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Icthyofauna from streams of Barro Alto and Niquelândia, upper Tocantins River Basin, Goiás State, Brazil

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Abstract: In face of the accelerated degradation of streams located within the Brazilian Cerrado, the knowledge of distribution patterns is very important to aid conservation strategies. The aim of this work is to increase the knowledge of the stream's fish fauna in the State of Goiás, Brazil. 12 streams from the municipalities of Barro Alto and Niquelândia were sampled with trawl nets. During this study, 1247 fishes belonging to 27 species, 11 families, and three orders were collected. Characiformes comprised 1164 specimens of the sampled fishes, the most abundant order, while Perciformes was the less abundant order, with 17 collected specimens. Perciformes fishes were registered only in streams from Niquelândia. *Astyanax elachylepis*, *Bryconops alburnoides* and *Astyanax* aff. *bimaculatus* were the most representative species, with 306, 233 and 158 collected individuals. The prevalence of Characiformes followed by Siluriformes in bodies of continental water is a pattern already established and found in other work done in streams, and the Characidae family the most abundant and diverse. The composition of the fish fauna of streams in the municipality of Barro Alto and Niquelâdia are similar to other studies conducted in Brazil, and the composition observed in Niquelândia may be more similar to impacted sites them Barro Alto, but the composition is consistent with studies in the upper Tocantins River basin.

Keywords: Cerrado; Fish diversity; Catchment; Species list; Sugar Cane; Mining.

Resumo. Peixes de riachos de Barro Alto e Niquelândia, bacia do alto rio Tocantins, Goiás, Brasil. Em virtude da acelerada degradação dos riachos localizados no Cerrado, o conhecimento dos padrões de distribuição de espécies é importante para ajudar nas estratégias de conservação. O objetivo deste trabalho é aumentar o conhecimento da distribuição da fauna de peixes de riachos no estado de Goiás, Brasil. Para isso, foram amostrados 12 riachos, com redes de arrasto, dos municípios de Barro Alto e Niquelândia. Um total de 1247 peixes pertencentes a 27 espécies, 11 famílias e três ordens foram coletados. Characiformes compreenderam 1164 indivíduos dos peixes amostrados, a ordem mais abundante, enquanto Perciformes foi ordem menos abundante, com 17 espécimes coletadas registrados apenas em riachos de Niquelândia. *Astyanax elachylepis*, *Bryconops alburnoides* e *Astyanax* aff.

bimaculatus foram as espécies mais representativas, com 306, 233 e 158 indivíduos coletados. A predominância de Characiformes seguido de Siluriformes em corpos d'água continentais é um padrão já consolidado e encontrado em outros trabalhos feitos em riachos, sendo a família Characidae a mais abundante e diversa. A composição da ictiofauna de riachos do município de Barro Alto e de Niquelândia é similar a outros estudos realizados no Brasil, sendo que a composição observada em Niquelândia pode ser mais parecida com locais impactados que Barro Alto, no entanto a composição ainda é condizente com estudos realizados na bacia do alto rio Tocantins.

Palavras-Chaves: Cerrado; Diversidade de espécies de peixes; Riachos de cabeceira; Lista de espécies; Cana de açúcar; Mineração.

Introduction

The existing drainage basins located in the Midwest region of Brazil are inserted in the Cerrado domain, which is the second largest Brazilian morpho-climatic domain, covering an area of approximately 2 million Km² (Ratter *et al.* 1996). In this context, stands the state of Goiás, which is drained by four major rivers: the Araguaia River (north), Tocantins River (north and northeast), Paranaíba River (south) and tributaries of San Francisco (east). Tocantins-Araguaia basin drains as area of approximately 767.000 km2 (Mérona *et al.*, 2010), rising in Goiás State (central region of Brazil), and ending in the Amazon delta, in the Bay of Marajó, Pará State (Santos *et al*. 2004). Although the ichthyofauna of the Tocantins river basin is closely related to the Amazon basin, (Goulding *et al.* 2003) it is possible to find a greater number of endemic species, that occur only in Tocantins river basin (Abell *et al.* 2008; Bertaco *et al.* 2011; Bertaco & Carvalho, 2010; Carvalho *et al.* 2010; Hubert & Renno, 2006; Lucinda *et al.* 2007; Santos *et al.* 2004).

Despite the highest diversity and endemism in the Tocantins river basin, we observe few studies on fish streams for the state of Goiás (e.g. Araújo & Tejerina-Garro, 2007, 2009; Benedito-Cecilio *et al.* 2004; Claro-García &Shibatta, 2013; Dias & Tejerina-Garro, 2010; Mazzoni *et al.* 2010; Miranda & Mazzoni, 2009; Vieira & Tejerina-Garro, 2014) and only three studies in that was performed in the Tocantins river in the Goiás state (e.g. Claro-García & Shibatta, 2013; Mazzoni *et al.* 2010; Miranda & Mazzoni, 2009). This article aimed providing a list of fish species from stream of Barro Alto and Niquelândia, Goiás and comparing the composition between Barro Alto and Niquelândia drainages.

Materials and Methods

Study Site. The study was conducted in 12 streams (Figure 1, Table I), located in two municipalities in the state of Goiás, five in Niquelândia (14º26’09”S 48º29’02”W) and seven in Barro Alto (14°58’15”S 48°54’57”W). These sites was selected according the accessibility, presence of vegetation in the point (all streams had at least 15m of riparian vegetation in each border), presence of riparian vegetation in the catchment upstream sampled point and order smaller than three. These criteria were select to avoiding sample bias and ensure able comparisons between sites. For these reason only 12 sites were selected. According to the Köppen classification, the climate ranges from humid to sub-humid and has two distinct seasons: a rainy season between October and March and dry season between April and September (Ferreira &Tokarski 2007). Local drainages comprise the sub-basins of Almas and Maranhão (Barro Alto) and Traíras (Niquelândia) rivers, with similar deep, width and drainage area.

Data Collection. During 25 days in November 2009 (beginning of rainy season) and 22 days in March 2010 (end of the rainy season), fish were sampled in Barro Alto and Niquelândia. In each site, in a section of 100m demarcated in each stream and split into 10 subsections of 10 m each. In each subsection, we used trawl net and sieve, dragging the trawl net in the upstream-downstream direction. Collected specimens were identified with the name of the stream and the sample number, anesthetized with eugenol 10% and immersed in formalin 10%.

During screening, total and standard length and weight were obtained from each fish. The identification was performed using the current literature keys (e.g.: Buckup, 1993; Chernoff & Machado-Allison, 1999; Lucena & Kullander, 1992; Reis, 1997; Soares-Porto, 1994; Vari & Reis, 1995) and help of specialists. After identification, the specimens were separated into lots according to their species and collection site, packed in glass jars and preserved in 70% alcohol. The taxonomic classification follows Reis *et al.* (2003). All collected specimens were deposited in the Zoological Collection of the Federal University of Goiás (ZUFG).

Table I. Streams sampled in Barro Alto and Niquelândia with geographic coordinates

Point	Municipality	Acronym	Coordinates	
			Latitude	Longitude
P01	Barro Alto	Ribeirão de Fora	15°02’ 53’’S	48°57’ 54’’W
P02	Barro Alto	Dois Córregos	15° 04’ 45”S	48° 57’ 45”W
P03	Barro Alto	Serrinha	15° 06’ 29”S	49° 01’ 19”W
P04	Barro Alto	Lages	15° 05’ 53”S	49° 02’ 34”W
P05	Barro Alto	Lages 2	15° 07’ 39”S	49° 04’ 08”W
P06	Barro Alto	Reserva	15° 08’ 47”S	49° 03’ 21”W
P07	Barro Alto	Gaiola	15° 06’ 53”S	48° 55’ 39”W
P08	Niquelândia	Bezerro	14° 11’ 12”S	48° 20’ 12”W
P09	Niquelândia	Ribeirão da Roça	14° 11’ 57”S	48° 20’ 10”W
P10	Niquelândia	Córrego Forquilha II	14° 12’ 58”S	48° 20’ 10”W
P11	Niquelândia	Córrego Forquilha I	14° 14’ 13”S	48° 20’ 10”W
P12	Niquelândia	Do Carmo	14° 06’ 26”S	48° 21’ 39”W

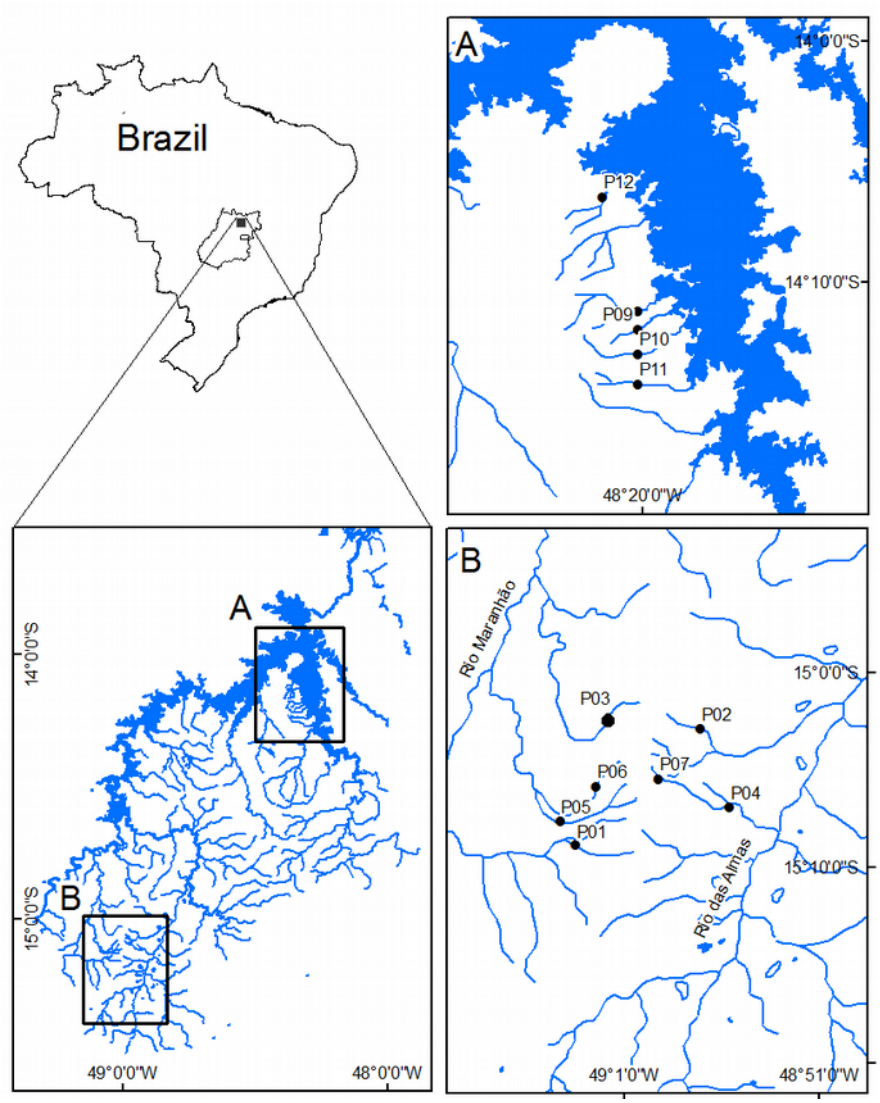

Figure 1. Spatial location of sampled streams, during this study, in Niquelândia (A) and Barro Alto (B) GO - Brazil. P01 - Ribeirão de Fora, P02 - Dois Córregos, P03 – Serrinha, P04 – Lages, P05 - Lages 2, P06 – Reserva, P07 – Gaiola, P08 – Bezerro, P09 - Ribeirão da Roça, P10 - Córrego Forquilha II, P11 - Córrego Forquilha I e P12 - Do Carmo. The blue lines represent streams.

Data Collection. During 25 days in November 2009 (beginning of rainy season) and 22 days in March 2010 (end of the rainy season), fish were sampled in Barro Alto and Niquelândia. In each site, in a section of 100m demarcated in each stream and split into 10 subsections of 10 m each. In each subsection, we used trawl net and sieve, dragging the trawl net in the upstream-downstream direction. Collected specimens were identified with the name of the stream and the sample number, anesthetized with eugenol 10% and immersed in formalin 10%.

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Data Analysis. Each of the 12 streams had their richness estimated through Jackknife procedure (Heltshe & Forrester, 1983), under 1000 iterations in software EstimateS 9.1 (Colwell & Elsensohn, 2014). Species richness was independently estimated for both Barro Alto and Niquelândia municipalities and subsequently compared with confidence interval inference (Zar, 1999). In order to estimate species richness for Barro Alto and Niquelândia, we used each stream as pseudo replica. To estimate the richness in each stream we consider the 10 subsection on beginning of rainy season and the 10 subsection on the end of the rainy season as replica. In this way all streams have 20 replicas (Heltshe &Forrester, 1983).

Similarity in fish composition of both sampled municipalities was carried out on a MRPP - Multi-Response Permutation Procedure (McCune & Grace, 2002) using the function mrpp, package vegan (Oksanen *et al.* 2017), R software (R Core Team, 2015). We made these comparisons by applying Bray Curtis dissimilarity in a matrix that included species abundance per stream and grouped streams by municipality. The statistics considered in this test is denominated *A*, and varies from 1 to -1. Near-zero positive values mean that the difference in species composition between the compared areas is not different from expected by chance. However, positive values next to 1 mean that the difference in species composition between the two sampled areas is not explained by chance. Negative values occur when the variation within each considered area is significantly greater than between different areas (McCune & Grace, 2002). We performed a Detrended Correspondence Analysis (DCA) to plot and search for differences in species composition between the sampled areas (McCune & Grace, 2002).

Results

We collected 1247 individuals belonging to 27 species and 11 families (Table II) belonging to the orders Characiformes, Perciformes and Siluriformes. Characiformes contributed with 1164 individuals being the most abundant order. Perciformes had the lowest abundance values, with 17 individuals, which were collected only in streams sampled in Niquelândia. *Moenkhausia aurantia* Bertaco *et al.* 2011 was the most represented species, with 395 individuals, followed by the characids *Astyanax elachylepis* Bertaco & Lucinda, 2005, *Bryconops alburnoides* Kner, 1858, and *Astyanax* aff. *bimaculatus* (Linnaeus, 1758) with, respectively, 306, 233 and 158 collected specimens. On the other hand, we collected only one individual of *Tatia neivai* (Ihering, 1930) (family Auchenipteridae) and of *Pyrrhulina australis* Eigenmann & Kennedy, 1903 (family Lebiasinidae).

Stream P01 showed the highest species richness (11 species), subsequently followed by P04, P08, P09 and P10, with each one having 10 species. On the other hand, stream P11 presented the lowest richness and abundance values, having only one specimen of *Astyanax* aff. *bimaculatus* (Linnaeus, 1758) sampled. Regarding species abundance, P09 and P07 presented the highest values of abundance, with 316 and 208 collected individuals. When considering each stream as a sample unit, we observed that the estimated species richness varied from two species in P11 to 14 species in P01 (Figure 2).

For some streams (P05, P08, P09, P10, and P12), estimated species richness (Jackknife) did not differ from observed species richness (Sobs) (confidence intervals superposed averages). For these streams, the number of collected species represents the total species existing in them. In the remaining eight streams, it appears that it is still possible to capture new species with new sampling. It is possible to conclude that the average species richness of fish from Barro Alto (Jackknife = 24

Table II. List of species and abundance of fishes sampled in 12 streams from Barro Alto e Niquelândia (GO, Brazil) during 2009/2010. Species are sorted in order and family

ORDER	Barro Alto							Niquelândia					Abundance
Family													
Species	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	
CHARACIFORMES													1164
Characidae													1124
Astyanax aff. bimaculatus (Linnaeus, 1758)	15	13	42	64	12	0	1	1	2	4	1	3	158
Astyanax elachylepis Bertaco and Lucinda, 2005	1	0	0	0	0	1	0	27	125	49	0	103	306
Astyanax sp.	0	3	0	2	0	0	0	0	0	0	0	0	5
Bryconops alburnoides Kner, 1858	8	0	0	12	11	55	5	4	126	12	0	0	233
Bryconops caudomaculatus (Günther, 1864)	0	0	0	0	0	0	0	1	2	1	0	0	4
Creagrutus cf. *menezesi* Vari and Harold, 2001	4	0	1	8	4	0	6	0	0	0	0	0	23
Moenkhausia aurantia Bertaco, Jerep and Carvalho, 2011	3	39	0	13	56	9	185	3	40	47	0	0	395
Crenuchidae													26
Characidium sp.	0	3	0	1	2	1	0	0	0	0	0	0	7
Characidium zebra Eigenmann, 1909	1	0	2	0	0	6	0	0	2	8	0	0	19
Erythrinidae													8
Hoplias malabaricus (Bloch, 1794)	2	0	0	0	1	1	0	2	2	0	0	0	8
Lebiasinidae													1
Pyrrhulina australis Eigenmann and Kennedy, 1903	0	0	0	0	1	0	0	0	0	0	0	0	1
Parodontidae													5
Apareiodon machrisi Travassos 1957	0	0	0	0	4	0	1	0	0	0	0	0	5
SILURIFORMES													66
Auchenipteridae													1
Tatia neivai (Ihering, 1930)	0	0	0	1	0	0	0	0	0	0	0	0	1
Callichthyidae													10
Aspidoras sp.	0	0	0	0	0	6	4	0	0	0	0	0	10
Heptapteridae													5
Pimelodella sp.	0	0	0	1	0	0	1	0	0	0	0	0	2
Rhamdia quelen (Quoy and Gaimard, 1824)	3	0	0	0	0	0	0	0	0	0	0	0	3
Loricariidae													46
Hemiancistrus cf. *cerrado* Souza et al, 2008	0	0	0	0	0	0	1	0	6	0	0	0	7
Hypostomus plecostomus (Linnaeus, 1758)	1	0	0	1	6	0	0	1	0	6	0	0	15
Loricaria cataphracta Linnaeus, 1758	0	0	0	0	0	0	0	0	6	0	0	0	6
Hisonotus sp.	1	0	0	0	0	12	4	0	0	0	0	0	17
Rineloricaria sp.	1	0	0	0	0	0	0	0	0	0	0	0	1

Trichomycteridae													4
Trichomycterus sp.	0	0	0	0	0	0	0	0	0	4	0	0	4
PERCIFORMES													17
Cichlidae													17
Aequidens hoehnei (Miranda Ribeiro, 1918)	0	0	0	0	0	0	0	1	5	3	0	0	9
Satanoperca jurupari (Heckel, 1840)	0	0	0	0	0	0	0	3	0	4	0	0	7
Species Richness	11	5	3	10	9	8	9	10	10	10	1	2	
Abundance	40	58	45	103	97	91	208	44	316	138	1	106	1247

species; Sobs = 21 species) is higher than the fish richness from Niquelândia (Jackknife = 17 species; Sobs = 14 species) (Figure 3).

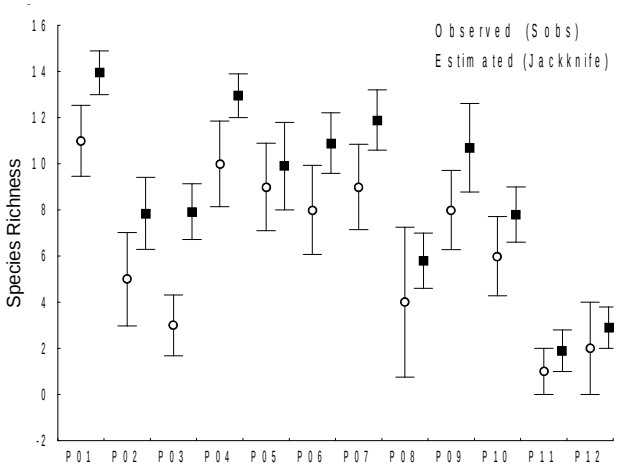

Figure 2. Observed (Sobs) and estimated richness of fish (Jackknife with 20 pseudoreplicas for each stream) for the 12 sampled streams in Barro Alto (P01 a P07) and Niquelândia (P08 a P12), Goiás, Brazil, during the year of 2009/2010. Bars represent the interval confidence of 95%.

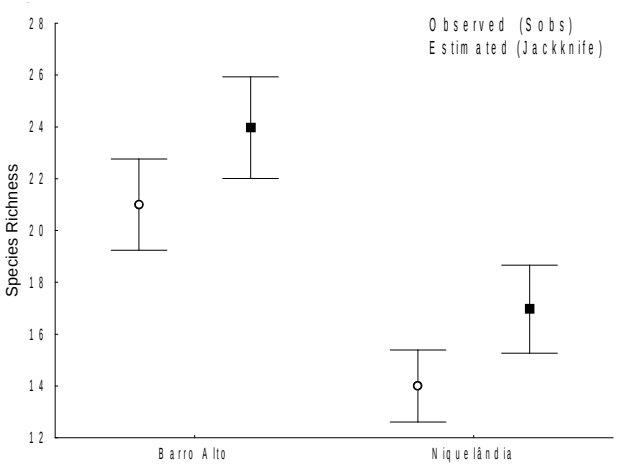

Figure 3. Observed (Sobs) and estimated species richness (Jackknife) of fish for Barro Alto (140 pseudoreplicas) and Niquelândia (100 pseudoreplicas). Bars represent the interval confidence of 95%.

Species compositions of these municipalities are different to (A = 0.292, p = 0.004). We observed that the species *Aequidens hoehnei* (Miranda-Ribeiro, 1918), *Bryconops caudomaculatus* (Günther, 1864), *Satanoperca jurupari* (Heckel, 1840), *Loricaria cataphracta* Linnaeus, 1758 and *Trichomycterus* sp. are mainly associated with streams sampled in Niquelândia. On the other hand, *Apareiodon marchrisi* Travassos, 1957, *Characidium* sp., *Moenkhausia aurantia* Bertaco *et al.* 2011 and *Pimelodella* sp. were more associated with streams located in Barro Alto (Figure 4). We also observed the clustering of points into two groups: one formed by streams from Barro Alto plus stream P11 (which is located in Niquelândia), and another group formed by Niquelândia and stream P06 (located in Barro Alto).

Discussion

Sampled ichthyofauna was dominated by the orders Characiformes followed by Siluriformes, which is a pattern already found in another studies in streams of the state of Goiás (e.g. Araújo & Tejerina-Garro, 2007; Benedito-Cecilio *et al.* 2004; Claro-García & Shibatta, 2013; Mazzoni *et al.* 2010; Miranda & Mazzoni, 2009) and indicated by Lowe-McConnell (1987) for non-estuarine sites. Among the Characiformes, Characidae is the family most abundant and rich in species (Santos *et al.* 2004), a pattern confirmed in our study. We observe differences in the observed and estimated richness in both areas (Barro Alto and Niquelandia) since the the confidence interval does not overlap the mean. This result shows that streams are under sampled yet and new fieldworks can result in new species. However, our results, in terms of species richness, are similar with others studies performed in streams (e.g.: Casatti *et al.* (2006) - 22 species; Benedito-C*ecilio* et al. (2004) 22 species; Araújo & Tejerina-Garro (2007, 2009) 15 35 species), and the low diversity of headwater default, once headwater are considered sites with minor habitat complexity and, consequently low diversity (Montgomery, 1999; Vannote *et al.* 1980).

Several factors might be responsible for the variation in species richness and composition found in different surveys: (1) sampling time; (2) season of the fieldwork (rainy or dry); (3) sampling methods; (4) point location in the drainage (headwater or outfall of the drainage); (5) type of sampled environment (streams, rivers or flood plains) and (6) the deforestation index of the drainage. The difference between Barro Alto and Niquelândia in fish diversity could be associated to the higher deforestation index in Niquelândia. In fact, Niquelândia show a great process of deforestation, started in the construction of Serra da Mesa dam and the occupancy of the lake shore for recreation like fishing and aquatic sports and later for sugar cane culture. For these reason, Niquelândia show a landscape more impacted, and less diverse streams, than Barro Alto. These hypotheses should be corroborate when we observe that the stream with high richness (p1) was located on Barro Alto and the

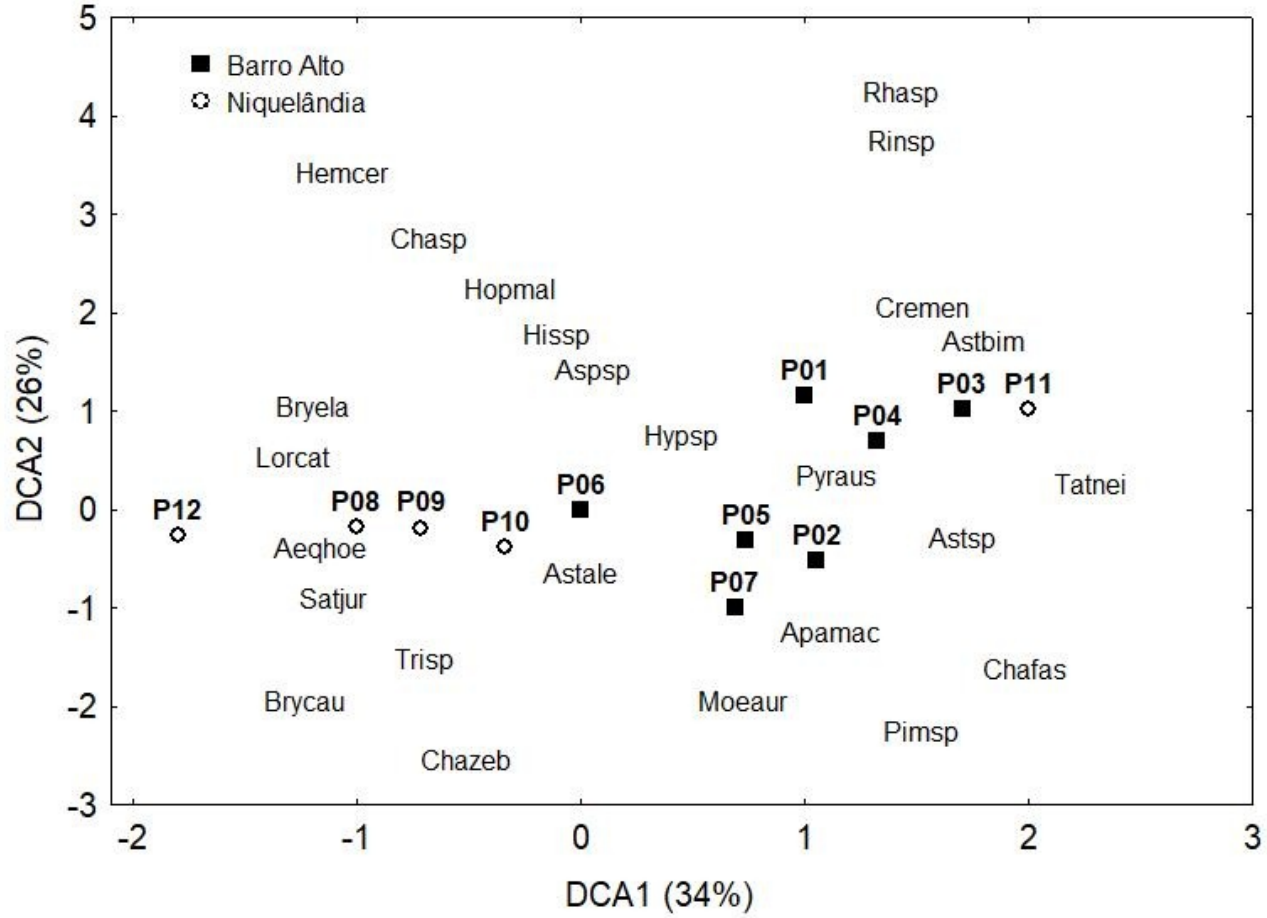

Figure 4. Ordination of the abundance data for the 12 streams sampled in Barro Alto and Niquelândia (GO, Brazil) during the years of 2009/2010. Aeqhoe - *Aequidens hoehnei*; Apamac - *Apareiodom machrisi*; Aspsp - *Aspidoras* sp; Astbim - *Astyanax aff. bimaculatus*; Astela - Astyanax elachylepis; Astsp - *Astyanax* sp; Bryalb - *Bryconops alburnoides* ;Brycau - *Bryconops caudomaculatus*; Chasp - *Characidium* sp.; Chazeb - *Characidium zebra*; Cremen - *Creagrutus* cf. *menezesi*; Hemcer - *Hemiancistrus* cf. *cerrado*; Hissp - *Hisonotus* sp.; Hopmal - *Hoplias malabaricus*; Hypple - *Hypostomus plecostomus*.; Lorcat - *Loricaria cataphracta*; Moeaur - *Moenkhausia aurantia*; Pimsp - *Pimelodella* sp.; Pyraus - *Pyrrhulina australis*; Rhasp - *Rhamdia* sp.; Rinsp - *Rineloricaria* sp.; Satjur - *Santanoperca jurupari*; Tatnei - *Tatia neivai*; Trisp - *Trichomycterus* sp.

two lower richness were observed in streams on Niquelândia (P11 and P12). Additionally Barro Alto shows a recent mining historical (early 5 to 10 year) and Niquelândia an ancient mining activity (more than 15 years). Differences in land use can be responsible for composition differences, too. These results suggest that landscape is more important than riparian vegetation structure, once all streams have at least 15 meters of riparian vegetation. Or these 15 meters cannot be considered as an efficient filter. Riparian zones with 15 meters are considered efficient to minimize or mitigate the effects of deforestation on communities in tropical headwater streams (Lorion & Kennedy, 2009). On the other hand, the effect of landscape on fish community was examined in few studies and the relationship between fish communities of tropical headwater streams and landscape is poorly understood.

The ichtyofauna found in streams of the municipalities of Barro Alto and Niquelândia are still under sampled (observed and estimated richness are different) and more species can be found with an increase in sampling effort, and addition of new streams and rivers (like dos Patos River in Barro Alto and Traíras River in Niquelândia) and other methodologies like electrofishing to increase the effectiveness of samplings. The difference in the richness and composition of fish fauna is probably caused by the land use, once all streams had, at least, 15 m of riparian vegetation and the basins had the equal area. However, only with new samples we will be able to understand the relationship between land use and fish diversity in stream.

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