

**Life history and ontogenetic diet shifts of
Pimelodella lateristriga (Lichtenstein 1823) (Osteichthyes, Siluriformes)
from a coastal stream of Southeastern Brazil**

Maíra MORAES^{1,2}, Jorge José da SILVA FILHO¹, Raquel COSTA^{1,2}, Jean Carlos MIRANDA¹,
Carla Ferreira REZENDE³ and Rosana MAZZONI^{1,*}

1. Departamento de Ecologia, Instituto de Biologia Roberto Alcântara Gomes, Universidade do Estado do Rio de Janeiro (UERJ), Rua São Francisco Xavier 524, Rio de Janeiro, CEP 20550-900, Brazil.

2. Programa de Pós-graduação em Ecologia e Evolução / UERJ, Brazil.

3. Departamento de Biologia, Centro de Ciências, Universidade Federal do Ceará (UFC), Avenida da Universidade 2853, Fortaleza, Ceará, CEP 60020-181, Brazil.

*Corresponding author, R. Mazzoni, E-mail: mazzoni@uerj.br

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Abstract. Life-history aspects of *Pimelodella lateristriga* from Mato Grosso stream (23°11'12" S and 44°12'02" W) were assessed by quantifying the length structure, length-weight relationship, reproductive traits, feeding habits, and its ontogeny. Samples were obtained bimonthly between March/2006 and January/2007. Length structure showed that females were larger than males. Length-weight relationship showed significant differences between sexes and indicated that females were heavier than males, after controlling for individual size. The sex ratio was 1:1.77 (male:female). Size at first maturation was 4.45 cm, without differences between sexes. Reproductive specimens were recorded year round, with a small peak of ripe individuals during spring and summer - September/December. Fecundity (F) varied from 824 to 10333 oocytes for fish with 5.2 and 11.3 cm, respectively. Relationship between weight and number of oocytes/weight was positive and indicated that bigger specimens produced more oocytes. Ripe eggs measured 800 µm. We recorded significant differences ($F_{(1, 199)} = 308.08$; $P = 0.001$) for the intestinal coefficient of adult and juveniles, predominance of autochthonous items in the diet of juveniles ($\chi^2 = 88.134$; $P < 0.001$) and no differences among adults ($\chi^2 = 4.137$; $P > 0.001$). Differences were also found in the size of consumed items. Juveniles consumed smaller items. We conclude that *P. lateristriga* from Mato Grosso stream presented life-history adaptations to an unpredictable environment, which enables the species to maintain viable populations along the stream in a temporal sequence of environmental features that require specific abilities obtained through life span.

Key words: trophic ecology, *Pimelodella*, Heptapteridae, diet, ontogenetic shift.

Introduction

Freshwater fishes have a wide variety of resource allocation strategies for growth and reproduction. The patterns of growth and reproduction are referred to as life history (Blanck & Lamouroux 2007). The understanding of variations in life-history traits is a key issue in different fields of fish ecology (Pianka 1970, Stearns 1989). Life-history traits have been used to develop general models of fish distribution. The 'habitat template' theory (Southwood 1977, Townsend & Hildrew 1994), for example, suggests that the spatial and temporal features of the habitat are major determinants of species' traits in a community. As a consequence, traits of communities could respond similarly to anthropogenic stress in different regions (Statzner et al. 2001).

The ongoing habitat loss may result in biodiversity losses as well as life history changes and is commonly caused by river damming, deforesta-

tion, water pollution, poor agricultural practices, or inadequate management (Barletta et al. 2010). Understanding the effects of such environmental changes on specific life-history traits is a key step for a more complete understanding of the linkage between fish biology and their surroundings, and may provide the basis for effective management plans. Thus, the knowledge about life-history traits, such as sexual dimorphism, egg size, fecundity, spawning time and feeding habit is fundamental to implement conservation programs in streams affected by human activities (Matthews 1998). These traits are normally adapted to respond to the unpredictable hydrology and anthropogenic influences of coastal streams from tropical rain forests (Mazzoni & Lobón-Cervià 2000). Life-history traits of fishes from Brazilian coastal streams have been reported at different occasions and the works developed by Garutti (1988), Menezes & Caramaschi (1994), Soares-Porto (1994), Aranha & Caramaschi (1999), Maz-

zoni & Petito (1999) and Mazzoni & Iglesias-Rios (2002) are among the pioneers.

Siluriformes is a speciose group of freshwater catfishes (Buckup et al. 2007), varying in size and feeding habits (Bockmann & Guazzelli 2003). Heptapterids are endemic to the Neotropics (Menezes et al. 2007), and one of the most speciose family among Siluriformes. They are small-bodied, leader catfishes distributed from Central to South America (Bockmann & Guazzelli 2003). *Pimelodella* is an heptapterid catfish genus with a wide variety of feeding habits (Trajano 1989, Soares-Porto 1994, Horeau et al. 1998, Viana et al. 2006, Mazzoni & Costa 2007, Pereira et al. 2007, Novakowski et al. 2008).

In the Mato grosso stream, *Pimelodella lateristriga* is one of the most abundant and active catfishes (Mazzoni & Lobón-Cerviá 2000, Mazzoni & Iglesias-Rios 2012), with an important role in the organization of the local fish community. In the present study, we describe life history traits of this population of *Pimelodella lateristriga* (Lichtenstein 1823), including population structure, reproductive parameters, diet, and morphological traits related to feeding ecology. Considering that juveniles and adults change feeding requirements throughout development, and that these changes affect the dynamic availability of food resources, we also tested for ontogenetic differences in the items consumed by adults and juveniles, as well as for modifications in gut structures during development.

Material and methods

The Mato Grosso fluvial system (22°55'S and 42°35'W – Fig. 1) composes one of the many isolated microbasins of Bacia do Leste. It discharges into the Saquarema lagoon system, located 90 km north of Rio de Janeiro (Costa 1987) and its headwaters are located in the Serra do Mato Grosso, approximately 800 m a.s.l. (Mazzoni et al. 2010, Rezende et al. 2010).

The Mato Grosso stream is the main watercourse in the microbasin and is a typical 3rd order stream of the Serra do Mar (Barbieri & Coe-Neto 1999). It is a 12-km long stream, draining the oriental slopes of Serra do Mar and has a number of environmental problems as a consequence of deforestation of the slopes and the occupation of lowlands, mainly for agriculture and cattle ranching (Miranda 2009). Its headwater is surrounded by preserved remnants of Atlantic Forest (Costa 1987). However, points of illegal extraction of sand and eviction of domestic sewage are found on its midstream and downstream areas (Miranda 2009).

The study area was in the lower Mato Grosso stream,

in a 70-meter long site with runs and pools and predominantly sandy substratum. Samplings were made bi-monthly between March/2006 and January/2007. We used seines (5 mm mesh) as a sampling technique. Each collected fish was anesthetized with Eugenol and killed with a diluted solution of MS222, according to Brazilian environmental laws (collecting permit IBAMA/MMA 02022.002475/2006-10, authorization number 118/2006 – DIFAP/IBAMA). Voucher specimens of *Pimelodella lateristriga* were placed in the ichthyological collection of Museu Nacional do Rio de Janeiro – MNRJ 29965, MNRJ 29972, MNRJ 29995, MNRJ 30019, MNRJ 30020 and MNRJ 30022.

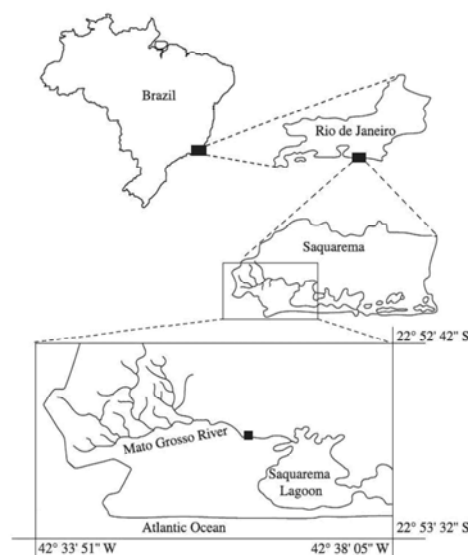


Figure 1. Sampling site (black square) in the Mato Grosso fluvial system.

Fishes were conditioned in ice, processed in laboratory, and the following data were obtained: (i) standard length (SL - cm), (ii) weight (Wt - g), (iii) sex, (iv) gonad weight (Wg - g), (v) macroscopic gonadal maturation stage, and (vi) intestine length (IL - cm). Ovaries were preserved in Gilson's solution (Vazzoler 1996), stored for two weeks, and shaken periodically to promote oocyte release. Oocytes were then cleaned by subsequent alcohol change and removal of ovarian walls, and stored in a 70° GL alcohol solution. Fecundity (Bagenal & Braum 1971) was determined after counting all vitelogenic oocytes from 25 ripe ovaries. Vitelogenic oocytes were then correlated with SL. Spawning type was evaluated based on the distribution of oocyte diameter (measured in subsamples of 10 ml under a stereomicroscope-50x magnification) from dissociated ovaries in final stages maturation, ripe, and partially spent.

Population parameters, such as SL distribution, SL/Wt relationship, and sex ratio were obtained. Reproductive traits, such as size at first maturity (SL₅₀), reproductive season, and spawning type were described. SL structure

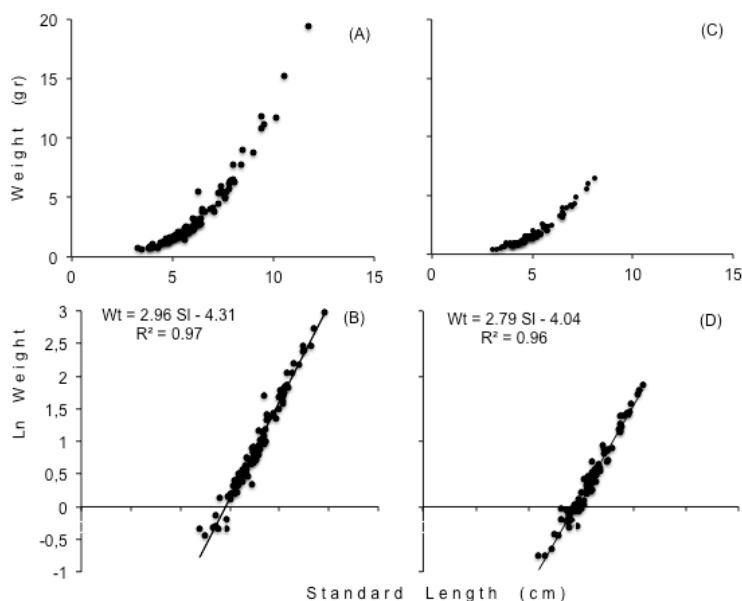


Figure 2. Length (SL)/weight (Wt) relationship of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Brazil. (A) and (B) SL and Wt data of females and males, respectively and (C) and (D) SL and Wt ln transformed data for females and males, respectively.

was determined based on the number of individuals at different size classes. SL/Wt relationship was established from the ln transformed data of SL and Wt, throughout the Minimum Square Method. SL_{50} was determined according to the methodology presented in Vazzoler (1996). All analyses were made separately for males and females, but if no significant difference were found males and females were treated together. Sex ratio was determined for the whole sample and the bias in the proportion of individuals of each sex were tested by the G test. Reproductive season was determined based on temporal variation of individuals with ripe, gonads at final maturation, and female Gonadosomatic Index ($GSI = Wg/Wt * 100$).

Stomachs of specimens were fixed in 5% formalin and preserved in 70% alcohol for posterior analysis. Standard length and intestine length were used to calculate the intestinal coefficient (IC) (Angelescu & Gneri 1949), following the model: $IC = IL/SL$, where IL = intestine length (cm) and SL = Standard length (cm). The IC was used as an accessory tool to characterize feeding habits according to the proposition of Barbieri et al. (1994). Differences in mean values of IC of juveniles and adults were tested by one-way ANOVA. Stomach contents were analysed under a stereoscopic microscope using Frequency of Occurrence (FO) and Volumetric (VO) methods (Hynes 1950, Hyslop 1980). These values were combined in the Alimentary Index (AI_i) as follow: $AI_i = (Fi * Vi) / (\sum Fi * Vi) * 100$, where $i = 1, 2, \dots, n$ food items; Fi = frequency of occurrence and Vi = volume of a given food item (Kawakami & Vazzoler 1980, Hahn et al. 1997). Feeding items were identified to the lowest taxonomic level with specialized bibliography (Salles et al. 2004, Pes et al. 2005,

Passos et al. 2007, Mugnai et al. 2010). The relative importance of AI_i values of each food item was compared between juveniles and adults. These AI_i values were also grouped according to source (allochthonous or autochthonous) to access their contribution to the diet. The difference between these two groups was tested by a chi-squared test.

Size of larvae ingested was measured using a stereoscopic microscope with graph paper. Then, we run a regression analysis between fish standard length (SL) and the size of larvae ingested. A Mann-Whitney U test was used to test for differences between prey size of adults and juveniles.

Results

The length / weight relationship indicated sexual dimorphism ($P < 0.01$) as well as a high correlation of the observed points for both sexes (Fig. 2). There was no dimorphism for the onset of sexual maturity: males and females reached sexual maturity (SL_{50}) at 4.45cm (Fig. 3). Males and females ($n=158$) differed in the standard length structure, with females reaching larger sizes than males, juveniles ($n=51$) reached maximum of 4.45 cm (mean=3.8) of standard length, (Fig. 4). Sex ratio was 1:1.77 (male:female) and differed significantly ($G=17.1$; $DF = 1$; $P < 0.001$) from the expected 1:1. Reproductive season spanned the whole year,

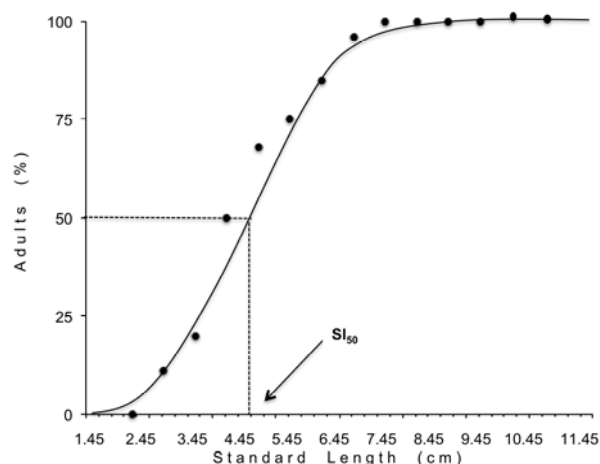


Figure 3. Length-frequency distribution of adult females and males of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil. The dotted line indicates the median standard length (SL_{50}) at the onset of sexual maturity.

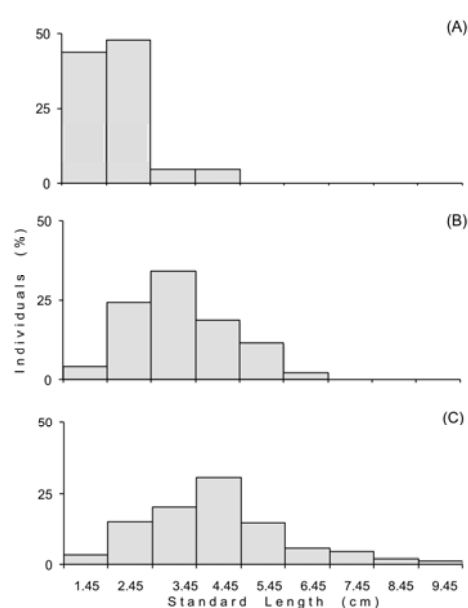


Figure 4. Standard length distribution of juveniles (A), males (B), and females (C) of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil.

with a small peak of ripe individuals during spring and summer – September/December (Fig. 5). Females presented group-synchronic partial spawning in two groups (Fig. 6). Fecundity was significantly correlated with SL and varied from 824 to 10.333 for fish of 5.2 and 11.3 cm, respectively. Relative fecundity was 545 eggs/g. Ripe eggs measured 800 μ m.

Intestinal coefficient (IC) did not differ ($F_{(1, 152)} = 4.23$; $P = 0.07$) between sexes but differed ($F_{(1, 199)}$

$= 308.08$; $P = 0.001$) between adults and juveniles (Fig. 7). Both adults and juveniles fed mainly on animals, but differed in the quality of preys consumed. Fragments of aquatic insects ($AI_i=53.2\%$) and coleopteran larvae (Curculionidae) ($AI_i=24.2\%$) had the highest occurrence among juveniles. Fragments of terrestrial ($AI_i=32.4\%$) and aquatic insects ($AI_i=24.5\%$) and coleopteran larvae (Curculionidae) ($AI_i=22.8\%$) were the most important preys consumed by adults (Table 1). We also observed an increase in the food spectrum of adults (23 prey items) and a reduced spectrum among juveniles (17 prey items). Juveniles consumed a significant higher ($\chi^2=88.134$; $P < 0.001$) proportion of autochthonous items ($AI_i=93\%$), whereas there was no difference ($\chi^2=4.137$; $p > 0.001$) either in the consumption of allochthonous ($AI_i=40\%$) or autochthonous items for adults ($AI_i=60\%$; Fig. 8). We did not find significant correlation between fish and prey size ($r=0.142$; $P=0.35$), but prey items consumed by juveniles were significantly ($U=4470.00$; $P=0.047$) smaller than those consumed by adults.

Discussion

Sexual dimorphism, egg size, fecundity, spawning type, and reproductive season are the main life-history traits representing reproductive strategies of species (Matthews 1998). Understanding these traits and their variability is fundamental to the identification of processes that maintain viable populations in the environment (Blanck & Lamouroux 2007).

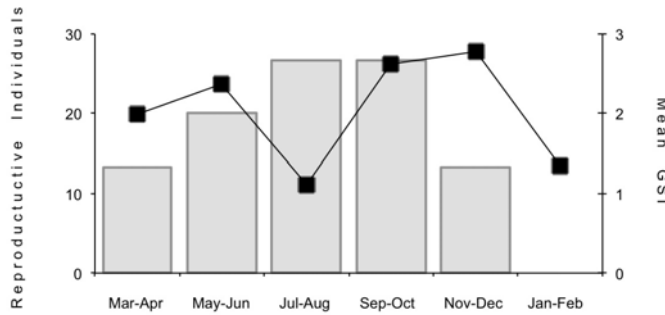


Figure 5. Temporal variation of reproductive females and Gonadosomatic Index (GSI) of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil.

Fish dimorphism has been frequently discussed in the literature and body size differences were referred as a frequent expression of this character (e.g., Gilbert & Epel 2009) being determined by both biological and environmental factors (Raikova-Petrova et al. 2012). Larger sizes among females could be interpreted as an evolutionary advantage as larger individuals produce, potentially, more and larger offspring. The correlation between SI and fecundity in *P. lateristriga* confirm this observation and could explain the larger sizes of females.

The onset of sexual maturity is a critical life history trait, in which individuals have to balance the allocation of energy among growth, survival, and reproduction (Wootton 1998). Anticipating the first reproduction usually enhances future survivorship in unpredictable environments increasing the chance of an individual to leave viable offspring (Stearns 1989). Considering the unpredictable harsh conditions of the studied coastal stream (e.g., Garuti 1988, Mazzoni & Iglesias-Rios 2002, Mazzoni & Lobón-Cervià 2000), we suggest that *P. lateristriga* is anticipating the first reproduc-

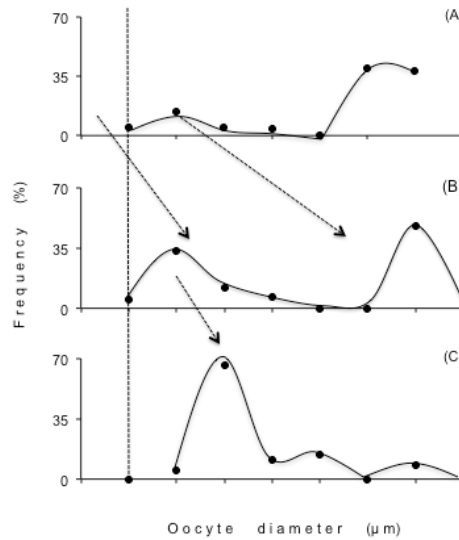


Figure 6. Oocyte size distribution in ovaries of *Pimelodella lateristriga* at different maturation stages, from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil. Oocytes on the left side of dotted line are stock cells. (A) Final maturation ovaries, (B) Ripe ovaries, and (C) Partially spent ovaries.

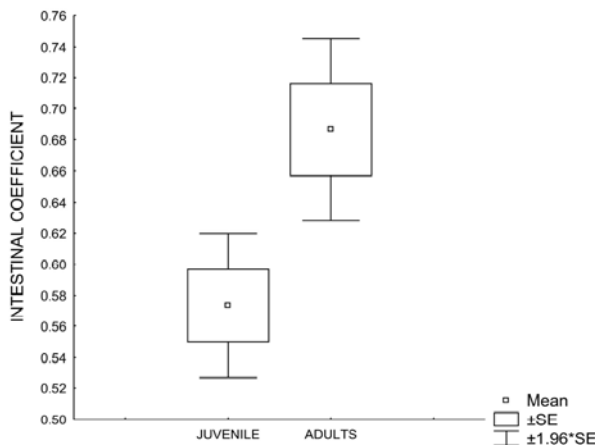


Figure 7. Mean values of Intestinal Coefficient of juveniles and adults of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil.

Table 1. Alimentary Index of food items consumed by juveniles and adults of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil.

Food Items	Juveniles	Adults
Fragment of aquatic insect	53.21	24.54
Fragment of terrestrial insect	1.23	32.42
Coleoptera		
Curculionidae larvae	24.16	22.82
Elmidae adult	0.04	0.01
Elmidae larvae	-	0.03
Decapoda		
Trichodactylidae	-	0.10
Diptera		
Chironomidae	10.93	7.90
Ceratopogonidae	-	0.01
Empididae	0.30	0.02
Tipulidae	0.04	0.37
Unidentified larvae	0.06	-
Ephemeroptera		
Baetidae	0.28	0.20
Haplotaaxida		
Unidentified Oligochaeta	0.38	0.10
Hymenoptera		
Formicidae	0.30	4.24
Odonata		
Anisoptera	-	0.012
Orthoptera		
Unidentified Adult	-	0.25
Podocopida		
Unidentified Ostracoda	2.72	0.48
Terrestrial plant		
Leaves	0.74	2.71
Trichoptera		
Hydropsychidae	4.09	1.02
Hydroptilidae	-	0.03
Leptoceridae	1.08	1.84
Other		
Unidentified item	-	0.01
Unidentified insect 1	0.38	-
Unidentified insect 2	-	0.09
Scales	0.08	0.82
Number of stomachs full (empty)	42 (9)	41 (22)
Standard length min - max (mean)	3-4.4 (3.85)	4.5-10.5 (5.46)

tion, achieving sexual maturity with 1/3 of their final size. This same pattern of size at first maturity was recorded for many stream-dwelling fishes from other coastal streams from Atlantic Rain Forest (Menezes & Caramaschi 1994, Mazzoni et al. 2002, Mazzoni & Iglesias-Rios 2002).

Obtaining accurate values for the length-weight (Sl/Wt) relationship and Sl_{50} is important because estimates of biomass from analytical and stock assessment models, such as a virtual popula-

**Figure 8.** Relative proportion (IAi) of allochthonous and autochthonous food items in the diet of adult and juveniles of *Pimelodella lateristriga* from Mato Grosso stream, Saquarema, Rio de Janeiro, Brazil.

tion, requires the average weight of individuals (e.g., Frota et al. 2004, Garcia-Lizárraga 2011, Flores et al. 2012). The Sl/Wt relationship in fishes can be affected by a number of factors including season, habitat, and sex (Önsoy et al. 2011, Yapici et al. 2012), which is usually described by a linear model whose regression slope varies between 2 and 4. Although males and females of *P. lateristriga* differed in the Sl/Wt relationship, both sexes had isometric growth, since the regression slope of males and females were close to 3 (e.g. Yapici et al. 2012).

Sex ratios may vary due to many factors, such as differential mortality and population growth rates (Vazzoler 1996). Since these factors may affect the two sexes differentially, shifts in the sex ratio may also represent an adaptation to the availability of feeding resources, leading to a predominance of females when food is abundant (Nikolsky 1969). Nikolsky (1969) also proposed that deviations in the sex ratio could be the product of the selective collection of specimens, in which males and females occupy different habitats. Mazzoni & Caramaschi (1995) suggested that the decrease of males of *Hypostomus* during the reproductive season might indicate low capturability during spawning time, when males are engaged in parental care and less prone to be caught.

Both juveniles and adults of *P. lateristriga* fed mainly on aquatic and/or terrestrial arthropods, corroborating previous studies (Mazzoni et al. 2010, Rezende et al. 2011). Nonetheless, this same species has been assigned to different trophic posi-

tions, such as carnivorous/insetivorous (Mazzoni & Costa 2007), omnivorous (Soares-Porto 1994), or carnivorous/piscivorous, omnivorous tending to herbivorous or even exclusively invertivorous (Trajano 1989, Horeau et al. 1998, Viana et al. 2006, Pereira et al. 2007 and Novakowski et al. 2008).

We also detected ontogenetic changes in the diet of *P. lateristriga*. Juveniles consumed large quantities of animal items whereas adults consumed relatively higher amounts of vegetals, although in general both adult and juvenile consumed low quantities of vegetal items. Although subjected to ontogenetic changes the IC values registered in the present study were similar to those recorded in another *Pimelodella* population (Mazzoni & Costa 2007). These IC values suggested a carnivorous/invertivorous feeding habit and were among the range of IC values proposed by many authors studying carnivorous species (e.g. Fryer & Iles 1972, Barbieri et al. 1994, Fugi et al. 2001, Gomiero et al. 2007).

Juveniles and adults differed in the source of food items consumed. Juveniles fed mainly on autochthonous items, while adults fed equally on autochthonous and allochthonous items. Soares-Porto (1994) found that both juveniles and adults of *P. lateristriga* consumed autochthonous benthic invertebrates. However, Mazzoni & Costa (2007) years later working on the same stream found that adults and juveniles of *P. lateristriga* differed in the preference for autochthonous and allochthonous items, indicating that diet may change over time and/or according to resource availability. The consumption of autochthonous items by juveniles and an increasing intake of terrestrial items by adults were described for *Pimelodus maculatus* by Lima-Junior & Goitein (2003). These authors concluded that smaller individuals consumed mainly larvae and pupae of chironomids, which are small benthic organisms with limited movements, while larger individuals fed mainly on fish, which are more difficult to capture.

Aquatic/autochthonous insects are found on the bottom of streams, while terrestrial/allochthonous insects become available to fishes when they fall and drift in the mid-water or water surface. Therefore, our results suggest that adults and juveniles of *P. lateristriga* feed on different strata of the water column. Silva et al. (2007) found similar results for *P. maculatus*, with juveniles/smaller individuals foraging on the bottom, while larger individuals fed more on the water

column. Lima-Junior and Goitein (2003) concluded that juveniles of *P. maculatus* were less dependent on vision when foraging. Chemical orientation allowed the capture of slow preys, living close to stream bottom, whereas visual orientation was the main approach used by fish while capturing swimming/mobile preys (Lima-Junior & Goitein 2003).

Ontogenetic shifts in size and source of prey can minimize intraspecific competition for food (Lima-Junior & Goitein 2003), indicating an intraspecific trophic partitioning (Mendoza-Carranza & Vieira 2009). We recorded ontogenetic changes in the diet of *P. lateristriga* from Mato Grosso stream, with adult and juvenile individuals differing in the source and size of items consumed. Ontogenetic shift in diet may be explained by morphological changes, mainly related to oral apparatus, such as teeth development (Menezes 1969, Hahn et al. 2000), body increase (Labropoulou et al. 1997, Platell et al. 1997, Schafer et al. 2002), and motor abilities (Wootton 1998, Xue et al. 2005), which may increase the number and size of prey (Wainwright & Richard 1995, Piet 1998, Maghagen & Heibo 2001, Gill 2003, Lima-Junior & Goitein 2003, Ward-Campbell & Beamish 2005). Other factors, such as eye diameter, body and head height, and snout length can also influence prey size (Ward-Campbell & Beamish 2005). The positive correlation between fish and prey sizes recorded for *P. lateristriga* was also observed for several Siluriformes (Merigoux & Ponton 1998, Lima-Junior & Goitein 2003, Mendoza-Carranza & Vieira 2009) and other groups (Keast 1977, Hahn et al. 1997). Increment of prey size may be the result of morphological changes related to feeding ability (Wainwright & Richard 1995, Wootton 1998) and increased capacity in prey handling (Xue et al. 2005). It can be also related to differences in energy demand at different developmental stages (Abelha et al. 2001).

Thus, ontogenetic and seasonal variations caused by changes in food ingestion and environmental conditions (Gilbert & Epel 2009) could be influencing the trophic dynamic of *Pimelodella* population, as well as resource availability for other species in the community. Such results should also be used in a broader context of community ecology studies of Mato Grosso stream and help to explain the organization of stream-dwelling fish community.

Finally, we conclude that fish diet can vary due to different causes. Circadian rhythm (Sabino

& Castro 1989), seasonality (Deus & Petrere-Junior 2003), space (Sabino & Castro 1989), ontogeny (Mazzoni & Costa 2007, Gilbert & Epel 2009), and food resource availability (Adams et al. 1982) influence the feeding habits of stream-dwelling fishes. Analysis of the quantity and quality of resources available in the environment is important to understand fish food selection (Deus & Petrere-Junior 2003) and food preference (Emlen 1968, Menge 1972, Manly et al. 2002, Pinto & Uieda 2007, Zandonà et al. 2011). Our results indicated many shifts in food consumption suggesting environmental and/or developmental causes. In this context, further experimental studies should clarify and confirm the mechanisms that account for the observed processes.

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