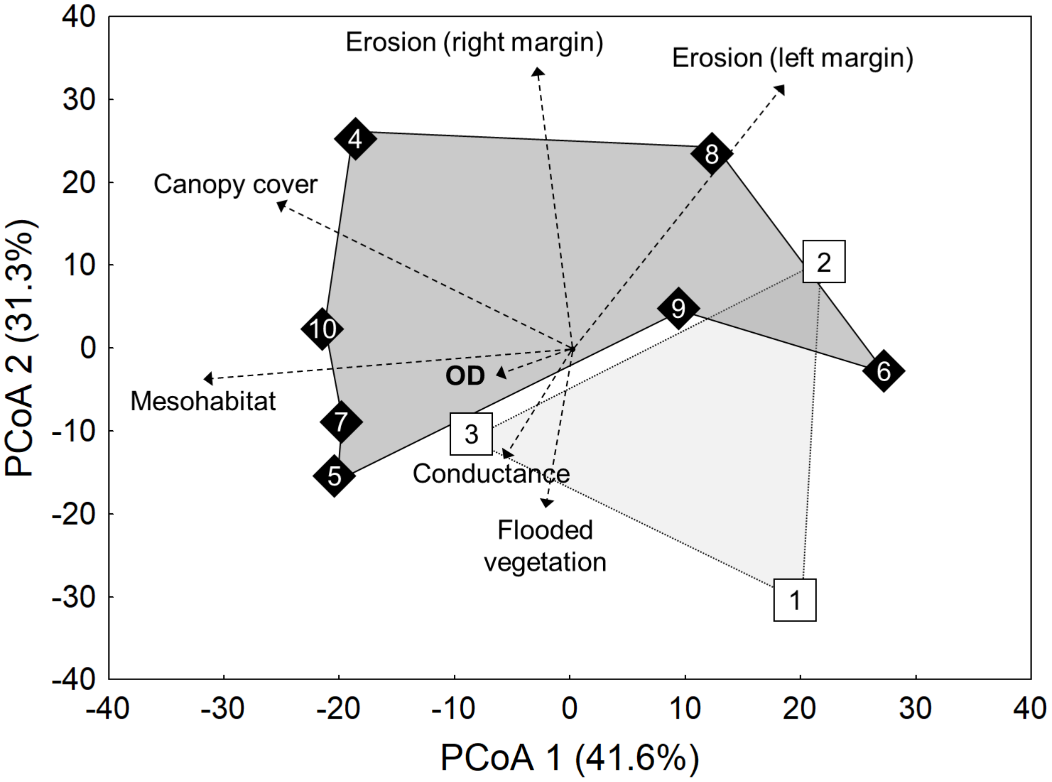

Fig. 2. Ordination of two axes generated by the principal coordinates analysis (PCoA) applied to the environmental data of Urban (white squares) and Rural streams (black diamond) of Maringá, Paraná, Brazil (1, Ribeirão Maringá; 2, Miosótis; 3, Mandacaru; 4, Roseira; 5, Granada; 6, Lombo; 7, Zaúna; 8, Remo; 9, Romeira; 10, Água Queçaba).

Tab. I. Species list of the sampled streams, with the abundance (N) and average biomass (B), Pirapó River basin, Maringá City, Paraná state, Brazil.

	Granada		Romeira		Zaúna		Roseira		Remo		Queçaba		Lombo		Mandacaru		Miosótis		Maringá Stream	
	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B
CHARACIFORMES																				
Astyanax lacustris (Lütken, 1875)	14	10.44	10	5.55	-	-	-	-	-	-	19	6.32	-	-	1	13.70	-	-	2	3.54
Astyanax **aff.** *paranae* Eigenmann, 1914	8	3.73	-		14	6.29	8	5.55	8	1.94	-	-	-	-	-	-	-	-	6	5.60
Astyanax fasciatus (Cuvier, 1819)	3	6.20	3	7.57	-	-	31	6.62	-	-	28	3.20	1	10.02	-	-	-	-	1	4.00
Astyanax bockmanni Vari & Castro, 2007	-	-	-	-	-	-	-	-	-	-	1	5.60	8	8.23	-	-	-	-	-	-
Bryconamericus exodon Eigenmann, 1907	-	-	-	-	-	-	-	-	3	0.79	-	-	-	-	-	-	-	-	-	-
Byconamericus **aff.** *iheringii* (Boulenger, 1887)	4	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piabarchus stramineus (Eigenmann, 1908)	7	1.15	-	-	-	-	-	-	3	0.56	1	2.66	1	1.96	-	-	-	-	-	-
Piabina argentea Reinhardt, 1867	12	1.44	-	-	-	-	-	-	-	-	15	0.62	2	3.31	-	-	-	-	-	-
Oligosarcus paranensis Menezes & Géry, 1983	-	-	-	-	-	-	1	9.7	-	-	-	-	-	-	-	-	-	-	-	-
Characidum **aff.** *zebra* Eigenmann, 1909	5	1.36	-	-	7	1.42	-	-	-	-	9	0.80	1	1.32	-	-	-	-	-	-
Hoplias malabaricus (Bloch, 1794)	1	5.60	-	-	-	-	1	50.4	-	-	-	-	-	-	-	-	-	-	-	-
SILURIFORMES																				
Corydoras **aff.** *aeneus* (Gill, 1858)	-	-	-	-	-	-	-	-	-	-	27	1.83	-	-	-	-	-	-	-	-
Cetopsorhamdia iheringi Schubart & Gomes, 1959	2	7.00	1	1.26	3	6.83	2	3.41	-	-	1	1.29	-	-	2	0.55	6	0.70	6	0.83
Rhamdia quelen (Quoy & Gaimard, 1824)	2	6.08	1	12.80	3	11.98	2	2.22	4	28.02	4	9.77	-	-	8	15.31	1	9.00	10	7.74
Imparfinis mirini Haseman, 1911	-	-	2	1.98	-	-	-	-	-	-	3	0.95	-	-	-	-	-	-	1	3.30
Imparfinis schubarti (Gomes, 1956)	-	-	5	1.26	-	-	50	0.73	-	-	-	-	20	1.91	-	-	-	-	-	-
Pimelodella avanhandavae Eigenmann, 1917	-	-	-	-	-	-	-	-	-	-	2	3.90	-	-	-	-	-	-	-	-
Phenacorhamdia tenebrosa (Schubart, 1964)	-	-	11	0.86	1	2.35	-	-	1	0.06	-	-	-	-	-	-	1	0.40	-	-
Heptapterus mustelinus (Valenciennes, 1835)	-		-	-	16	6.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypostomus ancistroides (Ihering, 1911)	7	6.74	5	2.15	1	1.07	25	1.16	3	2.29	2	0.91	7	5.87	16	3.36	7	0.97	118	2.28
Hypostomus strigaticeps (Regan, 1908)	1	3.65	-	-	1	8.32	-	-	-	-	2	13.80	-	-	-	-	-	-	1	23.70
Hypostomus sp.	-	-	-	-	1	5.80	-	-	-	-	1	19.00	-	-	-	-	-	-	1	0.30
GYMNOTIFORMES																				
Gymnotus sylvius Albert & Fernandes-Matioli, 1999	1	1.48	1	8.60	-	-	-	-	1	1.72	-	-	-	-	-	-	-	-	-	-
Gymnotus inaequilabiatus (Valenciennes, 1839)	1	7.14	-	-	-	-	-	-	1	11.03	-	-	1	13.08	-	-	-	-	-	-
Cyprinodontiformes																				
Poecilia reticulata Peters, 1859	3	0.27	-	-	15	0.30	14	0.16	93	0.10	5	0.05	-	-	105	0.86	36	0.41	83	0.41
SYNBRANCHIFORMES																				
Synbranchus marmoratus Bloch, 1795	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	11.90
PERCIFORMES																				
Crenicichla britskii Kullander, 1982	-	-	-	-	-	-	-	-	-	-	2	1.21	-	-	-	-	-	-	-	-
Geophagus brasiliensis (Quoy & Gaimard, 1824)	-	-	-	-	-	-	-	-	-	-	-	-	1	2.86	-	-	-	-	-	-

diversity and dissolved oxygen and positively correlated with marginal erosion of both left and right margins.

Spearman correlations to species abundance showed that *Hypostomus strigaticeps*, *Characidium* **aff.** *zebra*, *Corydoras* **aff.** *aeneus*, *Crenicichla britskii*, *Pimelodella avanhandavae*, and *Synbranchus marmoratus* were related to the rural, whereas *Hypostomus ancistroides*, *Geophagus brasiliensis*, *Imparfinis schubarti*, *Synbranchus marmoratus*, *Gymnotus inaequilabiatus*, *Oligosarcus paranensis* to the urban streams (Tab. II). To biomass, *Astyanax lacustris*, *C.* **aff.** *zebra*, *H. strigaticeps*, *C. aeneus*, *C. britskii*, *Pimelodella avanhandavae*, *H. ancistroides* and *S. marmoratus* were related to the rural, while *G. brasiliensis* and *O. paranensis* to the urban (Tab. III).

The urban streams had the highest negative values for W index (Mandacaru: W = −0.38; Miosótis: W = −0.23;

Tab. II. Spearman's correlation of species' abundance data in Pirapó River basin, Maringá City, Paraná state, Brazil with axes 1 and 2 (PCoa1 and PCoa1) of the PCoA on environmental data (see Fig. 2). Species with coefficients of correlation higher than 0.5 were bolded.

Species	ρPCoA1	Species	ρPCoA2
Hypostomus strigaticeps	**-0.68**	***Synbranchus marmoratus***	**-0.52**
Characidium aff. _zebra_	**-0.56**	***Hypostomus strigaticeps***	**-0.50**
Corydoras aff. _aeneus_	**-0.52**	*Astyanax lacustris*	-0.43
Crenicichla britskii	**-0.52**	*Bryconamericus* **aff.** *iheringii*	-0.41
Pimelodella avanhandavae	**-0.52**	*Rhamdia quelen*	-0.38
Hoplias malabaricus	-0.45	*Characidium* **aff.** *zebra*	-0.33
Astyanax bockmanni	-0.42	*Piabina argentea*	-0.31
Astyanax lacustris	-0.41	*Cetopsorhamdia iheringi*	-0.18
Bryconamericus **aff.** *iheringi*	-0.41	*Hypostomus* sp.	-0.17
Piabina argentea	-0.38	*Heptapterus mustelinus*	-0.17
Hypostomus sp.	-0.29	*Astyanax bockmanni*	-0.11
Heptapterus mustelinus	-0.29	*Gymnotus inaequilabiatus*	-0.10
Rhamdia quelen	-0.26	*Imparfinis mirini*	-0.10
Astyanax **aff.** *paranae*	-0.25	*Geophagus brasiliensis*	-0.06
Oligosarcus paranensis	-0.17	*Piabarchus stramineus*	-0.05
Imparfinis mirini	-0.14	*Poecilia reticulata*	-0.03
Piabarchus stramineus	-0.14	*Hoplias* sp. 2	0.02
Gymnotus sylvius	-0.13	*Hypostomus ancistroides*	0.02
Cetopsorhamdia iheringi	-0.04	*Corydoras* aff.*aeneus*	0.06
Poecilia reticulata	0.14	*Crenicichla britskii*	0.06
Bryconamericus exodon	0.17	*Pimelodella avanhandavae*	0.06
Phenacorhamdia tenebrosa	0.19	*Gymnotus sylvius*	0.08
Gymnotus inaequilabiatus	0.23	*Astyanax* **aff.** *paranae*	0.24
Synbranchus marmoratus	0.29	*Phenacorhamdia tenebrosa*	0.37
Imparfinis schubarti	0.32	*Imparfinis schubarti*	0.38
Geophagus brasiliensis	0.52	*Bryconamericus exodon*	0.41
Hypostomus ancistroides	**0.64**	***Oligosarcus paranensis***	**0.52**

Tab. III. Spearman correlation of species' biomass data in Pirapó River basin, Maringá City, Paraná state, Brazil with axes 1 and 2 (PCoA1 and PCoA1) of the PCoA on environmental data (see Fig. 2). Species with coefficients of correlation higher than 0.5 were bolded.

Species	ρPCoA1	Species	ρPCoA2
Astyanax lacustris	**-0.56**	***Hypostomus strigaticeps***	**-0.55**
Characidium aff. _zebra_	**-0.56**	***Hypostomus ancistroides***	**-0.54**
Hypostomus strigaticeps	**-0.53**	***Synbranchus marmoratus***	**-0.52**
Corydoras aff. _aeneus_	**-0.52**	*Astyanax lacustris*	-0.48
Crenicichla britskii	**-0.52**	*Bryconamericus* **aff.** *iheringi*	-0.41
Pimelodella avanhandavae	**-0.52**	*Characidium* **aff.** *zebra*	-0.33
Cetopsorhamdia iheringi	-0.47	*Rhamdia quelen*	-0.31
Hoplias malabaricus	-0.42	*Piabina argentea*	-0.31
Bryconamericus **aff.** *iheringii*	-0.41	*Poecilia reticulata*	-0.22
Astyanax bockmanni	-0.39	*Hypostomus* sp.	-0.17
Piabina argentea	-0.38	*Heptapterus mustelinus*	-0.17
Piabarchus stramineus	-0.30	*Imparfinis mirini*	-0.17
Hypostomus sp.	-0.29	*Piabarchus stramineus*	-0.14
Heptapterus mustelinus	-0.29	*Cetopsorhamdia iheringi*	-0.13
Rhamdia quelen	-0.21	*Geophagus brasiliensis*	-0.06
Oligosarcus paranensis	-0.17	*Astyanax bockmanni*	-0.01
Astyanax **aff.** *paranae*	-0.12	*Gymnotus inaequilabiatus*	0.01
Gymnotus sylvius	-0.05	*Corydoras* **aff.** *aeneus*	0.06
Imparfinis mirini	-0.04	*Crenicichla britskii*	0.06
Phenacorhamdia tenebrosa	0.14	*Pimelodella avanhandavae*	0.06
Poecilia reticulata	0.16	*Hoplias malabaricus*	0.16
Bryconamericus exodon	0.17	*Gymnotus sylvius*	0.19
Synbranchus marmoratus	0.29	*Astyanax* **aff.** *paranae*	0.20
Hypostomus ancistroides	0.30	*Phenacorhamdia tenebrosa*	0.34
Gymnotus inaequilabiatus	0.31	*Imparfinis schubarti*	0.38
Imparfinis schubarti	0.32	*Bryconamericus exodon*	0.41
Geophagus brasiliensis	**0.52**	***Oligosarcus paranensis***	**0.52**

Maringá Stream: W= −0.059), and showed the abundance curves above the biomass, which indicates stressing condition (Fig. 3). Negative value of W appeared only in one rural stream, Remo (W= −0.048). Queçaba, Lombo, Romeira and Roseira streams presented positive W scores (0.08, 0.002, 0.049 and 0.035 respectively). The major values for W index were registered for streams Granada (W= 0.18) and Zaúna (W= 0.12).

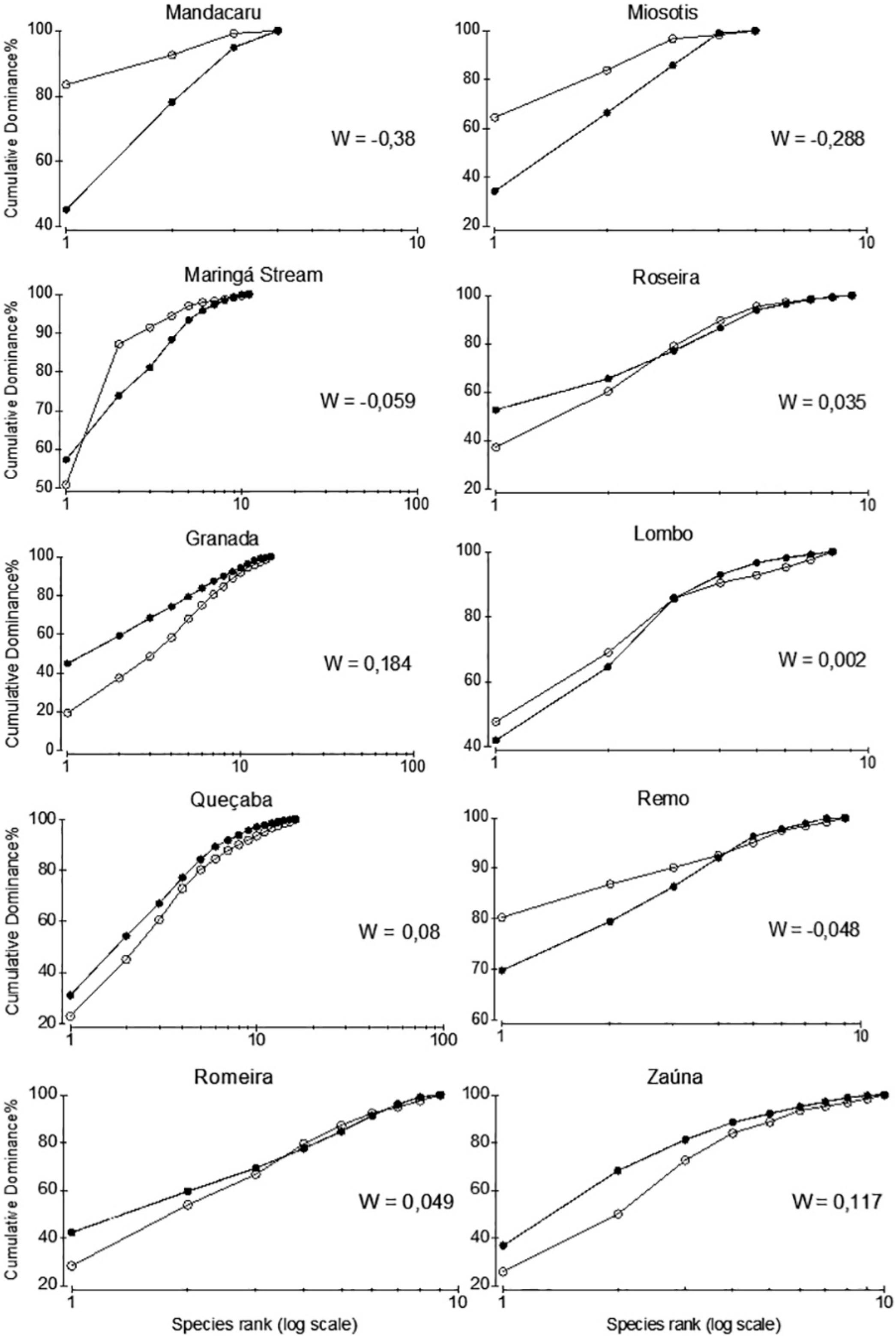

Fig. 3. Accumulation curves of abundance (white circles) and biomass (black circles) to show the ABC method and values of W index for fish assemblages sampled in the streams of Maringá, Paraná, Brazil. Negative values of W suggest environmentally stressed (following Warwick & Clarke, 1994) ecosystems, and positive values indicate not stressed environments.

The Spearman correlation showed a negative relation ($\rho = -0.68$; $p = 0.02$) between of W and PCoA 1 scores and suggested that W negative values were in urban (more impacted) streams, while W positive values were in rural (less impacted) streams (Fig. 4).

DISCUSSION

Our results showed that all urban streams were environmentally stressed (negative scores of W index), while only one rural stream (Remo) had negative W value. We reinforced the trends in other studies that used ABC curves, such as Pinto *et al*. (2006) about the need of complementarities of methods in environmental assessment. Here, ABC curves and W index were very useful to evaluate the environmental stress of the streams, however, more precise conclusions were obtained when we analysed the PCoA and the correlations of both abundance and biomass of the species with the environmental conditions. We recommend that stress evaluation in tropical streams rivers would be done by a set of environmental indices and statistical tools (here we used the ABC curves, W indices, PCoA of environmental data, and correlation of abundance and biomass by species versus the environmental PCoA's axes) to avoid weak interpretations about human impacts in stream ecosystems.

In this study, the influence of urban and rural location of the streams was clearly revealed by an environmental pattern displayed by both PCoA and W values. The urban streams were impacted by low diversity of mesohabitat and canopy cover, showing great erosion of both right and left margin because of the human occupation. On the other hand, the rural streams were not completely free of impact, which was observed mainly from the erosion of left margin.

Yet, despite the environmental gradient from urban to rural streams detected by the PCoA, the species more related with both urban and rural streams were basically the same. The explanation for this pattern is the ecological specificity (or specialization) of the species more correlated with PCoA1 and PCoA2 for both abundance and biomass data. The species more correlated with the urban (impacted) streams were those suited to live in siltation (a condition derived from low canopy cover and representative of low mesohabitat diversity), such as *H. ancistroides* (Casatti *et al*., 2005), *I. schubarti* (Severo-Neto *et al.*, 2015), and *H. strigaticeps* (Jepep *et al.*, 2007), with high feeding plasticity (impacted streams are frequently recorded as food resource restricted), like *R. quelen* (Gomiero *et al.*, 2007), *G. inaequilabiatus* (Hahn *et al.*, 2004), *G. brasiliensis* (Bastos *et al.*, 2011), *Bryconamericus iheringii* (Oliveira & Bennemann, 2005; Oricolli & Bennemann, 2006), *A. lacustris* (Bennemann *et al*., 2005, under *A. altiparanae*), and *O. paranensis* (Abelha *et al.*, 2012), adapted to feed on organic detritus (a typical food resource in impacted streams), as *H. ancistroides* and *H. strigaticeps* (Pagotto *et al.*, 2011), and with high reproductive plasticity, as *S. marmoratus* (Favorito *et al.*, 2005). All these species are adapted to use scarce alimentary, shelter, and reproductive resources, as appears to be the case here. Other important species in the streams which showed negative W was *Poecilia reticulata* (Tab. I), which is well-recognized as an opportunistic species with rapid

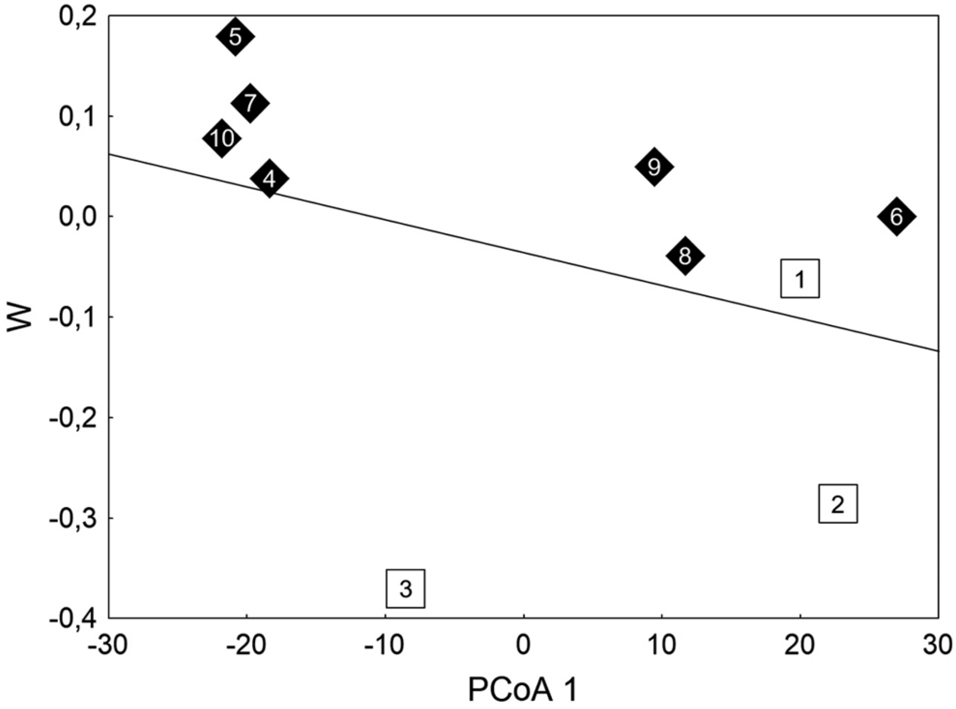

Fig. 4. Spearman correlation ($\rho = -0.68$; $p = 0.02$) between W and PCoA1, Pirapó River basin, Maringá City, Paraná state, Brazil (White squares, urban streams; black Diamond, rural streams)(1, Ribeirão Maringá; 2, Miosótis; 3, Mandacaru; 4, Roseira; 5, Granada; 6, Lombo; 7, Zaúna; 8, Remo; 9, Romeira; 10, Água Queçaba).

development (*r*-strategist) and typical of impacted streams (Winemiller *et al*., 1989; Lemes & Garutti, 2002).

The pattern we found here of representative species with high abundance and low biomass is common in urban streams (Pinto *et al*., 2006). The rural stream (Remo) that showed negative values of W index seems to be under influence environmental impact (not identified here), which is reinforced by the high abundance of *P. reticulata* that also contributed to the lower W value. Tests using invertebrates have indicated that Maringá rural streams have received agricultural (toxic) wastes (Kühl *et al*., 2010). Then the use of W index and ABC curves can be useful in identifying cumulative effects that are difficult to assess, such as impacts caused by agricultural wastes, and another kind of pollutants that are not visually detected.

We strongly recommend this multi analytical approach for the assessment of environmental condition (stress) of streams. The trend of diminution in fish biomass and increase of abundance in the urban streams was successfully detected by both ABC method and W index (as confirmed by the Spearman correlation between W and PCoA1) and the ecological meaning was explained by PCoA and Spearman correlation analyses. The applied method allowed to detect other potential kinds of impacts in rural streams (as observed in Remo).

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