Influence of a cage farming on the population of the fish species *Apareiodon affinis* (Steindachner, 1879) in the Chavantes reservoir, Paranapanema River SP/PR, Brazil

Influência de uma piscicultura em tanques-rede na população da espécie de peixe *Apareiodon affinis* (Steindachner, 1879) no reservatório de Chavantes, rio Paranapanema SP/PR, Brasil

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Abstract: Aim: The aim of the present study was to evaluate the diet and biological attributes of the population of *Apareiodon affinis* residing near net-cage fish farming activities in the Chavantes reservoir. **Methods:** Samples were collected from two populations: one near the net cages (NC) and one from an area not influenced by these cages denominated the "reference site" (RS). Monthly sampling was carried out from Mar/ 2008 to Feb/ 2009. Fish were caught with a standardized effort using gill nets deployed for 14 hours. After all individuals were measured (standard length) and weighed (total weight, carcass weight , body weight without gonads). To determine the composition of the diet, the alimentary index was calculated (AI). We also calculated the length-weight relationship, condition factor, gonad-somatic index (GSI) and reproductive potential. **Results:** A total of 3050 individuals were caught. The results of the (AI) revealed that the item detritus was the main food used for populations of *A. affinis* studied in two areas (NC = 73.1% and RS = 95.7%). The use of feed on diet *A. affinis* was recorded for the populations of NC adding (20.5%) of the total items consumed by the population. The resident populations residing near net-cage showed higher condition factor and more reproductive period. **Conclusions:** The results show the ability of the species to benefit from the input of organic matter from fish farming activities, inserting a new item in their diet (ration). This work indicates that the species *A. affinis* managed to establish near net-cage, allocating enough energy to increase their reproductive period and maintain viable populations close to net-cage, evidenced by the high abundance. This study suggests that systems of fish farming in net-cage influence diet and biological attributes of the species *A. affinis* residents Chavantes reservoir, Brazil.

Keywords: fish, Paradontidae, biological attributes, fish farming impacts, teleost.

Resumo: Objetivo: O objetivo deste estudo foi avaliar a influência de uma piscicultura em tanques-rede na dieta e nos atributos biológicos da espécie *Apareiodon affinis* na represa de Chavantes. **Métodos**: Foram coletadas amostras da população ao redor dos tanques-rede (TR) e comparada com uma área sem esta influência, denominada controle (CT). As amostragens foram realizadas mensalmente de mar/2008 até fev/2009. Os peixes foram capturados utilizando-se de rede de espera com esforço padronizado, expostas por 14 horas. Todos os peixes foram medidos (comprimento padrão) e pesados (peso total, peso da carcaça, peso corporal sem as gônadas). Para determinar a composição da dieta, foi calculado o índice alimentar (IAi). Também foram calculados a relação peso comprimento, fator de condição, índice gonodossomático (IGS) e o potencial reprodutivo. **Resultados**: Um total de 3050 indivíduos foi capturado. Os resultados do (IAi) revelou que o item detrito, foi o principal alimento utilizado pelas populações de *A. affinis* nas duas áreas estudas (TR = 73,1% e CT = 95,7%). A utilização da ração na dieta de *A. affinis* foi registrada para as populações do TR somando (20,5%) do total de itens consumidos pelas populações. As populações residentes ao redor dos tanques-rede apresentaram maiores valores de fator de condição e período reprodutivo. **Conclusão:** Os resultados mostram a habilidade da espécie em se beneficiar da entrada de matéria orgânica proveniente das atividades da piscicultura, inserindo um novo item em sua dieta (ração). Este trabalho indica que a espécie *A. affinis* conseguiu se estabelecer ao redor dos tanques-rede, alocando energia suficiente para aumentar o seu período reprodutivo e manter suas populações viáveis ao redor dos tanques-rede, comprovado pela elevada abundancia. Este estudo sugere que os sistemas de pisciculturas em tanques-rede influenciam a dieta e os atributos biológicos da espécie *A. affinis* residentes na represa de Chavantes, Brasil.

Palavras-chave: peixe, Paradontidae, atributos biológicos, impactos de piscicultura, teleósteos.

1. Introduction

In recent decades, Brazilian hydrographic basins have been dammed in order to generate hydroelectricity, according to government guidelines, to meet the growing energy demanding. However, the artificial lakes that result from these projects have caused damage to native flora and fauna, as well as severe socioeconomic problems (Naik et al., 2011; Agostinho et al., 2011).

Fish communities have been suffering from other impacts that reduce their diversity, such as the introduction of non-native species (Latini and Petrere Junior, 2004; Zanatta et al., 2010). Furthermore, encouraged by the government, cage-farming activities are currently expanding in reservoirs of hydroelectric plants, where the inclusion of these systems may be a new source of impact on the ichthyofauna of reservoirs (Henry-Silva and Cardoso 2008; Lachi and Sipaúba-Tavares, 2008; Brasil, 2009, 2011). Nevertheless, the possibility to increase aquaculture production in the future seems to be very high (Gjedrem, 2012).

According to the Agência Paulista de Tecnologia dos Agronegócios (APTA, 2008), there are 360 fish farmers in the middle Paranapanema River region, and at least 40 species of freshwater fish in Brazil are used in aquaculture, which represents only 1.5% of all known species (Godinho, 2007). Fish farming activities have been increasing and becoming an important source of protein for human consumption. Brazil has a great potential for the development of aquaculture, due to its vast territory and favorable climate conditions, which is also internationally acknowledged (Pavanelli et al., 2008).

Fish farming in cages provides resources in the form of matter and energy for aquatic trophic webs, serving as an attraction for many organisms (Nickell et al., 2003; Machias et al., 2004; Giannoulaki et al., 2005; Kutti, 2008; Sales-Luís et al., 2009; Zambrano et al., 2010), through the release of leftover ration from the development of the activity, which also indirectly contributes to the growth of algae (Mannino and Sara, 2008; Borges et al., 2010). Håkanson et al. (1998) and Håkanson (2005) argue that part of the food ingested by farmed fish is eliminated as excreta (feces and metabolites), which is also utilized by resident fish fauna occupying areas close to fish farming cages. Thus, part of this ration is not fully exploited by organisms in the farming cage, and therefore lost to the aquatic environment and may be used by local biota (Beveridge et al., 1991).

The physical structure of net cages may serve as shelter and refuge to different components of the biota (Beveridge, 1984, 1996), which might lead to environmental problems (Dalsgaard and Krause-Jensen, 2006). The communities of organisms reflect the conditions of the hydrographic basin better than any physical-chemical variable of water quality as the organisms respond to the full range of biogeochemical factors of the environment (Karr and Chu, 2000). Fish are highly sensitive components of aquatic ecosystems and have several attributes that make them useful as biological indicators of the conservation status of environments (Simon and Lyons, 1995).

Studies with fish can present environmental changes associated with the watershed. Thus, some attributes of the community, such as abundance and trophic structure, are used to assess the environmental conditions in which fish live (Karr, 1981). These will also have great biological and socioeconomic importance, justifying their use in biological monitoring programs (Roset et al., 2007). This study used the fish species, *Apareiodon affinis* (Steindachner, 1879), belonging to family Parodontidae Characiformes, which presents a wide geographical distribution in the neotropical region (Nelson, 1994; Reis et al., 2003), and is one of the most abundant fish species in the Paranapanema River basin (Dias and Garavello, 1998; Britto and Carvalho, 2006; Teixeira and Bennemann, 2007; Brandão et al., 2009).

The species is specifically characterized as detritivores (Casatti et al., 2003) and omnivorous (Vidotto-Magnoni and Carvalho, 2009). It is considered small and of no commercial value, being used only as bait for professional and amateur fishing (Shibatta et al., 2002; Ratton et al., 2003; Bialetzki and Nakatani, 2004). Moreover, this species is a major prey for numerous piscivorous fishes (Bialetzki et al., 1998) and negative impacts on this species may also have consequences on higher trophic levels (Gurgel, 2004; Santos et al. 2006).

This study aimed to evaluate the influence of fish farming in Chavantes reservoir, Paranapanema River on the diet and biological attributes of the fish species *Apareiodon affinis* captured around a system of fish farm cages, compared to a reference site (not influenced by a cage farm system).

2. Material and Methods

The Chavantes reservoir (S 23° 22' W 49° 36') is located in the medium stretch of the Paranapanema River at the border of São Paulo (SP) and Paraná (PR) States. The reservoir is located at 480 m above sea level, with a maximum depth of 70 to 90 m, a total volume of 9410 × 106 m^3 and an area of 400 km^2 (Duke Energy, 2002).

The study was conducted within a private enterprise for the breeding of tilapia, *Oreochromis niloticus* in cages, in a lentic segment of the reservoir, located between the municipalities of Ipaussu and Chavantes (SP). To carry out the study, two sites were selected for the study - the first one close to the area where the fish farm system was installed designated as net cage site (NC). The second site, located in a stretch below the NC, was designated as reference site (RS), located at geographic coordinates 23° 7' 56.89" S and 49° 36' 13.24" W, approximately 3 km from NC (Figure 1).The two study sites were bordered by rocks, fragments of mesophytic forests and some areas of aquatic macrophytes.

The fish farm studied has been operating since the beginning of 2008. It is classified as medium size and has about 200 net cages, each one with a

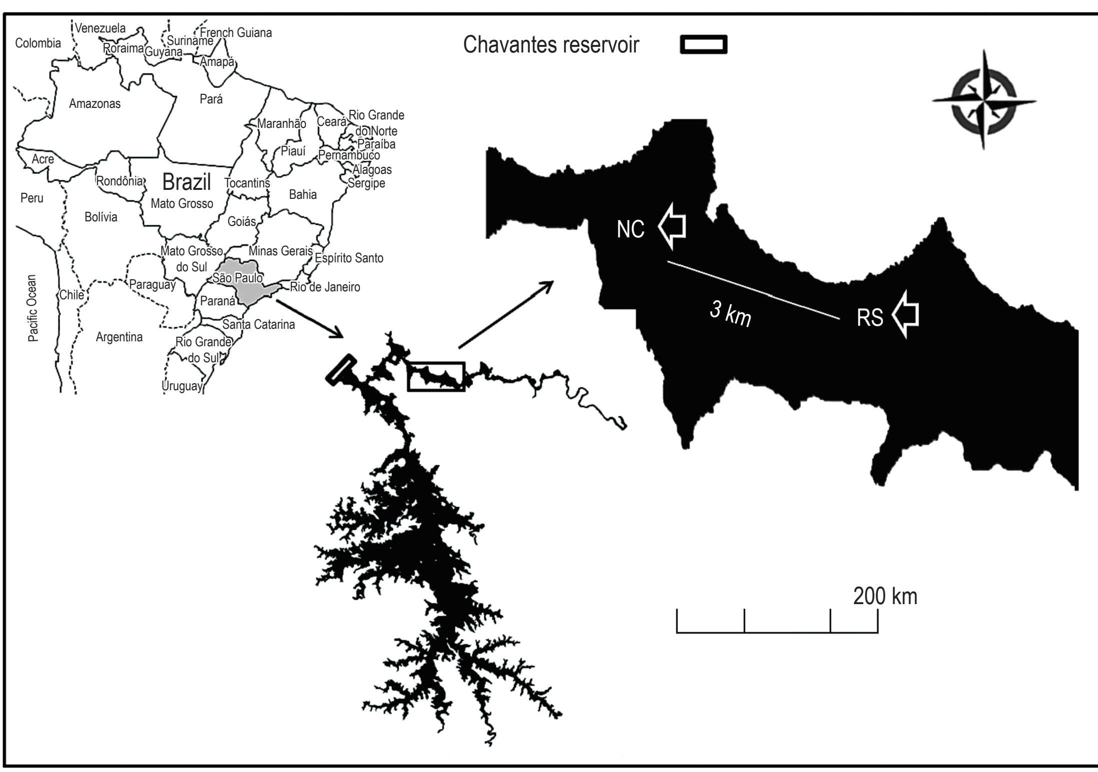

Figure 1. Political map of Brazil highlighting (gray color) the state of São Paulo, where it entered the Chavantes reservoir in the middle Paranapanema River SP/PR. (arrow) Study site - a system of fish farming in net cages (NC) and reference site (RS). (Source: Satellite image of GoogleEarth – DigitalGlobe; IBGE).

volume ranging from 6 to 18 m^3. The population of *A. affinis* has increased in the surrounding area of the fish farm since the beginning of its construction and has continuously grown in the area near the net cages.

The fish were collected monthly (License nº Ibama Register: 2629349) at the two sites from March 2008 to February 2009 in normal environmental conditions. Fish were captured with gill nets, grouped in three sets with five nets each (mesh sizes = 3 to 14 cm, not opposite knots and height from 1.44 to 2.20 m). Nets were set at 5:00 PM and removed at 6:00 AM (exposure time of 14 hours). Right after capture all individuals were measured and weighed.

Hydrological and environmental data for this reservoir, such as rainy and dry seasons (cumulative monthly rainfall) were obtained from the Department of Hydrobiology of Duke Energy - Generation Paranapanema. Voucher specimens were deposited in the Laboratory of Biology and Genetics of Fish, Institute of Biosciences, UNESP, Botucatu, Brazil.

The species biometric data were determined using an ichthyometer and precision balance. Stomach contents were analyzed under a stereomicroscope, identified to the most detailed taxonomic level possible and weighed (wet weight) on a scale with 0.0001 g of approximation. The results were expressed as the frequency of occurrence and gravimetric method, generating an index that shows the main food items of the diet of a given population (Kawakami and Vazzoler, 1980), adapted by Hahn et al. (1998): $AI = Fi \times Wi \times 100/\sum Fi \times Wi$, when: AI = alimentary index; i = 1.2 ... n, food items, Fi = frequency of occurrence of item i (%); Wi = wet weight of item i (%). The identification of food items was performed based on identification keys (Strixino and Strixino, 1982; Merritt and Cummins, 1996; Costa et al., 2006).

The sex was determined through macroscopic visualization of the gonads (Veregue and Orsi, 2003). The calculation of the length-weight relationship was based on Santos (1978) and King (2007), as follows equation: $W_t = \phi * L_s^{\theta}$ where W_t = total weight of the individual (g) and/or carcass weight (W_c), ϕ = parameter that measures the degree of fish fattening; L_s = standard length (cm) and ϕ = parameter that defines the type of growth of the species with the aid of the STATISTICA 7 program (ZAR, 1984).

The condition factor was obtained from the mathematical expression of length-weight relationship using the value of θ (type of specie's growth) calculated for the two sections combined. To calculate the individual condition factor (K) the mathematical expression $K = Wt/Ls^{\theta}$, and K = condition factor was applied, according to Vazzoler (1996). The values obtained for the condition factor were tested using the non-parametric Mann-Whitney test (U Test; $p < 0.0001$) to determine possible statistical differences between sexes and locations (NC and RS).

To investigate the occurrence of reproductive stages, we examined seasonal variations in the gonads with the gonadosomatic index (GSI): $GSI = Wg/Wt * 100$, where, Wg = weight of gonads and wt = weight total (Vazzoler, 1996). To obtain the reproductive potential, counts were performed in oocytes of 437 females from NC and 219 from RS using stereomicroscopy, utilizing a previously-fixed ovary sample from each individual. The morphometry of oocytes was performed as follows: Ten oocyte units from five samples of monthly individuals were randomly selected to determine the mean biometrics area, and horizontal and vertical diameter, with the aid of the QWin Lite 3.1 and LAZ V3 programs (Leica Application Suite).

For all statistical analysis, differences between variables were considered significant when $p < 0.05$ (5% significance level).

3. Results

We collected a total of 3,050 specimens of *A. affinis* (voucher, LBP 4793); 2,183 were collected in the NC, of which 799 had their stomach contents analyzed; and 867 were collected in the RS, of which 575 had their stomach contents analyzed. The most important item of the diet in the two selected study sites (NC and RS) was detritus (AI = 73.1% and 95.7% respectively). The remains ration was the second most important item in the NC (AI = 23%), and for the RS, the second important item was vegetal fragments (AI = 4.3%) (Figure 2).

The length-weight relationship was examined in two manners; firstly, we considered the total wet weight of the fish and, secondly, we considered the wet weight of carcasses. Negative allometric growth was observed in both tests for this species (Table 1). The values of the condition factor of the species were higher in the NC, where the wet weight and weight of the carcasses suggest a strong effect of the net cages on the physical condition of the fish (Figure 3a, b). Nevertheless, an analysis of the condition factor, considering the weight of the gonads, did not demonstrate statistical differences

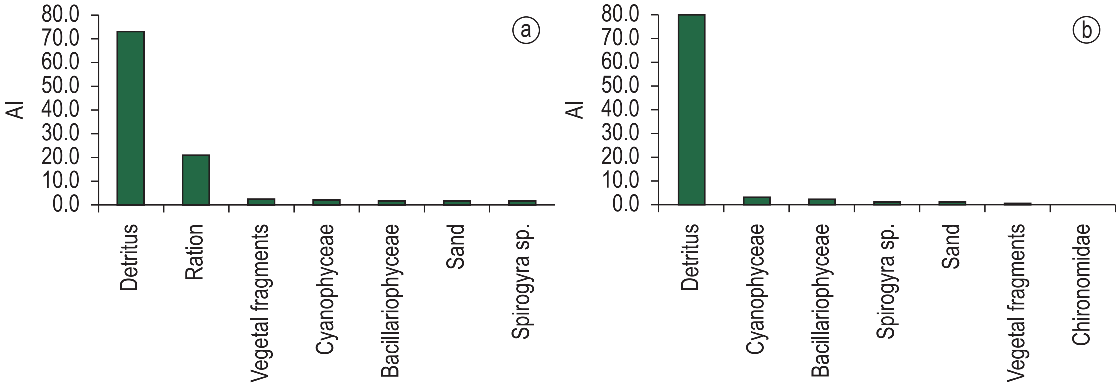

Figure 2. Alimentary Index (AI) of *A. affinis* in NC (a) and RS (b), collected in Chavantes reservoir, Paranapanema River SP/PR.

Table 1. Relationship weight-length in the species *A. affinis* in sites (NC) = Net Cage and (RS) = Reference Site in the Chavantes' reservoir, Paranapanema River SP/PR, where: (n) = number of analyzed specimens, (ϕ) = condition factor, (θ) = growth type, (r^2) = determination coefficient, (p) = significance level, *values statistically different p = <0.0001.

Length-weight relationship					
Variable	**n**	**ϕ**	**θ**	**r^2**	**p**
Wet weigth (NC)	2,612	0.95	2,192	0.65	*<0.0001
Carcass weigth (NC)	2,612	0.99	2,234	0.66	*<0.0001
Wet weigth (RS)	829	0.07	2,404	0.71	*<0.0001
Carcass weigth (RS)	829	0.09	2,254	0.65	*<0.0001

between the two study sites (Mann-Whitney test U; p = 0.2) (Figure 3c).

The mean monthly gonad-somatic index (GSI) exhibited substantial differences among the months and permitted the identification of the reproductive period. Both females and males showed the highest GSI during an apparently longer period in the NC. The reproductive period in the NC lasted from October to January, and attained the highest GSI values for both sexes in January, with a decline in February. Maximum gonad values for females in the RS occurred between October and December and showed the highest values, for both sexes, in November and a decline for females in January (Figure 4a-c).

During the study period, smaller oocytes were observed in the NC for this species, presenting monthly averages of 0.40 mm to 0.79 mm for the horizontal diameter, 0.44 mm to 0.76 mm for the vertical diameter and an area of 0.14 mm to 0.41 mm. In contrast, in the RS horizontal diameters of 0.47 mm to 0.80 were recorded, and 0.42 mm to 0.77 mm in diameter, 0.18 mm in vertical diameter, and 0.41 mm in area. However, the species had a higher reproductive potential at the NC site; for the NC, the maximum fertility in the population ranged from 12,816 to 78,557 oocytes and for RS ranged from 9,327 to 49,738 oocytes (Table 2).

4. Discussion

This study demonstrates differences in abundance, biomass and biological attributes between the population of *A. affinis* sampled around the net cages and also from the reference site. The diet at both sites was based on detritus, however, populations of NC used the ration from fish farming as part of their diet, thus added a new food item in your diet (Carvalho et al., 2012). Energy transmission is confirmed by high abundance of *A. affinis* feeding on remains ration around the net cages.

Opportunistic consumption is considered an important tactic for successful colonization in habitats affected by anthropogenic activities, allowing species to maximize energy input due to the supply and quality of available food. Attraction to the area under the influence of fish farming is likely related to the secondary input of matter and energy. Thus, one may infer that fish seek areas near net cages due to the availability of food of an allochthonous (remains of ration) or autochthonous (algae, zoobenthos and fish) origin.

Fish farming in cages releases resources, such as matter and energy for the aquatic tropic webs,

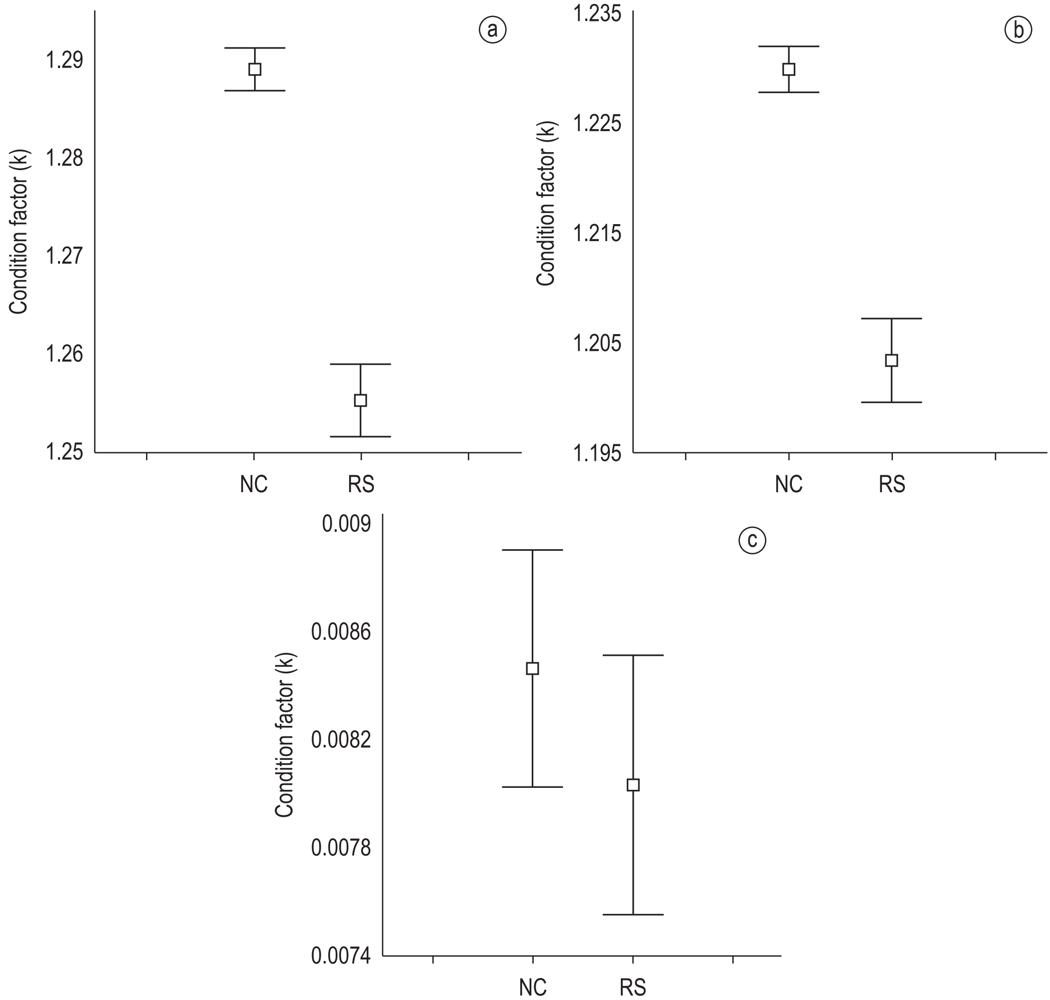

Figure 3. "Mean-Plot" - Individual condition factor of *A. affinis* for net cage site (1) and reference site (2) where: a) populations considering the total weight, b) carcass weight and c) gonad weight in Chavantes reservoir, Paranapanema River SP/PR (values significantly different Mann-Whitney test (U Test; $p < 0.0001$).

serving as an attractant for many organisms (Beveridge, 2004), through discharge of remains of ration from the development of the activity (feeding). These effluents have different degrees of impact on the aquatic ecosystem, depending on the amount released, dilution, and time of release and dispersal capacity in the water column (Carroll et al., 2003; Yokoyama, 2003). The input of leftover ration and feces from fish farming activities becomes the primary source of nutrients in the surrounding aquatic ecosystems (Ono and Kubitza, 2003) and the increased availability of food resources can cause changes in the potential productivity of aquatic organisms through trophic interactions.

The physical condition for both wet weight and carcasses appeared higher in the fish farm population, suggesting that this process might be caused by the additional food supply from the fish farm, which might induce both higher growth rates and earlier maturity (Cushing, 1981; Gomiero and Braga, 2005). Nevertheless, the physical condition for the body weight without gonads showed no obvious differences among females. This is probably due to larger investment of energy (i.e., lipids), and additional food supply.

The population of the fish farm also showed a prolonged reproductive period, in the NC compared within RS populations. This also suggests that the fish farm population might have some reproductive advantages. When comparing reproductive potentials, it is possible to observe higher values in NC. However, the population of the NC produced smaller oocytes during the study period. This might be related to the reproductive strategy of the species, characterized by small oocytes, which may facilitate release to the environment in a shorter time and in larger quantities. Agostinho et al. (2007) reported that small eggs and rapid development are components of the reproductive strategy of fish in

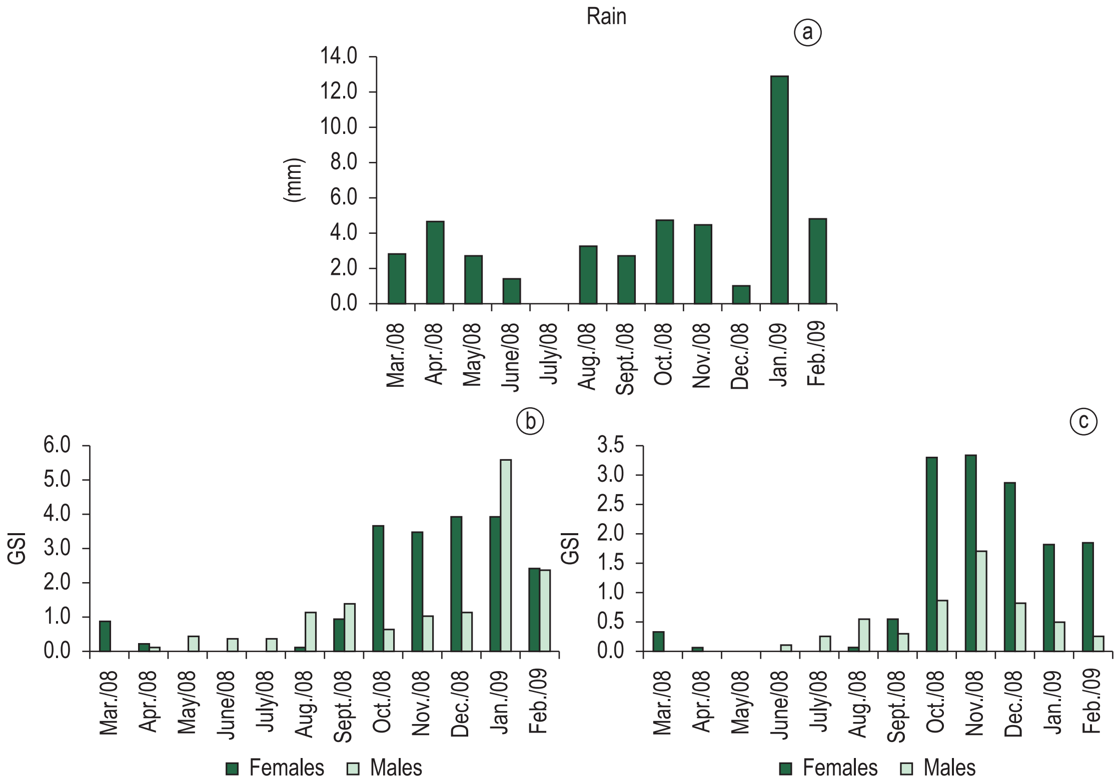

Figure 4. Precipitation (a) and monthly variation of the gonadosomatic index (GSI) of females from net cage site (NC) and reference site (RS) (b); for males in the NC and RS (c) of *A. affinis* in the Chavantes reservoir, Paranapanema River SP/PR.

Table 2. Results in Reproduction Potential monthly, where: (n) = number of individuals; (SD) = standard deviation; (DH) = Biometrics Horizontal Diameter of oocytes, (DV) = vertical diameter of oocytes and Area of oocytes in population of species *A. affinis* in the sites NC and RS, reservoir Chavantes SP/PR, using Biometry performed with the program QWin Lite 3.1 and LAZ V3 (Leica Application Suite).

				NC				
Month	**n**	**Minimum**	**Maximum**	**Average**	**SD**	**DH**	**DV**	**Area**
Mar./08	9	8,267	78,557	33,370	24,035	0.63	0.62	0.27
Apr./08	14	3,512	28,239	13,220	7,134	0.63	0.60	0.25
May./08	3	6,678	12,816	9,280	3,173	0.56	0.63	0.24
July./08	1	2,149	-	-	-	0.59	0.64	0.30
Aug./08	74	706	18,472	6,208	3,545	0.40	0.44	0.14
Sept./08	59	4,605	25,529	12,092	4,961	0.60	0.63	0.27
Oct./08	58	6,466	48,214	21,870	10,671	0.59	0.65	0.28
Nov./08	65	5,128	29,156	13,245	4,572	0.55	0.61	0.25
Dec./08	34	7,434	29,383	16,499	5,703	0.74	0.76	0.41
Jan./09	95	1,350	31,536	15,242	5,659	0.70	0.72	0.36
Feb./09	25	5,472	30,326	15,640	5,283	0.79	0.74	0.41
				RS				
Month	**n**	**Minimum**	**Maximum**	**Average**	**SD**	**DH**	**DV**	**Area**
Mar./08	3	5,999	23,908	14,416	9,002	0.66	0.68	0.33
Apr./08	2	10,829	37,678	24,253	18,985	0.62	0.63	0.27
May./08	21	2,361	16,269	7,788	3,264	0.47	0.42	0.18
July./08	14	2,708	16,851	9,871	3,816	0.65	0.61	0.36
Aug./08	127	4,191	49,738	20,880	9,826	0.69	0.66	0.32
Sept./08	25	4,091	28,624	14,298	6,686	0.63	0.64	0.29
Oct./08	14	384	16,696	10,826	4,404	0.80	0.77	0.44
Nov./08	1	-	9,327	-	-	0.70	0.71	0.41
Feb./09	12	8,169	23,932	15,994	4,354	0.68	0.73	0.38

artificial reservoirs, indicating r-strategist behavior and the ability to adjust to environments altered by humans.

The potential negative impacts caused by fish farming have been assessed in different marine and freshwater environments throughout the world (Beveridge, 1996; Dempster et al., 2002; Menezes and Beyruth, 2003; Machias et al., 2005; Tuya et al., 2006; Brigolin et al., 2009; Romana-Eguia et al., 2010; Dias et al., 2011; Wetengere, 2011). For the effective development of aquaculture in both ecosystems (marine and freshwater), experts agree that the sustainable management requires the involvement and cooperation of the government, academia, private sector, investors, communities and society (Devoe and Hodges, 2002).

Temporal variations in conditions and resources may be predictable or may operate on a time scale ranging from minutes to millennia, which can profoundly influence species richness (Begon et al., 2007). Although the present study did not perform an analysis on the community level, the findings suggest that the input of organic matter (ration) exerts an influence on the population of *A. affinis* residing near the net cages, as evidenced by increased abundance and biomass detected, as well as the insertion of a new food item in their diet (ration), prolonged reproductive period with better physical conditions, and greater reproductive potential.

The conservation and sustainable use of continental waters for fish farming in cages requires knowledge and understanding of the aquatic ecosystem in which they have been installed. Data suggest the need for administrative controls for the establishment of fish farms and monitoring processes to prevent undesired changes in fish assemblages and declines in fish diversity. This study offers a starting point as a tool for the design of future management strategies and plans for the conservation of the study species vis á vis the aquatic ecosystem conditions in which they live.

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