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Fish trophic structure in a first order stream of the Iguatemi River basin, Upper Paraná River, Brazil

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ABSTRACT. We described the spatial distribution of fish trophic groups in the Água Boa Stream, MS, Brazil. Specimens were caught using electrofishing in the upper, intermediate and lower stretches of the stream, between March and November 2008. We analyzed 415 stomach contents of 24 species. Detritus/sediment and aquatic invertebrates were the main exploited resources. Ordination analysis categorized the species in six trophic groups. Aquatic invertivores showed the highest richness (10 species), followed by detritivores (08 species), omnivores (03 species), terrestrial invertivores (03 species), algivores (02 species) and herbivore (01 species). Three trophic groups occurred in the upper stretch, six in the intermediate and five in the lower. Detritivores, omnivores and algivores showed the highest density, while detritivores and aquatic invertivores presented the highest biomass. Autochthonous resources were particularly important to the studied fish fauna, especially aquatic invertebrates, so, conservation actions reducing the simplification of the habitat by silting and recovering the riparian forest are essential to maintain the ichthyofauna of the Água Boa Stream.

Keywords: diet, trophic group, ichthyofauna, freshwater.

Estrutura trófica de peixes em riacho de primeira ordem da bacia do rio Iguatemi, alto rio Paraná, Brasil

RESUMO. Este trabalho descreve a distribuição espacial de grupos tróficos de peixes do riacho Água Boa, MS, Brasil. Os espécimes foram coletados por meio de pesca elétrica nos trechos superior, intermediário e inferior do riacho, entre março e novembro de 2008. Foram analisados 415 conteúdos estomacais de 24 espécies, sendo detrito/sedimento e invertebrados aquáticos os recursos mais explorados pela ictiofauna. A análise de ordenação discriminou as espécies em seis grupos tróficos. Os invertívoros aquáticos foram os de maior riqueza (10 espécies), seguidos dos detritívoros (08 espécies), omnívoros (03 espécies), insetívoros terrestres (03 espécies), algívoros (02 espécies) e herbívoro (01 espécie). Três grupos tróficos ocorreram no trecho superior, seis no intermediário e cinco no inferior. As maiores contribuições em densidade foram de detritívoros, omnívoros e algívoros. Em biomassa, detritívoros e invertívoros aquáticos foram predominantes. Recursos autóctones foram particularmente importantes para a manutenção da ictiofauna estudada, especialmente invertebrados aquáticos, portanto, ações conservacionistas que reduzam a simplificação do hábitat pelo assoreamento e que recuperem a mata ciliar são essenciais para manter as populações de peixes do riacho Água Boa.

Palavras-chave: dieta, grupo trófico, ictiofauna, água doce.

Introduction

Most fish assemblages in low order streams have common characteristics, such as small size, high endemism, restricted geographical distribution, no commercial value and dependence on riparian vegetation for feeding, reproduction and shelter (Casatti, Langeani, & Castro, 2001). These fish have a crucial role in the ecosystem dynamics since they act both as predators, regulating invertebrates and algal populations, and as a link in the food chain, serving as prey to larger fish (Castro & Menezes, 1998). The assemblages are strongly affected by the removal of riparian vegetation, pollution, siltation and species introduction (Ferreira & Casatti, 2006), because the reduced dimensions of the streams make them expressively sensitive to human action (Oliveira & Bennemann, 2005). So, when thinking about conservation of inland aquatic biodiversity, it is essential to encourage studies focused on streams (Langeani et al., 2007).

Considering that survival, growth and reproduction of fish depend on the amount of energy and nutrients generated by feeding activity (Wootton, 1999), the knowledge of the food resources explored provides a means to understand fish population dynamics and the relationship with biotic and abiotic components. In addition, from the knowledge of fish diet, the species can be grouped into trophic groups, which indicate fish function in the ecosystem (Matthews, 1998). For streams subjected to siltation, removal of the riparian forest and consequent environmental simplification, it is expected a reduction in trophic groups diversity, which means the reduction of functional roles played by fish (Cross et al., 2013).

The current scientific literature contains an expressive number of studies on fish feeding in Brazilian streams, e.g., Casatti (2002), Casatti et al. (2001), Uieda and Motta (2007), Wolff, Carniatto, and Hahn (2013), Cruz, Teshima, and Cetra (2013), Takahashi, Rosa, Langeani, and Nakaghi (2013), among others, but the existing information is still fragmented and scarce when considering the exuberance of the Brazilian river network and fish species richness (Langeani et al., 2007). This is particularly true for the streams in the south of the State of Mato Grosso do Sul, where fish biology and ecology are still poorly known. In this region, the Água Boa Stream stands out as a first order stream of the Upper Paraná River basin that runs through rural areas, where silting and scarce/absent riparian forest are common components of the landscape. The knowledge of fish diet and the distribution into trophic groups are fundamental information to understand how the assemblages respond to the available food resources in an environment under such anthropic interference. Therefore, the present study aimed to investigate, in a descriptive way, the fish diet and the trophic structure along the longitudinal axis of the Água Boa Stream, MS, Brazil.

Material and methods

Study area

Água Boa is a first order stream, which runs for about 6.0 km through rural areas of the southern State of Mato Grosso do Sul and flows into the right bank of the Iguatemi River, Upper Paraná River basin (Figure 1). Água Boa is a plain stream (see Uieda & Castro, 1999 for a characterization of plain streams), which flows at an average altitude of 258 m. The native vegetation in the basin belongs to the Atlantic Forest biome (semi-deciduous forest), which has been largely replaced by agriculture and pasture, resulting in a landscape composed of scarce or even absent riparian forest surrounding the streams in the studied region, including Água Boa Stream. Siltation is another anthropogenic stressor. The soil is sandy and frequently impacted by gullies, intensifying the input of sediments into the streams (Mendonça et al., 2014). Moreover, rural populations indiscriminately use the stream water for livestock watering, which worsens the siltation process due to animal trampling, whose impact is easily visible in the upper stretch of the Água Boa Stream. The location are detailed in Figure 1.

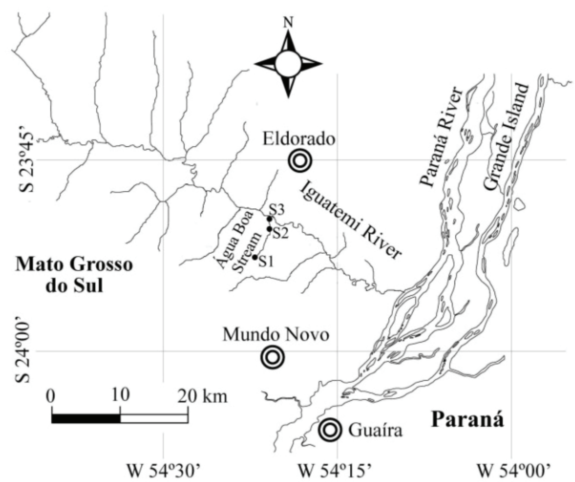

Figure 1. Location of the sampling sites along the Água Boa Stream, Iguatemi River basin, state of Mato Grosso do Sul, Brazil. S1, S2 and S3 correspond to Site 1, Site 2 and Site 3, respectively.

Environmental characteristics of the each sampling site

Site 1 (23° 52' 42.24" S; 54° 21' 55.37" W): Backwater; clayey bed; marginal vegetation consists of scattered trees, shrubs and grasses for grazing; abundant aquatic grasses, width between 2.0 and 6.0 m and depth between 12.0 and 15.0 cm.

Site 2 (23° 50' 16.65" S; 54° 20' 55.54" W): Backwaters alternate with rapids and pools; rocky and sandy bed; marginal vegetation composed of small clusters of trees and pasture grasses; use in recreational activities; width between 2.2 and 5.5 m and depth from 30.0 to 90.0 cm.

Site 3 (23° 50' 3.33" S; 54° 20' 58.53" W): Rapid water flow; sandy bed; marginal vegetation consists of scattered trees, shrubs and grasses for grazing; natural course changed to create a fish farming, width between 2.2 and 2.7 m and depth from 30.0 to 63.0 cm.

Samplings

Samplings were conducted quarterly from March to November 2008 in the upper (Site 1), intermediate (Site 2) and lower (Site 3) stretches of Água Boa Stream. Fish were caught using electrofishing (portable generator, direct current-DC). The sampling effort was standardized for the different months. The length of each sampled stretch was determined according to Fitzpatrick et al. (1998): five width measurements were taken from each stream (with emphasis on environmental heterogeneity, including habitats with fast flows, rapids and pools) and then calculated the arithmetic mean of these measurements, with the result multiplied by twenty. Thus, the length of the stretch sampled in the upper, intermediate and lower stretches were 82.0, 71.0 and 50.0 m, respectively. Blocking nets were set at the end of each stretch (10.0 x 2.0-5.0 mm in diameter) to prevent fish escape. A single electrofishing pass was used to collect the fish in each stretch.

Specimens were fixed in 10% formalin in the field and sorted and placed in glass vials containing 70% alcohol in the laboratory. The species identification followed Graça and Pavanelli (2007). Voucher specimens were deposited in the fish collection of Nupélia (*Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura*), *Universidade Estadual de Maringá* (NUP 16121, NUP 16138 to 16148 and NUP 16151 to 16155).

Data analysis

Stomach contents were analyzed according to volumetric method (percentage of volume of each item in relation to the total volume of the stomach contents) (Hyslop, 1980). Volume of each food item was determined using graduate test tubes and a counting chamber for items whose volume was lower than 0.1 mL (*sensu* Hellawell & Abel, 1971). In cases that the small size of food items (algae, testate amoebae and others) made impracticable their separation, the volume was estimated through attribution of percentage values in relation to the total volume of the stomach content. The contribution of food items in the diet was expressed in percentage of volume (%V).

In order to characterize the trophic groups, a Principal Coordinate Analysis (PCoA; Legendre & Legendre, 1998) was applied to the matrix of percentage volume of food resources using the Bray-Curtis distance to visualize the distribution of species according to the consumed food resources using the axes with higher eigenvalues. This analysis was performed using the software PCORD (McCune & Mefford, 2011). Species with low total number of stomachs (n < 5) were also included in the analysis, since the diets were consistent with the literature.

In the analyses, all food resources were grouped into five categories denominated as: aquatic invertebrates (larvae of Diptera, such as Chironomidae and Ceratopogonidae, Coleoptera, Ephemeroptera, Plecoptera, Trichoptera; nymphs of Odonata and Hemiptera; adults of Hemiptera, such as Corixiidae; Annelida; Cladocera; Copepoda, Hydracarina; Testacea), terrestrial invertebrates (adults of Coleoptera, Diptera, Homoptera, Hymenoptera, Orthoptera; larvae of Lepidoptera; Arachnida; Isopoda); algae (Bacillariophyceae, such as Centrales and Penales; Chlorophyceae, such as *Spirogyra*, *Closterium*; Cyanophyceae, such as *Oscillatoria*); plant material (roots, leaves, stems of Angyospermae) and detritus/sediment (particulate organic matter at different stages of decomposition with variable portions of mineral particles). Based on area values of each sampled stretch, we determined the density (number of individuals m^{-2}) and biomass (grams of fish m^{-2}) of trophic groups to characterize those with greater representativeness in the three sites.

Results

We analyzed 415 stomachs of 24 species collected in the Água Boa Stream, being 196 (five species) from Site 1, 82 (13 species) from Site 2 and 137 (16 species) from Site 3 (Table 1). The main resources exploited by the fish fauna were detritus/sediment and aquatic invertebrates. Considering the total resources consumed by the assemblage in each site, detritus/sediment was the dominant item in the diet of species in sites 2 (V=55.5%) and 3 (V=37.5%), while aquatic invertebrates predominated in Site 1 (V=37.7%)

The trophic groups were established from species ordination in relation to diet similarity synthesized by the PCoA, using the first axis scores between the distances of species and five food resources listed in Table 1. The first axis (eigenvalues=0.51, 1.17 and 1.83 for sites 1, 2 and 3, respectively) was the most informative and discriminated the fish fauna of the Água Boa Stream into six trophic groups (detritivores, herbivore, algivores, aquatic invertivores, terrestrial invertivores and omnivores) (Figure 2). All groups occurred in Site 2, whereas five and three occurred in Sites 3 and 1, respectively (Figure 2).

Table 1. Diet composition of fish assemblage of Água Boa Stream, Iguatemi River basin, MS, Brazil. Diet data are expressed as percentage volume and predominant items are in bold. N = number of stomachs analyzed; SL = standard length; minimum-maximum in cm; Aqiv = aquatic invertebrates; Triv = terrestrial invertebrates; Alga= algae; Plmt = plant material; Dtsd = detritus/sediment; species with total number of stomachs < 5 = *diet consistent to Hahn, Fuji, and Andrian (2004); ** Giora and Fialho (2003); ***Ferreira and Casatti (2006).

Sites	Code	N	LS min/max	Aqiv	Triv	Alga	Plmt	Dtsd
Site 1								
Astyanax aff. *paranae* Eigenmann, 1914	Apar	50	2.3-6.3	11.3	8.9	**46.6**	23.8	9.4
Callichthys callichthys (Linnaeus, 1758)	Ccal	8	3.6-6.5	**54.7**	5.1	0.0	8.9	31.3
Gymnotus inaequilabiatus (Valenciennes, 1842)	Gina	64	2.1-11.1	**74.3**	1.8	0.9	8.1	14.9
Hypostomus strigaticeps (Regan, 1908)*	Hstr	1	2.0	0.0	0.0	0.0	0.0	**100.0**
Phalloceros harpagos Lucinda, 2008	Phar	73	1.4-3.4	8.2	0.0	15.6	8.0	**68.3**
Site 2								
Astyanax aff. *paranae* Eigenmann, 1914	Apar	2	2.7-3.6	0.0	0.0	**100.0**	0.0	0.0
Astyanax altiparanae (Garutti & Britski, 2000)	Aalt	41	4.0-8.0	12.4	12.9	21.9	**29.6**	23.1
Bryconamericus stramineus (Eigenmann, 1908)	Bstr	3	4.1-5.0	**37.3**	28.8	0.0	11.5	22.5
Characidium aff. *zebra* Eigenmann, 1909	Czeb	4	3.8-5.4	**100.0**	0.0	0.0	0.0	0.0
Crenicichla britskii Kullander, 1982)***	Cbri	2	5.4-6.7	**100.0**	0.0	0.0	0.0	0.0
Cyphocharax modestus (Fernández-Yèpez, 1948)*	Cmod	1	7.9	0.0	0.0	0.5	4.5	**95.0**
Hypostomus aff. *iheringii* (Regan, 1908)*	Hihe	4	2.7-7.5	4.6	0.0	0.3	0.0	**95.1**
Hypostomus ancistroides (Ihering, 1911)***	Hanc	2	3.6-13.1	0.0	0.0	3.9	6.0	**90.1**
Hypostomus strigaticeps (Regan, 1908)*	Hstr	1	10.5	0.0	0.0	0.0	5.0	**95.0**
Knodus moenkhausii (Eigenmann & Kennedy, 1903)	Kmoe	14	1.8-3.6	**39.2**	5.7	24.3	3.5	27.4
Leporinus obtusidens (Valenciennes, 1836)*	Lobt	1	6.5	29.6	7.1	0.0	**63.3**	0.0
Moenkhausia aff. *sanctaefilomenae* (Steindachner, 1907)	Msan	2	4.6-5.5	0.0	**62.2**	0.0	0.0	37.8
Otothyropsis cf. *polyodon* (Calegari, Lehmann & Reis 2013)	Opol	5	2.9-3.9	0.6	0.0	3.5	2.3	**93.7**
Site 3								
Astyanax aff. *paranae* Eigenmann, 1914	Apar	3	2.8-2.8	20.0	0.0	**47.9**	27.9	4.2
Astyanax altiparanae (Garutti & Britski, 2000)	Aalt	12	2.5-8.6	21.6	**26.6**	19.6	13.0	19.2
Bryconamericus stramineus (Eigenmann, 1908)	Bstr	4	3.5-5.1	**89.5**	8.4	0.0	2.2	0.0
Characidium aff. *zebra* Eigenmann, 1909	Czeb	1	5.5	**100.0**	0.0	0.0	0.0	0.0
Corydoras aeneus (Gill, 1858)	Caen	18	3.1-5.0	**65.2**	0.0	0.0	8.9	25.9
Gymnotus inaequilabiatus (Valenciennes, 1842)	Gina	2	16.0-18.5	**45.8**	16.3	0.0	13.7	24.2
Hyphessobrycon eques (Steindachner, 1882)	Hequ	6	1.6-2.8	**63.2**	0.0	0.0	0.0	36.8
Hypostomus ancistroides (Ihering, 1911)***	Hanc	2	5.0-5.9	0.0	0.0	3.1	14.6	**82.3**
Knodus moenkhausii (Eigenmann & Kennedy, 1903)	Kmoe	3	2.9-3.8	**79.8**	0.0	9.5	9.5	1.2
Moenkhausia aff. *sanctaefilomenae* (Steindachner, 1907)	Msan	21	2.1-4.2	27.0	**36.8**	5.6	13.7	16.9
Moenkhausia bonita Benine, Castro & Sabino, 2004	Mbon	11	2.5-3.5	16.0	**49.6**	4.8	1.9	27.8
Pyrrhulina australis Eigenmann & Kennedy, 1903	Paus	24	1.7-3.3	5.5	29.5	3.0	3.4	**58.6**
Rhamdia quelen (Quoy & Gaimard, 1824)***	Rque	2	1.9-2.9	**100.0**	0.0	0.0	0.0	0.0
Serrapinnus notomelas (Eigenmann, 1915)	Snot	25	1.2-2.8	3.7	0.3	49.1	2.7	44.1
Steindachnerina brevipinna (Eigenmann & Eigenmann, 1889)**	Sbre	1	4.2	0.0	0.0	0.0	0.0	**100.0**
Trachelyopterus galeatus (Linnaeus, 1766)*	Tgal	2	1.6-8.5	**57.8**	0.0	38.6	0.0	3.6

The trophic group of aquatic invertivores was the most species-rich, with ten species. The number of such species was notably higher in Site 3. Another characteristic of this group was the inclusion of different species among the sites. *Gymnotus inaequilabiatus* was common to Sites 1 and 3 and *Characidium* aff. *zebra* was common to Sites 2 and 3. *Callichthys callichthys* and *Crenicichla britskii* were exclusive to Sites 1 and 2, respectively. *Bryconamericus stramineus*, *Corydoras aeneus*, *Hyphessobrycon eques, Knodus moenkhausii*, *Rhamdia quelen* and *Trachelyopterus galeatus* were exclusive to Site 3. Aquatic insects dominated the species diet, represented in over 50% by larvae of Ephemeroptera, Trichoptera and Chironomidae.

Detritivores exhibited the second highest species richness (eight species). This group was represented by loricariids in all sampled stretches. Site 2 was the most species-rich, with *Hypostomus* aff. *iheringii* exclusive to this local. *Hypostomus strigaticeps* and *H. ancistroides* were common to Sites 1 and 2, and Sites 2 and 3, respectively. The other species included in this trophic group showed restricted spatial distribution, with *Phalloceros harpagos* exclusive to Site 1, *Cyphocharax modestus* and *Otothyropsis* cf. *polyodo*n exclusive to Site 2 and *Pyrrhulina australis* and *Steindachnerina brevipinna* exclusive to Site 3.

The trophic group of omnivores, absent in Site 1, included three species, which were represented by *Astyanax altiparanae*, *B. stramineus* and *K. moenkausii*. These species occurred in Site 2 and only the former was present in Site 3. Filamentous Chlorophyta (*Spirogyra*), fruits/seeds, Hymenoptera and Chironomid larvae were the most important items in the species diet.

The group of terrestrial invertivores was formed by *Moenkhausia* aff. *sanctaefilomenae* and *Moenkhausia bonita*, which consumed mainly adults of Diptera and Hymenoptera. Both species occurred in Site 3 and only the former was observed in Site 2. Algivores also included two species, *A.* aff. *paranae* and *Serrapinnus notomelas,* whose diet consisted predominantly of Cianophyta and Chlorophyta

(*Spirogyra*). This group was present in all sampled stretches, with *Astyanax* aff. *paranae* present in the three sites and *M.* aff. *sanctaefilomenae* and *M. bonita* occurring only in Site 3. The trophic group of herbivores was restricted to Site 2 and comprised only *Leporinus obtusidens*, whose diet was mainly composed of stems and leaves of Angiospermae.

The trophic groups still showed variations in density and biomass among the sampled stretches (Figure 3). The higher density values were demonstrated by detritivores in Site 1, detritivores and omnivores in Site 2 and algivores, in Site 3. The major contribution in biomass came from to detritivores in Site 2 and aquatic invertivores in Sites 1 and 3.

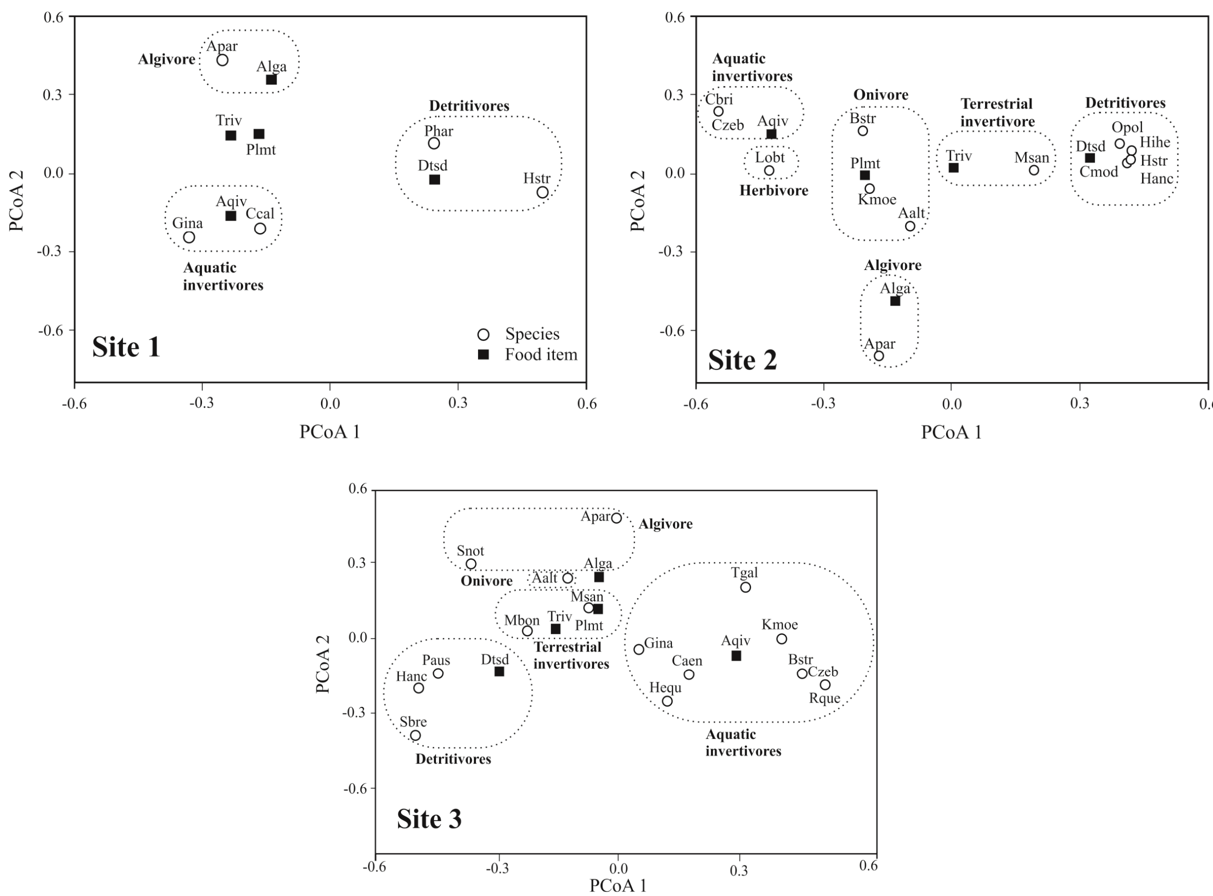

Figure 2. Ordination of fish species in trophic groups in Sites 1, 2 and 3 of the Água Boa Stream, Iguatemi River basin, MS, Brazil. Dotted lines indicate species belonging to the same trophic group. Codes according to Table 1.

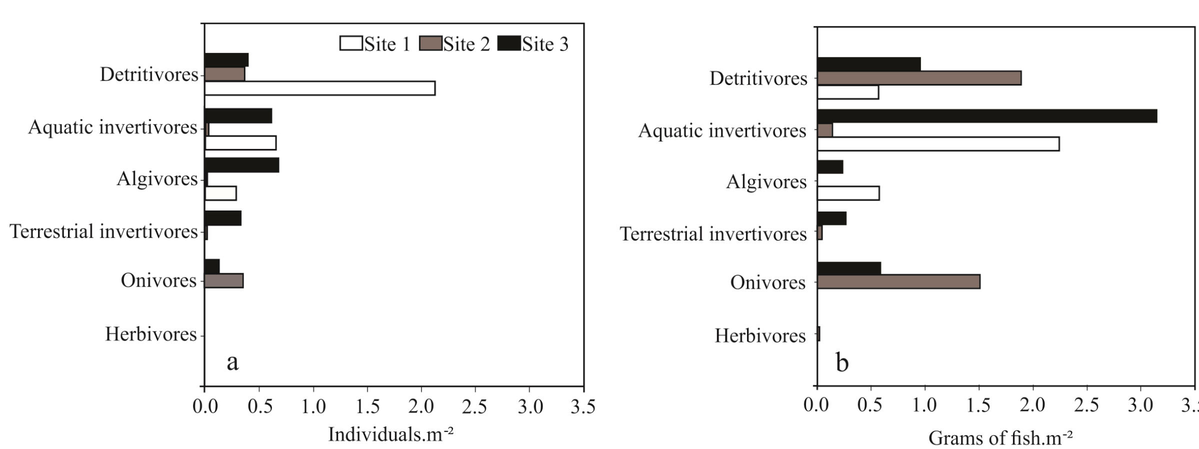

Figure 3. Density (a) and biomass (b) of trophic groups in Sites 1, 2 and 3 of the Água Boa Stream, Iguatemi River basin, Mato Grosso do Sul State, Brazil.

Discussion

In most streams, there is a progressive increase in the number of fish species downstream (Matthews, 1998) as observed herein in the Água Boa Stream. This pattern is usually associated with a gradual increase of living space, habitat diversity and environmental stability downstream (Horwitz, 1978) and was also described for other streams of the Upper Paraná River basin (Pavanelli & Caramaschi, 2003; Casatti, 2005; Apone, Oliveira, & Garavello, 2008; Bennemann, Shibatta, & Vieira, 2008). With respect to the main food resources exploited by the fish fauna of Água Boa Stream, our findings were consistent with other studies conducted in Brazilian streams, in which invertebrates or/and detritus were among the most representative items in the diet of fish (see Casatti, 2002; Araújo, Ribeiro, Doria, & Torrente-Vilara, 2009; Braga & Gomiero, 2009; Schneider, Aquino, Silva, & Fonseca, 2011; Ximenes, Mateus, & Penhas, 2011; Wolff et al., 2013; Cenevita-Bastos, Casatti, & Uieda, 2012; Neves, Delariva, & Wolff, 2015).

The high consumption of aquatic invertebrates, especially in Site 1 and Site 3, highlighted the importance of autochthonous resources to fish fauna in Água Boa. The riparian forest is degraded along the stream and particularly sparse in Site 1. Conditions, such as light reaching the stream bottom and low water flow, allowed the development of aquatic grasses, whose roots and stems accumulate detritus and periphyton, probably offering shelter and food to aquatic invertebrates. Unlike this result, for pristine or minimally disturbed systems, allochtonous resources prevail in the headwaters, once the canopy of the riparian forest limits light penetration, hindering autotrophic production (Vannote, Minshall, Cummings, Sedell, & Cushing, 1980). The fish fauna diet in these places are dominated by food of terrestrial origin (Teresa & Casatti, 2010). As the streams widen towards the mouth, they become less shaded and more productive (Vannote et al., 1980), increasing the offer of autochthonous food to fish (Teresa & Casatti, 2010). In Site 3, we observed that aquatic invertebrates colonized leaves and branches of abundant pasture grasses submerged along the banks, favoring the supply of this type of food to the fish fauna.

Although the origin of detritus is not determined, the inexpressive colonization by macrophytes (restrict to Site 1) suggests that the detritus are predominantly allochtonous and mainly composed of remains of pasture grasses, which are the most abundant vegetation in the landscape surrounding the Água Boa Stream. As fish are excellent environmental samplers (Winemiller, 1989), the expressive consumption of detritus/sediment in Sites 2 and Site 3 points out the apparent greater availability of this food at these sites. The stream substrate composition is consistent to that. Except for the stretches of rapids in Site 2, where the bottom is rocky, the stream bed is composed of clay and/or sand. Additionally, pools are frequent in the channel, favoring the accumulation of detritus/sediment. Apparently, accumulation of mineral and organic particles is a progressive process in the stream once siltation is easily observed along the longitudinal axis of Água Boa Stream.

As we analyzed a fish assemblage in relation to trophic groups, Angermeier and Karr (1984) alerted that the type and number of trophic groups varies with the species composition, availability of prey and taxonomic resolution adopted by the authors for the classification of fish. Concerning the number of trophic groups, usually, it increases downstream due to the increase in richness and food availability (Angermeier & Karr, 1984). Unlike this pattern, our results pointed out the higher number of trophic groups in Site 2, which was located, approximately, in the middle section of the Água Boa Stream. Among the three sampled sites, Site 2 had the highest variation in water flow (with rapids, riffles and polls) and in the type of bed substrate (rocky and sandy), probably providing a wide range of different microhabitats to fish fauna. Similar results were found by Wolff et al. (2013), who stated that the middle section of streams may have high heterogeneity and greater availability of different types of food resources, thus allowing more species to coexist and form distinct trophic groups.

Considering the richness observed among the trophic groups, the higher number of aquatic invertivores species indicated abundant supply of this resource in the Água Boa Stream, especially immature stages of Ephemeroptera, Trichoptera and Chironomidae. Immature stages of Insecta are widely distributed in streams, with a fundamental role in the aquatic food chain (Allan, 1995). The importance of these invertebrates in the diet of fish in tropical streams was also reported by other authors (Casatti, 2002; Braga & Gomiero, 2009; Ximenes et al., 2011; Neves et al., 2015). Aquatic invertivory was particularly expressive among species in Site 3, in which half of them (eight species) consumed predominantly aquatic insects. The success of aquatic invertivores in Site 3 was also evidenced by the high biomass; despite the small body size of most of them, since only specimens of

G. inaequilabiatus were medium in size (LS > 15 cm; Casatti et al., 2001). According to the River Continuum Concept, it is expected an increase in the consumption of insects by fish in the upstream-downstream direction, since large amounts of organic matter tend to accumulate in the lower stream areas, favoring the colonization of the substrate by insects (Vanotte et al., 1980; Schneider at al., 2011). It is also worth mentioning the high biomass of this trophic group in Site 1, evidencing the importance of aquatic invertebrates to the fish fauna, especially to *G. inaequilabiatus*, which was the most abundant invertivore in this stretch. Another characteristic of this trophic group was the change in the species composition along the stream axis, which can be associated with the availability of micro- or mesohabitats that meets the ecological requirements of species. It is well known that substrate, current flow and depth are the main physical variables determining the distribution of fish in streams (Horwitz, 1978; Angermeier & Karr, 1984; Casatti, 2005).

Detritivores also constituted a successful trophic group at Água Boa Stream, particularly in Sites 1 and 2. The numerical abundance of *P. harpagos* influenced the highest density of this group in Site 1. This species is specialized (small size, upper mouth and small fins) to live in slow flowing waters (Mazzoni, Novaes, & Iglesias-Rios, 2011), so that the large and shallow backwater area with clayey bed and aquatic grasses in Site 1 meets the species requirements of food and shelter. Differently, the relevance of detritivores in Site 2 resulted from the increase in the number of armored catfish species (Loricariidae), which quadrupled in this section, contributing to the high biomass of this trophic group in this site. Loricariidae fish are often considered as trophic specialists, with a long intestine necessary for adequate adsorption of slow-digesting foods from detritus (Bowen, 1983). They are also well adapted to environments with rapid flow, where they forage on foods attached to rocky substrates, especially periphyton and organic detritus (Casatti et al. 2001; Rolla, Esteves, & Ávila-da-Silva, 2009). Such conditions and resources were found in Site 2, as afore mentioned.

The representativeness of omnivore fish in trophic groups of streams is somewhat controversial. The predominance of such species can be expected in impacted streams, since a flexible diet is advantageous when the type of food available is very variable, as in these environments (Casatti, 2004; Uieda & Motta, 2007). However, omnivores were also described as a successful trophic group in a stream located in a well-preserved area and this result was attributed to the abundance of resources of plant origin (Schneider et al., 2011). This is not the case of the Água Boa Stream, since the riparian forest is predominantly scarce, limiting the availability of plant material to fish. However, calls attention the high biomass of omnivores in Site 2, coincidentally, where the riparian forest is relatively better conserved. Otherwise, the omnivores group was composed only of three characin species and two of them changed to the invertivores group in Site 3, indicating that species diet was induced by local availability of food resources.

The low richness and little participation in number and biomass of terrestrial invertivores trophic group in the Água Boa Stream indicated low supply of this food resource, but, apparently, this is not restricted to this environment. Data on fish diet from 15 New Zealand streams showed that the use of terrestrial invertebrate prey was relatively low compared to the use of aquatic invertebrates, regardless of land-use type (pasture grasses or forest) (Edwards & Huryn, 1996). For Brazilian streams, even those located in preserved areas in which allochtonous food was recognized as important for fish assemblages, the species foraging predominantly on terrestrial insects, complemented their diets with autochthonous foods, such as aquatic insects or algae (see Schneider et al., 2011; Wolff et al., 2013). Another point to consider is the species ability to capture this type of prey. Usually, terrestrial invertebrates are consumed by visual predators able to swim against the flow to capture drifting food in the water column (drift feeding), a role usually played by small characins in Brazilian streams (Sabino & Castro, 1990; Casatti, 2002). Specifically for the aquatic invertivore species in Água Boa (*M. bonita* and *M.* aff. *sanctaefilomenae*), aquatic and terrestrial insects are frequent items in the diet, however, *M.* aff. *sanctaefilomenae* seems to have preference for terrestrial insects (Tófoli, Hahn, Alves, & Novakowski, 2010; Carniatto, Fugi, Thomaz, & Cunha, 2014).

On the other hand, although the trophic group of algivores was composed of only two species, it reached high density in Site 3. This result reflected the relative high abundance of *S. notomela*s in the lower stretch of the Água Boa Stream. This species is described as a specialist in the consumption of algae (Hahn & Loureiro-Crippa, 2006) and occurs in warm shallow marginal pools in lower stream reaches, where filamentous algae are abundant (Casatti, 2004). In general, algivores fish are favored in streams when the environment is devoid of riparian forest, enabling primary production (Teresa & Casatti, 2010), a condition found in Água Boa.

Apparently, favorable microhabitats were offered to *S. notomelas* in Site 3 by submerged leaves and branches of pasture grasses, reducing the flow close to the banks and providing substrates for algal colonization.

Conclusion

Fish species in the Água Boa Stream play different roles in the ecosystem, since they occupy a variety of trophic groups. This scenario can be changed by environmental simplification, due to silting and progressive loss of riparian forest, then, actions focused on riparian forest restoration and systematic implementation of soil conservation techniques in the Iguatemi River basin are essential to conserve the fish fauna of the Água Boa Stream.

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