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THE IMPORTANCE OF FREE STRETCHES IN A DAMMED RIVER TO THE MAINTENANCE OF *Schizodon intermedius* POPULATIONS

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ABSTRACT

This paper focuses on to evaluate the importance of a free stretches upstream of a Neotropical reservoir for the maintenance of *Schizodon intermedius* populations, a medium size migratory species and important fisheries resources. Quarterly samplings were carried out in 8 sampling sites, distributed in Jurumirim Reservoir and two tributaries upstream reservoir. Reproductive, populational and feeding strategies were used to evaluate the importance of each sample area in the biological cycle of this species. Results showed that *S. intermedius* makes different uses of the sites. In the rainy season, individuals in the lower areas presented higher condition factor and average repletion degree of stomach, assuming that are used for growth and feeding and; in the upper areas, higher size and GSi values, suggesting that are reproductive area. We conclude that *Schizodon intermedius* uses lentic areas to gain energy in dry season, and in the rainy season, uses this energy to migrate to lotic stretches to reproduction. The stretches upstream free of dam are essential for this migratory species maintain viable populations in an environment impaired by dams.

Key words: fish migration; damming impacts; fisheries ecology; neotropical ichthyofauna; fisheries resources.

A IMPORTÂNCIA DE TRECHOS LIVRES DE BARRAMENTO EM AMBIENTES REPRESADOS NA MANUTENÇÃO DE POPULAÇÕES DE *Schizodon intermedius*

RESUMO

Este trabalho teve como objetivo avaliar a importância de um trecho livre a montante de reservatório neotropical para a manutenção de populações de *Schizodon intermedius*, espécie migradora de médio porte e importante recurso pesqueiro. Amostragens trimestrais foram realizadas em oito pontos de amostragem, distribuídos no reservatório de Jurumirim e em dois tributários a montante do reservatório. Estratégias reprodutivas, populacionais e alimentares foram utilizadas para avaliar a importância de cada área amostral no ciclo biológico desta espécie. Os resultados mostraram que *S. intermedius* faz usos diferentes dos locais. Na estação chuvosa, os indivíduos das áreas mais baixas apresentaram maior fator de condição e grau de repleção médio do estômago, assumindo que são utilizados para o crescimento e alimentação e; nas áreas superiores, maiores valores de tamanho e GSi, sugerindo que são áreas reprodutivas. Conclui-se que *Schizodon intermedius* utiliza áreas lênticas para obter energia na estação seca, e na estação chuvosa, usa essa energia para migrar para trechos lóticos para se reproduzir. Os trechos a montante da represa são essenciais para que esta espécie migratória mantenha populações viáveis em um ambiente impactado por barragens.

Palavras-chave: migração de peixes; impactos do barramento; ecologia de pesca; ictiofauna neotropical; recursos pesqueiros.

INTRODUCTION

River fragmentation caused by impoundments for hydroelectric generation lead to large interferences in the aquatic environment, affecting the hydrological patterns of basin (Tagliani et al., 1992; Ward, 1998; Pelicice et al., 2015), with consequences in the physical and chemical parameters, causing spatial heterogeneity in the limnological variables (Nogueira et al., 2006). Those interferences cause alterations in the flood regime, with negative reflects in resource availability, reproductive triggers and critical areas for development (Araújo et al., 2013). In consequence, communities can

restructure themselves differently in the new habitat, according to environmental changes, resilience and biological aspects (Prchalová et al., 2009; Terra et al., 2010; Queiroz et al., 2015).

In the large Neotropical reservoirs, often, in the fish community restructure process, migratory species tend to diminish their abundance, and opportunistic species, that are being used by fisheries resource, had an increase in their populations (Carvalho et al., 1998; Agostinho et al., 2008; Nobile et al., 2016). However, it has even been observed that in extensive longitudinal gradients subject to damming, upper regions are utilized as reproductive areas for rheophilic species, contributing to the maintenance of their populations (Silva et al., 2015; Angulo-Valencia et al., 2016; Silva et al., 2017). Despite of several studies evaluating damming impacts on large Brazilian river (Agostinho et al., 2007; Araújo et al., 2013; Ortega et al., 2015), few studies has been conducted in lateral tributaries, also under damming effects, mainly those focused on the management of fishery resources.

In Jurumirim Reservoir (age=50 years), *Schizodon intermedius* (Anostomidae) became a specie widely-used as fisheries resource for professional fisherman over species as *Salminus brasiliensis* and *Pseudoplatystoma corruscans*, that had a populational decline (Orsi and Shibatta, 1999; Novaes and Carvalho, 2009, 2013). *Schizodon intermedius* is a native species from Neotropical region and is widely distributed in the Upper Paraná River basin (Langeani et al., 2007). Presents medium size, lives in calm water, next to the margin and through the vegetation and perform short migrations in reproductive period (Shibatta et al., 2003), and, along with other representatives of the family, represent great part of biomass in several aquatic environments, such as reservoirs (Agostinho et al., 2007; Orsi and Britton, 2014) and rivers (Silvano and Begossi, 2001; Shibatta et al., 2003).

However, despite its importance in Jurumirim Reservoir and tributaries as a fisheries resources, little information is available about the life history trait of this species. Thus, based in the above information, the hypothesis of this work is that the free dam stretches upstream the Jurumirim reservoir are important areas to the life history traits of *S. intermedius* populations and crucial for the maintenance of its populations.

Thus, the objective of this paper is to evaluate importance of free stretches upstream of a Jurumirim Reservoir – SP, Brazil and tributaries, for the maintenance of *Schizodon intermedius* populations, subsidizing future management actions.

MATERIAL AND METHODS

Sampling sites

Eight sampling sites (SS), distributed in Jurumirim reservoir and two tributaries were sampled (Table 1). Of these, four SS were located in the Paranapanema River – a right side margin tributary, upstream the influence area of reservoir, being two in the river channel (SS1 and SS3) and two in marginal lagoons with permanent connection (SS2 and SS4); one SS was located in Veados River (SS6), a right side margin tributary, in the transition zone of the reservoir with great portion flooded; and three SS were located in the Reservoir area and contemplate the three sections of Jurumirim Reservoir: lotic (SS5), transition (SS7) and lentic (SS8) sections of (Figure 1). The selected sample areas showed different limnological variables, with the transition and lentic areas presenting higher values of temperature and transparency, while lotic areas showed higher values of conductivity (Table 2).

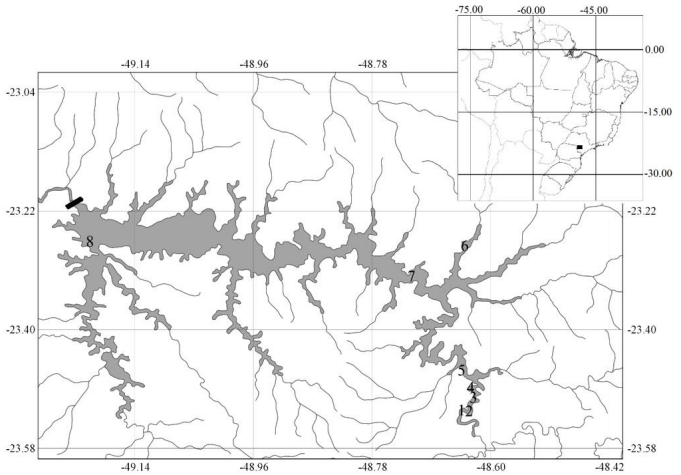

Figure 1. Sampling sites in the Jurumirim Reservoir and tributaries, SP, Brazil. 1 = SS1, 2 = SS2, 3 = SS3, 4 = SS4, 5 = SS5, 6 = SS6, 7 = SS7 and 8 = SS8. Black line = dam location.

Table 1. Environmental characterization of studied sampling sites in Jurumirim Reservoir and its tributaries, SP, Brazil.

Sampling site	Surrounding area	Coordinates
SS1	Lotic water, with river bank covered by grasses that extend to the water.	23°31'10.85"S; 48°38'34.08"W
SS2	Lentic water, with river bank covered by grasses that extend to the water.	23°31'15.75"S; 48°37'53.42"W
SS3	Lotic water, with river bank covered by grasses that extend to the water.	23°30'1.05"S; 48°37'29.86"W
SS4	Lentic water, with river bank covered by grasses that extend to the water.	23°29'8.02"S; 48°37'44.98"W
SS5	Lotic water with large flooded area.	23°27'32.72"S; 48°38'34.18"W
SS6	Transition area, margins varying between grasses and stones.	23°18'59.76"S; 48°43'8.25"W
SS7	Transition area, margins varying between grasses and stones.	23°16'12.79"S; 48°38'16.74"W
SS8	Lentic area, banks covered by sand or stones.	23°15'49.48"S; 49°12'25.87"W

Table 2. Limnological profile of studied sampling sites in Jurumirim Reservoir and its tributaries, SP, Brazil. Zmax = maximum depth (meters); ZDS = transparency Secchi disk (meters); Temp = water temperature (°C), DO = dissolved oxygen ($mg.L^{-1}$); K25 = Electrical conductivity ($\mu S.cm^{-1}$). Limnological data extracted from Paes et al. (2016). M = mean; SD = Standard deviation.

Sampling site	Zmax (M±SD)	ZDS (M±SD)	Temp (M±SD)	OD (M±SD)	K25 (M±SD)
SS1	5.58±1.44	0.57±0.41	22.3±3.05	8.09±1.30	70.92±35.73
SS2	2.03±0.57	1.05±0.48	24.4±3.57	6.52±1.14	53.17±25.95
SS3	5.69±2.10	0.52±0.32	22.5±2.82	7.97±1.35	70.88±37.03
SS4	2.18±1.00	0.69±0.40	24.4±3.10	7.44±1.37	64.38±31.79
SS5	8.46±1.03	0.53±0.31	22.0±3.00	8.05±1.56	74.95±40.54
SS6	4.51±1.05	0.92±0.46	24.13±3.77	7.88±1.14	54.86±28.77
SS7	7.27±3.23	1.21±0.53	24.4±3.57	8.66±1.74	61.38±23.68
SS8	20.61±6.67	3.00±0.98	23.6±3.97	8.19±1.25	58.38±6.98

Sampling procedures

Fish capture was carried out in eight samplings, from April 2011 to January 2013, with trimestral periodicity (IBAMA/ICMBio license: 15549-1). The specimens of *S. intermedius* were caught with gillnets with mesh size of 3 to 14 centimeters between opposite knots, which were exposed from dusk at down, totalizing 14 hours. After fish removal, fish were euthanized by immersion for 10 minutes (or more if necessary) in buffered benzocaine solution pH 7.0 at a concentration of 125 $mg.L^{-1}$, verifying operative movement of the operculum to verify euthanasia. Immediately after the euthanasia, of each individual, we measured total weight in grams (TW), standard length in cm (SL), sex, gonad weight in grams (GW) and stomach repletion index. Of that individuals with stomach content, the stomach was removed and fixed in formalin 10%, being transferred for alcohol 70% for analyses.

Data analysis

For seasonal analysis, the months of April and July were considered dry season and the months of October and January, rainy season (Henry et al., 2006). Differences in abundance between sampling sites and season were evaluated by permutational multivariate analysis of variance (PERMANOVA) using Primer 6 + PERMANOVA software. Factor sampling site was analyzed as an orthogonal, fixed factor with eight levels (SS1 – SS8), while the factor season was analyzed as a random factor with two levels nested in each sampling site.

To estimate the size at first maturation, the class interval were calculated following Sturges (1926): W=R/K, where W is amplitude of each class, R is amplitude of data and K is number of classes. After that, we estimated, for both sexes, the size at first maturation L_{50} as the one in which 50% of individuals in a determined class initiate the reproductive process for the first time and the L_{100}, as the size of 100% of the individuals started the reproductive process (Vazzoler, 1996). Condition factor (K) was obtained by the equation proposed by Vazzoler (1996): $K = TW/SL^b$, where: K = condition factor; TW = total weight (g); SL = standard length (cm); b = slope Φ, obtained from length-weight relationship, that was determined using the linear regression: log TW − log a + b log SL, where TW is the total weight (in grams), SL is the total length (in cm), "a" is the intercept and "b" is the slope of the linear regression (Nobile et al., 2015; Lima et al., 2017). Gonadosomatic relationship was calculated according to Vazzoler (1996), in which Wg/Wt x 100, where Wg = gonad weight and WT = total weight. For reproductive analysis, only females were utilized.

Stomach content analyses were performed with a stereomicroscope and items were identified to the lowest taxonomic level possible. Analyses of the diet were performed using the frequency of occurrence and gravimetric methods combined in the alimentary index (%AIi) (Kawakami and Vazzoler, 1980). Average repletion degree (ARD) (Santos, 1978) was applied to verify alimentary activity. $\%IAi = \frac{(Fi*Wi)*100}{\sum Fi*Wi}$ Where: AIi = Alimentary Index; i food items; Fi = frequency of occurrence to item i (%); Wi = Wet weight of item i (%)

For standard length (cm), weight (g), gonadosomatic index (GSi) and condition factor (K), possible significative differences were evaluated through Kruskal-Wallis, once data had non-normal distribution in Shapiro-Wilk analysis. The 95% value of significance was adopted.

RESULTS

In total, 1,089 individuals of *Schizodon intermedius* were caught, which represented 135.9 Kg. These individuals ranged from 7.4 to 25.9 cm and 7.6 to 416 g, and 423 were classified as females, 496 as males, 130 as immatures and 40 were unclassified. Differences in abundance between sites and season was evidenced by Crossed Permanova ($F = 2.7926$; $p (MC) < 0.009$) (Figure 2), which showed that individuals of *S. intermedius* inhabit preferably lentic areas during the dry season (SS2, SS4, SS6 and SS7) (April and July), while during the rainy season (October and January), they inhabit lotic areas (SS1, SS3 and SS5), except for SS4, in October (Figure 2). Only the lentic section of Jurumirim reservoir (SS8) had not caught individuals.

The size at first maturation (L_{50}), for both sexes, was determined in the size class of 13.4-14.9 cm and L_{100} was determined in the

Table 3. Absolut abundance, biomass, standard length (mean ± standard deviation (M±SD)) and total weight (M±SD) of *Schizodon intermedius* in Jurumirim Reservoir and its tributaries, SP, Brazil.

Sampling sites	Abundance	Biomass	Length (cm) (m±sd)	Weight (g) (m±sd)
SS1	187	25.34	$18.6 \pm 2.2^{a,b}$	135.5 ± 54.5^{a}
SS2	194	32.63	19.3 ± 2.5^{b}	168.6 ± 62.3^{b}
SS3	147	20.44	$19.0 \pm 2.1^{a,b}$	139.4 ± 49.2^{a}
SS4	111	16.08	18.1 ± 3.2^{a}	144.7 ± 74.7^{a}
SS5	104	14.63	$19.0 \pm 2.3^{a,b}$	140.5 ± 54.0^{a}
SS6	161	10.14	14.8 ± 4.1^{b}	89.6 ± 69.3^{c}
SS7	185	16.32	12.3 ± 4.7^{d}	63.7 ± 77.2^{d}
Total	1,089	135.9	-	-

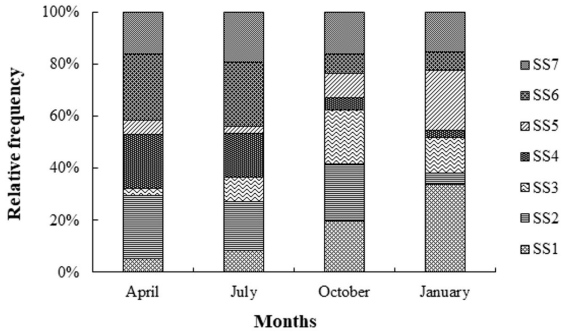

Figure 2. Spatial-temporal distribution of *Schizodon intermedius* in Jurumirim Reservoir and its tributaries, SP, Brazil. Crossed Permanova (Site x Season) (F = 2.7926; p (MC) < 0.009). SS1 = Sample Site 1; SS2 = Sample Site 2; SS3 = Sample Site 3; SS4 = Sample Site 3; SS5 = Sample Site 5; SS6 = Sample Site 6; SS7 = Sample Site 7.

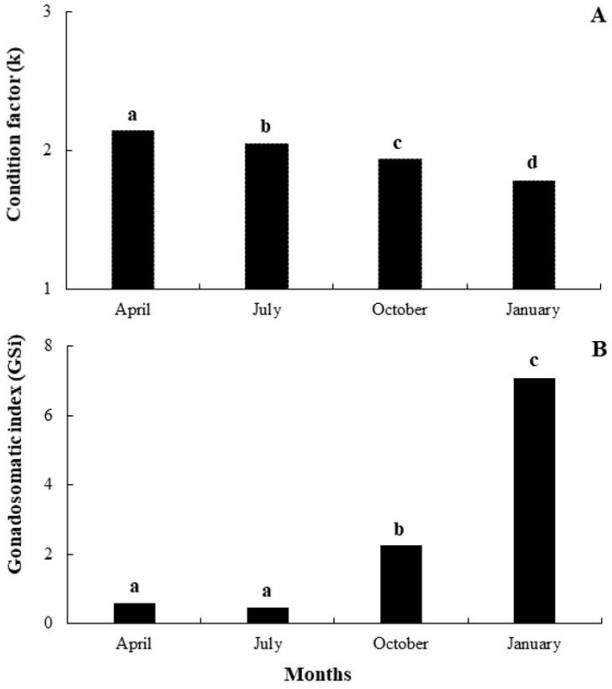

Figure 3. A) Gonadosomatic index (GSi) and B) condition factor (k) for females of *Schizodon intermedius* in the studied months in Jurumirim Reservoir and its tributaries, SP, Brazil. Different letters indicate significative differences (Kruskal-Wallis; p<0.05).

size class of 20.9-22.4 cm. In this sense, significative differences in standard length (SL) and total weight (TW) was also observed between sampling sites, being that the smaller (immature individuals) and lighter individuals were recorded in the lower areas, while the largest (adults) and heaviest in the upper (ls: F = 54.303; p < 0.001; tw: F = 113.66; p < 0.001) (Table 3).

In the temporal scale, gonadosomatic index (GSi) and condition factor (k), showed an inverse pattern. In the dry season, lower values of GSi (Figure 3A) and higher values of condition factor (Figure 3B), were observed, while in the rainy season, higher values of GSi and lower values of condition factor occurred (Figure 3A and 3B).

These two parameters also presented inverse patterns in the spatial scale. Considering the sampling sites, the higher values of GSi were observed in the upper sampling sites (SS1 and SS2), while in the lower areas (SS6 and SS7), GSi showed smaller values (Figure 4A). In the opposite way, the lower values of condition factor were observed in the lotic sampling sites, while the higher were observed in the lentic areas (Figure 4B).

The average repletion degree (ARD) showed that individuals collected in transition (SS6 and SS7) and lentic sampling sites (SS2 and SS4) had higher values of stomach repletion, when compared with those collected in lotic sampling sites (SS1 and SS3) (Table 4).

The Alimentary index showed that only in the transition stretch was identified a high occurrence of periphyton, while in the other sampling sites, *S. intermedius* diet shows plant matter, being mostly of allochthonous origin, coming from the flooded vegetation present on the banks of the sampled sections, as more important item (Table 5).

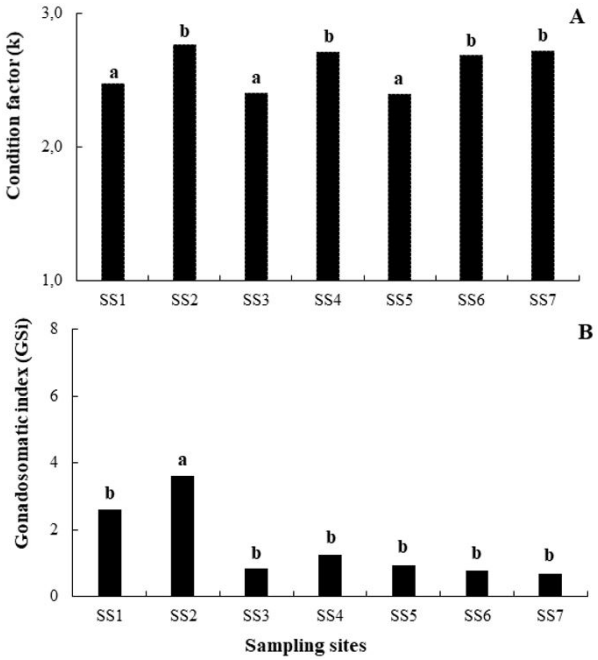

Figure 4. A) Gonadosomatic index (GSi) and B) condition factor for females of *Schizodon intermedius* in different sampling sites of Jurumirim Reservoir and its tributaries, SP, Brazil. Different letters indicated significant differences (Kruskal-Wallis; $p<0.05$).

Table 4. Average Repletion Degree (ARD) for *Schizodon intermedius* of Jurumirim Reservoir and its tributaries, SP, Brazil.

Sampling sites	ARD
SS1	0.71
SS2	1.51
SS3	0.58
SS4	1.36
SS5	0.53
SS6	1.40
SS7	1.19

DISCUSSION

The results reported here, demonstrated that *S. intermedius* are able to use the new environment created by the damming of Paranapanema river, performing shorting displacements, in the rainy season, to the lotic areas, upstream of the Jurumirim Reservoir, as demonstrated by significative differences in abundance between these areas along of the seasonal cycle (Permanova analysis). The majority of Neotropical fish species perform some spatial displacement in the reproductive period (Vasconcelos et al., 2014), being that the distance varies from tens to hundreds of kilometers for species of short migration (ie *S. intermedius*) up to thousands of kilometers for the great migrators (Agostinho et al., 2016; Barthem et al., 2017). Also, recent studies have argued that in dammed environments, even large migratory fish can maintain viable populations in short free damming stretches, as upstream tributaries (Makrakis et al., 2012; Ferreira et al., 2017).

The reproductive cycle is closely linked to the rainy season and is mediated by environmental triggers, as photoperiod, rainy and temperature (Agostinho et al., 2004). In line with differences in abundance between sites, the largest and heaviest individuals of *S. intermedius*, with the highest GSi values were also recorded in the upper sections of Jurumirim reservoir, in the reproductive period, while the smaller, lighter and with lower GSi values were reported in the sampling sites located in the transition area and lateral tributary in this season. In the rainy season, the majority of the individuals of *S. intermedius* leave the marginal lagoons and lower areas to inhabit the river channel, where they found appropriate conditions to spawning. Generally, river channel has lotic and oxygenated waters, when compared with other areas, as observed in the Jurumirim reservoir and tributaries (Paes et al., 2016). These conditions allow the maintenance of eggs viability and that the early larval stages can be carried to nursery areas downstream the spawning sites (Baumgartner et al., 2004).

Allied to this fact, Henry and Suiberto (2014), reported that in the river channel of the upper sampled areas (SS1 and SS3), occur high densities of eggs of fish and in the marginal lagoons (SS2 and SS4) and river channel downstream SS5, high density of fish larvae, being Anostomidae family one of the most frequent. After the initial development in the marginal lagoons, probably juveniles migrate to calm areas (SS6 and SS7) looking for feeding

Table 5. Alimentary index of *Schizodon intermedius* in Jurumirim reservoir and its tributaries, SP, Brazil. * Values of IAi < 0.01, **Very common the use of corn, rice or soy, which are placed in bags bored and thrown down the river to attract fish constantly.

Item	SS1	SS2	SS3	SS4	SS5	SS6	SS7
Plant Matter	100.00	98.81	99.99	96.23	99.99	96.96	39.69
Periphyton							50.48
Spyrogira sp.		0.02		*	0.01	0.18	9.62
Tecameba				3.75		*	*
Detritus/Sediment		1.15	0.01			1.66	
Fish bait**						0.92	
Seed						0.25	0.10

sites, were recorded the smallest and lighter individuals, with the great ARD and condition factor.

According to previous models, for migratory species in the Upper Paraná River Basin (see chapter 2 (Agostinho et al., 2007), three different areas were used through the year: reproductive, growth and feeding areas. Therefore, it's expected that *S. intermedius* follows this same pattern. In line with this, despite of reproductive and growth areas, discussed above, in the dry season, the majority of the individuals of *S. intermedius* inhabit preferably marginal lagoons and lower areas of the reservoir, looking for food in calm areas (Shibatta et al., 2003). This pattern was observed in several short or large distance migratory species (Vazzoler, 1996; Baumgartner et al., 2004). During the dry season, individuals of *S. intermedius* stay in the lentic areas to gain energy, which is transformed into energy source, and in the rainy season, migrates to lotic stretches to reproduce. However, besides of the adjustment, to maintain fish stocks, it is essential to maintain the integrity of spawning areas, which are responsible for the dispersion of eggs and larvae to feeding and development sites, making satisfactory recruitment possible (Baumgartner et al., 2004). To corroborate the above hypothesis, in these lentic areas, during the dry season, was observed the higher values of ARD and condition factor, denoting that are feeding sites of *S. intermedius*. In the majority of areas, plant matter was the most important recorded item, except for SS6. The high condition factor can be converted into abdominal fat, that is an important resource for migratory fish in the reproductive cycle (Lizama and Ambrósio, 2002; Peressin et al., 2012).

CONCLUSION

In conclusion, *Schizodon intermedius* makes different uses of the areas above the Jurumirim Reservoir, having well delimited reproduction and growth sites. The maintenance of the lotic section upstream the Jurumirim reservoir plays a crucial role in the reproductive cycle of this species, and its preservation is necessary for the maintenance of the *Schizodon intermedius* populations

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