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Biotic and abiotic features in water-supply ponds of two aquaculture farms covered by macrophytes

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Abstract. This study assessed the influences of the presence of macrophytes in two shallow water-supply ponds, on the plankton community and water column of a fish farm and a fee-fishing farm. Samples were collected monthly at both the inlet and outlet of the water-supply ponds over one year. In the fish farm, the water-supply pond was covered by *Salvinia auriculata* and *Eichhornia crassipes*, whilst in the fee-fishing farm, the pond was covered by *Typha domingensis*, both with continuous water flow. In both aquaculture enterprises, nitrate concentrations were reduced by the presence of macrophytes, while other nutrients remained constant. Phytoplankton (e.g. Bacillariophyceae and Zygnematophyceae) had relatively high abundance rates in both systems, with a decreased concentration of Cyanobacteria being observed in the ponds' outlet, especially regarding the free-floating macrophytes in the fish farm. Rotifera and Cyclopoida Copepoda (*Thermocyclops decipiens*), had the highest rates among zooplanktonic organisms in the water-supply inlets, mostly in the fee-fishing farm with rooted macrophytes. Cladocera and Calanoida Copepoda were found only in the free-floating macrophytes system. The presence of macrophytes favored the phytoplankton assemblage in terms of density and abundance, thus it represents an adequate tool for the maintenance of water-supply ponds in aquaculture enterprises.

Key words: phytoplankton, macrophytes, water parameters, zooplankton.

Resumo: Características bióticas e abióticas de dois viveiros de abastecimentento de água para aquicultura cobertos por macrófitas. Este estudo avaliou a influência da presença de macrófitas em dois sistemas de abastecimento de água rasos, com enfoque na comunidade planctônica e nas variáveis físico-químicas da água. Amostras foram coletadas na entrada e saída dos sistemas mensalmente, durante um ano. O sistema de abastecimento de água da piscicultura estava coberto por *Salvinia auriculata* e *Eichhornia crassipes*, enquanto o do pesque-pague estava coberto por Typha domingensis, ambos com fluxo contínuo de água. Nos dois sistemas as concentrações de nitrato foram reduzidas pela presença de macrófitas, enquanto outros nutrientes permaneceram sem diferenças na entrada e saída. O fitoplâncton (por exemplo, Bacillariophyceae e Zygnematophyceae) apresentou taxas de abundância relativamente altas em ambos os sistemas, com diminuição de cianobactérias nos pontos de saída, especialmente no sistema com macrófitas flutuantes. Rotifera e Copepoda Cyclopoida (*Thermocyclops decipiens*), apresentaram as maiores abundâncias relativas entre os organismos zooplanctônicos nas entradas dos sistemas de abastecimento de água, principalmente onde se encontravam as macrófitas enraizadas. Cladocera e Copepoda Calanoida foram encontrados apenas no sistema com macrófitas flutuantes. A presença de macrófitas favoreceu a assembléia fitoplanctônica em termos de densidade e abundância, sendo uma ferramenta adequada para a manutenção de tanques de abastecimento de água para aquicultura.

Palavras-Chave: fitoplâncton, macrófitas, parâmetros da água, zooplâncton

Introduction

Water quality is one of the most important features in aquaculture enterprises for a balanced production of aquatic organisms. Fish farms generally use water directly from springs, but this practice has changed over time due to water scarcity and lack of proper management (e.g. feeding and addition of nutrients into the water), which often degrades water by coming into direct contact with the fishponds. Aquaculture farms use old fishponds located near springs as water reservoirs and channel them in different ways to fishponds. However, as these ponds were used for fish farming in the past, its sediment is rich in nutrients and organic matter, which leads to the appearance of aquatic plants (Sipaúba-Tavares & Dias 2014).

Aquatic plants in tropical regions are common and appear when limnological conditions are adequate for their development. As primary producers, aquatic plants remove the necessary nutrients for their metabolism and release allelochemicals that are known to stimulate the development of many microorganisms, since that these plants provide different habitats for the microbial community (They & Marques 2019).

One of the most important requirements for the successful development of a fishpond is the existence of an adequate water supply, as ponds require large amounts of water to fill it up and to replace water for other ponds that lose water by evaporation or seepages (Kopp *et al.* 2016). Fishponds are artificial ecosystems with distinct hydrological characteristics, such as being man-made and having its nutrients' inputs under human control, having low depth, displaying great fluctuations of abiotic variables, and lacking thermocline (Kopp *et al.* 2016).

Dense macrophytes' beds covering the surface of water bodies enhance shelter spots for zooplankton, affect water flows and contribute to the maintenance of the physical structure of colonized aquatic habitats. Also, the presence of macrophytes reduces nutrient availability and particle suspension, releases allelochemicals and acts in the maintenance of the integrity of ecosystems, thus affecting productivity and nutrient recycling (Iacarella *et al.* 2018). The mechanisms by which diversity affects the functioning of an ecosystem depend on the characteristics of local communities. Therefore, assessing the relative importance of abiotic variables for the local assemblage of organisms, in terms of abundance and composition, is paramount for the comprehension of the ecosystem's dynamics and structure (Schneider *et al.* 2018).

The maintenance of water quality is of primary importance for fish farming, seen that it affects plankton assemblages according to temporal changes and/or fishpond management (Sipaúba-Tavares *et al.* 2017). However, there is limited information about the effects of aquatic vegetation on habitat differentiation and zooplankton occurrence. Several factors are expected to determine the success of phytoplankton and zooplankton communities in the presence of macrophytes, e.g. plants with dissected leaves may provide favorable conditions for foraging and shelter, in comparison to undissected helophytes (Celewicz-Goldyn & Kuczynska-Kippen 2017).

Zooplankton is a key component in freshwater systems that commonly use macrophytes as shelters in order to escape from predators, or even as a substrate for foraging. Furthermore, the specific sensitivity of zooplankton with distinct life habits and/or belonging to different taxonomic groups remains poorly studied (Gutierrez & Mayora 2016). It is currently known that the presence of macrophytes in aquatic habitats inhibits phytoplankton growth because of shading, reduced hydrodynamics, competition for nutrients and increased grazing, which is a consequence of the environment's use as shelter and foraging spot by zooplankton (They & Marques 2019).

The use of aquatic plants as phytoremediation in water-supply ponds remains poorly investigated, thus it is not possible to affirm that in this specific case, plants could act as a tool for the maintenance of water quality, and for promoting the aquatic microbiota. This study evaluated the influences of macrophytes in both biotic and abiotic variables of two water-supply ponds in two aquaculture farms, covered by macrophytes. The hypothesis for this study were: (1) different species of macrophytes might influence biotic and abiotic water conditions differently, (2) the use of macrophytes in water-supply ponds may be recommended as phytoremediation, and (3) the presence of macrophytes improves water quality in water-supply ponds.

Materials and Methods

Area: Two water-supply ponds with continuous water flow were used in this study (21°15'19''S and

48°19’21’’W), one located in a fish farm and the other in a fee-fishing farm, both covered with macrophytes. The water of these ponds flows through the spots where macrophytes stand and then is discharged into fishponds through an underground pipe grid (Fig. 1). The fish farm occupies a 14-hectare area containing 80 ponds with continuous water flow, and a water renewal equivalent to 5% of the total volume per day. The size of these ponds varies from 100 m^2 to 8057 m^2, and these receive water directly or indirectly from a previous pond, through the underground pipe grid. The water-supply pond located in the fish farm is covered with the free-floating plants *Eichhornia crassipes* (Mart.) and *Salvinia auriculata* Albl., which covers almost 80% of the water surface. On the other hand, the fee-fishing farm is smaller, containing a total area of 0.1 hectares, represented by four ponds, with an area ranging between 1501 m^2 and 1850 m^2, and the water flows from one pond directly to another. The water-supply pond in the fee-fishing farm is covered by rotted aquatic macrophytes *Typha domingensis*. Thus, the water-supply ponds measure 2816 m^2 in the fish farm and 1225 m^2 in the fee-fishing farm and the distance between these ponds is 5 km. Both farms discharge the water into a creek located in Jaboticabal municipality, through an underground pipe grid (Fig. 1).

Water and plankton sampling: Samples were collected over one year (March 2009 to February 2010) in both the inlet (IW) and outlet (WO) water of both water-supply ponds, namely IWFF and WOFF in the fish farm, and IWFE and WOFE in the fee-fishing farm. Water was collected from a 10 cm depth, using a 1-L van Dorn bottle, and transported in refrigerated polyethylene bottles (500 mL) to the laboratory for further analysis. Water conductivity (Cond), temperature (Temp), dissolved oxygen (DO), and pH were measured in situ, with the aid of a multiparameter probe Horiba U-10. Total phosphorus (TP), total ammonia nitrogen (TAN) and nitrate (NO_3) were quantified by spectrophotometry, according to the methods of Golterman et al. (1978) and Koroleff (1976) using calibration curves with $r^2 \geq 0.999$. Five-day biochemical oxygen demand (BOD_5) was determined according to Boyd & Tucker (1992).

Figure 1. Diagram of the aquaculture water-supply ponds: Inset A: the shaded area indicates the State of São Paulo (southeastern Brazil). Inset B: Fee-fishing farm. Inset C: fish farm. Sampling sites: IWFE= inlet water of the fee-fishing farm; WOFE = water outlet of the fee-fishing farm; IWFF= inlet water of the fish farm; WOFF = water outlet of the fish farm. The fee-fishing farm is cover with *Typha domingensis*, and the fish farm with *Eichhornia crassipes* + *Salvinia auriculata*.

Zooplankton was sampled by filtering 10 L of water using a 50-µm pore-size-net, then concentrating the sample in 50 mL of water. Samples were preserved in formalin 4% and allowed to settle. The total collected volume was measured and stored in amber glass jars. Copepoda and Cladocera were counted in a reticulated chamber under a stereoscope (40X), whilst Rotifera individuals were analyzed with the aid of a Sedgewick-Rafter chamber, using a Leitz microscope (100X). Phytoplankton samples were collected in polyethylene bottles and preserved in a Lugol solution (1%). The abundance of phytoplankton was estimated by counting the cells using Utermöhl sedimentation chambers, as suggested by Lund *et al.* (1958). Phytoplankton counting was carried out with the aid of an inverted microscope Axiovert 40 CFL (Carl Zeiss). Taxonomical identifications were made according to the available literature (Bourrely 1968, Koste 1978, Bourrely 1985, Segers 1995, Elmoor-Loureiro 1997, Bicudo & Menezes 2006, Franceschini *et al.* 2010).

Data analysis: Water data were tested for normality and homogeneity of variances, using the Lillierfors and Bartlett tests, with p = 0.05 (Siegel, 1975). Water data from sampled spots were compared (IWFF x WOFF; IWFE x WOFE) by using a paired, two-tailed Student's t-test, or a non-parametric Wilcoxon signed-rank test, when data were normal or nonparametric, respectively (Demšar 2006). All water variables were expressed graphically as means, standard deviations (SD), maximum and minimum.

Principal Components Analysis (PCA) was used to reduce the dimensionality of the environmental variables and to sampled spots in relation to the water biotic and abiotic parameters (Legendre & Legendre 1998).

The analyses of dominance and abundance of species were performed for both the zooplankton and phytoplankton assemblages. Species were considered dominant when density was superior to 50% of the total number of specimens in the sample and considered abundant when the number of specimens was higher than the mean density of all occurring species (Lobo & Leighton 1986). The diversity of the planktonic community was calculated using the Shannon-Wiener (H') index, richness (S) was considered the total number of species presents, evenness or equitability (E) was determined as H/H max, where H is the Shannon-Wiener index and H max = ln S (Pielou 1975).

Results

In both aquaculture farms, the water quality parameters were found to be different ($p<0.05$) considering inlet and outlet water, with the exceptions of Temp, TAN and TP ($p>0.05$). TAN concentrations were lower than TP in two fish farms, ranging between 0.5 µg L^{-1} (IWFF) and 14.5 µg L^{-1} (WOFE). TP concentrations were found above 68 µg L^{-1} (IWFF). Nitrate concentrations were higher than TAN, with the highest concentrations being observed at IWFF (315 µg L^{-1}), WOFF (293 µg L^{-1}) and IWFE (837 µg L^{-1}) (Fig. 2).

Dissolved oxygen was found to be low, especially at IWFE, ranging between 1.2 mg L^{-1} and 2.3 mg L^{-1}. The highest ($p<0.05$) DO concentration was obtained at IWFF (3.9 - 5.7 mg L^{-1}) (Fig. 2). Water temperature was influenced by local conditions, ranging between 17 - 25°C. Electrical conductivity was found below 60 µS cm^{-1}, and pH was acidic, below 6.7 (Fig. 2). The highest BOD_5 were observed at WOFF (1.8 - 5.8 mg L^{-1}), whilst in the other sampled spots it was similar, ranging from 0.2 (IWFF) and 3.4 mg L^{-1} (IWFE) (Fig. 2).

Four species of Cladocera, two of Copepoda and 29 Rotifera were found in the composition of the zooplankton assemblage of the fee-fishing farm. Nine and seven abundant species were found in IWFE and WOFE, respectively. However, *Keratella cochlearis* and *Asplanchna* sp. were found in IWFE. All abundant species belonged to the group of Rotifera and had over 95% relative abundance at IWFE and WOFE. By comparing IWFF with IWFE, it was possible to observe that Rotifera was the most abundant group, but still, there was a predominance of Cladocera and Copepoda (Fig. 3). IWFE displayed a high density of zooplankton (44,449 individuals mL^{-1}), as well as richness (27); however, evenness (0.7495) and diversity (1.0207) were higher in WOFE (Table I). Regarding the zooplankton assemblage in the fish farm, Rotifera had 42 species throughout the sampling period, with 100% relative abundance in August, September, October and February in IWFF, whilst in other months the most abundant specimens belonged to Cladocera (mostly *Daphnia ambigua*). In WOFF, Copepoda had a high relative abundance mostly because of *Thermocyclops decipiens*, and Rotifera species were absent in July and September, which were months when Copepoda was more abundantly found (Fig. 3).

In the fee-fishing farm, the phytoplankton assemblage comprised 61 species, being 8

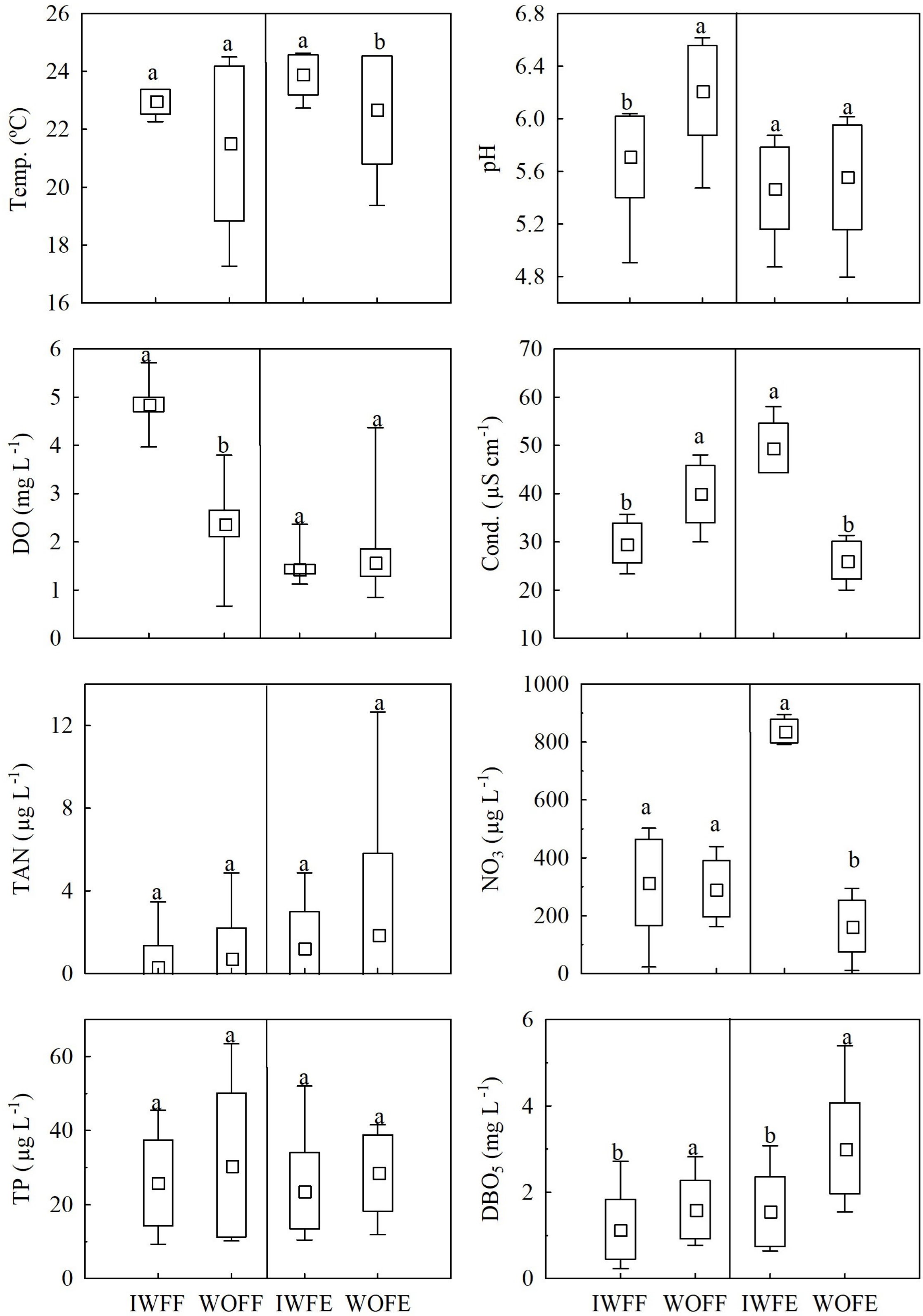

Figure 2. Mean (square), standard deviation (box), and minimum-maximum (whiskers) of the physical and chemical variables of the water, in both water-supply ponds. Sampling sites: IWFF = inlet water of the fish farm; WOFF = water outlet of the fish farm; IWFE = inlet water of the fee-fishing farm; WOFE = water outlet of the fee-fishing farm. Similar letters within vertical bars indicate no significant differences between sites in the same environment, according to the Wilcoxon nonparametric statistical test ($p<0.05$).

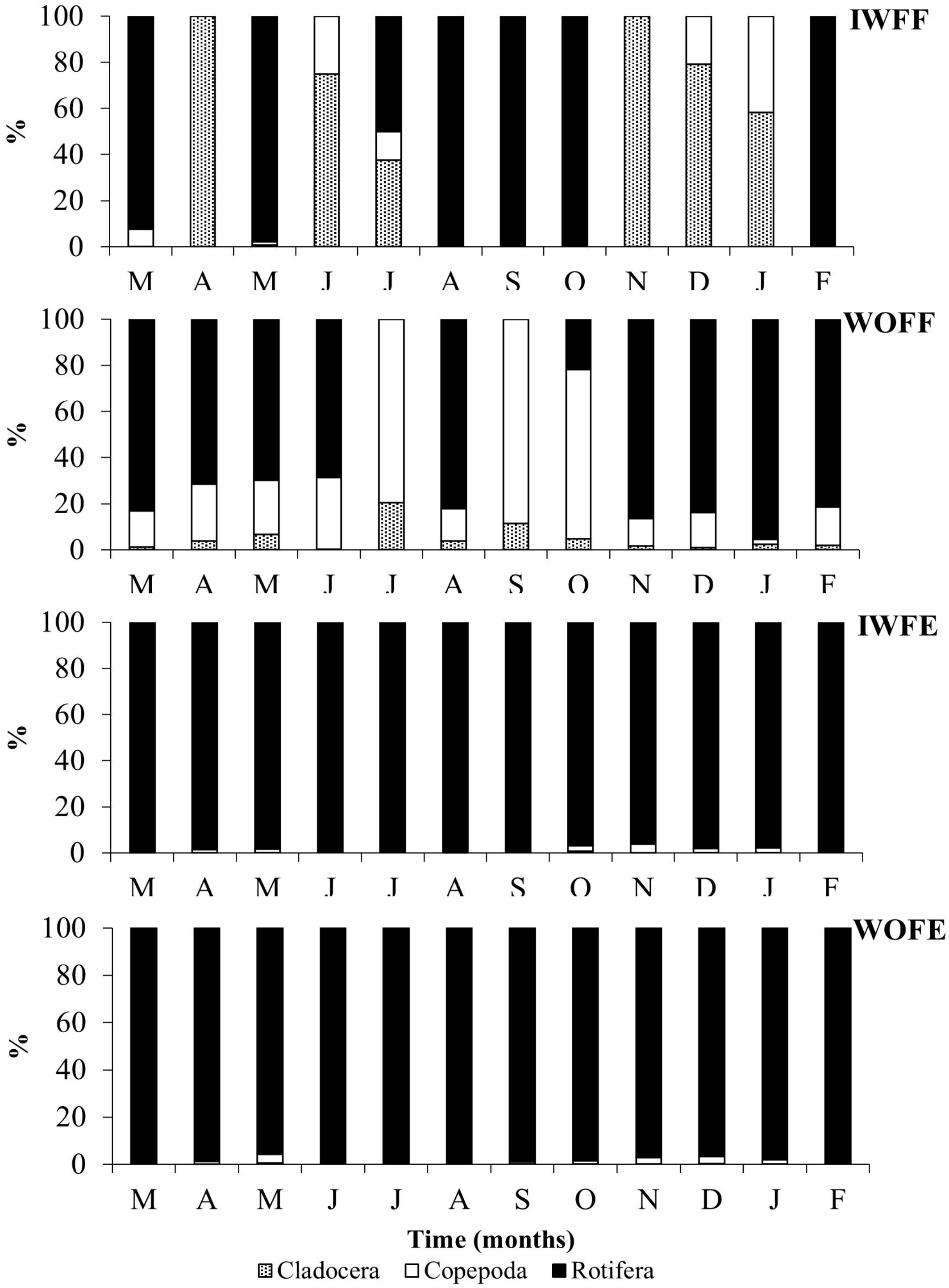

Figure 3. Relative abundance of the zooplankton assemblages of different sites in both water-supply ponds. Sampling sites: IWFF= inlet water of the fish farm; WOFF = water outlet of the fish farm; IWFE= inlet water of the fee-fishing farm; WOFE = water outlet of the fee-fishing farm.

Bacillariophyceae, 23 Chlorophyceae, 8 Cyanobacteria, 1 Dynophyceae, 5 Euglenophyceae, 15 Zygnematophyceae, and 1 Oedogonophyceae. All species occurred in both sites, with an exception of *Sutirella* sp., which was found only at WOFE. 14 species of phytoplankton were abundant; however, 3 species were abundant only at IWFE, being *Microcystis wesenbergei* (Cyanobacteria), *Coelastrum microporum* and *Nephrocytium* sp. (Chlorophyceae), whilst 2 species were found only at WOFE, *Mougeotia floridana* and *Spirogyra majuscula* (Zygnematophyceae) (Table I).

Table I. Total number of the zooplankton and phytoplankton (ind L^{-1}) assemblages, the total number of species, and the total number of abundant and dominant species, and ecological indexes of the plankton community at sites IWFF = inlet water of the fish farm, WOFF = water outlet of the fish farm, and IWFE = inlet water of the fee-fishing farm, WOFE = water outlet of the fee-fishing farm.

Ecological Index and	**Fish Farm**		**Fee-Fishing Farm**	
Number of Species	**IWFF**	**WOFF**	**IWFE**	**WOFE**
Total Zooplankton	1,963	14,979	44,499	21,494
Evenness	0.7859	0.7291	0.6902	0.7495
Richness	13	21	27	23
Diversity	0.8754	0.9640	0.9879	1.0207
Total number of abundant species	8	8	9	7
Total number of dominant species	nf	nf	nf	nf
Total Phytoplankton	7,189	16,472	39,306	39,684
Evenness	0.1520	0.4780	0.5988	0.5869
Richness	29	59	61	62
Diversity	0.2223	0.8464	1.0690	1.0519
Total number of abundant species	1	6	12	11
Total number of dominant species	1	nf	nf	nf

nf = not found.

Cyanobacteria were not observed throughout the sampling period at IWFF and WOFF, and displayed a low relative abundance (reaching a maximum at IWFF in August), showing a decrease at the spot WOFF, in comparison to IWFF. Besides, a decreased relative abundance of Zygnematophyceae at WOFF and an increased abundance of Bacillariophyceae was observed. Cyanobacteria were present every month at IWFE and WOFE, showing a decrease in their relative abundance at WOFE during nine months. On this sampling site, a greater relative abundance of Cyanobacteria was observed in June (23%), September (13%), January (12%) and February (48%). Also, comparison fee-fishing sites, a decreased relative abundance of Chlorophyceae and Bacillariophyceae was observed, whilst Zygnematophyceae increased. In WIFE, Chlorophyceae was the most prevalent class, ranging from 18% (August) to 76% (October) (Fig. 4).

Phytoplankton assemblages were similar between IWFE and WOFE, regarding their density and ecological indexes (Table I). In the fish farm, the plankton community had the highest density and ecological indexes in WOFF, with the richness exceptions of zooplankton. Moreover, the single dominant species *Mougeotia floridana* (Zygnematophyceae) was found at IWFF. For this reason, the ecological indexes at IWFF were lower in comparison to WOFF (Table I). The second most representative group was Bacillariophyceae, which in turn displayed low relative abundance, with an exception during February (75.9%), due to the presence of the species *Melosira* sp. (Fig. 4). At WOFF, Bacillariophyceae and Zygnematophyceae had high relative abundance throughout the year, but in January, this index was lower, due to the presence of *Peridinium* sp. (Dinophyceae), which had a density of 34% regarding the total phytoplankton assemblage (Fig. 4).

The biotic and abiotic data were submitted to a principal component analysis (PCA) and the results are presented in figure 5. IWFE was associated with the variables Temp, NO_3, Cond, Rotifera, Cyanobacteria and Chlorophyceae, contrasts with other treatments positioned on different sides of PC1. WOFF was associated with the variables pH, TP, Dinophyceae and Zygnematophyceae. WOFE was associated with the variables DBO, TAN and Euglenophyceae. IWFF was associated with DO (Fig. 5, Table. II).

Discussion

The results revealed that the presence of floating and rooted macrophytes in the water supply of two aquaculture farms, promoted an adequate water quality, especially regarding its conductivity, TP, and TAN, which can be classified as oligotrophic. CONAMA Resolution 357/2005 establishes a maximum 30 µg L^{-1} of TP and 3500 µg L^{-1} of TAN (BRASIL 2005). The concentrations of NO_3 and BOD_5 were elevated with low DO contents. In relation to the biotic conditions of the water-supply ponds, a predominance of Rotifera was observed mainly in the fee-fishing farm, and

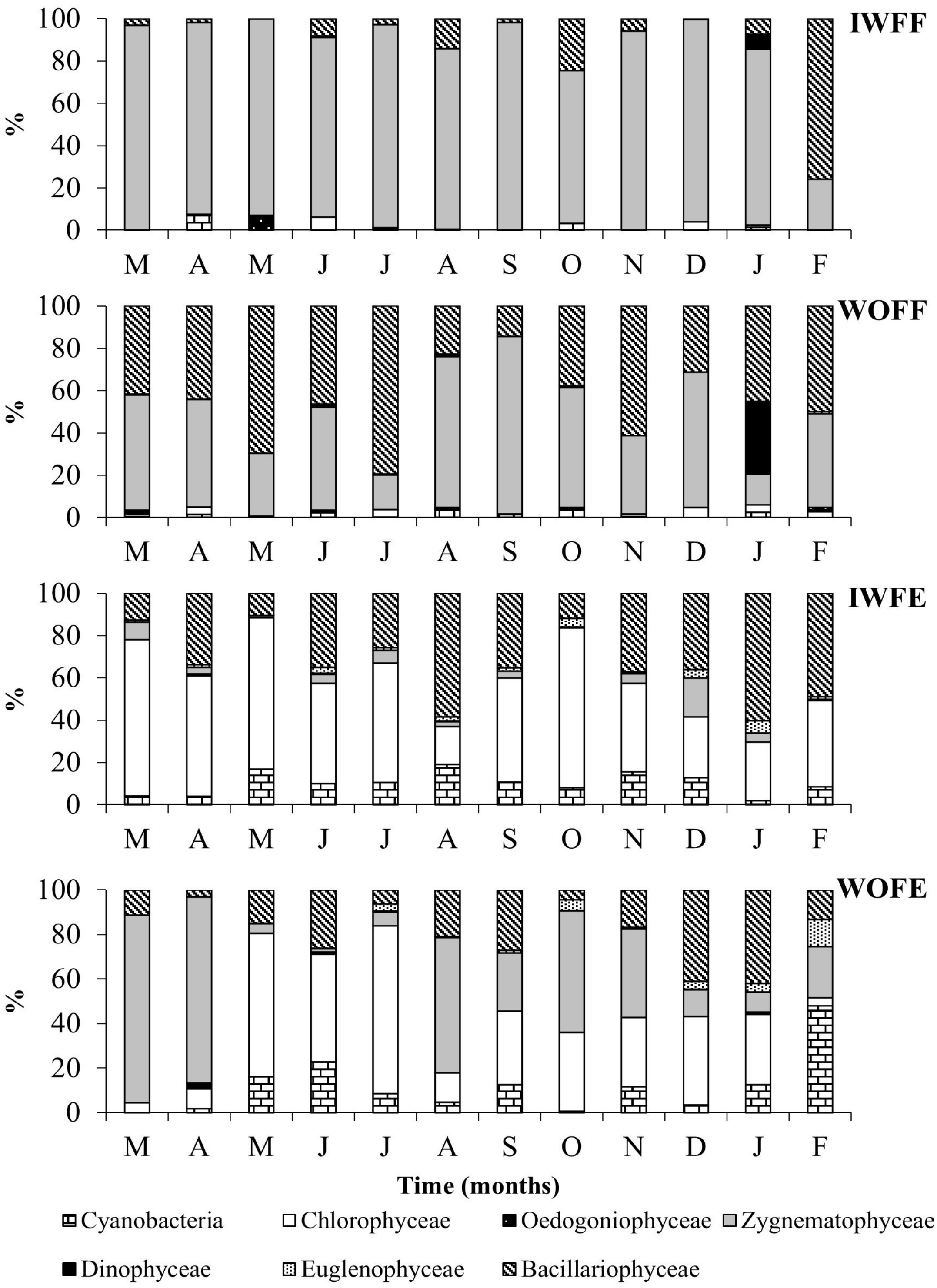

Figure 4. Relative abundance of the phytoplankton assemblages of different sites of both water-supply ponds. Sampling sites: IWFF= inlet water of the fish farm; WOFF = water outlet of the fish farm; IWFE= inlet water of the fee-fishing farm; WOFE = water outlet of the fee-fishing farm.

Zygnematophyceae and Bacillariophyceae in both ponds, associated with low pH and conductivity.

The abundance of plankton is affected by prevailing environmental conditions, nutrients and light conditions (Mutinová *et al.* 2016). However, depending on the type of aquatic plant present in water bodies, specific processes can lead to high concentrations of acidophilic algae, such as

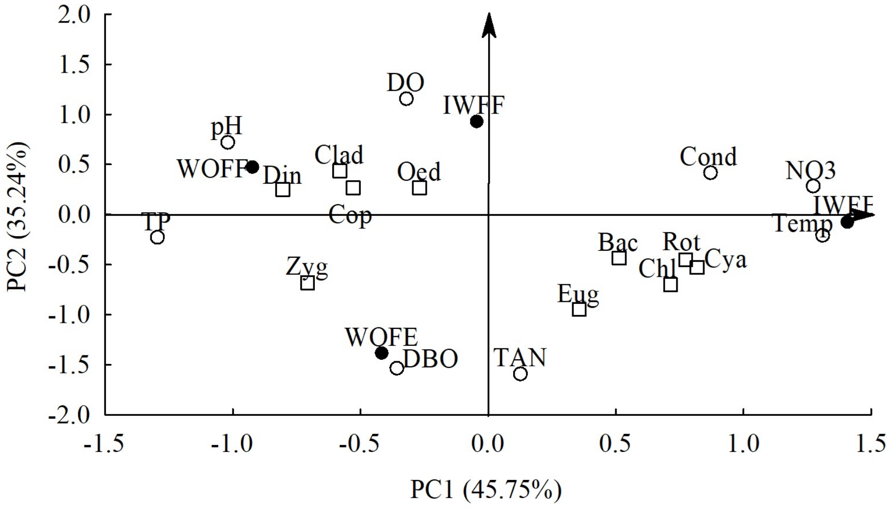

Figure 5. Interpolation of auto-values from the matrix of water variables. First two axes from the principal component analysis (PCA), where: close circle = sampling sites: IWFF= inlet water of the fish farm, WOFF = water outlet of the fish farm, IWFE= inlet water of the fee-fishing farm, WOFE = water outlet of the fee-fishing farm; open squares = biotic variables: Rot = Rotifera, Clad = Cladocera, Cop = Copepoda, Din = Dinophyceae, Zyg = Zygnematophyceae, Oed = Oedogoniophyceae, Eug = Euglenophyceae, Bac = Bacillariophyceae, Chl = Chlorophyceae, Cya = Cyanobacteria; open circle = abiotic variables: Cond = electric conductivity, Temp = temperature, DO = dissolved oxygen, TP = total phosphorus, TAN = total ammonia nitrogen, NO_3 = nitrate and DBO_5 = five-day biochemical oxygen demand.

Table II. Principal Component coefficients.

	PC1	**PC2**	**PC3**
Temperature	0,94	-0,12	0,31
pH	-0,74	0,47	-0,49
Electrical Conductivity	0,62	0,27	-0,73
Dissolved oxygen	-0,23	0,74	0,64
Nitrate	0,91	0,19	-0,36
Total Ammonia- N	0,09	-0,99	-0,07
Total Phosphorus	-0,94	-0,14	-0,32
Biol. Oxygen Demand	-0,26	-0,96	0,06
Cladocera	-0,59	0,45	-0,67
Copepoda	-0,53	0,27	-0,80
Rotifera	0,77	-0,45	-0,45
Cyanobacteria	0,82	-0,51	-0,26
Chlorophyceae	0,71	-0,69	-0,15
Oedogoniophyceae	-0,27	0,28	0,92
Zygnematophyceae	-0,71	-0,66	0,24
Dinophyceae	-0,81	0,25	-0,53
Euglenophyceae	0,35	-0,93	0,05
Bacillariophyceae	0,51	-0,42	-0,75
Variance expl. (%)	45.75	35.24	19.01

Bacillariophyceae and Zygnematophyceae. The low pH observed in the water-supply ponds (4.8 - 6.5) may have selected some microalgae species that are tolerant to acid environments, such as *Mougeotia floridana* (Zygnematophyceae), which was the only dominant species found in the plankton community in the water supply systems.

In the study of Silva *et al.* (2018), the authors evaluated eutrophic ponds and found the highest density of Zygnematophyceae when the electrical conductivity was below 57 µS cm^{-1}, highlighting the ecological preference of this algal group for low-conductivity water. Besides, those authors suggested that some Zygnematophyceae have high ecological tolerance concerning the trophic spectrum. The predominance of Bacillariophyceae, Zygnematophyceae, Cyanobacteria and Rotifera is commonly observed in eutrophic environments; however, some species display high tolerance to different trophic levels, especially in the presence of macrophytes, which offers protection and new habitats.

Ponds that are particularly structured by aquatic vegetation provide varied microhabitats in ponds, which is determinant for the composition of microalgae and zooplankton assemblages, in comparison to open water situations (Celewicz-Goldyn & Kuczynska-Kippen 2017). According to Gutierrez & Mayora (2016), the chemical composition of exudates of different macrophytes directly influences the evasive behavior of zooplankton, and hence its possible habitat selection, which is e.g. verified with *Eichhornia crassipes*, which has strong defensive and competitive abilities.

The fish farm water-supply pond containing free-floating macrophytes (*E. crassipes* and *S. auriculata*) displayed a high diversity of zooplankton, but the phytoplankton species belonging to Rotifera, Bacillariophyceae and Zygnematophyceae were predominant, although Cyanobacteria was found absent or at a lower density throughout the period of which the pond was covered by rooted macrophytes (*T. domingensis*). The highest diversity of species in the water-supply pond covered by free-floating macrophytes can be explained by the production and release of chemical compounds by *Salvinia* sp., as the chemical recognition of each plant by zooplankton species is more related to a specific combination of allelochemicals than the total concentration of these compounds in the exudate (Gutierrez & Mayora 2016). Nevertheless, Rojas & Hassan (2017) suggested that some diatoms have a predominantly physical relation with the environment instead of chemical interactions, which are mainly driven by area, microstructure and complexity of the macrophytes surface, as well as light intensity between both sides of the leaves.

Cladocera and Copepoda species were present throughout the sampling period in the fish farm, with Cladocera presenting a predominance of 100% in April and November at the IWFF. In these months, phytoplankton species were represented by members of the family Zygnematophyceae (densities > 90%), Bacillariophyceae and Cyanobacteria, both displaying relative abundances below 7%. Among the micro-crustaceans, Copepoda is known to be selective in terms of food type, and is able of manipulating phytoplankton particles, thus selecting high-quality cells of those microalgae that do not provide high-energy gains (Silva *et al.* 2019). In the fish farm, where micro-crustaceans were present throughout the entire sampling period, the high abundances of Copepoda and Cladocera species were due to the capacity to explore these microalgae. It is noteworthy that the composition of zooplankton remained unchanged during the sampling period.

Generally, all planktonic species of the analyzed community had a different response when facing the environmental shifts, regardless of the health status of aquatic plants (Gutierrez & Mayora 2016). Aquatic plants in shallow ponds are found within a complex structure of interactions with the abiotic environment, the living biota and handling practices in the pond (Francová *et al.* 2019).

The principal components analysis revealed that in the pond containing rooted macrophytes, the water outlet (WOFE) was associated with higher values of DBO_5, TAN and Euglenophyceae, demonstrating that the presence of these macrophytes modified the quality of the inlet water of the system (IWFE), which in turn was associated with higher values of nitrate, electrical conductivity, Rotifera, Cyanobacteria and Chlorophyceae. In the pond containing floating macrophytes, an increment of TP and higher pH were observed in the water outlet (WOFF), which was associated with a higher quantity of Dinophyceae and Zygnematophyceae.

Despite the hypothesis of this study, the results indicated that both free-floating (*S. auriculata* and *E. crassipes*) and rooted (*T. domingensis*) macrophytes, exerted an effect on the community structure at the aquaculture farms, with a dominance of Rotifera, Bacillariophyceae and Zygnematophyceae in the presence of rooted macrophytes, and a high diversity of zooplanktonic species in the presence of free-floating macrophytes covering the water-supply pond. However, when rooted macrophytes were abundant, Cyanobacteria species were present, with the highest relative abundance (48%) being observed in February, at the end of the rainy season. Conversely, when the water-supply pond was covered by free-floating macrophytes, Cyanobacteria were less abundant.

The presence of macrophytes in water-supply ponds of aquaculture farms is an interesting tool that should be further studied, as it causes beneficial effects on biotic and abiotic parameters of the water, reducing nutrients concentrations and electrical conductivity. Even though low DO and pH does not affect fishponds' supply, these systems received allochthonous and autochthonous loads that might change these variables to acceptable values. Therefore, supplying water to fishponds coming from other ponds with aquatic plants and microorganisms is a way of improving this valuable natural resource, as the equilibrium between primary and secondary producers favors the water abiotic conditions, thus reflecting positively in fish production.

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