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Influence of environmental quality on the diet of *Astyanax* in a microbasin of central western Brazil

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ABSTRACT. This study analyzed physicochemical characteristics of the water, degradation of the surroundings and the influence of these factors on the diet of two fish species of *Astyanax* in Tarumã stream microbasin, central western Brazil. Fish were collected in eight sites between 2007 and 2010, using gillnets and sieves. Environmental variables were evaluated by a principal component analysis and the diet based on Spearman's correlation. The variables width, type of riparian vegetation, pH, conductivity, total dissolved solids, temperature, oxidation and reduction potential, presence of waste, and altitude have separated the sampling sites into two groups: 'less impacted' and 'more impacted'. The two characid species presented omnivorous habit, typical of disturbed environments. The consumption of food resources was different over the space: terrestrial plants and sediment were more important in the most impacted sites for both species. And specifically to *Astyanax altiparanae* the order of importance of the food was distinct between most and less impacted sites. These data indicated that the diet of these species is a suitable tool for analyzing the environmental quality of the studied sites.

Keywords: environmental degradation, streams, ichthyofauna, food.

Influência da qualidade ambiental na dieta de *Astyanax* em uma microbacia do Centro-Oeste do Brasil

RESUMO. Este trabalho teve como objetivo analisar as características físico-químicas da água, degradação do entorno e a influência destes fatores na biologia alimentar de duas espécies de *Astyanax* na microbacia Touro-Tarumã, Centro-Oeste do Brasil. Os peixes foram coletados em oito locais, de 2007 a 2010, utilizando redes de espera e peneirões. As variáveis ambientais foram avaliadas por análise multivariada e a dieta pela correlação de Spearman. As variáveis ambientais largura, tipo de mata ciliar, pH, condutividade, sólidos totais dissolvidos, temperatura, potencial de oxidação e redução, presença de lixo e altitude permitiram diferenciar os locais de coleta em "mais impactados" e "menos impactados". As duas espécies de caracídeos estudadas apresentaram comportamento onívoro, que é típico de ambientes alterados. Os recursos alimentares consumidos pelas espécies diferiram espacialmente: vegetais terrestres e sedimento apresentaram maior importância nos locais mais impactados para as duas espécies. Especificamente para *A. altiparanae* a ordem de importância do alimento consumido diferiu entre os locais mais e menos impactados. Estes dados indicam que o estudo da dieta destas espécies mostrou-se uma ferramenta adequada para análise da qualidade ambiental destes locais.

Palavras-chave: degradação ambiental, riachos, ictiofauna, alimentação.

Introduction

Environment and natural resources have been strongly affected in recent decades by the increasing pressure from human activities due to urban sprawl. Aquatic ecosystems, in particular, have been significantly altered as a result of multiple environmental impacts caused by human activities such as mining, construction of dams and reservoirs, diversion of the natural course of rivers, discharge of raw sewage and industrial effluents, deforestation and inappropriate land use in riparian areas and floodplains, overfishing, introduction of exotic species, among others (OLIVEIRA; BENNEMANN, 2005; SCHULZ; MARTINS-JUNIOR, 2001).

According to Wootton (1990), environmental quality assessment has been done by analyzing physical and chemical parameters of water, such as dissolved oxygen, conductivity, pH, temperature, salinity and turbidity. However, in terms of water quality, these parameters are usually employed with a focus on human consumption, establishing values that demonstrate the levels of potability with no concern for the maintenance of aquatic organisms. Moreover, these parameters alone, are insufficient to reveal the reality of an environment, requiring thus biological indicators to become more effective (LIMA-JUNIOR et al., 2006; MAGURRAN; PHILLIP, 2001; SMITH et al., 1997; WOOTTON, 1990). The interaction between biomonitoring methods and abiotic variables of a system provides a more accurate diagnosis of its environmental quality, with data that converge and complement each other (BRIGANTE et al., 2003).

Smith et al. (1997) and Araújo (1998) suggest that fish are excellent for this purpose and widely used in assessments on the ecological quality of aquatic habitats, since they are relatively easy to sample given their conspicuousness in these environments.

Fish utilized in this study were 'lambaris' of the genus *Astyanax*, the most common and diversified Characidae (GARUTTI; BRITSKI, 2000; GÉRY, 1977). These fish have a small size, whose total length can reach up to 150 mm, and are widely distributed in Neotropical aquatic environments (BRITSKI et al., 2007). One of the studied species was *Astyanax altiparanae*, found in rivers, lagoons and channels, whose diet is centered mainly on insect larvae and algae (HAHN et al., 2004). The other species, *Astyanax paranae*, inhabits streams and consumes insect larvae (HAHN et al., 2004). These two species were the most captured in all sampling sites in the Tarumã microbasin, central western Brazil. The Tarumã stream, belonging to this microbasin, and its major affluent, the Touro stream, were objects of this study. These streams are small water bodies that pass through the urban area of Naviraí (State of Mato Grosso do Sul, Brazil), and consequently receive domestic and industrial sewage, lose riparian vegetation, and undergo many other human impacts that change the aquatic environment, as well its biota.

In this context, the purpose of this study was to analyze physicochemical characteristics of the water, the degradation of the surroundings and the influence of these factors on the diet of two fish species of *Astyanax* in the Tarumã microbasin, central western Brazil.

Material and methods

Sampling sites

Data were obtained twice a year from 2007 to 2010 at eight sampling sites in the Tarumã microbasin that crosses the urban area of Naviraí, in the State of Mato Grosso do Sul, central western Brazil (Figure 1 and Table 1).

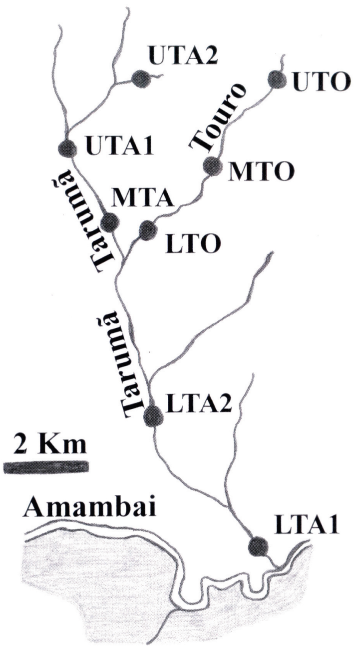

Figure 1. Location of the sampling sites in the Tarumã microbasin, central western Brazil.

Table 1. Name and location of the sampling sites in the Tarumã microbasin, central western Brazil.

Sampling sites	Location	Coordinates
UTA1	Upper Tarumã 1	23°02´55.8´´S and 54°14´40.7´´W
UTA2	Upper Tarumã 2	23°01´06.1´´S and 54°13´48.8´´W
MTA	Middle Tarumã	23°04´08.3´´S and 54°14´06.9´´W
LTA1	Lower Tarumã 1	23°08´13.8´´S and 54°12´04.8´´W
LTA2	Lower Tarumã 2	23°06´23.4´´S and 54°13´40.0´´W
UTO	Upper Touro	23°02´22.8´´S and 54°11´53.1´´W
MTO	Middle Touro	23°03´31.2´´S and 54°12´51.8´´W
LTO	Lower Touro	23°04´10.6´´S and 54°13´51.8´´W

The sites LTA1 and LTA2 are located in the vicinity of a sugar mill and alcohol distillery and a meat-packing plant. MTO is located at Naviraí city, and receives urban effluent and solid waste. LTO is located downstream of the urban region and MTO, and also receives domestic sewage and industrial effluents.

The less impacted sites (UTA1, UTA2, MTA and UTO) are at higher altitude and under low aquatic pollution (lower values of conductivity and total dissolved solids). However, the riparian vegetation is not preserved, prevailing pastures on the banks.

Environmental variables

The following environmental variables were analyzed: stream width (m), altitude (m), type of riparian vegetation (qualitative scale: 1 – pasture; 2 – shrub; 3 – degraded forest; 4 – preserved forest), presence of waste in the water and/or on the banks (qualitative scale: 1 – none; 2 – little; 3 – a lot), pH, water temperature (°C), conductivity (μS cm^{-1}), total dissolved solids (TDS) (mg L^{-1}) and oxidation-reduction potential (ORP) (mV). These environmental variables were evaluated using a principal components analysis (PCA), according to the methods described by Manly (1994).

Biological variables

Fish were captured with gillnets and sieves. For diet analysis, stomachs were removed and weighed and contents examined under a stereomicroscope and optical microscope. After identifying the food items, the data were pooled according the environmental classification of 'less impacted' and 'more impacted' sampling sites, and were analyzed using the following methods: Frequency of Occurrence (HYSLOP, 1980), Volumetric Analysis Index and Importance Index (LIMA-JUNIOR; GOITEIN, 2001). The results of the Importance Index (AI) obtained for each species in each sample were compared using the method proposed by Fritz (1974), which ranks the food based on the relative importance in each sample, and compares them using a Spearman's correlation coefficient.

Results

Environmental variables

The characterization of the sampling sites by environmental variables is shown in Table 2.

The first principal component (which explained 53.28% of the data variance) has separated out the sampling sites into two groups. The most impacted sites (LTA1, LTA2, MTO and LTO) were ordinated on the right of the first axis, and characterized by higher values of width, pH, conductivity, total dissolved solids (TDS) and lower values of altitude and oxidation and reduction potential (ORP), besides degraded riparian vegetation. On the left of the first axis were plotted the other points (UTA1, UTA2, MTA and UTO), considered less impacted owing the opposite values for the variables mentioned. The second principal component also allowed separating the most impacted sites into two subgroups, considering the presence of waste and water temperature. However, since the second component explained a much smaller fraction of data variance (18.40%), it was not used to create new groups for analysis, because it could also produce some bias related to the low number of individuals sampled in some sites (Figure 2).

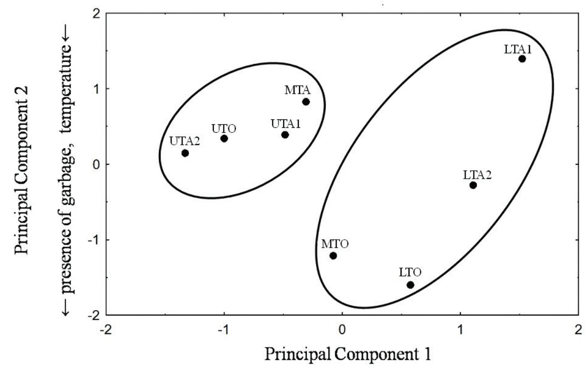

Figure 2. Scores distribution of sampling sites on the plane formed by the two first principal components obtained from the environmental data in the Tarumã microbasin, central western Brazil.

Biological variables

The number of individuals examined in the different types of environments (more and less impacted sites) is presented in the Table 3.

Table 3. Total number of individuals (n) and individuals with stomach contents (n_{sc}) analyzed in the more and less impacted sites in the Tarumã microbasin, central western Brazil.

Sites	*A. altiparanae*		*A. paranae*	
	n	n_{sc}	n	n_{sc}
More impacted	147	139	5	5
Less impacted	7	7	134	125

Fish consumed a wide array of food items such as algae (Chlorophytes), terrestrial plants (fragments of root, stem, leaves and seeds), aquatic arthropods (fragments of Diptera, Ephemeroptera, Trichoptera and Coleoptera larvae and pupae), terrestrial arthropods (fragments of Coleoptera, Hymenoptera, Hemiptera and Diptera), fish scales and sediment (sand and pebbles).

Table 2. Characterization of the eight sampling sites in the Tarumã microbasin, central western Brazil.

	UTA1	UTA2	MTA	LTA1	LTA2	UTO	MTO	LTO
Width (m)	3	1.5	2	10	3	1	2	4
Altitude (m)	292	341	268	237	252	329	301	267
Type of riparian vegetation	pasture	pasture	pasture	degraded forest	degraded forest	pasture	shrub	pasture
Waste	none	little	none	little	little	none	a lot	a lot
pH	7.1	5.9	7.1	7.3	7.3	6.3	6.7	7.4
Water temperature (°C)	23.5	23.2	23.6	23.3	23.6	22.2	24.7	27.1
Conductivity (μS cm^{-1})	11.5	11.6	13.7	186.5	255.4	29.2	96.7	161.7
TDS* (ppm)	6	5.9	7	118.7	129.4	14.9	48.7	79.9
ORP** (mV)	150.0	197.0	156.8	111.2	114.1	151.3	139.1	140.7

*Total dissolved solids. **Oxidation-reduction potential.

Food resources consumed by *Astyanax altiparanae* consisted of algae, terrestrial plants, aquatic arthropods (mainly larvae of Chironomidae), terrestrial arthropods, fish scales and sediment. The most expressive items, in the less impacted sampling sites, were aquatic and terrestrial arthropods (both with an AI of 3.06%), followed by algae and sediment (both with an AI of 1.02%). In the more impacted sites, the most expressive food resources were sediment (15.08%), terrestrial plants (13.52%), and terrestrial (2.21%) and aquatic arthropods (2.12%) (Figure 3).

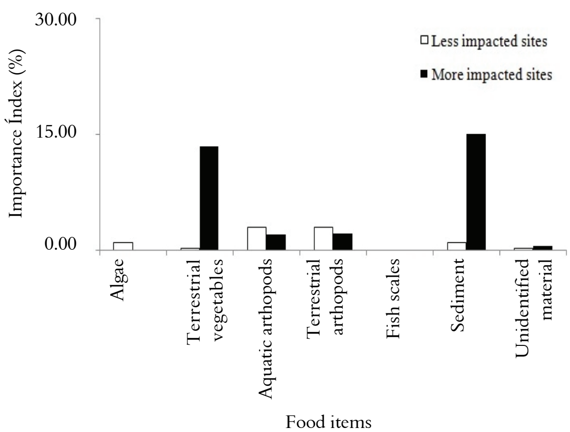

Figure 3. Alimentary Importance Index (AI) of *Astyanax altiparanae* caught in the less and more impacted sampling sites, in the Tarumã microbasin, central western Brazil.

A comparison between the AI of this species in each sample indicated no significant correlation ($p > 0.05$) between less and more impacted sites. The importance of aquatic and terrestrial arthropods in the diet was higher in the less impacted sites, while terrestrial plants and sediment were more important in the more impacted sites (Figure 3).

The diet of *Astyanax paranae* was composed of the same food resources as *A. altiparanae*, except for fish scales. Black fly (Diptera, Simuliidae, *Simulium*) were also found. In the less impacted sites, the food resources with the highest AI were aquatic (14.02%) and terrestrial arthropods (8.95%). In the more impacted sites, this sequence was terrestrial arthropods (27%), algae (22%) and aquatic arthropods (21%). For this species, the AI showed a significant correlation ($r = 0.8469$ and $p = 0.0162$), indicating that the most important resources were statistically equivalent between the sampling sites (Figure 4).

Discussion

From the data obtained in this study, the stream's width, water conductivity, pH, total dissolved solids and water temperature were higher in the more impacted sites. The riparian vegetation was degraded, but there were large tree species. This result in the downstream sites may be attributed to the width of the water body, which is larger than in the sampling sites in the headwaters, facilitating the supervision and preservation of this vegetation. This control is practically nonexistent in water bodies with little volume, where the riparian vegetation was poorly preserved, precisely due to the anthropic activities in the proximities of these sites.

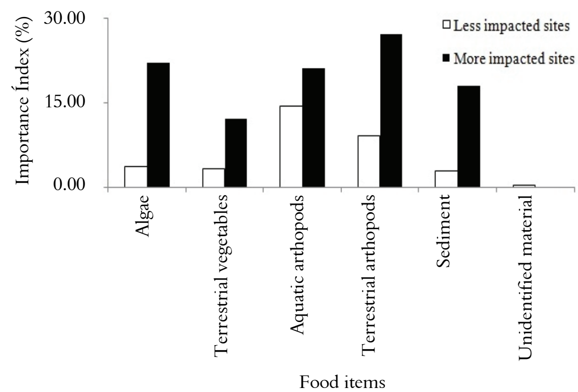

Figure 4. Alimentary Importance Index (AI) of *Astyanax paranae* caught in the less and more impacted sampling sites, in the Tarumã microbasin, central western Brazil.

During the samplings, the water conductivity increased towards the lower parts of the microbasin. According to Godoy (1986), the electrical conductivity is a measure of the ionization of the mineral salts present in the water, and may thus indicate the presence of pollutants. In the same way, higher levels of total dissolved solids (TDS) – the resultant matter from drying a water sample – are also associated with aquatic pollution and so, indicate inappropriate water to human use (CARVALHO; OLIVEIRA, 2003).

The oxidation-reduction potential (ORP) is the electromotive force developed when oxidizers or reducers are present in aqueous solution, and its values increased dramatically as organic matter was removed (LI; BISHOP, 2001). This parameter is largely applied on water treatment monitoring, and higher values indicate better water conditions. In fact, the lower values to this variable were registered in the more impacted sites (LTA1, LTA2, MTO and LTO).

In a study of the possible impacts on water resources resulting from changes to the Brazilian Forest Code (Law No. 4771/1965), Tundisi and Tundisi (2010) pointed out that the structure of the marginal vegetation of aquatic environments changes the potential energy, the chemistry of groundwater and surface water, and reduces erosion. Moreover, the removal of vegetation increases water conductivity and the transport of suspended solids, and degrades freshwater sources. Therefore, the physical, chemical and biological conditions of aquatic environments are essential for living organisms present. Fish depend on primary and secondary production of aquatic systems; hence, ecological problems are reflected in fish (YODER; SMITH, 1999).

Bruschi Junior et al. (2000) demonstrated that sites with low water quality presented a higher occurrence of generalist fish species. Orsi et al. (2002) found a large abundance of *A. altiparanae* in one of the most degraded portions of the Tibagi river (Paraná State). The findings of the aforementioned authors corroborate the present study, and characid of the genus *Astyanax* were found in all sampling sites, whose environmental characteristics revealed several types of anthropogenic influence. Despite this widespread sampling in the Tarumã microbasin, there was a large numerical difference in sampling between the more and less impacted sites, for both species. However, the observed results for species feeding are strongly supported by the literature, as discussed below, which induced to the consideration of samples with few individuals, keeping the spatial comparison for both species.

According to Lowe-McConnell (1999), the majority of fish in tropical regions exhibit a trophic flexibility given the availability of food resources and environmental changes. The available food items respond to these changes and to the dynamics of these streams (ABELHA et al., 2001). Our findings are similar, i.e., the species presented dietary plasticity, since the most exploited sources were possibly those available at that moment, with no food specificity, indicating thus the generalist behavior of the majority of fish inhabiting streams.

In relation to fish diet, the source of food (autochthonous or allochthonous) allows observing the importance of riparian vegetation as a source of food for the fish fauna (ALVIM; PERET, 2004; MONTAG et al., 1997) and the contribution of detritus and insects at immature stages (LOWE-McCONNELL, 1999). This was observed for the two studied species, which have consumed large amounts of aquatic arthropods, mainly Diptera larvae (Chironomidae), associated with plant material, evidencing an omnivorous diet with insects (immature and adult forms) and allochthonous plants as the major sources. Similarly Casatti et al. (2003) registered that the diet of *A. altiparanae* consisted of both allochthonous (Diptera, Hymenoptera and Poaceae seeds) and autochthonous food sources (mainly Chironomidae larvae).

The diet of *A. paranae* consisted of aquatic and terrestrial arthropods, algae and sediment as the main food resources. Abelha et al. (2006) found that this species consumed a large variety of foods, including detritus/sediment, resources of animal origin (immature forms of Hymenoptera, Coleoptera and other insects) and plant (fruits, seeds, leaves, stems and roots), showing a broad diet spectrum and revealing a generalist and opportunistic behavior. Likewise Bennemann et al. (2005) verified generalist feeding behavior for four species of the genus *Astyanax* in the Tibagi River basin in the state of Paraná, Brazil. All these findings corroborate the results of the present study.

Conclusion

The width, type of riparian vegetation, pH, conductivity, TDS, temperature, ORP, presence of waste and altitude have distinguished the sampling sites into two groups: 'less impacted' and 'more impacted'. The two species presented omnivorous habit and the consumption of food items was different over the space: terrestrial plants and sediment were more important in the most impacted sites for both species. Specifically to *A. altiparanae* the order of importance of items was different between the sites. Our results indicated that the study on the diet of these species is a suitable tool for the analysis of environmental quality.

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