Acta Scientiarum. Biological Sciences
ISSN: 1679-9283
eduem@uem.br
Universidade Estadual de Maringá
Brasil

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Acta Scientiarum. Biological Sciences, vol. 34, núm. 3, julio-septiembre, 2012, pp. 289-296
Universidade Estadual de Maringá
.png, Brasil

Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v34i3.7298

Influence of a net cage tilapia culture on the water quality of the Nova Avanhandava reservoir, São Paulo State, Brazil

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ABSTRACT. In order to understand the influence of a net cage tilapia culture on the environment, water quality parameters were investigated during the period between December, 2005 and November, 2007. Three sampling stations were established in the reservoir of Nova Avanhandava (Zacarias, São Paulo State) as follows: upstream of net cage area (P1), in the rearing place (P2) and downstream of net cage area (P3). The mean values of the parameters examined in the water sampling stations were within the standards of water quality recommended by resolution no. 357/2005 of the Conselho Nacional do Meio Ambiente for class 2 freshwater bodies. A significantly higher mean concentration of total phosphorus ($p < 0.05$) in the P2 (0.035 mg L^{-1}) was the result of the uneaten feed and feces of fish. The average concentration of total phosphorus in P3 was lower (0.015 mg L^{-1}), which was assimilated by the aquatic ecosystem. The frequent monitoring of the water parameters is fundamental, so the producer can adjust the management according to environmental conditions, by reducing fish density or changing feeding rates for example, to mitigate or avoid water quality deterioration.

Keywords: limnology, phosphorus, nutrients, intensive fish farming, tilapia.

Influência da tilapicultura em tanques-rede sobre a qualidade da água no reservatório de Nova Avanhandava, Estado de São Paulo, Brasil

RESUMO. O comportamento das variáveis da água na área do reservatório de Nova Avanhandava (Zacarias, Estado de São Paulo) com tanques-rede instalados para produção de tilápia foi avaliado no período de dezembro de 2005 a novembro de 2007, para estudar a influência deste sistema de piscicultura no ambiente. Três estações de coleta foram estabelecidas, sendo uma a montante (P1) da área aquícola, outra no centro da piscicultura (P2) e a última a jusante (P3). Os valores médios dos parâmetros da água analisados nas estações de amostragem ficaram nos padrões de qualidade da água recomendado pela Resolução n. 357/2005 do Conselho Nacional do Meio Ambiente para os corpos de água doce classe 2. A concentração média significativamente maior ($p < 0,05$) de fósforo total na estação P2 (0,035 mg L^{-1}) foi consequência dos restos de ração não ingerida e das fezes dos peixes. Na estação P3, o valor médio da concentração de fósforo total foi menor (0,015 mg L^{-1}), sendo este assimilado pelo ecossistema aquático. O monitoramento frequente das variáveis da água é fundamental para o produtor adaptar seu manejo de acordo com as condições do ambiente, reduzindo densidade ou alterando taxas de alimentação, por exemplo, para mitigar ou evitar a deterioração da qualidade da água.

Palavras-chaves: limnologia, fósforo, nutrientes, piscicultura intensiva, tilápia.

Introduction

Continental aquaculture is a fast growing activity in Brazil. Freshwater fish production in 1997 was 77 thousand tonnes, while in 2006 production was 191 thousand tonnes, a market estimated at about 715 million reais (IBAMA, 2008).

In São Paulo state, freshwater fish production was 20,952 ton. in 2006 (IBAMA, 2008), the third largest producer state in the country. Net cage production is expanding quickly and has contributed to the fast production growth. The number of net cage units in São Paulo is estimated to be about 10,000 (personal communication)[1] and still expanding. The interest for this system has been increasing, mainly due to availability of places where it can be installed, such as the artificial reservoirs built to generate energy. In addition, the investment to produce one ton of fish in net cage is 30 to 40% of

[1]Data provided by the Scientific Researcher Fabio Rosa Sussel, Agência Paulista de Tecnologia dos Agronegócios (APTA) in 2008.

the investment necessary in conventional ponds for the same production volume (OSTRENSKY et al., 2008).

Nile tilapia (*Oreochromis niloticus*) is the main species reared in net cages because it grows fast, adapts easily to high stocking density, presents good fillet yield and is widely accepted in the national and international markets (MALLASEN et al., 2008). In the reservoirs of hydroelectric dams on the Northwest of São Paulo state, cage tilapia farming is expanding due to the quality and quantity of hydric resources available, and the climate conditions favorable to the species.

Cage fish farming is an intensive rearing activity that uses basically high density stocking and plentiful food in order to obtain a production volume compatible with the regularity and demands of the consumer market. Consequently, large amounts of residue made up of uneaten feed and fish metabolic products is released to the environment. These residues increase nutrient levels in water, particularly phosphorous and nitrogen, which are considered the main eutrophication agents in aquatic environments (CARMO et al., 2002). When the increase of nutrients is controlled, the aquatic environment allows or even stimulates the changes in the physical, chemical and biological processes, without harming water quality (CALIJURI et al., 1999). However, when assimilative capacity of the water body is surpassed, water quality deteriorates and compromises the stability of the aquatic ecosystem. Very often, reduced growth rate, increased disease incidence and even fish mortality may be related to inadequate quality water. In addition, eutrophic water environments are appropriated to the development of the cyanobacterias, many of which produce metabolites that cause off-flavor in fish meat (TSUKAMOTO; TAKAHASHI, 2007). Consequently, the producer should be concerned about the water quality in order to have a successful business.

Fish farming in cages has great potential to play a role in the development of continental aquaculture. However, in order to be environmentally responsible, it is fundamental to study and monitor the impact of the activity on the environment. The aim of this study was to evaluate the behavior of the water quality parameters in area where there is a net cage tilapia production installed, located in the Nova Avanhandava reservoir.

Material and methods

The study was conducted in a net cage tilapia culture installed in the Santa Bárbara river, a tributary of Tietê river, in Zacarias, São Paulo State (Figure 1). The river is part of the Low Tietê basin, on the Northwest of São Paulo state. This basin covers approximately 200 km and contains the reservoirs of Nova Avanhandava and Três Irmãos (CETEC, 1999). According to CESP (1998), the reservoir of Nova Avanhandava is constituted by 21,700 ha of surface area, with accumulated volume of 2,720 10^6 m^3 and retention time of 45.7 days.

According to the “Relatório da Situação dos Recursos Hídricos do Baixo Tietê” (CETEC, 1999), the wet season is typically tropical lasting from October to April, and the dry season lasting from May to September; annual rainfall varies between 1,000 and 1,300 mm. During the study period, the rainfall monthly data were supplied by AES Tietê energy company.

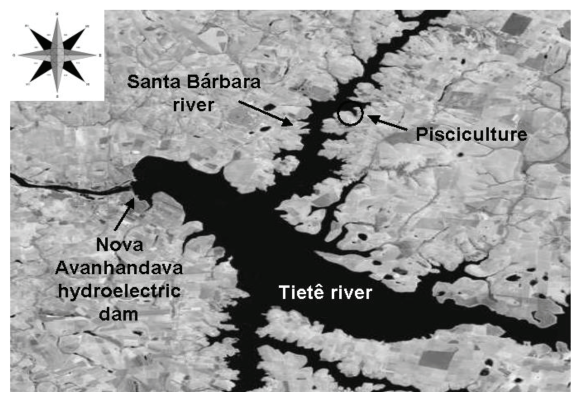

Figure 1. The location of the cage farm system (arrow, 21°03’41.94”S and 50°05’13.23”W) in the Low Tietê basin (Image was obtained in the site www.cdbrasil.cnpm.embrapa.br and adapted, scale 1:50,000).

The area of the fish culture comprises a 1 ha of water surface with an average depth of 6 m. The tilapia culture was being installed when the study began, and had about 60 net cages of 18 m^3 (3 x 3 x 2 m). At the end of the study period they had 120 net cages installed and operating.

The sampling stations were established according to the rearing area and the placement of the cages. Three sampling sites were defined and demarcated, using a GPS; one upstream of the net cage area-P1 (21°04’040”S and 50°05’461”W); the second in the place of the rearing-P2 (21°03’913”S and 50°05’483”W), and the third downstream of the net cage area-P3 (21°03’853”S and 50°05’591”W). The distances between the sampling stations were 200 m between P1 and P2 and 600 m between P2 and P3. The depths were 4, 6 and 8 m for P1, P2 and P3 stations, respectively.

At each station, *in situ* measurements were realized and water samples were collected for laboratory analysis at 1 m depth. The analysis and samplings were done between 8 and 11h a.m.. The water parameters determined *in situ* were: temperature and dissolved oxygen (YSI model 55), transparency (Secchi disk), electrical conductivity (Tecnopon model MCA150) and pH (Tecnopon model MPA210P). The water samples collected using a van Dorn bottle were placed in polyethylene bottles and frozen until analysis in the Ceaquim (Centro de Apoio Químico ao Ensino, à Pesquisa e de Prestação de Serviço) laboratory of Unesp (Universidade Estadual Paulista) in Botucatu, São Paulo State. In the laboratory, the following parameters were determined: suspended matter, total phosphorous, total nitrogen, ammonia, nitrite, nitrate and chlorophyll-*a*. The methodology used was in accordance with APHA (1998). Data were collected monthly from December 2005 to December 2006. In 2007, the *in situ* measurements and the laboratory analyses were performed in seven months and five months non-consecutive respectively.

The mean values obtained were subjected to ANOVA. When significant differences were observed among means, Tukey test ($p < 0.05$) was applied using Instat statistical program.

Results

Taking into account the entire study period, the mean values of the water parameters analyzed *in situ*, did not present significant differences among the sampling stations ($p > 0.05$), although dissolved oxygen (OD) and pH values were lower in P2 (Table 1). Only phosphorous level was significantly different ($p < 0.05$) among sampling stations, with the highest level determined in P2 (Table 1).

Table 1. Water parameters (mean ± standard deviation) in the three sampling stations. Means followed by different letters in the same row differ significantly (Tukey, $p < 0.05$).

Water parameters	Sampling stations		
	P1	P2	P3
Temperature (°C)	25.9 ± 2.7	26.0 ± 2.7	26.0 ± 2.7
Dissolved Oxygen (mg L^{-1})	7.4 ± 1.8	6.7 ± 1.7	7.8 ± 1.5
% saturation	92 ± 20	82 ± 20	96 ± 18
Transparency (m)	1.5 ± 0.5	1.5 ± 0.6	1.6 ± 0.7
Conductivity (μS cm^{-1})	154.2 ± 14.8	154.3 ± 14.2	153.1 ± 15.5
pH	8.2 ± 0.4	8.0 ± 0.4	8.2 ± 0.4
Suspended matter (mg L^{-1})	3.9 ± 3.2	3.6 ± 4.1	4.4 ± 4.2
Total phosphorous (mg L^{-1})	0.024 ± 0.014ab	0.035 ± 0.025a	0.015 ± 0.008b
Total nitrogen (mg L^{-1})	0.62 ± 0.13	0.65 ± 0.10	0.61 ± 0.22
Ammonia (mg L^{-1})	0.10 ± 0.04	0.11 ± 0.05	0.09 ± 0.05
Nitrite (μg L^{-1})	2.69 ± 1.76	3.09 ± 2.09	3.49 ± 3.00
Nitrate (mg L^{-1})	0.13 ± 0.11	0.14 ± 0.12	0.14 ± 0.15
Chlorophyll-*a* (μg L^{-1})	5.6 ± 5.9	5.9 ± 8.4	5.8 ± 4.9

In the period, rainfall was intense between December and February. In 2006, 43% of yearly pluviosity was registered during the months of January and February. In 2007, the rainfall was atypical for a tropical climate, and July, theoretically a dry period, registered 93.7 mm (Figure 2). Seasonality was observed for water temperature, a minimum of 21.5°C and maximum of 30.0°C was registered for July, 2006 and December, 2007, respectively (Figure 3a).

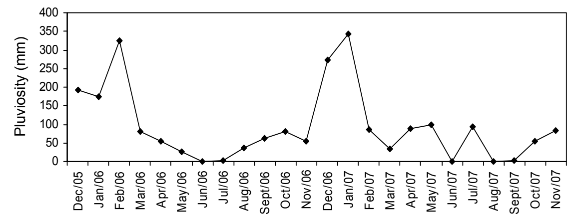

Figure 2. Pluviosity (mm) in Zacarias, São Paulo State from December of 2005 to November of 2007.

Dissolved oxygen levels varied inversely with rainfall, in the first semester of 2006. However, this trend did not repeat along the study period. The lowest values were observed during the months of February/April, 2006 and March/May, 2007 (Figure 3b).

In general, the water parameters behaved similarly among sampling stations; with the exception of phosphorous, nitrogen, ammonia, and nitrite concentrations, which showed more evident spatial differences (Figure 3).

The central area of fish farming (P2) displayed higher mean phosphorous levels (0,035 mg L^{-1}) (Table 1), and peaked during the study period (Figure 3g). Considering the other sampling stations, it was observed an abrupt variation of this nutrient concentration in August, 2006 in P1, and again in December, 2006, in P3. In this last sampling station, phosphorous levels were lower than the values obtained in the other sampling stations during practically the entire study period.

Maximum concentration of total nitrogen was 1.36 mg L^{-1} observed at station P3 in December, 2006 (Figure 3h). Mean ammonia values remained around 0.10 mg L^{-1} in the stations (Table 1); peaks concentrations were observed, coincident with the high rainfall in the first year of the study intercalated with stable periods and sudden drops (Figure 3i). Nitrite concentration oscillated greatly in all stations and during study period (Figure 3j). On the other hand, nitrate levels remained stable during the first semester, but in 2007, there were peaks in all sampling stations in the months of May and July (Figure 3k).

Chlorophyll-*a* values, in general, had little spatial and temporal variation during the study. However, concentrations were greater during the months of February, October, November, 2006 and September, 2007 (Figure 3l).

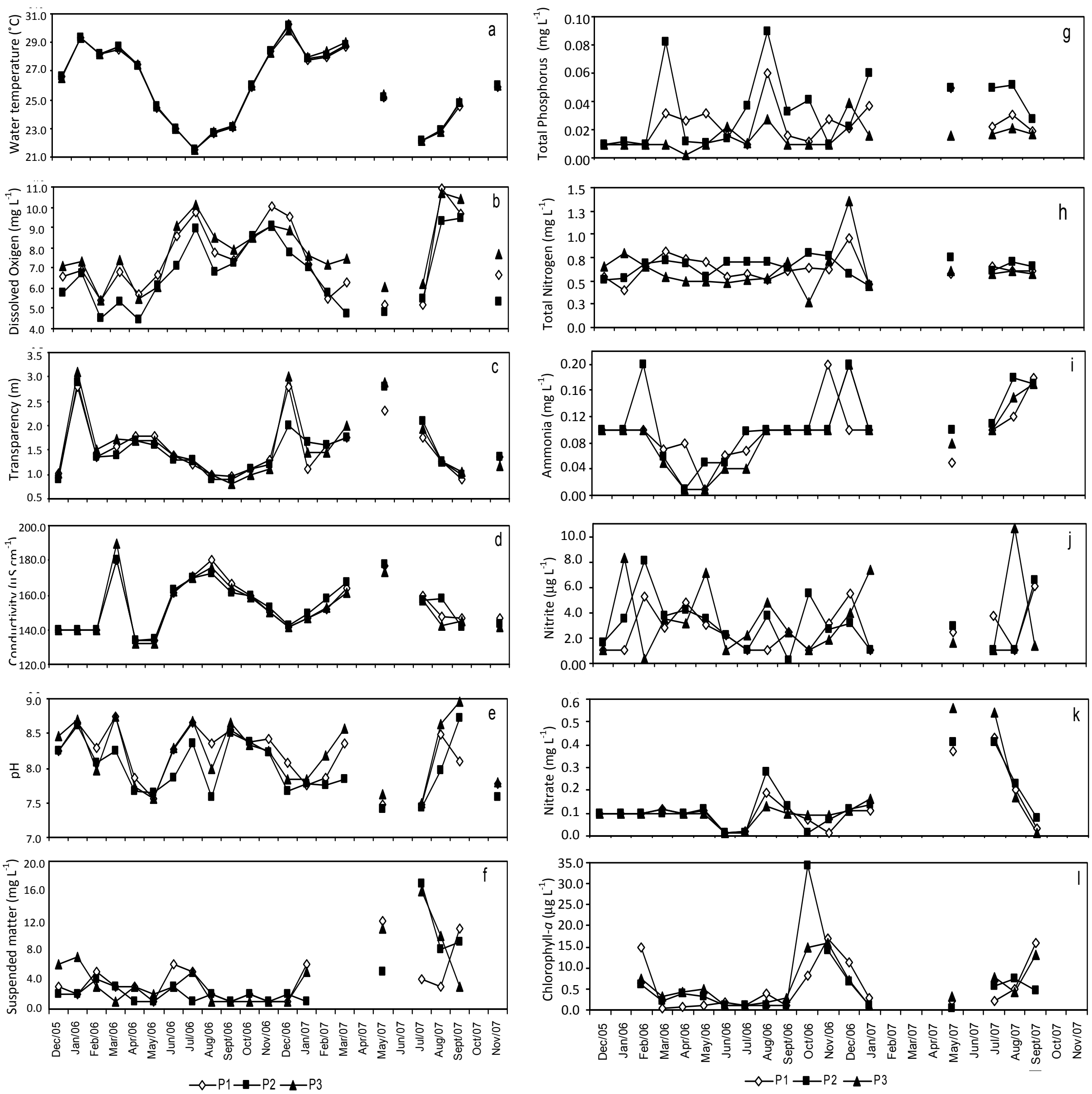

Figure 3. Seasonal fluctuation of the environmental parameters in the sampling stations during the study period.

Discussion

Mean values of dissolved oxygen, pH, suspended matter, total phosphorous, total nitrogen, ammonia, nitrite, nitrate and chlorophyll-*a* remained within the standards of water quality recommended by Resolution no. 357, of the Conselho Nacional do Meio Ambiente (CONAMA, 2005), for bodies of freshwater class 2, in which, among other activities for water use, aquaculture is included.

Rainfall plays a major role in the reservoir's water quality, since it is directly or indirectly related to the nutrients and suspended matter that are carried away from the surrounding areas and its tributaries, as well as with the retention time of the reservoir, which can change the dynamics of the medium into greater or lesser degree.

In the present study, few limnological data displayed temporal behavior clearly related to the seasonal rainfall. Nor distinct patterns were observed among the sampling stations of most of the limnological parameters monitored, which may indicate that the fish farm installed on the site has not impacted greatly the dynamics of the environment. On the other hand, being a place of refuge, located on an arm of the reservoir, the morphometric characteristics of the area interfere to a great extent in the environmental conditions, making it essential the understanding of these characteristics before installation of the net cages.

The low oxygen values observed in station P2 were due to increased oxygen demand by the fish stocked at high densities (70 kg m^{-3}), and an increased load of organic matter in this area (from uneaten feed and fish metabolic residues) which also demands oxygen to degrade it. However, the fish farm installed in the local does not seem to be the only responsible for decreasing oxygen levels, since the same temporal pattern was observed at stations P1 and P3.

In the first semester of 2006, the rainfall and high temperatures in the beginning of the year seemed to have contributed to decreasing oxygen level, as opposed to the dry season when this value increased. According to Esteves (1998), during wet season there is an increase in the concentration of the dissolved and particulate organic matter in the medium, which contributes to reduction of oxygen and water transparency in tropical lakes. Nevertheless, along the period oxygen levels never fell below 4.0 mg L^{-1}, which is considered to be the critical level for tropical fish rearing (CESP, 1999).

Water transparency may be considered as the opposite of turbidity (ESTEVES, 1998). Plankton, soil mineral particles suspended in the water and organic matter affect water turbidity (BOYD, 2004; CALIJURI et al., 1999). In this study, the concentration of suspended matter seemed not to have affect water transparency. This parameter, in this study, was affected more by the presence of humic compounds that darken the water originated from the vegetation still present on the bottom of the lake, remnants from the flood caused by the building of the dam.

The larger number of net cages in 2007 compared to 2006, may have caused an increase in the suspended matter in the water, since there was also an increase in the amount of ration supplied. In addition, according to Alves and Baccarin (2005), cage culture management, mainly during harvesting, causes re-suspension of particulate solids and therefore, an increasing level of suspended matter in the water.

Conductivity values were high, and the same oscillating behavior was observed for all three sampling stations. Conductivity values of approximately 140 μS cm^{-1} were also observed by Alves and Baccarin (2005) in the reservoir of Nova Avanhandava. High conductivity values may be an indicator of an eutrophication process. However, according to Esteves (1998), in tropical regions, this parameter is more affected by the geo-chemical characteristics of the region. Conductivity during the period varied inversely with rainfall. Rainfall is responsible for diluting the ions present in the water; therefore, conductivity levels decreased during the wet season and in the dry season, these values increased. The same behavior was observed by Alves and Baccarin (2005) and Henry et al. (2005).

The values of pH were in the alkaline range, varied little among the sampling stations and remained within the ideal range (6.5 to 9.0) for fish production (BALDISSEROTTO, 2002). The slightly lower pH values in station P2 can be attributed to fish breathing process and to the decomposition of organic matter from uneaten feed and fish excrement. Both processes, food decomposition and breathing release carbon dioxide, which reacts with the water and produces carbonic acid and hydrogen ions, acidifying the medium (ALVES; BACCARIN, 2005; ESTEVES, 1998).

The significantly higher ($p < 0.05$) mean values of total phosphorous and the several peaks observed in the central sampling station (P2) were also a consequence of uneaten feed and fish excrement. According to Boyd (2007), the rations commonly used to feed fish present between 1.0 and 1.5% of phosphorous in their composition. However, approximately 80% of the phosphorous present in the ration is not readily available and it is eliminated to the water in the soluble form and as feces (CHENG; HARDY, 2002). According to Boyd et al. (2007) for every ton of tilapia produced in net cages, 9.1 kg of phosphorous is released to the environment.

Therefore, considering that phosphorous is the principal nutrient to promote phytoplankton growth (BEVERIDGE, 1996; BOYD, 2007; HENRY, 1990), fish culture in cages is considered to be a production system with great potential for eutrophication of the aquatic environments (BOYD et al., 2007; GUO; LI, 2003). However at station P3, the mean value of total phosphorous concentration was lower. Possibly, the nutrient was assimilated by the physico-chemical and biological processes of the ecosystem, which indicates the resilience capacity of this water body. Another study with fish in the same Santa Bárbara river indicated that the organisms of the biota used both, the organic matter and energy produced by the net cage system, and were capable of reducing the impact on the eutrophication process (RAMOS et al., 2008). Bueno et al. (2008), while assessing total phosphorous concentration at internal and external points in an area where fish were produced (pacu, jundiá and curimbatá) in net cage systems in the Itaipu reservoir, also observed that the local biotic community was capable of absorbing this nutrient.

When comparing the three first months to the three last ones, it can be verified that there was an increase of phosphorous concentrations for all sampling stations, which could be related to the increasing number of net cages in the area and consequently, more supplied ration. This may indicate that a large number of cages in this area can exceed the carrying capacity of the aquatic environment, which may cause problems by high level of phosphorous.

Nitrogen is also an important element to the primary production of a water body, and favors eutrophication (CARMO et al., 2002; KELLY; ELBERIZON, 2001; TUNDISI, 1990). In this study, total nitrogen values remained within a narrow range and below the concentration of 1.27 mg L^{-1} recommended by resolution no. 357/2005 of CONAMA for lentic environments. The highest nitrogen concentration was observed at station P3 in December, 2006; the month with the highest rainfall after the dry season. This nutrient may be associated with the material carried away to the rivers by the rain (GUARINO et al., 2005) and flooding of pastures (FERRAREZE et al., 2005). In the Low Tietê basin area, pastures correspond to 83% of the use of the soil (CETEC, 1999).

Ammonia influences strongly the dynamics of the dissolved oxygen in the water, since it is necessary 4.6 mg of oxygen to oxidize 1.0 mg of ammonia (TIMMONS et al., 2002). It is also a stress causing agent that affects the fish community (URBINATI; CARNEIRO, 2004), by causing damage to the gills and to the osmo-regulatory processes (BALDISSEROTTO, 2002). The mean ammonia values remained close for all sampling stations, and even at its peak it did not reach concentrations that are harmful to the fish. According to Boyd (2001) ammonia levels between 3 and 4 mg L^{-1} may be toxic for tropical fish. The ammonia peak observed in February, 2006 at station P2 was associated with rain season that favors transport of nutrients and allochthonous materials (SIPAÚBA-TAVARES et al., 2007), and the net cage themselves might have caused some instability in the medium. In the subsequent months, the nitrification process seemed to have been more efficient, thus indicating a possible stabilization of biochemical dynamics of the ecosystem.

Nitrite is the intermediate product of the nitrification process (oxidation) of ammonia to nitrate (TIMMONS et al., 2002). In spite of large variations of nitrite levels during the study period and among sampling stations, the concentrations observed were very low, indicating adequate conditions to promote the nitrification process. It should be noticed that, during the period, the highest nitrite levels were observed at station P3, which indicates an external interference, resulting more from the reservoir tributaries than the fish culture itself. Nitrate levels were higher compared to the means during the winter, when the rainfall is minimum. Higher nitrate concentrations were observed during the second year of the study, which may indicate some degree of interference of the fish farm in the environment.

Chlorophyll-*a* levels were higher compared to the means during the end of the dry season. In station P2, chlorophyll-*a* level in October 2006, was higher than the 30 μg L^{-1} recommended by CONAMA (Resolution 357/2005). Probably higher phosphorous availability in this station associated with increasing temperatures and higher sun incidence may have favored phytoplankton growth. However, this high chlorophyll-*a* concentration was lower than the levels verified in eutrophicated reservoirs. According to Tundisi (1990) eutrophicated water bodies display chlorophyll-*a* concentrations between 200 and 300 μg L^{-1}.

The dynamics observed for the limnological parameters may be the result of environment adaptation to the biological, chemical and physical changes caused by the installation of the fish farm in the local. It should be reminded that the net cage system was installed at the beginning of the study period. The data obtained did not indicated any negative impact of the fish culture, and showed that up to depth of 1 m, the water body was capable of assimilating the nutrients and the organic matter from the net cages system without any harm to the water quality. According to Beveridge (1996), the eutrophication degree will depend on the size and characteristics of the water body and operational management of the cages. Although, it should be considered that during the second year of the study there was an increase of the levels of nitrate and suspended matter, which may suggest a greater influence of the fish culture in the ecosystem.

Also, in a reservoir other factors are capable of influencing the eutrophication process of the system. A reservoir is part of a hydrographic basin and, as such, it senses the effects of all kinds of anthropogenic interference (TUNDISI, 1999). Therefore, agricultural and/or urban activities around the area may be responsible for introducing nutrients in the water. This makes the management of a reservoir a very complex activity, that involves all activities that directly or indirectly depend on the water. The limnological and ecological studies of the reservoirs are fundamental for the management and sustainable exploration of their multiple uses (TUNDISI, 2005).

In general, the greater variations of the water parameters were observed along the study period and to lesser extent among the sampling stations. Zaniboni Filho et al. (2005) also reported a similar behavior in the reservoir of Machadinho hydroelectric (Uruguay river at the border between Santa Catarina and Rio Grande do Sul States) in sampling stations placed inside and outside of the cage fish farm area that reared jundia. The artificial reservoirs display large hydrodynamic variation during the year, due to rainfall and changes in the tributaries flow rates (HENRY, 2004), that affect nutrient dilution in the water and consequently, the carrying capacity. For this reason, constant monitoring of the water parameters is fundamental, so the producer can adjust the management according to environmental conditions, by reducing fish density or changing feeding rates for example, in order to mitigate or avoid water quality deterioration.

These types of changes in the routine of a fish farm should be part of best management practices (BMPs) of a net cage system. According to Tacon and Forster (2003) and Boyd et al. (2007), applying BMPs (ROTTA; QUEIROZ, 2003; SIPAÚBA-TAVARES et al., 2002) should be considered as an effective method to reduce the negative impacts of aquaculture. The BMPs need to be defined and implanted in the net cage systems according to the region where they are installed. The regions of Southeast and Northeast of Brazil are at the moment, the regions with the largest potential to produce tilapias in net cage system, but the behavior of the aquatic environment in these two regions may be very distinct.

Conclusion

The fish farm installed in the reservoir not impacted greatly the dynamics of the environment, and showed that up to depth of 1 m, the water body was capable of assimilating the nutrients and organic matter from the net cages system. The increase in the levels of nitrate and suspended matter in the second year of culture indicates the highest influence of the cage culture in ecosystem over time. Thus, the frequent monitoring of the water parameters is fundamental, so the producer can adjust the management (fish density or feeding rates) according to environmental conditions to mitigate water quality deterioration.

Acknowledgements

Thanks are due to ANPAP (Associação Nacional de Piscicultura em Águas Públicas) for the support to conduct the study.

References

ALVES, R. C. P.; BACCARIN, A. E. Efeito da produção de peixes em tanques-rede sobre sedimentação de material em suspensão e de nutrientes no córrego da Arribada (UHE Nova Avanhandava, Baixo Rio Tietê, São Paulo). In: NOGUEIRA, M. G.; HENRY, R.; JORCIN, A. (Ed.). **Ecologia de reservatórios**: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Rima, 2005. p. 329-347.

APHA-American Public Health Association. **Standard methods for the examination of water and wastewater**. 20th ed. Washington, D.C.: American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1998.

BALDISSEROTTO, B. **Fisiologia de peixes aplicada à piscicultura**. Santa Maria: UFSM, 2002.

BEVERIDGE, M. **Cage aquaculture**. 2nd ed. Oxford: Blackwell Science Ltd. Editorial Offices, 1996.

BOYD, C. E. Water quality standards: total ammonia nitrogen. **The Advocate**, v. 4, n. 4, p. 84-85, 2001.

BOYD, C. E. Secchi disk visibility: correct measurement, interpretation. **Global Aquaculture Advocate**, v. 7, n. 1, p. 66-67, 2004.

BOYD, C. E. Phosphorus: key to phytoplankton management. **Global Aquaculture Advocate**, v. 10, n. 4, p. 62-64, 2007.

BOYD, C. E.; TUCKER, C.; MCNEVIN, A.; BOSTICK, K.; CLAY, J. Indicators of resource use efficiency and environmental performance in fish and crustacean aquaculture. **Reviews in Fisheries Science**, v. 15, n. 4, p. 327-360, 2007.

BUENO, G. W.; MARENGONI, N. G.; GONÇALVES JÚNIOR, A. C.; BOSCOLO, W. R.; TEIXEIRA, R. A. Estado trófico e bioacumulação do fósforo total no cultivo de peixes em tanques-rede na área aquícola do reservatório de Itaipu. **Acta Scientiarum. Biological Sciences**, v. 30, n. 3, p. 237-243, 2008.

CALIJURI, M. C.; DEBERT, G. L. B.; MINOT, R. T. A produtividade primária pelo fitoplâncton na represa de Salto Grande. In: HENRY, R. (Ed.). **Ecologia de reservatórios**: estrutura, função e aspectos sociais. Botucatu: Fundibio, 1999. p. 109-148.

CARMO, C. F.; HENRY, R.; BICUDO, D. D.; BICUDO, C. E. M. A degradação nos reservatórios do PEFI. In: BICUDO, D.C.; FORTI, M. C.; BICUDO, C. E. M. (Ed.). **Parque estadual das fontes do Ipiranga (PEFI)**: unidade de conservação que resiste à urbanização de São Paulo. São Paulo: Imprensa Oficial do Estado, 2002. p. 273-296.

CESP-Companhia Energética de São Paulo. **Conservação e manejo nos reservatórios**: limnologia, ictiologia e pesca. São Paulo: CESP, 1998.

CESP-Companhia Energética de São Paulo. **Criação de peixes em tanques-rede**. São Paulo: Diretoria de Meio Ambiente, 1999.

CETEC-Centro Tecnológico da Fundação Paulista de Tecnologia e Educação. **Situação dos recursos hídricos do Baixo Tietê UGRH 19**. Lins: Cetec, 1999.

CHENG, Z. J.; HARDY, R. W. Effect of microbial phytase on apparent nutrient digestibility of barley, canola meal, wheat and wheat middlings, measured *in vivo* using raibow trout (*Oncorhynchus mykiss*). **Aquaculture Nutrition**, v. 8, n. 4, p. 271-277, 2002.

CONAMA-Conselho Nacional do Meio Ambiente. **Resolução n. 357/2005**. Available from: <http://www.mma.gov.br/port/conama/res/res05/res35705.pdf>. Access on: Jan. 14, 2009.

ESTEVES, F. A. **Fundamentos de limnologia**. 2. ed. Rio de Janeiro: Interciência, 1998.

FERRAREZE, M. F. F.; NOGUEIRA, M. G.; VIANNA, N. C. Transporte de nutrientes e sedimentos no rio Paranapanema (SP/PR) e seus principais tributários nas estações seca e chuvosa. In: NOGUEIRA, M. G.; HENRY, R.; JORCIN, A. (Ed.). **Ecologia de reservatórios**: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Rima, 2005. p. 435-459.

GUARINO, A. W. S.; BRANCO, C. W. C.; DINIZ, G. P.; ROCHA, R. Limnological characteristics of old tropical reservoir (Ribeirão das Lages reservoir. RJ, Brazil). **Acta Limnologica Brasiliensia**, v. 17, n. 2, p. 129-141, 2005.

GUO, L.; LI, Z. Effects of nitrogen and phosphorus from fish cage-culture on the communities of a shallow lake in middle Yangtze river basin of China. **Aquaculture**, v. 226, n. 1-4, p. 201-212, 2003.

HENRY, R. Amônia ou fosfato como agente estimulador do crescimento do fitoplâncton na represa de Jurumirim (Rio Paranapanema, SP). **Revista Brasileira de Biologia**, v. 50, n. 4, p. 883-892, 1990.

HENRY, R. A variabilidade de alguns fatores físicos e químicos da água e implicações para amostragem: estudos de caso em quatro represas do Estado de São Paulo. In: BICUDO, C. E. M.; BICUDO, D. C. (Org.). **Amostragem em limnologia**. São Carlos: Rima, 2004. p. 245-262.

HENRY, R.; PANARRELLI, E. A.; CASANOVA, S. M. C.; SUIBERTO, M. R.; AFONSO, A. A. O. Interações hidrológicas entre lagoas marginais e o rio Paranapanema na zona de sua desembocadura na represa de Jurumirim. In: NOGUEIRA, M. G.; HENRY, R.; JORCIN, A. (Ed.). **Ecologia de reservatórios**: Impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Rima, 2005. p. 57-82.

IBAMA-Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. **Estatística da pesca 2006**: Brasil, grandes regiões e unidades da federação. Brasília: Ibama, 2008.

KELLY, L. A.; ELBERIZON, I. R. Freshwater finfish cage culture. In: BLACK, K. D. (Ed.). **Environmental impacts of aquaculture**. Sheffield: Sheffield Academic Press, 2001. p. 32-50.

MALLASEN, M.; BARROS, H. P.; YAMASHITA, E. Y. Produção de peixes em tanques-rede e a qualidade da água. **Revista Tecnologia e Inovação Agropecuária**, v. 1, n. 1, p. 48-51, 2008.

OSTRENSKY, A.; BORGHETTI, J. R.; SOTO, E. D. **Aquicultura no Brasil**: o desafio é crescer. Brasília: SEAP/FAO, 2008.

RAMOS, I.; VIDOTTO-MAGNONI, A.; CARVALHO, E. Influence of cage fish farming on the diet of dominant fish species of a Brazilian reservoir (Tietê river, High Paraná river basin). **Acta Limnologica Brasiliensia**, v. 20, n. 3, p. 245-252, 2008.

ROTTA, M. A.; QUEIROZ, J. F. **Boas práticas de manejo (BPMs) para produção de peixes em tanques-rede**. Corumbá: Embrapa Pantanal, 2003.

SIPAÚBA-TAVARES, L. H.; FÁVERO, E. G. P.; BRAGA, F. M. S. Utilization of macrophyte biofilter in effluent from aquaculture: I. Floating plant. **Brazilian Journal of Biology**, v. 62, n. 4a, p. 713-723, 2002.

SIPAÚBA-TAVARES, L. H.; GUARIGLIA, C. S. T.; BRAGA, F. M. S. Effects of rainfall on water quality in six sequentially disposed fishponds with continuous flow. **Brazilian Journal of Biology**, v. 67, n. 4, p. 643-649, 2007.

TACON, A. G. J.; FOSTER, I. P. Aquafeeds and the environment: policy implications. **Aquaculture**, v. 226, n. 1-4, p. 181-189, 2003.

TIMMONS, M. B.; EBELING, J. M.; WHEATON, F. W.; SUMMERFELT, S. T.; VINCI, B. J. Biofiltration. **Recirculating aquaculture systems**. Ithaca: Cayuga Aqua Ventures, 2002. p. 205-258.

TUNDISI, J. G. Distribuição espacial, seqüência temporal e ciclo sazonal do fitoplâncton em represas: fatores limitantes e controladores. **Revista Brasileira de Biologia**, v. 50, n. 4, p. 937-955, 1990.

TUNDISI, J. G. Ecologia de reservatórios: aspectos teóricos. In: HENRY, R. (Ed.). **Ecologia de reservatórios**: estrutura, função e aspectos sociais. Botucatu: Fundibio, 1999. p. 19-38.

TUNDISI, J. G. Gerenciamento integrado de bacias hidrográficas e reservatórios: estudo de caso e perspectivas. In: NOGUEIRA, M. G.; HENRY, R.; JORCIN, A. (Ed.). **Ecologia de reservatórios**: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Rima, 2005. p. 1-21.

TSUKAMOTO, R. Y.; TAKAHASHI, N. S. O mau sabor do pescado: conjecturas e atualidades sobre *off-flavor*. **Panorama da Aquicultura**, v. 17, n. 104, p. 10-13, 2007.

URBINATI, E. C.; CARNEIRO, P. C. F. Práticas de manejo e estresse dos peixes em piscicultura. In: CYRINO, J. E. P.; URBINATI, E. C.; FRACALOSSI, D. M.; CASTAGNOLLI, N. **Tópicos especiais em piscicultura de água doce tropical intensiva**. São Paulo: Tecart, 2004. p. 171-194.

ZANIBONI FILHO, E.; NUÑER, A. P. O.; GUERESCHI, R. M.; HERMES-SILVA, S. Cultivo de peixes em tanques-rede e impactos ambientais. In: CARDOSO, E. L.; FERREIRA, R. M. A. (Ed.). **Cultivo de peixes em tanques-rede**: desafios e oportunidades para um desenvolvimento sustentável. Belo Horizonte: Epamig, 2005. p. 57-80.

Received on March 17, 2009.
Accepted on July 26, 2010.