Diel variation in the structure of fish assemblages in south western Amazon streams

Variação diária na estrutura de assembleias de peixes em igarapés da Amazônia Sul Ocidental

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Abstract: Aim: We investigate the influence of luminosity, habitat conservation and pluviometric periods in fish assemblages of in pasture and forest small streams in western amazon. **Methods:** Sampling was conducted every two months from July 2013 to April 2014 in nine first- and second-order streams using seine nets and dip nets during the day and night. Fish composition, richness and total abundance were determined for each sampling period. The PERMANOVA was used to evaluate the effects of land use, season, and photoperiod, on fish assemblages. Fish assemblage structure for each stream in the presence and absence of photoperiod was ordered by NMDS analysis. **Results:** In the light period, 3,484 specimens from 69 species were collected, while 4,574 specimens from 71 species where collected in the dark period. No significant differences in abundance and species richness were recorded between the presence and absence of luminosity periods, rainy and dry seasons and streams in forest and deforested areas. We found evidence of the dark phase composition and richness of exclusive species (22% of species collected were found at night), which were greater than in the light period (20% of species). **Conclusion:** Despite our failure to identify any nycterohemeral segregation, the results complement existing knowledge of regional ichthyofauna and help provide a better understanding of the distributional, behavioral and functional ecological patterns of fish assemblages.

Keywords: day-night shifts; fish assemblages; Rondônia; Machado River.

Resumo: Objetivo: Investigamos a influência da luminosidade, conservação do habitat e períodos pluviométricos nas assembleias de peixes de igarapés em pastagem e floresta na Amazônia Ocidental. **Métodos:** A amostragem foi realizada bimestralmente, de julho de 2013 a abril 2014 em nove igarapés de primeira e segunda ordem, utilizando redes de arrasto e puçá durante o dia e a noite. A composição, riqueza e abundância total da ictiofauna foram determinadas para cada período de amostragem. A PERMANOVA foi utilizada para avaliar os efeitos do uso da terra, estação e fotoperíodo sobre assembleias de peixes. A estrutura das assembleias de peixes para cada igarapé com presença e ausência de fotoperíodo foi ordenada através de NMDS. **Resultados:** No período de presença de luminosidade, 3.484 exemplares de 69 espécies foram coletadas, enquanto 4.574 exemplares de 71 espécies, foram coletados no período com ausência de luminosidade. Não foram encontradas diferenças significativas na abundância e riqueza de espécies entre os períodos de presença e ausência de luminosidade, estação chuvosa e seca e para igarapés em áreas florestadas e desmatadas. Nós encontramos evidências da composição de espécies exclusivas no período com ausência de luminosidade (22% das espécies), que foi maior do que no período com presença de luminosidade (20% das espécies). **Conclusão:** Apesar

de nossa incapacidade de identificar qualquer segregação nictemeral, os resultados complementam o conhecimento existente da ictiofauna regional e ajudam a fornecer uma melhor compreensão dos padrões ecológicos distribucionais, comportamentais e funcionais de assembleias de peixes.

Palavras-chave: substituição diurna-noturna; assembleias de peixes; Rondônia; rio Machado.

1. Introduction

Diel activity patterns are among the most evident and detectable rhythms in animals and the main subject of many chronobiological naturalistic and experimental studies (Naruse & Oishi, 1996; Anras et al., 1997; Volpato & Trajano, 2006). These patterns have already been investigated in different ecosystems such as seagrass beds, coral reefs and mangroves (Nagelkerken et al., 2000; Pereira et al., 2010). Many organisms studied, from protists to plants and animals, provide strong evidence of a more or less tight control of activity patterns by internal clocks (Volpato & Trajano, 2006).

Aquatic organisms are not exceptions; many studies have been devoted to different kinds of rhythms these organisms show (Volpato & Trajano, 2006). In fishes, there is evidence of endogenous and exogenous circadian rhythms in some species, which affects activity patterns, vision and the growth of scales and otoliths (Boujard & Leatherland, 1992; Volpato & Trajano, 2006). It has been shown that the teleost circadian system encompasses multiple self-sustained oscillators and that at least two organs, the pineal organ and retina, contain oscillators (Volpato & Trajano, 2006). Photoreceptors in the retina and pineal organ and deep in the brain are believed to be involved in photosignal transduction to establish circadian rhythms in fish (Iigo & Tabata, 1996). Each of these organs may be involved individually in the entrainment of locomotor activity in certain fish species (Volpato & Trajano, 2006).

Diel activity rhythms are expressed by locomotor activity patterns associated with alternating phases (active period *vs.* rest period), exploitation of habitat, feeding and intra- and interspecific interactions (formation of shoals, agonistic behavior, territory defense, breeding and predator-prey interactions) (Kavaliers, 1980; Helfman, 1986). Taking into account the circadian rhythms, fish can be classified as active during nocturnal, diurnal or crepuscular (mixed types, for which between 35% and 65% of activity occurs in the dark phase) periods (Iigo & Tabata, 1996). For instance, in inland Neotropical waters, Siluriformes and Gymnotiformes are more active at night, whereas most Characiformes and Cichlidae feed and migrate during the day (Lowe-McConnell, 1999; Carvalho, 2008).

Species-specific photoperiod variations can mean that the abundance of individuals and species in a given habitat changes over the course of 24-hours, as determined by feeding activities (Piet & Guruge, 1997), predation and the need to escape from predators (Gibson et al., 1998; Grossman et al., 1998). According to Lowe-Mcconnell (1999) the presence of predators and large species at dark phase, while small species protect themselves in the vegetation, is a common observation in Neotropical rivers. Many ecological studies of Neotropical fish assemblages have been carried out in larger water bodies, such as rivers and lakes (Arrington & Winemiller, 2003; Pelicice et al., 2005; Willis et al., 2005; Saccol-Pereira & Fialho, 2010; Costa & Freitas, 2010; Duarte et al., 2010, 2012; Costa et al., 2011, 2015).

Despite the immense literature on this topic, little is found regarding fishes - and even less regarding the tropical ones (Volpato & Trajano, 2006). Especially when related to studies of diurnal and nocturnal assemblages in Amazon small streams (e.g., Bührnheim, 2002). Thus, studies in amazon small streams are necessary, considering the high number of species, the accelerated deforestation and the degradation to the streams, mainly in Rondônia State. It very important acquire the taxonomic, geographical, and ecological knowledge of the ichthyofauna. As a potential additional threat to this fish fauna we can cite the expansion of hydroelectric power plants (Casatti et al., 2013).

Based on the premise that Characiformes is the most abundant and rich group species in amazon small streams, and is more active during the diurnal period, Siluriformes and Gymnotiformes, are most active during the nocturnal period (Lowe McConnell, 1999) and species-specific in the daily cycle variations can mean that the abundance and species in a given habitat changes, determined by intra-interspecific relationships (Gibson et al., 1998; Grossman et al., 1998), we tested the hypothesis that photoperiod influences fish activity, resulting in changes in the composition, abundance and species richness of the icthyofauna in pasture and forest small streams in the rainy and dry seasons, in the Machado River basin, state of Rondônia, Brazil.

2. Material and Methods

2.1. Study area

The Machado River is approximately 1,243 km long. It starts at the confluence of the Pimenta Bueno River and Comemoração River and flows in to the Madeira River in the north of the state of Rondônia (RO) (Fernandes & Guimarães, 2002). First to third order streams are predominat in the Machado River basin and have a total length of 27,497 km (Krusche et al., 2005). The climate is characterized by temperatures ranging from 19 to 33 °C and annual rainfall is around 2,500 mm (Krusche et al., 2005) and there are two well-defined seasons: the dry season (from late May to October) and rainy season (from November to May) (Fernandes & Guimarães, 2002).

2.2. Fish collections

A series of 18 samplings was conducted during three rainy and three dry months: June, August and October 2013 (dry season) and December, February and April 2014 (rainy season). Each sampling included the fish abundance in the nine first- and second-order streams in the middle section of the Machado River basin (Table 1) during high luminosity period (12:00-13:00 hours) and once again during dark period (19:30-20:30 hours).

To prevent the potential negative effects of sampling, samples of the absence luminosity period were conducted 20 m upstream and 10 days after high luminosity period samplings. We highlight out that both the samples collected during absence luminosity period, as in the high luminosity period, obeyed the minimum distance of 20 m. Failing to collect samples in the same location. Noting that the sites are similar in terms of habitat condition and heterogeneity.

In total, 108 samples were obtained (Table 1). Fishes were collected using a seine net (1.5 × 2 m, 2 mm mesh) and dip net (0.5 × 0.8 m, 2 mm mesh) along a 50 m stretch for three people for one hour. Flashlights were used for the nocturnal sampling to find and capture the fishes following Bührnheim (1999).

Fish specimens were euthanized using a lethal dose of clove oil and immediately preserved in a 10% formalin solution. After two days they were transferred to 70% alcohol and identified by specialists. Voucher specimens were deposited in the fish collection at the Federal University of Rondônia, Porto Velho, RO, Brazil (Vouchers: UFRO-ICT 023980 to 024000).

In order to better understand the state of those environments, we describe in Table 2 the physical conditions of each sampling site. Environmental variables at each sampling site were characterized following visual observation; substrate composition (i.e., the relative proportion of each substrate component) was visually estimated according to Cummins (1962), and the volume occupied by the submerged vegetation (roots, leaves and stems of the submerged terrestrial vegetation) on each side of the stream was estimated based on the height and width of the vegetation on the banks.

2.3. Data analysis

Fish composition, richness (S) and absolute abundance (N) were determined for presence and absence of luminosity periods. The Shapiro-Wilk normality test and Levene's test were applied to determine whether the assumptions used in the parametric (t test) or nonparametric (Mann-Whitney U test) analyses of abundance (log_{10}) and species richness (log_{10}) for each photoperiod.

Table 1. Identification of collection site, abbreviation, land use in the adjacent matrix, geographical coordinates and number of samples of the nine streams in the Machado river basin, from July 2013 to May 2014.

Stream	Abbreviation	Land use	Latitude	Longitude	Luminosity presence		Luminosity absent	
					Dry	Rainy	Dry	Rainy
Penha	PES	Pasture	11°11'05" S	62°04'40" W	3	3	3	3
Dom João	DJS	Pasture	11°10'56" S	62°04'51" W	3	3	3	3
Mangueira	MAS	Pasture	11°13'54" S	62°05'10" W	3	3	3	3
Emerson	SEM	Forested	11°13'37" S	61°51'16" W	3	3	3	3
128	128S	Forested	11°20'22" S	61°50'23" W	3	3	3	3
Django	DAS	Forested	11°07'40" /S	61°47'50" W	3	3	3	3
Minuano	MIS	Forested	11°01'50" S	61°54'42" W	3	3	3	3
Cris	CRS	Pasture	11°15'31" S	61°51'24" W	3	3	3	3
Douglas	DOS	Pasture	11°05'08" S	61°53'30" W	3	3	3	3

Table 2. Physiographic descriptors of each stream in the Machado River basin, July 2013 to May 2014.

Descriptors	DJS	PES	MAS	128S	EMS	DAS	MIS	CRS	DOS
Macrophytes	Rs	Aa	Re	X	X	X	Re	Re	X
Ecotone	G/Br	G	Aar/G	Aar/Sa	Aar/Sa	Aar/Sa	Aar/Sa	G	Aar/Br
Substrate	S/Sa/-Lbt	A/R	Sa/R/-Lbt	Sa/Tl/Gl/R/+Lbt	Sa/Gl/R/+Lbt	Sa/Tl/Gl/+Lbt	Sa/Tl/Gl/R/+Lbt	Sa/Tl/Lbt	Sa/R

DJS = Dom João stream; PES = Penha stream; MAS = Mangueira stream; 128S = 128 stream; CRS = Cris stream; EMS = Emerson stream; DAS = Django stream; DOS = Douglas stream; and MIS = Minuano stream. Presence of aquatic plants (Re = rooted emergent; Rs = rooted submerged; and Aa = adhered algae), riparian ecotone vegetation (Aar = Arboreal angiosperms; Sa = shrubby angiosperms; G = grasses; Br = bare ravine), substrate (S = silt; Sa = sand; R = rocks; Tl = thin litter; Gl = gross litter; and Lbt = large branches and trunks), - = small amount; + = large amount; and X = absence.

The Permutational Multivariate Analysis of Variance (PERMANOVA, Anderson, 2001) was used to evaluate the effects of land use (forest and pasture), season (rainy and dry seasons), and photoperiod (presence and absence of luminosity), on biological assemblages, and the interactions between these factors (Anderson, 2001). PERMANOVA is a multi-factorial ANOVA based on any measured distance using permutation methods (Anderson, 2001). The analysis was based on dissimilarity coefficients using Bray-Curtis index (richness and abundance data, were previously Log-transformed) and under 10,000 permutations.

Fish assemblage structure for each stream in the presence and absence of photoperiod was ordered by nonmetric multidimensional scaling (NMDS) analysis, a method for bi- or tridimensional arrangement which represents the association among samples in a similarity matrix (Clarke & Warwick, 1994). The method is considered robust and suitable for ordination ecological data (Minchin, 1987). To quantify the similarity between sites we used the Bray-Curtis distance measure applied data previously Log-transformed (Clarke & Gorley, 2001). We performed Mann-Whitney tests with NMDS axis 1 and 2 scores, to detect differences in fish assemblages in the presence and absence of photoperiod.

The PERMANOVA and Mann-Whitney test were performed in the R environment (R Development Core Team, 2013). The NMDS analyses was carried out using PAST version 2.17 (Hammer et al., 2001). Differences were considered significant when p ≤ 0.05.

3. Results

A total of 8,058 specimens representing 4 orders, 20 families and 88 species were collected. For both periods, *Knodus heteresthes* (Eigenmann, 1908) (N_{light} = 1,425, N_{dark} = 2,210), *Serrapinnus notomelas* (Eigenmann, 1915) (N_{light} = 357, N_{dark} = 413) and *Bryconops giacopinii* (Fernández-Yépez, 1950) (N_{light} = 258, N_{dark} = 272) were the most abundant species. A total of 18 species (20%) were not found during the diurnal period and 20 (22%) were not found during the nocturnal period (Table 3).

Sampling during the presence of luminosity period accounted for 3,484 specimens, 4 orders, 15 families and 69 species. During the absence of luminosity period, 4,574 specimens belonging to 4 orders, 20 families and 71 species were collected. No statistically significant differences were found in abundance (U = 869.0, p = 0.90) or species richness (U = 867.0, p = 0.89) between periods of presence and absence of luminosity. Considering all the samples together, Characiformes had the highest abundance and species richness, followed by Siluriformes, Perciformes and Gymnotiformes (Table 4).

The fish assemblages no differed significantly between seasons, type of land use and luminosity, both when considering the abundance and richness of species (Table 5). NMDS analysis of samples based on species abundance did not reveal any separation on axis 1 and 2 retained for interpretation (*Stress* = 0.41). Scores on axis 1 (U = 820.50, p = 0.58) and axis 2 (U = 845.00, p = 0.74) of the NMDS no differed with respect to period for fish assemblages.

4. Discussion

According to Lowe-McConnell (1999), the predominant groups in the Amazon basin are Characiformes (43%), Siluriformes (36%) and Gymnotiformes (3%), which account for approximately 82% of the Amazonian fish assemblage. The predominance of these orders has been reported in several rivers and small streams in the Neotropics (Sabino & Zuanon, 1998; Lowe-McConnell, 1999; Castro, 1999;

Table 3. Abundance data for species collected in presence of luminosity (PL) and absence of luminosity (AL) in each stream in the Machado River basin, July 2013 to May 2014.

Taxa	128S		CRS		DAS		DJS		DOS		EMS		MAS		MIS		PES		Total
	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	
CHARACIFORMES																			
Acestrorhynchidae																			
Acestrorhynchus falcatus (Bloch, 1794)	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	3
Anostomidae																			
Leporinus friderici (Block, 1794)	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	1	4
Leporinus gomesi Garavello & Santos, 1981	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
Characidae																			
Astyanax anterior Eigenmann, 1908	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Astyanax cf. *bimaculatus* (Linnaeus, 1758)	0	0	1	0	20	14	1	3	0	0	0	0	7	6	0	0	12	91	155
Astyanax cf. *maximus* (Steindachner, 1876)	0	1	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	6
Astyanax sp.	0	0	0	0	0	1	12	9	0	0	0	2	0	0	0	0	0	0	24
Brachychalcinus copei (Steindachner, 1882)	2	6	0	0	44	36	8	12	0	0	23	22	3	0	0	0	0	0	156
Bryconops giacopinii (Wingert & Malabarba, 2011)	26	17	1	0	0	0	160	162	1	0	33	50	27	12	0	0	10	31	530
Bryconops piracolina Wingert & Malabarba, 2011	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	12
Creagrutus anary Fowler, 1913	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0	0	2	8
Creagrutus beni Eigenmann, 1911	0	2	0	0	0	0	3	79	0	0	11	0	0	0	0	0	0	0	95
Creagrutus petilus Vari & Harold, 2001	0	3	0	0	0	0	28	8	0	0	7	26	51	120	0	0	0	0	243
Hyphessobrycon copelandi Durbin, 1908	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Jupiaba cf. *apenima* Zanata, 1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	7
Knodus heteresthes Eigenmann, 1908	62	79	5	5	180	239	119	309	1	0	410	571	601	872	1	0	51	9	3514
Moenkhausia collettii (Steindachner, 1882)	47	12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	60
Moenkhausia comma Eigenmann, 1908	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Moenkhausia cotinho Eigenmann, 1908	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
Moenkhausia cf. *pankilopteryx* Bertaco & Lucinda, 2006	2	1	0	0	3	4	2	8	0	0	0	6	9	1	0	0	22	6	64

DJS = Dom João stream; PES = Penha stream; MAS = Mangueira stream; 128S = 128 stream; CRS = Cris stream; EMS = Emerson stream; DAS = Django stream; DOS = Douglas stream; and MIS = Minuano stream.

Table 3. Continued...

Taxa	128S		CRS		DAS		DJS		DOS		EMS		MAS		MIS		PES		Total
	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	
Moenkhausia oligolepis (Günther, 1864)	9	28	0	0	41	25	2	6	1	0	4	17	7	14	2	0	4	0	160
Moenhhausia aff. *Colletii*	0	0	0	0	0	0	0	0	0	0	0	0	33	61	0	0	0	0	94
Moenhhausia aff. *Cotinho*	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
Moenhhausia aff. *lepidura alta*	0	0	0	0	0	0	0	0	0	0	0	0	137	75	0	0	0	0	212
Phenacogaster beni Eigenmann, 1911	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Phenacogaster retropinnus Lucena & Malabarba, 2010	5	1	0	0	0	0	15	63	0	0	0	1	14	9	0	0	0	0	108
Poptella compressa (Günther, 1864)	0	0	0	0	0	0	12	9	0	0	0	0	0	0	0	0	0	0	21
Serrapinnus notomelas (Eigenmann, 1915)	5	0	0	0	0	0	162	305	2	0	0	0	169	103	0	0	19	5	770
Serrapinnus microdon (Eigenmann, 1915)	95	9	0	0	3	0	6	29	0	0	1	10	16	17	0	0	1	0	187
Tetragonopterus argenteus Cuvier, 1816	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Xenurobrycon polyancistrus Weitzman, 1987	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Crenuchidae																			
Characidium aff. *Zebra*	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	3
Characidium sp.	31	7	0	0	0	0	0	0	0	0	2	1	14	10	0	0	0	0	65
Characidium aff. *etheostoma* Cope, 1872	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Curimatidae																			
Steindachnerina fasciata (Vari & Géry, 1985)	0	0	0	0	0	8	0	0	0	0	1	1	5	9	0	0	2	1	27
Steindachnerina guentheri (Eigenmann & Eigenmann, 1889)	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	3
Erythrinidae																			
Erythrinus erythrinus (Bloch & Schneider, 1801)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hoplias malabaricus (Block, 1794)	2	2	0	0	3	1	1	3	0	0	2	2	1	1	0	0	5	3	26
Parodontidae																			
Parodon sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Prochilodontidae																			
Prochilodus nigricans Spix & Agassiz, 1829	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Serrasalmidae																			
Myleus asterias (Müller & Troschel, 1844)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

DJS = Dom João stream; PES = Penha stream; MAS = Mangueira stream; 128S = 128 stream; CRS = Cris stream; EMS = Emerson stream; DAS = Django stream; DOS = Douglas stream; and MIS = Minuano stream.

Table 3. Continued...

Taxa	128S		CRS		DAS		DJS		DOS		EMS		MAS		MIS		PES		Total
	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	
Myleus setiger Müller & Troschel, *1844*	0	0	0	0	0	0	7	4	0	0	0	0	0	2	0	0	0	0	13
Serrasalmus rhombeus (Linnaeus, 1766)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
GYMNOTIFORMES																			
Apteronotidae																			
Apteronotus albifrons (Linnaeus, 1766)	0	0	0	0	0	0	1	1	0	0	0	2	0	2	0	0	0	0	6
Gymnotidae																			
Gymnotus carapo Linnaeus, 1758	0	1	0	0	0	7	39	45	0	0	0	1	0	2	0	0	29	67	191
Gymnotus curupira Crampton, Thorsen & Albert, 2005	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2
Hypopomidae																			
Brachyhypopomus sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Brachyhypopomus pinnicaudatus (Hopkins, 1991)	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Sternopygidae																			
Eigenmannia trilineata López & Castello, 1966	0	0	0	0	0	0	11	10	0	0	0	2	0	7	0	0	0	2	32
Eigenmannia limbata (Schreiner & Miranda Ribeiro, 1903)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2
Eigenmannia sp.	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Sternopygus macrurus (Bloch & Schneider, 1801)	6	1	0	0	0	4	51	53	0	0	0	10	1	3	0	0	0	0	129
PERCIFORMES																			
Cichlidae																			
Aequidens plagiozonatus Kullander, 1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Aequidens rondoni (Miranda Ribeiro, 1918)	0	0	0	0	27	19	21	12	0	0	2	5	17	29	0	0	53	61	246
Aequidens tetramerus (Heckel 1840)	0	0	28	13	0	0	0	0	7	0	0	0	0	0	1	1	0	0	50
Crenicichla lepidota (Heckel 1840)	0	0	8	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	11
Crenicichla santosi Ploeg, 1991	1	3	21	2	8	5	15	4	1	0	1	0	13	6	1	0	17	13	111
Crenicichla sp.	0	0	0	0	0	0	5	2	0	0	7	0	0	0	0	0	3	1	18
Satanoperca jurupari (Heckel, 1840)	0	0	0	0	0	0	5	12	0	0	0	2	0	0	3	2	0	0	24
SILURIFORMES																			
Auchenipteridae																			
Tatia aulopygia (Kner, 1858)	0	2	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	7
Tatia sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Callichthyidae																			

DJS = Dom João stream; PES = Penha stream; MAS = Mangueira stream; 128S = 128 stream; CRS = Cris stream; EMS = Emerson stream; DAS = Django stream; DOS = Douglas stream; and MIS = Minuano stream.

Table 3. Continued...

Taxa	128S		CRS		DAS		DJS		DOS		EMS		MAS		MIS		PES		Total
	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	
Corydoras bondi Gosline, 1940	0	11	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	12
Corydoras cf. *aeneus* (Gill, 1858)	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Hoplosternum littorale (Hancock, 1828)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lepthoplosternum beni Reis, 1997	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3	5
Heptapteridae																			
Cetopsorhamdia sp.	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	4	0	0	8
Imparfinis stictonotus (Fowler, 1940)	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Pimelodella sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	0	0	4
Pimelodella howesi Fowler, 1940	1	1	0	0	0	0	0	3	4	4	0	0	0	2	1	3	0	0	19
Phenacorhamdia sp.	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	4
Rhamdia quelen (Quoy & Gaimard, 1824)	0	0	0	0	3	4	0	0	0	0	0	0	0	2	0	0	0	2	11
Loricariidae																			
Ancistrus dubius Eigenmann & Eigenmann, 1889	14	5	0	0	20	22	0	0	0	0	34	42	24	33	2	0	8	3	207
Ancistrus sp.	7	0	0	0	1	2	0	4	0	0	3	1	10	9	0	0	0	0	37
Farlowella amazonum (Günther, 1864)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Farlowella oxyrryncha (Kner, 1853)	0	0	0	0	0	0	1	2	0	0	1	0	0	2	0	1	0	0	7
Hypostomus cf. *plecostomus* (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1	1	10
Hypostomus pantherinus Kner, 1854	0	0	0	0	0	0	8	6	0	0	0	0	0	0	0	0	0	0	14
Hypostomus pyrineusi (Miranda Ribeiro, 1920)	2	0	0	0	2	1	1	6	0	0	52	12	1	1	0	0	0	0	78
Hypostomus sp.	0	1	0	0	0	0	15	7	0	1	0	0	0	14	0	0	0	0	38
Rineloricaria castroi Isbrücker & Nijssen, 1984	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	11
Rineloricaria lanceolata (Günther, 1868)	4	7	0	0	1	1	24	30	0	0	2	0	9	31	0	0	0	0	109
Rineloricaria phoxocephala (Eigenmann & Eigenmann, 1889)	0	0	0	0	0	1	0	0	0	0	0	0	2	2	0	0	0	0	5
Rineloricaria sp.	0	3	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	6
Rineloricaria sp. 1	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	10
Spatuloricaria evansii (Boulenger, 1892)	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
Pseudopimelodidae																			
Batrochoglanis sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Trichomycteridae																			

DJS = Dom João stream; PES = Penha stream; MAS = Mangueira stream; 128S = 128 stream; CRS = Cris stream; EMS = Emerson stream; DAS = Django stream; DOS = Douglas stream; and MIS = Minuano stream.

Table 3. Continued...

Taxa	128S		CRS		DAS		DJS		DOS		EMS		MAS		MIS		PES		Total
	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	PL	AL	
Ituglanis amazonicus (Steindachner, 1882)	0	1	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	4
Total	344	214	66	26	361	396	746	1213	23	7	604	802	1184	1488	19	15	246	309	

DJS = Dom João stream; PES = Penha stream; MAS = Mangueira stream; 128S = 128 stream; CRS = Cris stream; EMS = Emerson stream; DAS = Django stream; DOS = Douglas stream; and MIS = Minuano stream.

Table 4. Data of numerical abundance (N) and richness (S) for each fish order in periods of presence and absence of luminosity of the nine streams in the Machado river basin, July 2013 to May 2014.

Order	Presence luminosity		Absent luminosity		Total	
	N	S	N	S	N	S
Characiformes	2,881	31	3,861	38	6,742	44
Siluriformes	268	23	313	24	581	35
Gymnotiformes	145	8	219	7	364	9
Perciformes	189	7	174	6	370	7

Table 5. PERMANOVA (Permutational Multivariate Analysis of Variance, Pseudo-F value) for fish assemblages in stream in the Machado River basin, July 2013 to May 2014.

Factors	d.f	F	Abundance		F	Richness	
			R^2	p		R^2	p
(1) Season (Rainy and Dry)	1	0.96	0.01	0.35	0.96	0.01	0.34
(2) Land use (Forest and Pasture)	1	2.29	0.02	0.09	2.29	0.02	0.10
(3) Luminosity (Presence and Absent)	1	1.41	0.01	0.22	1.41	0.01	0.22
Interaction (1) × (2)	1	0.31	0.00	0.77	0.31	0.00	0.76
Interaction (1) × (3)	1	0.24	0.00	0.84	0.24	0.00	0.83
Interaction (2) × (3)	1	0.41	0.00	0.67	0.41	0.00	0.68
Interaction (1) × (2) x (3)	1	0.11	0.00	0.94	0.11	0.00	0.95

d.f. = degrees of freedom; p = significance based on 10,000 randomizations.

Pouilly et al., 2004; Casatti et al., 2013). The most abundant families in the present study were Characidae, Crenuchidae and Loricariidae, a group widely distributed throughout the Amazon basin (Ferreira et al., 1998; Santos et al., 2006).

Our results corroborating the study by Mojica et al. (2014) in Colombian Amazon streams, who found no significant differences in abundance and species richness between light and dark phase. A dual phasing capacity, which is characteristic of a highly adaptable circadian system, appears to be a common fish trait, especially in temperate species, and an adaptation to marked seasonal changes in photoperiod, temperature and food availability (Volpato & Trajano, 2006). In tropical regions, however, where seasonal changes are not as marked as in temperate zones, this capacity does not appear to be adaptive, corroborating the pattern observed in our study. In tropical areas with well-defined rain cycles, there may be important annual fluctuations

in the quantity and quality of food available (Volpato & Trajano, 2006).

Temporal niche partitioning predicts that different species may be limited by the same resources but differ in terms of when they exploit the resource (Chesson, 1985). Previous studies have shown that the composition of fish populations can vary between light and dark periods (Volpato & Trajano, 2006). Arrington & Winemiller (2003) found that Characiformes were a dominant group in both periods, accounting for 80% and 97% of abundance during diurnal and nocturnal periods, respectively. This was also observed in the present study, where 82% and 84% of the abundance of Characiformes was represented in the diurnal and nocturnal periods, respectively, composed mainly by species *K. heteresthes*, *S. notomelas* and *B. giacopinii* (Characiformes order) which represented 60% of total abundance. These species need of high visual acuity, given that these are nektonic species that

collect food items drifting at mid-water and at the surface, predominantly in the main channel (Ceneviva-Bastos & Casatti, 2007; Carvalho, 2008; Brejão et al., 2013; Nogueira & Costa, 2014). Characiformes collected exclusively during nocturnal samplings belong to species that have large eyes, which presumably increase visual acuity in environments with limited light (Shand, 1997). This anatomical modification is described as an adaptation for foraging in deep water, where diurnal light is limited (Stewart et al., 2002) and capturing food in shallow waters with reduced nocturnal light (Arrington & Winemiller, 2003).

The variations are related to the different activities that these fishes perform, such as feeding, breeding and moving (Lowe-McConnell, 1999). Characiformes and Perciformes are visually oriented fish with diurnal habits and are found mostly in clear-water environments, while fish guided by chemical, electrical or tactile stimulus, such as Siluriformes and Gymnotiformes, are more active at night and found mostly in turbid waters (Matthews, 1998). Siluriformes from the genera *Trichomycterus* (Trichomycteridae) and *Ancistrus* (Loricariidae), which are generally nocturnal (Buck & Sazima, 1995; Casatti & Castro, 1998), were reported during the diurnal period, which is uncommon among small loricariids (Volpato & Trajano, 2006).

The absence of temporal segregation of fish assemblages in our study, corroborates the results of Arrington & Winemiller (2003). Many fish species have a daily movement pattern from marginal areas to open waters and vice versa and they are often members of different spatially defined assemblages (Matthews, 1998; Arrington & Winemiller, 2003; Costa et al., 2011). This spatial segregation makes it more difficult to detect nycterohemeral differences when assemblages of fish from specific habitats are analyzed. The lack of segregation between the periods analyzed is accounted for by the high similarity in the fish assemblages in both periods, as a large number of individuals from some taxa (e.g., Characiformes, Characidae and Perciformes) are active during the day and night (Barthem, 1987; Sazima & Machado 1990; Hahn et al., 1999; Costa et al., 2009; Duarte et al., 2010).

Therefore, for fish assemblages in which most of the species are active during both periods, no significant differences between these periods can be expected. Additionally, Willis et al. (2005) described a low degree of species replacement between diurnal and nocturnal periods (absence of light/dark period variation), especially during the dry season

in structurally complex environments. In these environments, fishes make fewer movements toward marginal areas (refuges) at night time (Willis et al., 2005), by the fact that structurally more complex environments show a higher stability of resources intrahabitat, resulting in the greater concentration of resources results in less movement between marginal areas and open waters for foraging during the day (Willis et al., 2005; Pelicice et al., 2005). This is corroborated by the structural conditions of the small streams analyzed in our study, which are composed mainly of rocks, logs, branches, exposed roots and emergent and submerged macrophytes (see Table 2).

The homogeneity of the assemblages in the light and dark periods, can also be related the artifact collection resulting from differences in sampling techniques and data analysis mainly in the case of independent studies (Volpato & Trajano, 2006). We use methods of active collection, which consists in catching fish with use of instruments that affects the environment by altering the structure of the microhabitat (e.g., submerged litter banks, trunks) (Uieda & Castro, 1999). The greater fish capture efficiency with active methods results in a higher probability of record low abundant species and cryptobiotic habits (Ribeiro & Zuanon, 2006), active or inactive (sheltered) in each photoperiod.

Despite our failure to identify any segregation based on photoperiod, we provided evidence of the nocturnal composition and richness of exclusive species (S = 20; 22%) of Machado river. While only a few studies have analyzed the fish assemblages in Amazonian streams in absence/presence of luminosity periods, it is reasonable to suppose that temporal niche partitioning could explain the high fish diversity in these assemblages. Hence, more studies on the temporal segregation of Amazonian fish are needed to understand the distributional, behavioral and functional ecological patterns of these assemblages.

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