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Intensive fish farming: changes in water quality and relationship with zooplankton community

Piscicultura intensiva: alterações na qualidade da água e a relação com a comunidade zooplanctônica

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Abstract: Aim: This study aimed to evaluate the interference of intensive fish farming in the physicochemical variables of water and in the zooplankton community from a tilapia (*Oreochromis niloticus* Linnaeus, 1758) pond in southern Brazil. In addition, it was verified whether the analyzed zooplankton groups could be bioindicators of changes in the quality of pond water. **Methods:** The water and zooplankton sample collections were carried out monthly in different places of the pond: at the water supply site (affluent), in the middle of the pond and at the water outlet site (effluent). Analyzes related to nitrogen series (total nitrogen, total ammonia, nitrite + nitrate), dissolved oxygen, total hardness, total alkalinity, total phosphorus, pH, turbidity and water temperature were performed at all sampling sites. In addition, the density of the zooplankton groups Copepoda (adults and nauplii), Rotifera and Cladocera was determined. **Results:** Regarding the changes between the quality variables of the affluent and effluent water of the pond, the outlet water showed a significant increase only in the variable total alkalinity. Rotifers were the most abundant organisms, and nauplii Copepoda showed a significant increase in the density of organisms in the middle of the pond compared to the inlet water. Both the redundancy analysis (RDA) and the Spearman correlation matrix revealed that zooplanktonic groups are associated with certain physicochemical variables of the water. According to the Analysis of Indicator Species (IndVal), the evaluated organisms are not related to bioindicator species in this environment. **Conclusions:** Therefore, intensive production of *O. niloticus* caused changes only in the total alkalinity of the pond water. The zooplanktonic organisms correlated with the physicochemical variables of the water and between the groups, and did not show potential for bioindicators of water quality in the different locations of the pond.

Keywords: effluent; environmental management; monitoring; *Oreochromis niloticus*; pollution.

Resumo: Objetivo: Este estudo teve como objetivo avaliar a interferência da piscicultura intensiva nas variáveis físico-químicas da água e na comunidade zooplanctônica de um viveiro de tilápias (*Oreochromis niloticus* Linnaeus, 1758) no sul do Brasil. Além disso, verificou-se se os grupos de zooplâncton analisados poderiam ser bioindicadores de alterações na qualidade da água do viveiro. **Métodos:** As coletas de amostras de água e zooplâncton foram realizadas mensalmente em diferentes locais do viveiro: no local de abastecimento de água (afluente), no meio do viveiro e no local de saída de água (efluente). Foram realizadas análises relacionadas a série nitrogenada (nitrogênio total, amônia total, nitrito + nitrato), oxigênio dissolvido, dureza total, alcalinidade total, fósforo total, pH, turbidez e temperatura da água em todos os locais de amostragem. Além disso, foi determinada a densidade dos grupos de zooplânctons Copepoda (adultos e náuplios), Rotifera e Cladocera. **Resultados:** Em relação às variações entre as variáveis de qualidade da água afluente e efluente do viveiro, a água de saída apresentou aumento significativo apenas na variável alcalinidade total. Os rotíferos foram os organismos mais abundantes, e os Copepoda náuplios apresentaram um aumento significativo na densidade de organismos no meio do viveiro em comparação com a água de entrada. Tanto a análise de redundância (RDA) quanto a matriz de correlação de Spearman revelaram que grupos zooplanctônicos estão associados a determinadas variáveis físico-químicas da água. De acordo com a Análise de Espécies Indicadoras (IndVal), os organismos avaliados não apresentam relação como espécies bioindicadoras deste ambiente. **Conclusões:** A produção intensiva de *O. niloticus* causou alterações apenas na alcalinidade total da água do viveiro. Os organismos zooplanctônicos apresentaram correlação com as variáveis físico-químicas da água e entre os grupos, e não apresentaram potencial para bioindicadores da qualidade da água nos diferentes locais do viveiro.

Palavras-chave: efluente; gestão ambiental; monitoramento; *Oreochromis niloticus*; poluição.

1. Introduction

Fish farming is commonplace worldwide, especially in Asian countries. World aquatic animals' production was approximately 178 million tons in 2020, and from this total, around 89% was destined for human consumption (FAO, 2022). The demand for animal protein increases the consumption of fish and its derivatives, and therefore reflects on the increase in fish farming (El-Hack et al., 2022). In Brazil, this activity has been developing at a fast rate, mainly due to the demand of the domestic consumer market (Embrapa, 2020). Nile tilapia (*Oreochromis niloticus*) is the most cultivated species in Brazil (IBGE, 2019), and widely used in aquaculture worldwide (FAO, 2023).

Intensive fish farming, such as tilapia farming, covers all stages of fish life, from eggs/brood stock to adults (Føre et al., 2018), and depends on a system that provides technology and external inputs for satisfactory production (Ottinger et al., 2016). Thus, for a good fish yield, some management practices are carried out in the pond, such as: providing daily artificial feeding, fertilization, disinfection and using corrective products for physical-chemical variables of water (pH, turbidity and total alkalinity). In addition, these practices aim to maintain important food components for fish, of natural origin, such as the zooplankton community. The abundance of these organisms in the pond complements the nutritional needs of the fish and reduces the artificial inputs that are added to the feed (Abdel-Wahed et al., 2018). Due to their environmental sensitivity, they act as pond water quality bioindicators (Perbiche-Neves et al., 2016; García-Chicote et al., 2018; Leppänen, 2018).

Inadequate management is one of the main causes of deterioration in pond water quality (Sipaúba-Tavares et al., 2011; Portinho et al., 2021). Water pollution from fish farming is a process that affects the world scenario (Ottinger et al., 2016; Ahmad et al., 2022). Wastewater from ponds is rich in organic matter and nutrients, such as nitrogen and phosphorus (Teodorowicz, 2013; Simangunsong & Hidayat, 2017) and, when released into the aquatic environment, without prior treatment, it can negatively impact the environment (Hinrichsen et al., 2022), such as the occurrence of eutrophication and oxygen deficits due to organic matter decomposition (Cao et al., 2007; Nguyen et al., 2019). The main source of ammonia in the pond is fish excretion; and the rate of excretion is directly related to the amount of artificial feeding and its protein content (Hargreaves & Tucker, 2004). Another source of nutrient enrichment and other pollutants in the water comes from the supply of chemicals and fertilizers in the pond (Sohel & Ullah, 2012). In addition, sediments are nutrient deposits from the decomposition of food debris, fish fecal content and dead algae, which are decomposed at the bottom of the pond and released into the water column (Hargreaves & Tucker, 2004; Sipaúba-Tavares et al., 2011). Moreover, the lack of standards and guidelines for releasing effluents into the environment in Brazilian

(Brasil, 2011) and state (Rio Grande do Sul, 2006) legislation makes this activity a potential risk of environmental pollution, and this is not a problem restricted only to Brazil (Schenone et al., 2011).

The purpose of evaluating the effluents produced by intensive fish farming is to combine production with environmental sustainability so that these residues are not precursors to negative impacts on the environment. Furthermore, the results of this assessment can serve as a basis for improving management and establishing adequate production controls (Leung et al., 2015). To do this, in addition to monitoring the physicochemical variables of the pond water, using bioindicators is a promising and widely used tool to assess the negative impacts of human activities on the environment (Amaral et al., 2018; Cerezer et al., 2020). This study aimed to evaluate the interference of intensive fish farming on the physicochemical variables of the water and on the zooplankton community (Rotifera, Cladocera and Copepoda) of a tilapia (*O. niloticus*) pond in southern Brazil. In addition, this study evaluated whether these zooplankton organisms could be used as bioindicators of water quality in this fish pond.

2. Materials and Methods

2.1. Study area

Tilapia (*Oreochromis niloticus*) ponds are located in the state of Rio Grande do Sul, southern Brazil, in a region with an economy based on agriculture. The region mainly consists of Oxisol type soil (Soil Survey Staff, 2014) and a small portion comprises the *Nitossolo Vermelho* (IBGE, 2002). According to the Köppen classification, the region under study has a temperate climate of the Subtropical type, classified as Humid Mesothermal (Cfa), and therefore presents variations in temperature according to the seasons (hot summers and colder winters) (Rio Grande do Sul, 2002). The rainfall indices were recorded monthly throughout the sampling period, from April 2015 to March 2016, and ranged from 46 to 505 mm from August to December 2015, respectively, with an average corresponding to 250 ± 131.5 mm/month.

In the study area, there are four excavated fishponds that are associated in series, that is, water leaving one pond is the water entering the next. The first pond is supplied by springs; the second and fourth are ponds for species polyculture, extensive production, without commercial purposes; and the third, in this sequence, has intensive fish farming activity and was evaluated in this work. The ponds are located close to agricultural areas with seasonal annual crops (Figure 1).

The monitored pond has a water area surface of 0.2 ha and was populated with eight thousand juvenile tilapias (*O. niloticus*) (305 ± 0.67g) in April 2015, which were removed in March 2016 (1100 ± 100g). The food provided to the fish was commercial feed, three times a day, totaling around 60 kg of feed daily during the production period.

Figure 1. Water and zooplankton sampling sites in a pond with intensive fish farming activity of *Oreochromis niloticus*, during the productive period of the species. (S1) location of pond inlet (tributary) water; (S2) sample collection sites corresponding to the pond environment; (S3) outlet water location (effluent).

2.2. Collection and analysis of water samples

Water samples were collected at the entrance (S1), in places in the middle (S2) and at the exit of the pond (S3) (Figure 1) (triplicate), during the entire production cycle of *O. niloticus*. Water collections began one day before the pond population, in April 2015, followed monthly until the fish were removed, after 11 months of production. Subsurface waters (± 10 cm deep) were collected with plastic bottles and kept under refrigeration until the beginning of the physicochemical analysis (CETESB, 2011). The physicochemical variables of the water evaluated in this study were dissolved oxygen, total hardness, total alkalinity, total phosphorus and total nitrogen according to the Standard Method for the Examination of Water and Wastewater (APHA, 2012) (Table 1).

2.3. Zooplankton community collection and identification

Zooplanktonic organisms were sampled on the water surface, at the same water collection sites, using a conical-shaped plankton net, coupled to the collector with a 25 μm mesh opening. The net was dragged horizontally on the water surface for approximately 4 m, and three bottle of 100 mL each were collected at each site, totaling a volume of 300 mL. Afterwards, the collected material was placed in polyethylene bottles, fixed with buffered formaldehyde solution (4%) and stained with Rose Bengal dye. In the laboratory, the samples were concentrated at 60mL. From the concentrated volume of 60 mL, 5 subsamples of 1mL were taken with a volumetric pipette and transferred to a Sedgwick-Rafter counting chamber to determine the density of the Rotifera, Cladocera, and Copepoda groups under an optical microscope (Golombieski et al., 2008). For the collection sites related to the pond medium (S2), the zooplankton was quantified and the average between the points was calculated.

2.4. Statistical analysis

The physicochemical variables of the inlet (S1) and outlet (S3) water samples were compared, and the normality and homoscedasticity of the data were tested using the Shapiro-Wilk test and the F test, respectively. Afterwards, they were submitted to the Student's t test or, when necessary, to the Wilcoxon-Mann-Whitney test. Data referring to the fluctuation of zooplankton community abundance between sampling sites were tested for normality by the Shapiro-Wilk test, followed by the Kruskal-Wallis test with Dunn's post-test. The results were expressed as mean ± standard deviation and were considered significant when $p \leq 0.05$.

To analyze the relationship between the zooplankton community and the physical-chemical variables of the water, a Redundancy Analysis (RDA) was performed using the R software (R Core Team, 2021). The RDA proved to be appropriate for our dataset because a Detrended Correspondence Analysis (DCA) showed that the dominant gradient is less than 3 (i.e., gradient length ranged from 1.88 to 1.04; Lepš & Šmilauer, 2003). The degree of multicollinearity between physicochemical variables of water was also verified using the Variance Inflation Factors (VIFs) method, in which values above ten indicate that the variable considered is redundant (O'Brien, 2007). However, the VIF values were all below ten (VIF values ranged from 1.25 to 3.47), indicating that the predictor variables considered are not redundant in the model. Then, Spearman's Correlation Matrix analysis was performed to relate the measured water quality variables with the zooplanktonic groups.

Finally, to identify the most representative taxa (Rotifera, Cladocera and Copepoda) for each habitat site (S1, S2, and S3), we calculated the species' indicator value (IndVal) (Dufrêne & Legendre, 1997). This procedure was performed using the

Table 1. Methods used to determine the physicochemical analysis of water from an intensive production pond of *Oreochromis niloticus*.

Variable	Method
Dissolved Oxygen	Winkler method (1888) modified by Pomeroy & Kirschman (1945) and Golterman et al. (1978)
Total Hardness	EDTA titration
Total Alkalinity	Titration with indicator
Total Phosphorus	Colorimetric method of Vanadomolybdophosphoric Acid
Total Nitrogen	Micro Kjeldhal
Total ammonia	Tedesco et al. (1995)
Nitrite + nitrate	Tedesco et al. (1995)
pH	pHmeter T-1000 TEKNA
Turbidity	Turbidimeter TB 1000p, MS TECNOPON
Temperature	Digital thermometer, INCONTERM

'multipatt' function from indicspecies R package (Cáceres & Legendre, 2009; Cáceres, 2013).

3. Results

3.1. Water quality in and out of the pond

The water inlet (S1) and outlet (S3) samples of the pond, which were evaluated during the productive period of *O. niloticus*, showed a significant difference only in the variable total alkalinity. The other physicochemical variables of the water, such as total hardness, total ammonia, nitrite + nitrate, pH, total phosphorus, turbidity, temperature and dissolved oxygen did not show a significant difference during the sampling period (Table 2). The concentrations of total nitrogen Kjeldhal and total phosphorus were below the detection limit of their respective method (<LOD).

Table 2. Physicochemical variables of water from an intensive fish pond of *Oreochromis niloticus*, monitored between 2015 and 2016.

Variable/Site	Affluent (S1)	Effluent (S3)
Total Alkalinity (mgCaCO$_3$ L^{-1})	48 ± 11.22	59 ± 13.97*
Total Hardness (mgCaCO$_3$ L^{-1})	52 ± 9.67	60 ± 11.93
Total Ammonia (mg L^{-1})	0.52 ± 0.36	0.77 ± 0.93
Nitrite + Nitrate (mg L^{-1})	0.56 ± 0.44	0.67 ± 0.32
pH	6.47 ± 0.71	6.55 ± 1.04
Turbidity (NTU)	46.64 ± 25.02	54.73 ± 22.09
Temperature (ºC)	21.97 ± 2.02	21.98 ± 2.09
Dissolved Oxygen (mg L^{-1})	4.98 ± 3.78	6.48 ± 2.92

*Corresponds to the significant difference between the water quality in the analyzed sites, at the 95% probability level (p ≤ 0.05).

3.2. Zooplankton community

The Rotifera group showed the highest abundance of organisms throughout the sampling period, followed by adult Copepoda and nauplii, and finally the Cladocera group. In general, the density between the same group of organisms did not show a significant difference between the entrance, medium and exit of water from the pond. Copepoda nauplii differed significantly between the inlet and midpond water during the sampling period (Figure 2).

3.3. Redundancy analysis (RDA)

The first two axes of the RDA explained 31% of the total variation in the analyzed data (Figure 3). The first canonical axis explained 24% of the data variation and clearly distinguished Rotifera from other zooplankton groups (Cladocera, Copepoda adults and nauplii). The predictor variables that most contributed to this separation in the positive portion of the first axis were nitrite+nitrate, pH and total ammonia in positive loadings, while turbidity was the variable with the greatest contribution in the negative portion of the first axis. The second axis of the RDA explained 7% of the data variation and mainly separated the Rotifera-Cladocera groups from the adult Copepoda nauplii-copepods groups. The predictor variables that contributed the most in the second axis were nitrite+nitrate and pH in the positive loadings, while total hardness was the variable with the greatest contribution in the negative portion of the second axis.

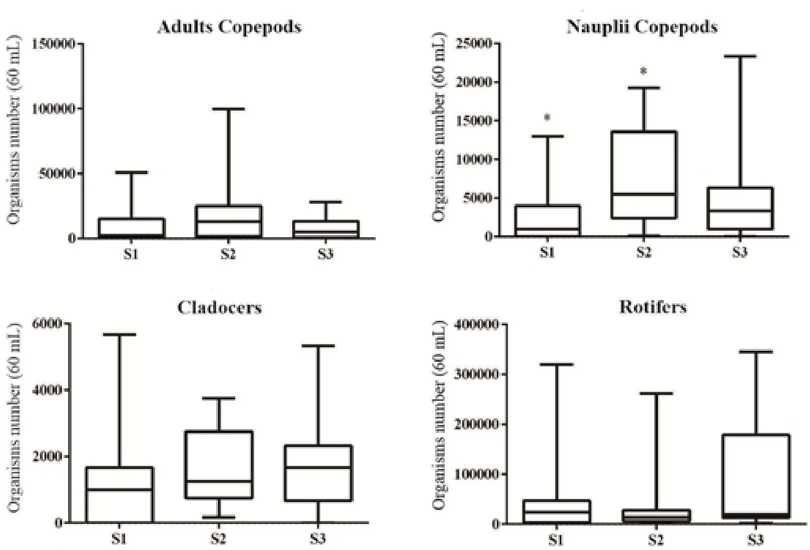

Figure 2. Abundance of the zooplankton community (Adult Copepoda and Nauplii, Cladocera and Rotifera) in an intensive fish pond of *Oreochromis niloticus*. *Corresponds to the significant difference between organisms' abundance in the analyzed sites, at the 95% probability level (p ≤ 0.05).

Additionally, the structure of zooplankton groups was related to some physicochemical variables of the water. For example, water turbidity was closely associated with Rotifera, nitrite+nitrate and pH were more associated with Cladocera, dissolved oxygen with adult Copepoda and total ammonia with Copepoda nauplii. Furthermore, this interaction between zooplankton and the water quality variables revealed by the RDA was congruent with the results obtained by the Spearman correlation matrix (Table 3). The Rotifera group showed a positive correlation with water turbidity, and a negative correlation with nitrite+nitrate and pH. On the other hand, Cladocera showed a positive correlation with nitrite+nitrate and pH. Copepoda nauplii showed a positive correlation with dissolved oxygen and a negative correlation with turbidity; adult Copepoda were positively correlated with total water hardness.

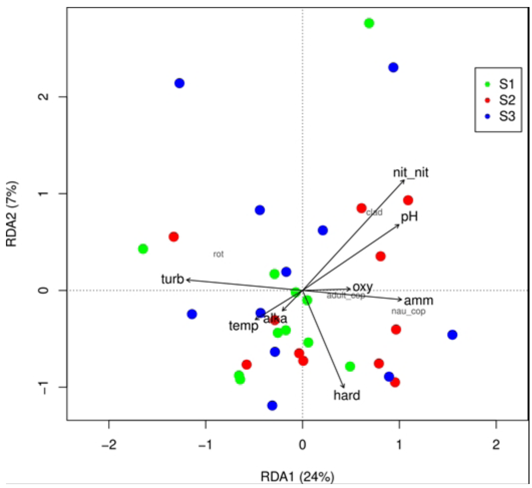

Figure 3. Redundancy analysis ordering (RDA) in the relationship between the physicochemical variables of water and the zooplankton community in an intensive fish pond of *Oreochromis niloticus*. (S1) collection site for water entering the pond (affluent); (S2) water from the middle of the pond; and (S3) water leaving the pond (effluent). Turb: turbidity (NTU); temp: temperature (°C); alka: total alkalinity (mg $CaCO_3$ L^{-1}); hard: total hardness (mg $CaCO_3$ L^{-1}); amm: total ammonia (mg L^{-1}); oxy: oxygen dissolved (mg L^{-1}); nit_nit: nitrite+nitrate (mg L^{-1}); rot: Rotifera; adult_cop: Copepoda adults; nau_cop: Copepoda nauplii; clad: Cladocera.

Regarding the correlations between zooplanktonic communities, Cladocera showed a positive correlation with adult Copepoda and nauplii, and a negative correlation with rotifers. Adult Copepoda were positively correlated with nauplii and were also negatively correlated with Rotifera (Table 3).

3.4. Indicator Species Analysis (IndVal)

Our indicator analysis showed that none of the taxa (Rotifera, Cladocera, and Copepoda adult and nauplii) were strongly associated with any specific group of sites.

4. Discussion

Fish and its derivatives are one of the most traded food products worldwide. Most of the population engaged in fish farming is located in developing countries and corresponds to artisanal workers, with small-scale productivity (FAO, 2022). Tilapia has a greater tolerance to variations in water quality than most farmed freshwater fish

Table 3. Spearman correlation between the physicochemical variables of water and the zooplankton community in an intensive fish pond of *Oreochromis niloticus*.

	clad	adult_ cop	nau_ cop	rot	alka	hard	amm	nit_nit	pH	temp	turb	oxy
clad	1											
adult_ cop	**0.411***	1										
nau_cop	**0.373***	**0.518****	1									
rot	**-0.511****	**-0.427***	-0.268	1								
alka	-0.145	0.059	-0.112	0.227	1							
hard	-0.047	**0.409***	0.209	0.007	**0.588****	1						
amm	0.149	0.059	0.132	-0.148	0.253	0.216	1					
nit_nit	**0.503****	0.138	0.194	**-0.457****	**-0.570****	-0.303	0.179	1				
pH	**0.522****	0.168	0.284	**-0.418***	**-0.351***	-0.168	0.253	**0.631****	1			
temp	-0.176	0.008	-0.051	-0.006	**0.485****	0.246	0.123	-0.277	**-0.387***	1		
turb	-0.161	-0.272	**-0.454****	**0.393***	**0.339***	-0.014	-0.036	**-0.491****	-0.083	-0.213	1	
oxy	0.219	-0.021	**0.366***	-0.214	**-0.455****	-0.029	-0.287	0.296	0.093	**-0.392***	**-0.364***	1

Turb: turbidity (NTU); temp: temperature (°C); alka: total alkalinity (mg $CaCO_3$ L^{-1}); hard: total hardness (mg $CaCO_3$ L^{-1}); amm: total ammonia (mg L^{-1}); oxy: dissolved oxygen (mg L^{-1}); nit_nit: nitrite+nitrate (mg L^{-1}); rot: Rotifera; adult_cop: Copepoda adults; nau_cop: Copepoda nauplii; clad: Cladocera. *$p \leq 0.05$; **$p \leq 0.01$.

(Rahman et al., 2021). However, understanding the physicochemical and microbiological characteristics of pond water goes beyond establishing standards for optimizing satisfactory tilapia productivity (Ntengwe & Edema, 2008).

Intensive fish farming generates effluent rich in ammoniacal nitrogen metabolites, fish feces and unconsumed feed (Kajimura et al., 2004; Enwereuzoh et al., 2021), and as a consequence, there can be nutrient enrichment, oxygen depletion, direct toxics from nitrogen, in addition to the effects of suspended solids, and impact wildlife in adjacent ecosystems (Sindilariu, 2007; Coldebella et al., 2018). One of the ways to evaluate the dynamics established by the activity under water quality, as well as the direct evaluation of the physicochemical variables, is by using zooplankton as bioindicators. Evaluating these zooplankton is a useful tool, due to their wide occurrence, abundant species and sensitive responses to environmental changes (Zhou et al., 2008; Josué et al., 2021).

4.1. Water quality in and out of the pond

The characteristics of the effluent generated by the intensive activity of fish farming are mainly related to the management and quality of the feed provided (Mo et al., 2014; Schumann & Brinker, 2020). The quantity and quality of food must be adequate, both to avoid excess waste and its negative impact on the physicochemical variables of the water. Thus, food must have high digestibility by fish, low nitrogen excretion rate and less protein in the diet, aiming to minimize the nutrient content in the effluent (Cao et al., 2007). In this study, fish farming activity increased the total alkalinity of the pond water, and this fact may be related to the breakdown of the feed in the water, as the artificial feed also contains calcium carbonate in its composition. In addition, another factor that may be related to the increase in total effluent alkalinity is the practice of liming the pond with dolomitic limestone or other lime products, which is frequently performed (Ntengwe & Edema, 2008).

The total alkalinity of water is a very important variable in fish farming, mainly due to its interaction with other physicochemical variables. These interactions can bring benefits to the health of aquatic organisms, such as protecting water from changes in pH, decreasing the potential for metal toxicity and increasing the natural fertility of water (Boyd & Tucker, 1998; Michałowski & Asuero, 2012). Straus (2003) observed that the acute toxicity of copper sulfate (a compound used in freshwater aquaculture to treat pathogens in fish) in tilapia (*Oreochromis aureus*) increases when the total alkalinity of the water decreases.

After evaluating the quality of the fish farm effluent, there are several management alternatives. Initially, the preference for foods with better nutritional content, in which there is greater absorption and assimilation, and more suitable for fish should be prioritized to minimize negative impacts on water quality (Sugiura et al., 2006). The treatment of effluents through closed and semi-closed water systems, which aim at series recirculation between reservoirs, treatment ponds (with fish and bivalves, for example) and that return to production ponds, reduce the amount of discarded waste and its reuse (Cao et al., 2007; Zhang et al., 2011). Kuhn et al. (2010) produced bioflocs from the biological treatment of effluent from tilapia farming, which were satisfactorily incorporated into shrimp feed. Omeir et al. (2020) and Kolozsvári et al. (2022) demonstrated that the effluent from fish farming can be used as a source of irrigation in agriculture and is a viable alternative in areas affected by water scarcity.

4.2. Zooplankton community

The zooplankton that inhabits inland waters is classified into microzooplankton organisms, such as Rotifera, and mesozooplankton, such as Cladocera and Copepoda. These organisms are microscopic invertebrate animals that live in suspension, and that play a very important role in the aquatic ecosystem, as they are a trophic link between producers and predators, promoting nutrient cycling and the maintenance of trophic chains (Araujo et al., 2017; Tundisi & Matsumura-Tundisi, 2008). The rate of reproduction, growth and survival of zooplankton is directly related to the quality conditions of the environment they inhabit, such as dissolved oxygen concentration, water temperature and food availability (Tundisi & Matsumura-Tundisi, 2008; Wang et al., 2012). Thus, the susceptibility to environmental changes makes zooplanktonic communities an indication of the intensity of these changes (Eskinazi-Sant'Anna et al., 2013). In addition, the abundance of these organisms in the nursery, which are a source of food for the fish, reduces the need to supply artificial food, that is, there is less generation of effluents with polluting potential (David et al., 2022).

In this study, the highest abundance of Rotifera was observed among the sampling sites, followed by the adult Copepoda, Copepoda nauplii and, to a lesser extent, the Cladocera. The diversity and abundance of Rotifera species is a recurrent pattern in tropical freshwater ecosystems, lakes, ponds, reservoirs and rivers (Yermolaeva, 2015; De-Carli et al., 2018; Picapedra et al., 2021), mainly due to their opportunistic characteristics, such as a wide food spectrum, high population turnover and adaptation to different environmental conditions (De-Carli et al., 2018; Dorche et al., 2018). Another important characteristic of this group is its short life cycle and rapid reproduction, making these organisms one of the shortest generation times among metazoans (Snell & Janssen, 1995), unlike Copepoda and Cladocera, which have a life more complex life cycle (Tundisi & Matsumura-Tundisi, 2008). This may be related to the greater number of Rotifera found in the nursery of this study. In addition, Rotifera positively correlated with water turbidity. This relationship can be attributed to the foraging of these organisms, as this group feeds on small particles, such as bacteria, organic debris and suspended material (Degefu et al., 2011). Moreover, Golombieski et al. (2008) also found that Rotifera are more tolerant to certain environmental contaminants. These results agree with the RDA, which distinguished Rotifera from other zooplankton groups (Cladocera, Copepoda adults and nauplii) and this group showed a relationship with turbidity.

The adult Copepoda population was more abundant than that of nauplii in the sampling sites, however, only the density of Copepoda nauplii showed a significant difference between the inlet (affluent) and middle water of the pond. In the Copepoda population, the predominance of juvenile forms is commonly observed, such as the nauplii (Sampaio & López, 2000; Neves et al., 2003), contrary to what was observed in this study. However, the significant increase in the density of Copepoda nauplii in the pond may be the result of more stable and adequate conditions with a consequent increase in reproduction and juveniles. Copepoda can reproduce quickly, in view of the sperm reserve by the female after many fertilizations from a single copulation (Tundisi & Matsumura-Tundisi, 2008). In addition, another factor that relates the proportion between juvenile and adult forms of copepods is the intensity and balance of predation by organisms (Golombieski et al., 2008).

The Copepoda and Cladocera groups showed a positive correlation with each other, and both had a negative correlation with the Rotifera, according to Spearman's correlation. The RDA also demonstrated a relationship between the Copepoda and Cladocera groups, and separated them from Rotifera. These results may suggest predation or competition between the mesozooplankton and microzooplankton groups. Finally, the composition and density of zooplanktonic communities may also be related to the trophic state of the environment (Branco et al., 2002; Parra et al., 2009; Jeppesen et al., 2011; Picapedra et al., 2021). However, further studies should be conducted in the area to clarify this.

The Indicator Species Analysis (IndVal) relates the abundance and frequency of species within a group in certain locations, that is, these species can be bioindicators of environmental conditions (Carvalho et al., 2017; Trindade & Carvalho, 2018). In this study, it was not possible to determine a zooplankton group that could be a bioindicator for the nursery. In fact, in general, the occurrence and abundance of organisms in each group remained stable between the locations evaluated throughout the sampling period. Also, this result agrees with the RDA, which was not possible to distinguish the preferential occurrence of some group in a determined place of the tilapia nursery.

5. Conclusion

The intensive production of tilapia (*O. niloticus*) only caused changes in the water quality regarding the total alkalinity variable. Zooplanktonic organisms (Rotifera, Copepoda adults and nauplii, and Cladocera) generally maintained a stable population. In addition, they correlated with some physicochemical water variables, and also between species. However, these organisms were not related as bioindicators of changes in pond water quality.

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