Influence of cage fish farming on the diet of dominant fish species of a Brazilian reservoir (Tietê River, High Paraná River basin)

Influência da piscicultura em tanques-rede na dieta de espécies de peixes dominantes de um reservatório brasileiro (Rio Tietê - bacia do alto Paraná)

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Abstract: The cage farming of aquatic organisms was initiated 50 years ago, and was introduced to Brazil in the 1990's. In these systems, there is an input of organic matter from ration that is not totally used by the cage fishes, becoming available for the organisms of adjacent biota, including fish fauna. The aim of this work is to evaluate the interference in the diet of three dominant fish species (*Plagioscion squamosissimus* Heckel, 1840, *Astyanax altiparanae* Garutti and Britski, 2000 and *Metynnis maculatus* Kner, 1858) associated with fish cage farming. For determination of the diet, the Alimentary Index (AI) was used. In both stretches (around cage farm and control), *P. squamosissimus* selected aquatic insects, while *A. altiparanae* preferred terrestrial insects and *M. maculatus* eats ration remains. Differences in abundance of these feeding resources found of the stomach content were observed among the two stretches. Thus, the small alterations in the diets of *P. squamosissimus* and *A. altiparanae,* indicate that cage farming can change the diet of resident species in reservoirs. This practice also influences the population structure of fish species, since higher middle standard lengths were found in *A. altiparanae* and *P. squamosissimus* populations resident around cage farms, in relation to the control stretch.

Keywords: cage-farming, diet, *Plagioscion squamosissimus*, *Astyanax altiparanae*, *Metynnis maculatus*, Tietê River.

Resumo: A utilização de sistemas de criação em tanques-rede iniciou-se há mais de 50 anos, sendo implantada no Brasil em meados de 1990. Nesses sistemas, há uma entrada de matéria orgânica decorrente do manejo, que se torna disponível para os demais organismos da biota adjacente, incluindo a fauna de peixes residentes. O objetivo deste trabalho é avaliar a influência da atividade de piscicultura em tanques-rede na composição da dieta das três espécies de peixes mais abundantes (*Plagioscion squamosissimus* Heckel, 1840, *Astyanax altiparanae* Garutti and Britski, 2000 and *Metynnis maculatus* Kner, 1858) atraídas por essa atividade. Para determinação da dieta utilizou-se o Índice Alimentar (IAi). Em ambos os trechos (tanques-rede e controle), *P. squamosissimus* apresentou preferência por insetos aquáticos, enquanto *A. altiparanae* por insetos terrestres e *M. maculatus* por restos de ração. Constata-se que há diferenças quanto à abundância desses itens alimentares encontrados no conteúdo estomacal entre os trechos estudados. Assim, infere-se que as pequenas alterações na dieta de *P. squamosissimus* e *A. altiparanae*, aliadas a dieta caracterizada para as três espécies alvo, quando comparadas com a literatura, indicam que os empreendimentos de piscicultura em tanques-rede alteram a dieta das espécies de peixes residentes nos reservatórios. Também, influenciam na estrutura populacional, visto que já foram evidenciados maiores comprimentos padrões médios nas populações de *A. altiparanae* e *P. squamosissimus* residentes no entorno dos tanques-rede em relação ao trecho controle.

Palavras-chave: tanques-rede, dieta, *Plagioscion squamosissimus*, *Astyanax altiparanae*, *Metynnis maculatus*, Rio Tietê.

1. Introduction

The utilization of cage farming systems began 50 years ago in the River Mekong delta, Asia (Medeiros, 2002). Currently, this activity is considered a new form of employment of public waters, allowing reservoirs to use cage farm systems, especially for fish farming (Reis et al., 2004). In Brazil, these systems were implanted intensively around 1990, mainly in the Southeast region (Medeiros, 2002; Brandão et al., 2004). Currently, fish cage farming is common in Brazilian reservoirs (Castagnolli et al., 2000), where the most important species is the Nile-tilapia (*Oreochromis niloticus*), a species derived from the African region that presents fast growth and good adaptation to containment (Hayashi, 1995; Boscolo et al., 2004).

The physical structure of the cage farms allows continuous water flow, increasing the oxygenation and removal of excreta and ration residues (Beveridge, 1996). However, similarly to traditional ponds, the cage farm systems have an input of organic matter from ration, and outlet of organic matter by conversion in biomass of fish (Esteves, 1998). In addition, part of the organic matter that enters the aquatic system is not utilized by cultivated fishes, becoming available to other organisms of the adjacent biota, such as phytoplankton and zooplankton, macroinvertebrates and fishes. According to Ono (1998) and Medeiros (2002), the enrichment of the aquatic system, resulting from the input of organic matter and nutrients, can severely compromise the water quality. This process, known as artificial eutrophication, can be considered as a cause-effect response, characterized by the loss of environment stability (Esteves, 1998).

Recent studies show an increase in the sedimentation process and concentration of sediment nutrient after implantation of cage farms for pisciculture (Alves et al., 2004) and a higher abundance of zooplankton and macroinvertebrates in areas near cage farm systems (Hermes-Silva et al., 2004). In addition, Boyra (2004), Håkanson (2005) and Paes (2006) demonstrated that cage fish farming play an important role in the attraction of resident fauna, since, around these systems, a higher abundance of some species is encountered in relation to the natural environment. The aim of the present study is to characterize possible differences in the diet of three fish species *Plagioscion squamosissimus* Heckel, 1840, *Astyanax altiparanae* Garutti and Britski, 2000 and *Metynnis maculatus* Kner, 1858 which are abundantly found around cage farm systems, in relation to a control stretch (not influenced by cage farm system).

2. Material and Methods

The reservoir of Nova Avanhandava is located in the county of Buritama (São Paulo), being the penultimate of a series of six reservoirs in the cascade system of the Tietê River (Figure 1). The main water body presents an inundated area of 210 km^2, an available volume of 3.8×10^8 m^3/s, a perimeter of 462 km, a water residence time of between 32 and 119 days and a mean discharge rate of 688 m^3/s (Rodgher et al., 2002). The vicinity of the drainage basin is composed of pasturing areas, but also has cane sugar, coffee and corn cultivation and, in some stretches, small areas of secondary forest (CESP/UFSCar, 1990).

The study was performed in a tilapias (*Oreochromis niloticus*, Linnaeus, 1758) cage farm with approximately 80 cages, located in the Santa Bárbara River (21° 05' 25" S and 050° 07' 18" W), main tributary of the Nova Avanhandava Reservoir (Figure 1). Samplings were performed every two months, from April to October 2004, in two distinct stretches: around the cage farm system and near a stretch without influence from the cage farm system (Control) with distance about of 1,000 m between both.

Fish were caught using gill nets with mesh sizes from 3 to 14 cm (opposite knot length), grouped in four lots with five nets each. Gill nets were placed in the afternoon and removed the following morning (14 hours exposure) in the two sampling sites. Fish collected were identified for species, preserved in 10% formalin and, conserved in 70° GL alcohol. Voucher specimens were deposited in the collection of the Museu de Zoologia da UEL (MZUEL) of the Universidade Estadual de Londrina (*P. squamosisssimus* – 4757; *A. altiparanae* – 4732 and 4702; *M. maculatus* – 4743).

A sub-sampling was performed (15 specimens) from different size classes. The fish were weighed (g) and measured (standard length, in centimeters), and their stomachs with contents were removed and fixed in 10% formalin and conserved in 70° GL alcohol. Stomach contents were examined under a stereoscopic microscope, identified to most detailed taxonomic level possible and weighed (wet weight) in a scale with centigram approximation; when this procedure were not possible (for small items), a percentage of total content weight. was established. Results were expressed with a frequency of occurrence and gravimetric methods (Hyslop, 1980), combined in the Alimentary Index - AI (Kawakami and Vazzoler, 1980).

Sixty-two specimens of *P. squamosissimus* from the cage farm stretch and 57 from the control stretch were analyzed; 41 specimens of *A. altiparanae* from the cage farm stretch and 44 from the control stretch were analyzed, as well as 39 specimens of *M. maculatus*, captured around the cage farm and 16 in the control stretch. Differences in the length values between the specimens from the cage farm stretch and the control stretch were calculated using the non-parametric Mann-Whitney test (U Test; $p < 0.05$). Statistical analyses were performed with Biostat 5.0 software, available for download at http://www.mamiraua.org.br/noticias.php?cod=3.

3. Results

The standard length values of fish species (except to *M. maculatus*) were statistically higher for specimens sampled around the cage farming system, in relation to those of the control stretch ($p < 0.05$) (Figure 2).

The three fish species consumed 28 food items, where 13 were utilized by *P. squamosissimus*, 12 by *A. altiparanae* and 19 by for *M. maculatus*. The items were grouped in 10 food categories: Crustaceans (*Macrobrachium* sp.); Microcrustaceans (a - Cladocera: *Bosmina* sp., *Diaphanosoma* sp. and non-identified others; b - Copepoda: Calanoida, Cyclopoida and non-identified others); Aquatic Insects (Odonata Libelulidae nymphs, Odonata Gomphidae nymphs; and non-identified remains; Trichoptera Leptoceridae larvae; Diptera Chironomidae larvae and pupae; Ephemeroptera Polymitarcyidae nymphs); Terrestrial Insects (non-identified remains, adults of Diptera, Coleoptera, Hemiptera and Hymenoptera); Fish (remains of muscle, bones and scales); Macroinvertebrates (Mollusca Bivalvia and egg of invertebrates); Vegetal remains (stalk, seeds and leaves in different digestion degrees);

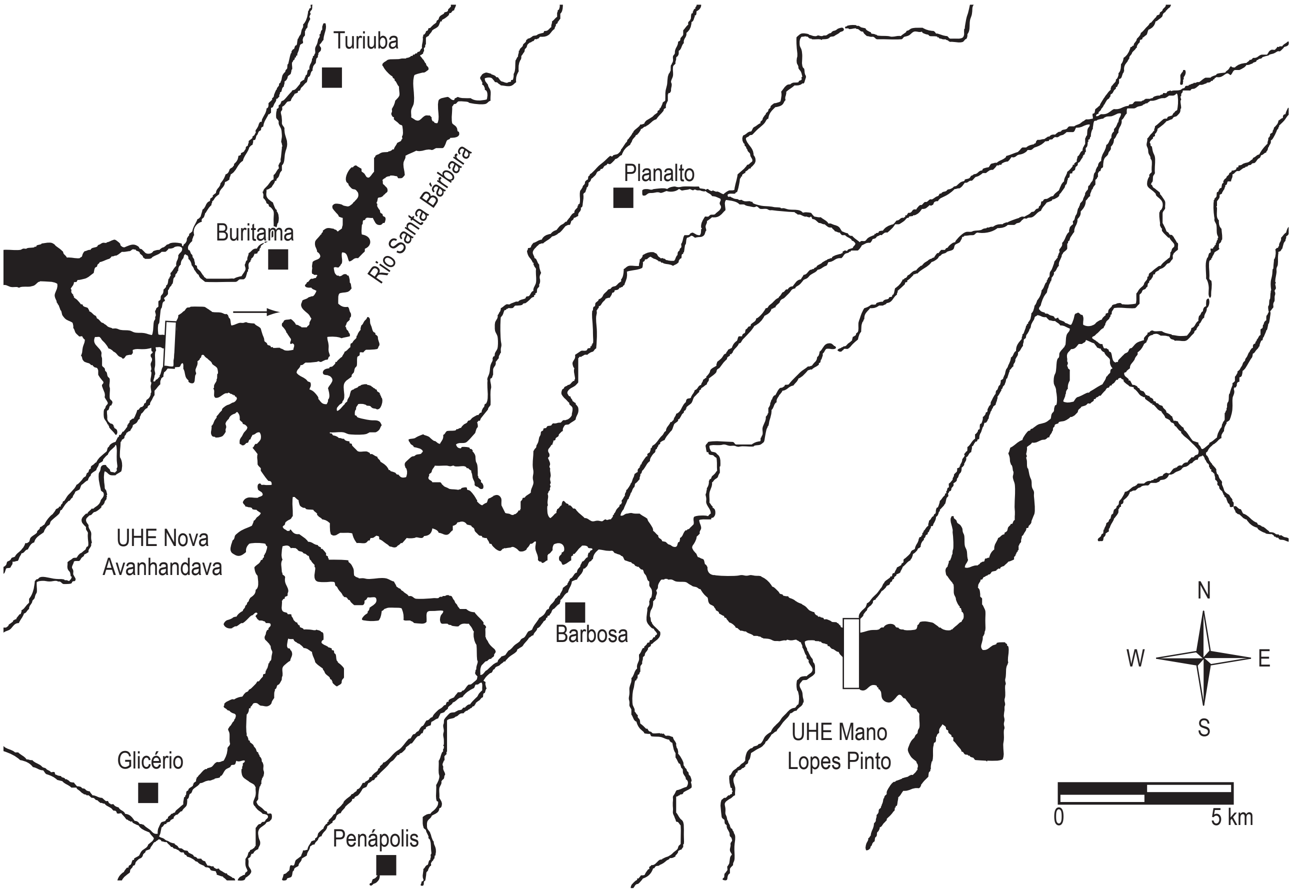

Figure 1. Nova Avanhandava Reservoir (low Tietê River) and Santa Bárbara River, with indication of the cage farm system in study (arrow) (modified from CESP, 1998).

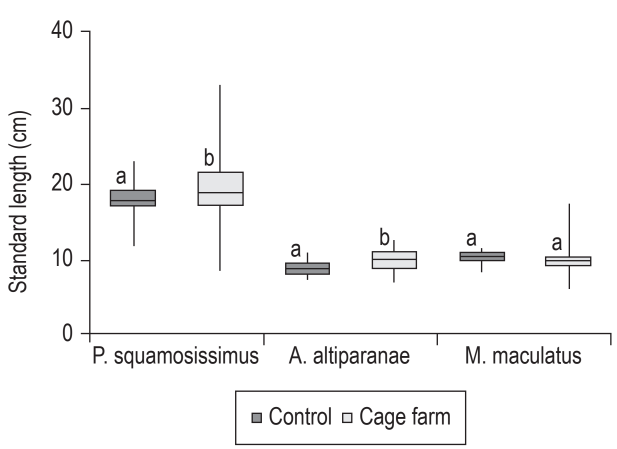

Figure 2. Box-Plot of standard length (Sl) of the three species. (Different letters shows statistically different values, Mann-Whitney Test, $p < 0.05$).

Algae (remains and filamentous algae – predominantly *Spirogyra* sp.); Detritus (organic matter in different decomposition degrees with presence of mineral particles) and Ration (ration scraps utilized from the cage farm).

Plagioscion squamosissimus shows preference for aquatic insects in both stretches (Figure 3a); however, in the control stretch, this category was more representative (Control - AI = 79.95; Cage AI = 57.56). Crustaceans were more important in the cage stretch (AI = 37.96), than in the control stretch (AI = 15.37) (Table 1).

Astyanax altiparanae (Figure 3b), in both stretches, consumed preferentially terrestrial insects, and, in the control stretch, this category were more representative (Control - AI = 89.24; Cages - AI = 67.65). The second most representative food was aquatic insects, which presented a higher contribution in the cage stretch (AI = 28.71), in relation to the control (AI = 5.72).

In both stretches, *M. maculatus* (Figure 3c) fed predominantly on ration scraps, in similar proportion in both stretches (Control - AI = 87.65; Cages - AI = 87.80). The second food category was vegetal remains, also found in a similar proportion for both stretches (Control - AI = 5.56; Cages - AI = 5.90).

4. Discussion

In Brazil, studies about ecological effects and interferences of fish cage farming in publics waters are recent, since this activity has been stimulated from 2003 (Decree n° 4.895/2003). Håkanson (2005) showed the "bottom-up"

Table 1. Diet composition of *Plagioscion squamosissimus*, *Astyanax altiparanae* and *Metynnis maculatus* by food categories (control and cage farm).

Categories and items	*P. squamosissimus*		*A. altiparanae*		*M. maculatus*	
	Control n = 57	Cage farm n = 62	Control n = 44	Cage farm n = 41	Control n = 16	Cage farm n = 39
CRUSTACEANS						
Decapoda	-	-	-	-	-	-
Shrimp (*Macrobrachium* sp.)	15.37	37.96	-	-	-	-
MICROCRUSTACEANS						
Cladocera	-	-	-	-	-	-
Bosmina sp.	-	-	-	-	0.04	-
Diaphanosoma sp.	-	-	-	-	0.38	-
non-identified others	-	-	-	-	0.17	-
Copepoda	-	-	-	-		-
Calanoida	-	-	-	-	0.04	-
Cyclopoida	-	-	-	-	0.04	-
Others	-	-	-	-	-	0.04
AQUATIC INSECTS						
Odonata	-	-	-	-	-	-
Libelulidae (nymphs)	32.13	13.09	-	4.29	0.17	-
Gomphidae (nymphs)	41.43	27.64	-	-	0.04	-
Remains	-	0.04	-	-	-	-
Trichoptera (larvae)	-	-	-	-	-	-
Leptoceridae	0.003	0.01	-	-	-	-
Diptera			-	-	-	-
Chironomidae (larvae and pupae)	0.01	0.08	0.10	6.60	1.51	0.05
Ephemeroptera (nymphs)	-	-	-	-	-	-
Polymitarcyidae	6.37	16.70	5.62	17.82	0.46	1.18
TERRESTRIAL INSECTS						
Díptera	-	-	0.90		-	-
Coleoptera	-	-	3.61	1.98	-	-
Hemiptera	-	-	0.10	1.98	0.04	-
Hymenoptera	-	-	12.04	14.85	0.25	-
Formicidae	-	-	12.35	13.20	-	-
Insect remains	-	0.054	60.24	35.64	0.38	0.39
FISH						
Fragment of muscle and bones	4.45	4.26	-	-	-	-
Scales	0.01	-	0.40	0.16	0.38	-
MACROINVERTEBRATES						
Mollusca	-	-	-	-	-	-
Bivalvia	0.003	0.02	-	-	-	-
Invertebrate eggs	-	-	2.51	0.66	0.17	-
VEGETAL FRAGMENTS	-	-	-	-	-	-
Stalk, leaves and seeds	0.21	0.15	2.10	2.80	5.56	5.90
ALGAE						
Filamentous (*Spirogyra* sp.)	-	-	-	-	2.69	2.75
Algae remains	-	0.004	-	-	-	-
DETRITUS	-	-	-	-	-	1.87
RATION						
Ration scraps	-	-	-	-	87.65	87.80

effect of the trophic web, caused by emission of nutrients of cage farms in temperate lakes, emphasizing the attraction feature of these systems for fish species and the changes in the diet of resident fish. Dempster et al. (2002), Boyra et al. (2004) and Giannoulaki et al. (2005) reported the effect of aggregation of native fish to cage farming systems, and the great discharge of nutrients (phosphorous and nitrogen) that affect the productivity in the marine environment.

Considering the relationship between the input of effluents (nutrient and fish metabolites) in the cage farming stretch with the diet of the three species studied, we can assume that the fish cage farming provides the enrichment of the trophic web, attracting aquatic insects such as aquatic Odonata, Ephemeroptera, Diptera and other components of the local biota. According to Paes (2006), who studied the ichthyofauna and limnological aspects of cage fish farming,

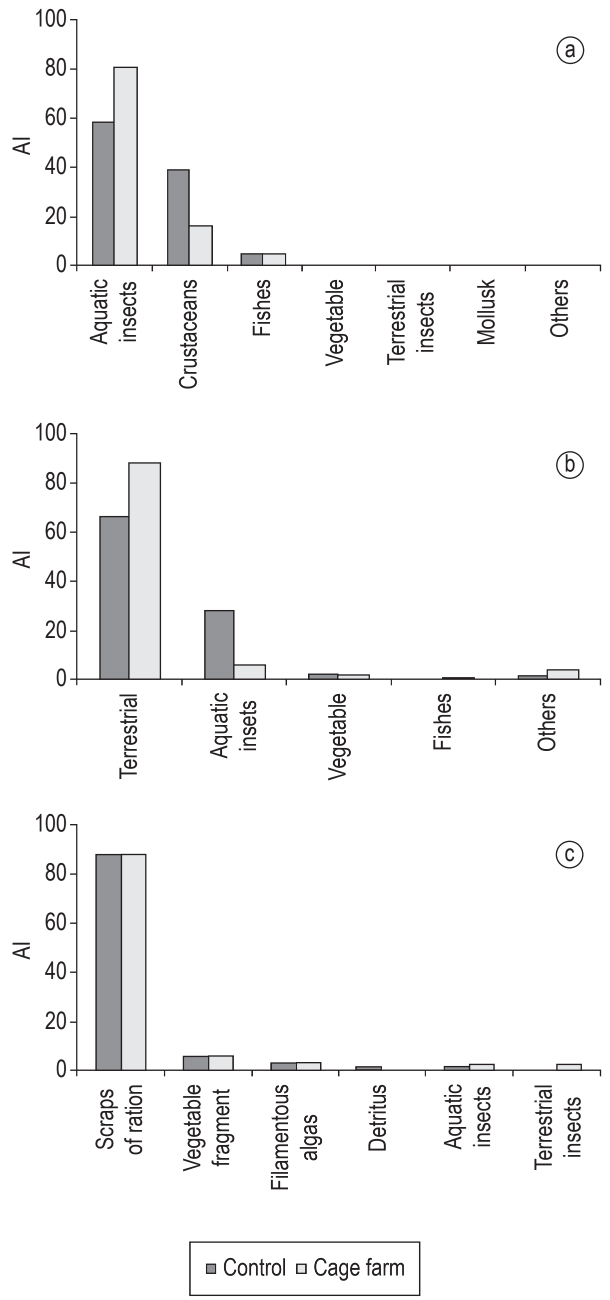

Figure 3. Diet composition of a) *Plagioscion squamosissimus*, b) *Astyanax altiparanae* and c) *Metynnis maculatus* by food category (control and cage farm).

possible reallocation of effluent for aquatic biota prevents a probable eutrophication process.

In addition, the higher standard length of fish sampled around the cage fish farm demonstrates that *P. squamosissimus, A. altiparanae* and *M. maculatus* use the feeding resources generated from the input of organic matter of the cage farming system in distinct ways. *Metynnis maculatus* directly consumes ration scraps, while *P. squamosissimus* and *A. altiparanae* feed mainly on aquatic insects, organisms that benefiting from this input. Furthermore, *M. maculatus*, in contrast to the other two species, presents a similar standard length in both stretches may be due to the similar consumption of ration scraps in both stretches, indicating that fish migrate between the two stretches for feeding.

In its natural habitat in the Amazonian region, *P. squamosissimus* feeds mainly on shrimps (Goulding and Pereira, 1984 in Torloni et al. 1993), similarly to fish from a tributary of Capivara Reservoir (Bennemann et al., 2006). However, in Barra Bonita Reservoir, where this item is rare, the corvina feed preferentially on fish and aquatic insects (Braga, 1998). Bennemann et al. (2006) indicated that fish are the main food item of corvina, but when this item is reduced or unavailable, the species becomes opportunistic, replacing this item with others that may be more abundant. Hahn et al. (1997) also observed that *P. squamosissimus* presented high trophic plasticity, using the most abundant resources in the environment.

In the present study, *P. squamosissimus* was observed to be carnivorous with a tendency towards an insectivore habit in the cage farming stretch; while in the control stretch, this species was predominantly insectivorous, where the diet was composed mainly of Odonata nymphs (Libelullidae and Gomphidae). Smith et al. (2003) reported that this species feed mainly on shrimp and aquatic insects, and almost do not use fish in their diet in the reservoirs of the Tietê River cascade, in contrast to the piscivorous habit encountered by Hahn et al. (1997), Hahn et al. (1998) and Bennemann and Shibatta (2002). According to Pereira et al. (2002), a possible explanation is that reservoirs from the middle and low Tietê River have high water transparency, propitious to the proliferation of shrimp and, consequently, a higher consumption of this item by *P. squamosissimus*, which has the behavior of a visual predator. Vidotto (2005), studying the diet of the most abundantly introduced species of the Nova Avanhandava Reservoir, also observed this feeding tactic.

Higher consumption of aquatic insects by *P. squamosissimus,* near the ponds, may be related to the local attraction (abundance of feeding resources), where the effluents become available to primary production and, consequently, to superior levels of the trophic web. Therefore, the differences observed in the diet of this species indicates the interference caused by cage fish farms.

Diet of *Astyanax altiparanae* in the two stretches studied was composed mainly of aquatic insects, vegetal remains, shrimp and fish and, preferentially, terrestrial insects. The preference for terrestrial insects was also observed in the Itaipu Reservoir (Hahn et al., 1998) and the high Paraná River floodplain (Hahn et al., 2002). However, this species presents a herbivore tendency in the Salto Caxias Reservoir, Iguaçu River (Cassemiro et al., 2005) and in the Tibagi River basin (Bennemann et al., 2005), demonstrating the high trophic plasticity of the species in different environments (lakes, reservoirs, rivers and streams) in the high

Paraná River basin. Insectivorous-herbivorous feeding habit of the species has been observed by many authors (Esteves and Galetti, 1995; Uieda et al., 1997; Lobón-Cerviá and Bennemann, 2000; Cassemiro et al., 2002; Casatti et al., 2003 and Oliveira and Bennemann, 2005), and a tendency towards this habit has been displayed by all species of the genus *Astyanax* (Andrian et al., 2001; Vilella et al., 2002; Bennemann et al., 2005).

The proportion of food categories in the diet of *A. altiparanae* presented differences among the cage farming and control stretches, where terrestrial insects had a higher contribution in the control stretch, and aquatic insects were more abundant in the cage farm stretch. Ration scraps, terrestrial insects, aquatic insects, filamentous algae and microcrustaceans composed the diet of *M. maculatus*, in both stretches. Thus this species presents a high trophic plasticity in the Nova Avanhandava Reservoir, as also observed by Vidotto (2005), where adults were omnivorous, consuming organic detritus, vegetal remains and aquatic insects in similar proportions, while the young used rather filamentous algae.

Metynnis maculatus presented high preference for ration scraps, composed of crushed grain of corn thus, preserving the preference for food of vegetal origin. However, despite its herbivorous habit, this species displayed tactics of food exploration of other trophic levels, depending on the food availability. According to Bennemann and Shibatta (2002) and Smith et al. (2003), *M. maculatus* consume preferentially filamentous algae in the reservoirs of the Tietê and Tibagi Rivers and, in the Miranda River, this species consumed vegetable parts of roots, stalks and leaves (Resende et al., 1998). In conclusion, the basic diet of this species is composed preferentially of items of vegetal origin.

The contribution by food categories of *M. maculatus* was practically identical between specimens from the cage farming and control stretch. However, a parallel study in the same area performed by Paes (2006) indicates a high abundance of this species from the cage farming stretch in relation to the control. According to Boyra et al. (2004), this is related to the attraction that the cage fish farming system exerts to resident biota.

A relevant fact is the discrepancy in the classification of the herbivore feeding habit of the present study (between 2005/2006) and the omnivorous habit described by Vidotto (2005) em 2003/2004, in the same stretch of Nova Avanhandava Reservoir. The most plausible hypothesis would be due to the interference of cage farming in the diet of *M. maculatus*, since this species directly uses food resources from the system.

Feeding ecology of this species indicates that, cage fish farming system interferes in the dynamics of ecological processes and nutrient contribution, increasing the primary production and reorganization of communities. In addition, our results indicate that this and other organisms of the biota are using the matter and energy produced by the cage farming system, reducing the impact of the eutrophication process.

Acknowledgements

The authors thank Ricardo A. S. Teixeira, Renato Devidé and Jaciara V. K. Paes for assistance in the field works; and the Universidade Estadual Paulista and FAPESP for financial support (process nº 03/11239-2 and 05/53110-1).

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Received: 30 May 2008
Accepted: 08 October 2008