Research, Society and Development, v. 11, n. 11, e211111133429, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i11.33429

Assessment of the influence of a net cage fish culture on the water quality in Furnas reservoir, Brazil

Avaliação da influência de uma piscicultura em tanques-rede na qualidade da água do reservatório de Furnas, Brasil

Evaluación de la influencia de una piscifactoría en jaulas en la calidad del agua del embalse de Furnas, Brasil

Received: 07/26/2022 | Reviewed: 08/09/2022 | Accept: 08/11/2022 | Published: 08/20/2022

Bruna Barçante
ORCID: https://orcid.org/0000-0001-6114-0654
Universidade Federal de Minas Gerais, Brazil
E-mail: brunabarcante94@gmail.com
Ramom Lopes Viana
ORCID: https://orcid.org/0000-0002-8908-8082
Universidade Federal de Minas Gerais, Brazil
E-mail: ramomviana@yahoo.com.br
Stella Rubim de Sousa
ORCID: https://orcid.org/0000-0003-0991-133X
Universidade Estadual Paulista "Júlio de Mesquita Filho", Brazil
E-mail: stellarubim@gmail.com
Rogéria Maura Pazini Xavier
ORCID: https://orcid.org/0000-0002-8393-4161
Universidade Federal de Minas Gerais, Brazil
E-mail: rogeriapazini@hotmail.com
Daniele Salgueiro de Melo
ORCID: https://orcid.org/0000-0002-3525-8613
Universidade Federal de Minas Gerais, Brazil
E-mail: danielesalgueiro08@hotmail.com
Israel José da Silva
ORCID: https://orcid.org/0000-0001-6670-2628
Universidade Federal de Minas Gerais, Brazil
E-mail: israelvp@gmail.com
Luciano dos Santos Rodrigues
ORCID: https://orcid.org/0000-0003-0555-8305
Universidade Federal de Minas Gerais, Brazil
E-mail: lsantosrodrigues@gmail.com
Rosângela Francisca de Paula Vitor Marques
ORCID: https://orcid.org/0000-0001-6646-0809
Universidade Vale do Rio Verde, Brazil
E-mail: roeflorestal@hotmail.com
Claudiomir da Silva Santos
ORCID: https://orcid.org/0000-0002-0007-7273
Instituto Federal Sul de Minas, Brazil
E-mail: claudiomirsilvasantos@gmail.com
Fabrício dos Santos Ritá
ORCID: https://orcid.org/0000-0003-2009-3673
Instituto Federal Sul de Minas, Brazil
E-mail:fabriciosantosrita@gmail.com

Abstract
Aquaculture is growing rapidly around the world. In Brazil, fish farming in net tanks has high potential due its large number of reservoirs. However, cultivable areas of tanks with a high fish density may be more susceptible to eutrophication compared to other production systems, and may impair the ecosystem where they are installed. Therefore, attention is needed to this type of system to avoid environmental impacts. The objective of this study was to evaluate the influence of a fish farming in net tanks on the water quality of the Furnas reservoir, Brazil. For physical-chemical analysis, water samples were collected monthly during two production cycles. The results were compared to the limits proposed by the environmental legislation for water bodies in Brazil. It was noted that nitrite and phosphate presented mean values higher than those allowed; however, these results were not associated with fish farming, and there is no influence on the water quality of the Furnas reservoir during the study period. Water quality

in the reservoir may be influenced by other activities developed in its basin, such as livestock and intensive agriculture that use many fertilizers, released into the reservoir through runoff.
Keywords: Environmental impact; Aquaculture; Tilapia farming.

Resumo
A aquicultura vem crescendo rapidamente em todo o mundo. No Brasil, a piscicultura em tanques-rede apresenta elevado potencial devido ao seu grande número de reservatórios. Entretanto, áreas cultiváveis de tanques com altas densidades de peixes podem ser mais susceptíveis à eutrofização em relação aos outros sistemas de produção, podendo influenciar o ecossistema onde estão inseridos. Portanto, é necessária atenção a este tipo de sistema para evitar impactos ambientais. O objetivo deste estudo foi avaliar a influência de uma piscicultura em tanques-rede na qualidade da água do reservatório de Furnas, Brasil. Para análises físico-químicas, amostras de água foram coletadas mensalmente, durante dois ciclos de produção. Os resultados obtidos foram comparados aos limites propostos pela legislação ambiental para corpos d'água no Brasil. Foram notados que os parâmetros de nitrito e fosfato apresentaram valores médios superiores aos permitidos, contudo, estes resultados não foram associados à piscicultura, não havendo influência significativa na qualidade da água do reservatório de Furnas durante o período de estudo. A qualidade da água no reservatório pode ser influenciada por outras atividades desenvolvidas em sua bacia, como a pecuária e a agricultura intensiva que utilizam muitos fertilizantes, lançados no reservatório pelo escoamento.
Palavras-chave: Impacto ambiental; Aquicultura; Cultivo de tilápia.

Resumen
La acuicultura está creciendo rápidamente en todo el mundo. En Brasil, la piscicultura en jaulas tiene un alto potencial debido a su gran cantidad de reservorios. Sin embargo, las áreas cultivables de estanques con alta densidad de peces pueden ser más susceptibles a la eutrofización en relación con otros sistemas de producción, lo que puede influir en el ecosistema donde se insertan. Por lo tanto, es necesario prestar atención a este tipo de sistemas para evitar impactos ambientales. El objetivo de este estudio fue evaluar la influencia de la piscicultura en tanques-red sobre la calidad del agua del embalse de Furnas, Brasil. Para los análisis físico-químicos, se recolectaron muestras de agua mensualmente, durante dos ciclos de producción. Los resultados obtenidos fueron comparados con los límites propuestos por la legislación ambiental para cuerpos de agua en Brasil. Se observó que los parámetros de nitritos y fosfatos presentaron valores medios superiores a los permitidos, sin embargo, estos resultados no se asociaron a la piscicultura, sin influencia significativa en la calidad del agua del embalse de Furnas durante el período de estudio. La calidad del agua en el embalse puede verse influenciada por otras actividades desarrolladas en su cuenca, como la ganadería y la agricultura intensiva que utilizan una gran cantidad de fertilizantes, liberados al embalse por la escorrentía.
Palabras clave: Impacto ambiental; Acuicultura; Cultivo de tilapia.

1. Introduction

Aquaculture is an activity that has been growing worldwide as a result, mainly, of the global population growth, increase in the demand for protein foods and the stagnation of extractive fishing, which has led to an increase in the production of aquatic animals (Tacon and Halwart, 2007; Degefu et al., 2011; FAO, 2016). Among the several aquatic organisms that can be grown, fish is considered one of the main sources of protein for humans, with almost half of the global production coming from aquaculture activity (FAO, 2020).

In Brazil, aquaculture is also growing rapidly as the country is favored for having excellent conditions for its applicability and development, presenting abundant availability of water and reservoirs, a wide variety of native species that have relevant zootechnical characteristics for fish farming and a climate diversity (Kubtiza, 1999; Sidonio et al., 2012, Barçante and Sousa, 2015). In tropical and subtropical regions, Nile tilapia (Oreochromis niloticus) production is highly relevant to aquaculture, especially in developing countries. The species Oreochromis niloticus and its hybrids stand out for their characteristics, such as: rapid growth, prolificity, rusticity, and meat quality (FAO, 2020; Silva et al., 2020).

In Brazil, net-tank fish farming is one of the most used techniques, mainly in the state of Minas Gerais. This system has stood out as an important economic activity in food production since the 1990s (Américo et al., 2013). However, net-tank production has a high potential for pollution of aquatic ecosystems (Feiden et al., 2015), since production residues (eg feed waste, feces, scales, mucus, soluble waste) are released directly into the aquatic environment, causing an increase in organic matter and nutrients in the water (Cornel and Whoriskey, 1993; Demir et al., 2001; Kashindye et al., 2015; Bozkurt, 2016).

In cultivation areas where net-tanks are present, there is usually an increase in phosphorus and nitrogen concentrations, which are considered the main responsible for aquatic eutrophication (Mallasen et al., 2012). Eutrophication is a global concern for the management of reservoirs and lakes due to a series of ecological impacts that it can cause to the ecosystem, such as the increase in the intensity and frequency of toxic cyanobacterial blooms, which represent a serious risk to human and animal health (Chorus et al., 2000; Giani et al., 2005) Cyanobacteria blooms, besides to modifying the energy flow in the food chains, cause serious risks to the biodiversity and threaten public health, as many species can produce toxins. In this sense, cyanobacteria blooms may also cause significant economic losses, since they increase the costs of water treatment from the reservoir to obtain good quality drinking water for consumption, reduce the potential for recreation, and can promote the decline of extractive fishing and aquaculture activities (Vanderlei et al., 2021). Therefore, it is of great importance that fish farming in net tanks is constantly monitored for water quality to ensure good production performance and the sustainability of the system (Morengoni, 2006; Mwebaza-Ndawula et al., 2013; Zitti et al., 2021).

Frequent monitoring of water quality parameters allows aquaculture farmers to adjust their management (for example, stocking density and feeding frequency) to mitigate deterioration in water quality (Mallasen et al., 2012). The use of good management practices makes it possible for fish farms to comply with current legislation in the region, such as CONAMA Resolution 357/05 in Brazil (Brazil, 2005). Therefore, it is avoided that the activity is identified as causing impacts on the aquatic ecosystem. In addition, good management practices allow the production of fish in net tanks to develop in a sustainable way, supporting the country's economic development and the promotion of new jobs.

Thus, the objective of this study was to evaluate the influence of fish farming in net tanks on water quality parameters in an arm of the Furnas-MG reservoir, located in the city of São José da Barra, Brazil. The evaluated parameters were compared to the limits allowed by CONAMA Resolution 357/05 for class II water bodies in Brazil.

2. Material and Methods

Sample collection and water quality measurements

The study was carried out in a tilapia (Oreochromis niloticus) farming located in the city of São José da Barra (20°43'04 "S; 46°18'39"W), in Furnas Reservoir, state of Minas Gerais, Brazil. The climate of the region, according to Köppen classification, is Cwa, being characterized by two well defined seasons: a rainy and warm season between October and March and a dry and colder season between April and September. The altitude of the region is 716 m.

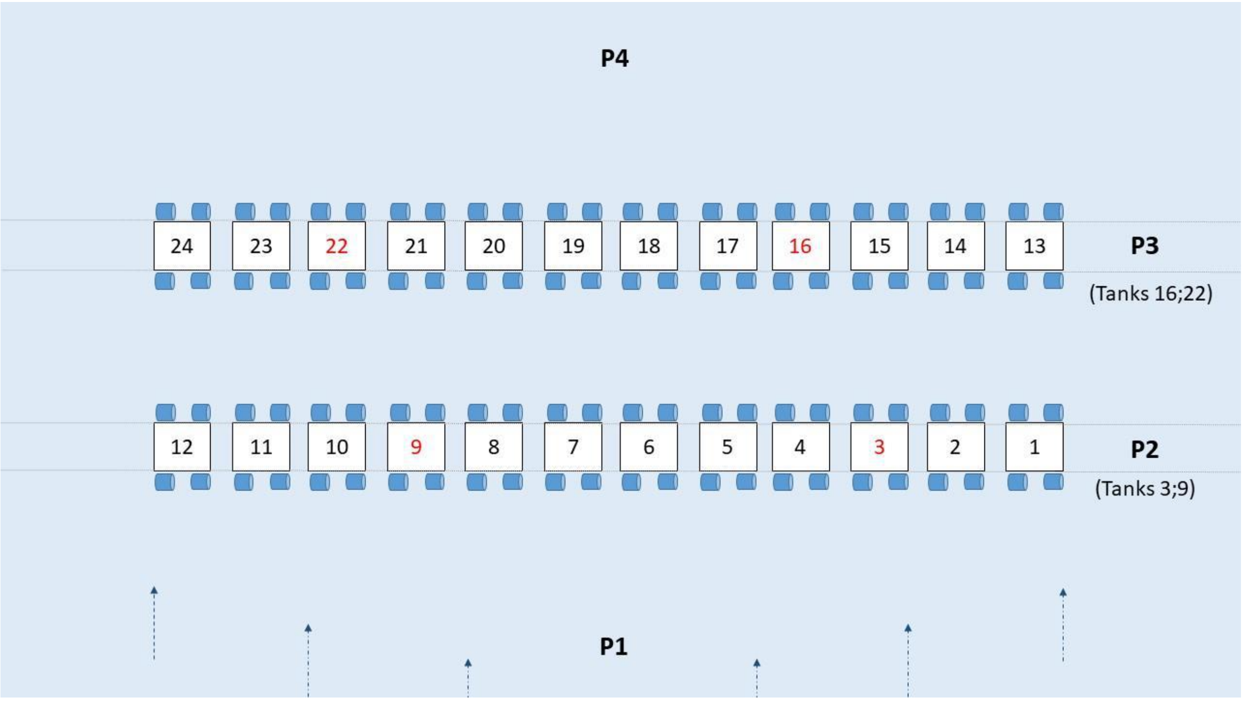
The system production under study had 24 net cages of 3.0 x 3.0 x 1.80 m, corresponding to a total volume of 16.2 m^3. The cages were fixed up in two lines, anchored perpendicular to the major current of the reservoir, so that each line contained a total of 12 net cages (Fig. 1).

Four sampling stations were defined to this study, as following: station 1 (P1)= upstream of the cage lines (50 meters away); station 2 (P2) = inside two cages in the first line (cages 3 and 9); station 3 (P3)= inside two cages in the second line (cages 16 and 22); station 4 (P4)= downstream of the cage lines (50 meters away).

Sampling was carried out monthly between 2015 and 2016 (n=10), covering two production cycles and a complete hydrological cycle. Water samples for the physicochemical analysis were collected at 0.5m and processed in the laboratory. Water temperature (WT), dissolved oxygen (DO), pH, total dissolved solids (TDS), electric conductivity (EC), alkalinity, biochemical oxygen demand (BOD), ammonia, nitrite, nitrate and phosphate analysis were performed according to APHA (2008).

The dataset was checked for normality and heteroscedasticity and submitted to an Analysis of Variance (ANOVA), followed by a Tukey post-hoc test to identify significantly different stations, using SISVAR 5.6 program

Figure 1. Schematic drawing of the experimental facility in Furnas reservoir. Collection points: P1, P2, P3 and P4. P1: Upstream to the cage lines; P2: inside two cages on line 1 (cages 3 and 9); P3: inside two cages on line 2 (cages 16 and 22); P4: Downstream of the cage lines.



Source: Authors (2022).

3. Results and Discussion

Table 1 presents the mean values of each environmental variable analyzed in the present study.

Water temperature showed a trend of seasonal variation. The lowest values were observed in the dry season and, the highest values, were observed in the rainy season. The minimum value observed was 17ºC in June/2016 while the maximum value observed was 24ºC, in October/2016. Regarding to pH, it ranged from neutral to slightly alkaline, ranging from 6.6 in August/2016 to 8.0 in May/2016. Mean pH values were in accordance with the range proposed by CONAMA 357/05 Resolution.

Dissolved oxygen levels during this study ranged from 3.4 mg L^{-1} in May/2016 (station 1) to 5.85 mg L^{-1} in April/2016 (station 3). Mean concentration of this variable was very close to the minimum concentration established by the legislation (5 mg L^{-1}). Electrical conductivity means ranged from 50.08 ± 2.42 to 54.44 ± 7.55 µS cm-1 in stations 4 and 1, respectively. Total dissolved solids (STD) mean concentration ranged from 24.83 ± 0.86 to 26.46 ± 4.06 mg L^{-1} in stations 4 and 1, respectively, remaining below the maximum allowed value (500 mg L^{-1}) by CONAMA resolution.

Table 1. Mean values and standard deviation of the physicochemical variables evaluated in Furnas reservoir during the study period.

Variables	Sampling stations				
	P1	P2	P3	P4	CONAMA Resolution CONAMA 357/2005 Class 2
Temperature (°C)	21.0 ± 2.58a	21.5 ± 2.58a	20.7 ± 2.58a	21.5 ± 2.58a	-
pH	7.10 ± 0.35a	7.16 ± 0. 32a	7.26 ± 0.45a	7.35 ± 0.44a	6 - 9
Dissolved Oxygen (mg L^{-1})	5.13 ± 0.82a	5.14 ± 0,55a	5.01 ± 0.68a	4.97 ± 0.55a	> 5.0
Electric Conductivity (µS cm^{-1})	54.44 ± 7.55a	51.38 ± 3.16a	52.33 ± 4.42a	50.08 ± 2.42a	-
Total Dissolved solids (mg L^{-1})	26.46 ± 4.06a	25.40 ± 1.26a	25.89 ± 2.08a	24.83 ± 0.86a	500
Biochemical oxygen demand (mg L^{-1})	0.60 ± 0.65a	0.59 ± 0.74a	0.67 ± 0.74a	0.52 ± 0.37a	3.0
Alkalinity (mg L^{-1})	29.75 ± 8.54a	29.05 ± 3.69a	29.45 ± 6.57a	28.4 ± 7.91a	-
Nitrite (mg L^{-1})	1.13 ± 0.84a	1.13 ± 0.78a	1.16 ± 0.78a	1.17 ± 0.79a	1.0
Nitrate (mg L^{-1})	1.35 ± 0.87a	6.49 ± 0.55a	1.21 ± 0.63a	1.25 ± 0.83a	10.0
ammonia (mg L^{-1})	1.78 ± 0.87a	0.98 ± 0.42b	1.09 ± 0.54b	1.25 ± 0.58ab	3.7
phosphate (mg L^{-1})	0.21 ± 0.14a	0.19 ± 0.10a	0.19 ± 0.10a	0.19 ± 0.10a	0.025

*$p < 0.05$. Source: Authors (2022).

According to the limits established by CONAMA 357/05 legislation for class II water bodies, dissolved oxygen (DO) concentration in any water sample should not be less than 5 mg L^{-1}. In this study, it was observed that the mean concentration of this variable was very close to the limit established by the legislation.

The mean pH values observed in this study remained within of the ideal range (between 6.5 and 9.0) for fish production (Baldisserotto, 2002). Other authors evaluated the influence of net cages fish farms on water quality and also observed that the pH remained close to neutrality and within the standard limits established by CONAMA 357/05 legislation (Bueno et al., 2008; Américo et al., 2012; Mallasen et al., 2012; Bartozek et al., 2014). The similarity of mean pH values found in this study shows that the fish farming did not affect this variable in Furnas reservoir. Cornel and Whoriskey (1993), studying the effects of rainbow trout production on cages in a lake in Canada, found very similar mean pH values in their different treatments, as observed in this study. On the contrary, Mallassen et al. (2012), studying the influence of tilapia farming in net cages on water quality in Nova Avanhandava reservoir (São Paulo, Brazil), found slightly lower pH values due to fish respiration process and decomposition of organic matter from uneaten food and fish droppings.

The mean values of electrical conductivity (EC) obtained in this study were considered relatively low (< 55 µS cm-1), indicating a good water quality. Contrariwise, Mallasen et al. (2012) found high EC values and an oscillating behavior of this variable in their sampling stations in the Nova Avanhandava reservoir, São Paulo. Alves and Baccarin (2005) found EC values of approximately 140 µS cm-1 also in the Nova Avanhandava reservoir. According to the authors, high EC values may be an indicator of eutrophication process.

Total dissolved solids (STD) are related to components dissolved in the aquatic environment and that give color to the water body. Turbidity, on the other hand, is caused by particles in suspension, which in turn compromises the penetration of light into the environment. Turbidity can occur naturally, but it can be accentuated through anthropogenic activities. Many aquatic bodies of high productivity already have turbidity in a natural way, however, agricultural activities and other human activities, can promote the carrying of some elements that can induce the eutrophication process, contributing to the increase of turbidity, altering natural habitats of diverse species (Wing et al., 2021). In the case of fish farming, leftover rations can influence water quality and, consequently, contribute to the process of raising turbidity. Brazilian legislation allows for waters classified as class 2 true color values of up to 75 mg Pt L^{-1} and turbidity of up to 100 UNT are allowed.

In this study, the mean alkalinity values were appropriate for fish production and did not influence the water quality of the water body. Alkalinity higher than 20 mg L^{-1} CaCO3 maintains pH ranging from 6.0 to 9.5 and, according to Boyd et al. (2016), allows the good development of the fish farming system and does not impair the water quality. Wedemeyer (1997) also cited that concentrations above 20 mg L^{-1} are ideal for intensive fish farming.

Nitrite results showed that other factors must be influenced its concentration in Furnas reservoir, since station 1, which had no influence of fish farming (it was upstream of the cage lines), presented a mean value above that allowed by legislation. Thus, it seems that the fish farming received loads of nitrite above the allowed by legislation, showing that the cultivation of fish had not contributed to a significant change in this parameter in the period of study. Nitrite is a nitrogenous compound that can be toxic to fish when in high concentrations. The limit value for nitrite recommended by Wedemeyer (1997) in fish farming water is 0.1 mg L^{-1}. In this study, all sampling stations presented nitrite concentration considered inappropriate for fish farming. Despite this, no unexpected mortality was recorded during the study period.

Although the mean nitrate values found in this study did not exceed the maximum limit allowed by CONAMA legislation, they exceeded the limit recommended by Wedemeyer (1997) for the maintenance of fish farming (1.0 mg L^{-1} of nitrate in the water of culture). Ammonia is a nitrogenous component that can cause several problems in aquacultural environments, as it can affect the fish community, causing damage to the gills and the osmoregulation of these animals (Baldisserotto, 2002). Our results showed safe concentration of this parameter for fish production in the local of study, since the mean values obtained in this work were lower than the levels considered toxic for tropical fish. According to Boyd (2001) levels above 3 mg L^{-1} can be toxic to tropical fish.

Phosphorus-containing compounds occur in natural waters in the form of phosphates. Phosphorus, together with nitrogen, is a potential eutrophication agent for aquatic bodies, as it is one of the limiting nutrients for the growth of algal biomass. This study demonstrated that phosphate compounds should be a concern in Furnas reservoir, as all sampling station showed values above what is allowed by the legislation, including the station without influence of the fish farming (station 1), indicating that other activities must had influenced the concentration of this nutrient in the reservoir. One suggestion is the agricultural activities present in the watershed that use phosphate-based fertilizers that could be released into the reservoir, increasing their concentration mainly in the rainy season.

Our results demonstrated that the fish farming was not significantly affecting the water quality of the Furnas reservoir, because, even if some parameters was not in agreement with the legislation, such as nitrite and phosphate, the station without influence of fish farming (station 1) also showed values above those recommended by CONAMA Resolution 357/2005, showing that external events to the production system were interfering in the water quality of the reservoir during the period of study and then, they need to be taken account.

The fact that fish farming did not significantly affected the water quality parameters in Furnas reservoir during the period of study may be due to the large volume of water in the reservoir and also due the low stocking density in that fish farming, since the system under study had only 24 cages and the large water volume of the reservoir could dilute the nutrients of the fish farming and carry them away from the area of the cages. Thus, the reservoir has demonstrated self-purification capacity at each production cycle of this fish farming. In systems with higher stocking density, the water body may not be able to do the self-purification, resulting in its fast degradation, impairing the ecosystem for multiple uses. The highest mean phosphate concentration during this study was found in the upstream station, similar to that reported by Molisani et al. (2015) studying the influence of tilapia culture in cages in the Castanhão reservoir, Ceará, Brazil.

The effect of net cages on water quality depends on several factors, such as the annual fish production, the area and depth of the lake and the residence time of the water Guo and Li (2003). Eutrophication degree depends on the number of cages installed, the number of fish stocked, the characteristics of the water body and the management practiced in the fish farming Beveridge (1996), as we stated before. Most of the studies carried out evaluating the influence of fish farms in net cages on the water quality of aquatic ecosystems was made based on the monitoring of limnological parameters with a very small sample period. However, Henny and Nomosatryo (2016) monitored the Lake Maninjau, Indonesia, for eight years (2005-2013), demonstrating that the trophic state of the lake changed from mesotrophic, in the period 2005-2007, to eutrophic, in the period 2008- 2013 due to the installation of cages. This demonstrates that short-term studies may not be ideal for assessing the influence of fish farming in net cages on the water quality of reservoirs as a whole.

Long-term studies may be more effective in elucidating the effects of fish farming in cages on the ecology of the aquatic ecosystems and on the influence on their trophic state, making it possible to analyze if this activity can modify the trophic state and the class of a lake, according to the legislation. A more detailed study, taking into account all the compartments of the water column and the ecological communities would be necessary. The analysis of biological parameters, such as the monitoring of phytoplankton, the biomass of cyanobacteria, and chlorophyll levels, would allow to assess with sure the influence of fish farming on the ecology of the water body. Therefore, further studies are needed to evaluate the influence of fish farming in cages on water quality, focusing in systems with higher number of cages and with higher stocking densities.

4. Conclusion

Our study presents the results obtained of a water quality monitoring of the Furnas reservoir during two production cycles of fish farm in net cages. Results demonstrated that the system under study had not significantly influence on the water quality of the reservoir, that was able to performed its self-purification in the period of 2 years. Also, these results show the importance of the stocking density on water quality, since that in super-intensive systems, with large number of cages and high stocking density, the loads of nutrients released in the ecosystems are much higher than a production system like this that we analyzed in the present study and can cause irreversible damage to water bodies.

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 Tiête, SP). In Nogueira, M.G., Henry, R., Jorcin, A. (Eds.). *Ecologia de Reservatórios: impactos potenciais, ações de manejo e sistemas em cascata*. São Carlos: Rima. p. 329-347, 2005.

Américo, J. H. P., Cicigliano, G. D., & Carvalho, S. L. (2012) Avaliação de alguns parâmetros físico-químicos da água de uma piscicultura com sistema de cultivo em tanques-rede. *VIII Fórum Ambiental da Alta Paulista*, 8(2), 60-71.

Américo, J. H. P., Torres, N. H., Machado, A. A. M., & Carvalho, S. L. C. (2013) Piscicultura em tanques-rede: impactos e consequências na qualidade da água. *Revista Científica ANAP Brasil*., 6(7), 137-150.

APHA - American Public Health Association. *Standard methods for examination of water and wastewater*. USA: 2008.

Baldisserotto, B. (2002) *Fisiologia de peixes aplicada à piscicultura*. Santa Maria: Ed. UFSM. 212p.

Barçante, B., & Sousa, A. B. (2015) Características zootécnicas e potenciais do tambaqui (Colossoma macropomum) para a piscicultura brasileira. *PubVet*., 9(7), 287-290.

Bartozek, E. C. R., Bueno, N. C., & Rodrigues, L. C. (2014) Influence of fish farming in net cages on phytoplankton structure: a case study in a subtropical Brazilian reservoir. *Braz. J. Biol*., 74(1), 45-15

Beveridge, M. (1996) Cage *Aquaculture. Fishing News Books*, Publ., Farnham, Surrey, England, 352 pp.

Boyd, C. E. (2001) Water quality standards: total ammonia nitrogen. *The Advocate*., 4(4), 84-85.

Boyd, C. E., Tucker, C. S., & Somridhivej, B. (2016) Alkalinity and hardness: critical but elusive concepts in aquaculture. *Journal of the World Aquaculture Society*., 47(1), 6-41.

Bozkurt, A. (2016) Zooplankton of dam lake (Kahramanmaras) and the effect of cage fish farming on water quality and zooplankton fauna of the dam lake. *Journal of aquaculture engineering and fisheries research*., 2(3), 97-108

Brasil. Conselho Nacional DO Meio Ambiente. Resolução nº 357, de 17 de março de 2005. *Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências*. Diário Oficial [DA] República Federativa do Brasil, 18 mar. p. 58-63, 2005.

Bueno, G. W. B., Marengoni, N. G., Júnior, A. C. G. et al. (2008) Estado trófico e bioacumulação do fósforo total no cultivo de peixes em tanques-rede na área aquícola do reservatório Itaipu. *Acta.Sci. Biol. Sci.* 30(3), 237-243.

Chorus, I., Falconer, I. R., Salas, H. J., & Bartram, J. (2000) Health risks caused by freshwater cyanobacteria in recreational waters. *J. Toxicol. Environ*. Health Part B., 3(4), 323-347

Cornel, G. E., & Whoriskey, F. G. (1993) The effects of rainbow trout (Oncorhynchus mykiss) cage culture on the water quality, zooplankton, benthos and sediments of Lac du Passage, Quebec. *Aquaculture.* 109, 101-117.

Degefu, F., Mengistu, S., & Schagerl, M. (2011) Influence of fish cage farming on water quality and plankton in fish ponds: A case study in the Rift Valley and North Shoa reservoirs, Ethiopia. *Aquaculture*., 316, 129-135

Demir, N., Kirkagac, M. U., Pulatsü, S., & Bekcan, S. (2001) Influence of trout cage culture on the water quality, plankton and benthos in an Anatolian Reservoir. The Israeli *Journal of Aquaculture* – Bamidgeh, 53, 115-12

Fao. *The state of world fisheries and aquaculture 2016*.Contributing to food security and nutrition for all. Rome. 2016. 200 pp.

Fao. *The State of World Fisheries and Aquaculture 2020*. Sustainability in action. Rome.

Feiden, I. F., Oliveira, J. D. S., Diemer, O., & Feiden, O. (2015) Qualidade da água, capacidade de suporte e melhor período para criação de peixes em tanques rede no reservatório de Salto Caxias. *Eng Sanit Ambient*., 20(4), 589-594

Giani, A., Bird, D., Prairie, Y., & Lawrence, J. (2005) Empirical study of cyanobacterial toxicity along a trophic gradient of lakes. Can. J. Fish. *Aquat. Sci*., 62, 1-10

Gou, L., Li, Z. (2003) Effects of nitrogen and phosphorus from fish cage-culture on the communities of a shallow lake in middle Yangtze River basin of China. *Aquaculture.*, 226(1-4), 201-212

Henny, C., & Nomosatryo, S. (2016) *Changes in water quality and trophic status associated with cage aquaculture* in Lake Maninjau, Indonesia. IOP conference series: Earth and Environmental Science 31, 12-27

Kashindye, B. B., Nsinda, P., Kayanda, R., Ngupula, G. W. et al. (2015) Environmental impacts of cage culture in Lake Victoria: the case of Shirati Bay-Sota, Tanzania. *SpringerPlus.,* 4:475

Kubitza, F. (1999) *Tanques-rede, rações e impacto Ambiental. Panorama da aquicultura*, 9(51).

Kubitza, F. *Tilápia: tecnologia e planejamento na produção comercial*. Jundiaí: Fernando Kubitza, 2000. 289 p.

Mallasen, M., Barros, H. P, Traficante D. P, & Camargo, A. L. S. (2012) Influence of a net cage tilapia culture on the water quality of the Nova Avanhandava reservoir, São Paulo State, Brazil. *Acta Scientiarum Biological Sciences*. 34(3), 289-296

Marengoni, N. G. (2006) Produção de tilápia do Nilo Oreochromis niloticus (linhagem chitralada), cultivada em tanques-rede, sob diferentes densidades de estocagem. *Arch. Zootec*., 55(210), 127-138

Molisani, M. M., Monte, T. M., Vasconcellos, G. H. et al. (2015) Relative effects of nutrient emission from intensive cage aquaculture on the semiarid reservoir water quality. *Environ Monit Assess*., 187-707

Mwebaza-Ndawula, L., Kiggundu, V., Magezi, G., Naluwayiro, J. et al. (2013) Effects of cage fish culture on water quality and selected biological communities in northern Lake Victoria, Uganda. Uganda *Journal of Agricultural Sciences*, 14(2), 61-75

Phillips, M. J. (1985) *The environmental impact of cage culture on Scottish freshwater lochs*. Institute of Aquaculture, University of Stirling, 106 pp.

Sidonio, L., Cavalcanti, I., Capanema, L. et al. (2012) *Panorama da aquicultura no Brasil: desafios e oportunidades*. BNDES Setorial, 35, 421-463

Silva, M. S., Melo, J. F. B., Vasconcelos, R. T. et al. (2021) Digestibility of spineless cactos meals in extrused diets for Nile tilapia (Oreochromis niloticus): energy, protein, amino acids, and carbohydrates. *Trop Anim Health Prod*., 53(4).

Tacon, A. G. J., & Halwart, M. *Cage aquaculture: a global overview*. In Halwart, M., Soto, D., Arthur, J.R. (eds). Cage aquaculture – Regional reviews and global overview, pp. 1–16.FAO Fisheries Technical Paper. No. 498. Rome, FAO. 2007. 241 pp.

Vanderley, R. F., Ger, K. A., Becker, V. et al. (2021) Abiotic factors driving cyanobacterial biomass and composition under perennial bloom conditions in tropical latitudes. *Hydrobiologia*., 848, 943-960

Wedemeyer, G. A. *Effect of rearing conditions on the health and physiological quality of fish in intensive culture*. In: Iwama, G. K., Pickering, A. D., Sumpter, J. P., Schreck, C. B. (Ed.). Fish stress and health in aquaculture. Cambridge, Inglaterra: Cambridge University Press, 1997. p. 35-71. (Society for Experimental Biology Seminar Series, 62).

Wing, J. D. B., Champneys, T. S., & Ioannou, C. C. (2021) The impact of turbidity on foraging and risk taking in the invasive Nile tilapia (Oreochromis niloticus) and a threatened native cichlid (Oreochromis amphimelas*). Behav Ecol Sociobiol*., 75(49).

Zitti, W. G., Novelli, N., & Brocchini, M. (2021) Preliminary results on the dynamics of a pile-moored fish cage with elastic net in currents and waves. J. Mar. *Sci. Eng*., 9-14