Effect of floating macrophyte cover on the water quality in fishpond

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ABSTRACT. A study was conducted during 23 days in order to evaluate the impact of floating aquatic macrophyte on the water quality of a fishpond. Water samples were collected in four points, three inside the pond and one in water inlet. Drastic reduction of dissolved oxygen was observed in the pond, down to 0.87 mg/L. No significant differences ($P > 0.05$) were observed for total CO_2, nitrite and ammonia with respect to inlet water (P_1) and inside the pond (P_2, P_3 e P_4). Chlorophyll ***a*** displayed an inverse relationship with phosphorus. Among nitrogen compounds, ammonia presented the highest concentrations except in water inlet where nitrate was higher, 513.33 μg/l, as well as the highest conductivity values. The pH was slightly acid. The results obtained showed that the macrophyte cover promoted an adverse effect in the medium. Under control, aquatic plants might impact positively due to its capacity to reduce total phosphorus and nitrate in the water column as observed in this study.

Key words: fishpond, macrophytes, water quality, aquaculture

RESUMO. Efeito da cobertura de macrófitas flutuantes na qualidade da água em um viveiro de piscicultura. Com o objetivo de avaliar o impacto das macrófitas aquáticas flutuantes na qualidade da água em um viveiro de piscicultura, foi realizado um estudo durante 23 dias consecutivos com coletas de água realizadas em quatro pontos, sendo três dentro do viveiro e um à entrada de água. Foi verificada uma redução drástica do oxigênio dissolvido dentro do viveiro, chegando a 0.87 mg/L. Não foram observadas diferenças significativas ($P > 0.05$) para o CO_2 total, nitrito e amônia em relação à água de entrada (P_1) e à água do viveiro (P_2, P_3 e P_4). A clorofila **a** apresentou uma relação inversa com o fósforo na água. Dentre os compostos nitrogenados, a amônia apresentou as maiores concentrações, com exceção do ponto de entrada (P_1), em que o nitrato foi mais elevado, com 513.33 μg/L, apresentando os maiores valores para condutividade. O pH manteve-se ligeiramente ácido no viveiro, influenciando diretamente as concentrações de CO_2 livre na água. Os resultados obtidos evidenciaram que a cobertura de macrófita flutuante promoveu um efeito adverso no meio. Se esta cobertura for utilizada de forma controlada, as plantas aquáticas poderão ter um efeito de impacto positivo, devido à capacidade de redução do fósforo total e nitrato na coluna d'água, como observado neste estudo.

Palavras-chave: viveiros, macrófitas, qualidade da água, aqüicultura.

Introduction

Fishponds are systems that work on the limit of their capacity; therefore they are appropriate for the appearance and development of aquatic plants, with large amounts of nutrients and particles in suspension.

In general, aquatic plants in aquaculture are seen as prejudicial to the system. However, if well monitored they have multiple uses, such as biofilter, fish feeding, non-pollutant agent, turbidity reducing agent, and since they compete with algae for nutrients they may also help to reduce algae bloom. They also eliminate pathogens due to their anti-bacterial action and provide a large number of ecological niches for several microorganisms (Hammer, 2000).

Aquatic plants contribute to nutrient transformation by a setting of the physical, chemical and microbial processes besides removing nutrients for their own growth. They offer mechanical resistance to the flow, increase retention time and facilitate setting of suspended particles. They improve conductance of the water through the soil as the roots grow and aerate spaces after death.

Some plant species produce large amounts of carbon that are able to support heterotrophic microbes important in nutrient transformations. Macrophytes roots and floating plants are the primary producers supporting all the other lives in the system (Gopal, 1999).

Ecological theory has long recognized the possibility that ecosystems may have multiple stable equilibria which can differ drastically from one another. However, environments with intermediate input of nutrients and high transparency are appropriate for aquatic plants (Smarth *et al.*, 1996).

Most comparative studies of plant and fish abundance conclude that intermediate vegetation levels, including 10 – 40% coverage of study sites, including areas ranging from individual coves to entire water bodies, promote high species of richness and are optimal for growth and survival (Dibble *et al*., 1996).

In eutrophic systems such as fishponds, aquatic plants tend to propagate quickly and to cover the entire surface of the pond, mainly due to lack of adequate management that impacts these systems negatively.

The common forms of integration are those in which there is a simple and direct link between management and adequate use of aquatic plants in the systems. Knowledge of the ecology of these plants is essential to redefine new technologies and solve some of the existing problems, mainly with respect to excess nutrients in the medium.

The objective of this work was to evaluate the effect of floating macrophyte in water quality when the pond was completely covered by aquatic plants of the type *Eichhornia crassipes* and *Salvina* sp.

Material and methods

Study area and data

The project was developed at Aquaculture Center of "Universidade Estadual Paulista" ($21^0$15' S; $48^0$18' W), Jaboticabal, São Paulo state, Brazil. The continuous flow fishpond had a 27-day residence time and surface area of 2.305.67 m^2, a maximum depth of 1.7 m, mean depth of 1.47 m and volume of 3.396.8 m^3.

The fishpond was populated with adult *Brycon cephalus* (Matrinxã), *Pseudoplatystoma corruscans* (Pintado) and *Piaractus mesopotamicus* (Pacu), a total of 134 fish. The fish were fed daily with 27% crude protein (20 kg/d).

The study was conducted during fish peak production and high precipitation in a pond totally covered by floating aquatic macrophyte, represented by *Eichhornia crassipes* and *Salvinia* sp., in such a way that the first occupied only the first 30 m of the fishpond (Figure 1).

Water samples were collected at the surface using a 5 L Van Dorn bottle. Samples were taken during 23 consecutive days from February to March 2001, at 09:00 a.m., in four different locations assigned for sample collection: P_1= water inlet and P_2, P_3, P_4= inside the fishpond (Figure 1).

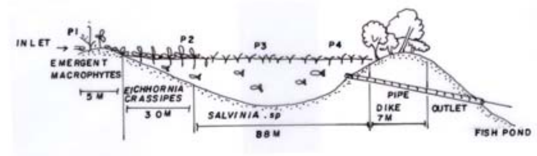

Figure 1. Systems transect of the fishpond studied, where P_1-P_4 refer to water collecting points as follows: P_1= pond water inlet and P_2-P_4= collecting points inside the pond

The limnological characteristics that were analyzed are shown in Table 1. Only the variables temperature, pH, electrical conductivity and dissolved oxygen were measured "*in situ*".

Table 1. Limnological characteristics analysed

Limnological characteristics	Methods
Dissolved Oxygen	Horiba U 10
Temperature	Horiba U 10
pH	Horiba U 10
Electrical Conductivity	Horiba U 10
Total Alkalinity and Inorganic Carbon	Mackereth *et al.* (1978)
Ammonia	Koroleff (1976)
Nitrite, Nitrate, Total Phosphorus and Orthophosphate	Golterman *et al.* (1978)
Chlorophyll **a**	Nush (1980)

Statistical analysis

Limnological characteristics were analyzed in two points to verify if there was difference between the inlet water (P_1) and the water inside the pond (P_2, P_3 and P_4). Since bodies of water are dynamic systems, samples collected during the 23-days period were considered replicates. The number of replicates was standardized to 23 inside the pond and replicates were obtained using random numbers. When estimated variances for each limnological characteristics were heterogeneous the Mann-Whitney test for large samples was used (Siegel, 1975), and when homogeneous t test (Fowler *et al*, 1998), both at significance level of 0.05.

Water conditions inside the pond were evaluated at points P_2, P_3 and P_4. A homogeneity test was used for each limnological characteristic (Fowler *et al*, 1998). Homogeneous variances were analyzed using ANOVA one-way (Fowler *et al.*, 1998). The non-parameter Friedman test for k-correlated samples (Siegel, 1975) was used for heterogeneous variances.

Results

No significant differences ($P>0.05$) were observed when comparing limnological characteristics between water inlet and water from the pond covered with floating macrophyte for total CO_2, nitrite and ammonia. In general, variances were heterogeneous with exception of nitrite and orthophosphate ($P\text{-}PO_4$) (Table 2).

The values for alkalinity, conductivity, dissolved oxygen (DO), temperature, $P\text{-}PO_4$, total phosphorous (TP), pH, nitrate, carbonate and bicarbonate were higher for water inlet (P_1). Inside the pond (P_2, P_3 and P_4) chlorophyll ***a*** and Free CO_2 pretended higher values (Table 2).

DO, pH, conductivity, alkalinity, bicarbonate, carbonate, and nitrate presented higher levels at the inlet (P_1), but tended to diminish inside the pond. Among the studied limnological characteristics only temperature was homogeneous at about 25 ± 1^0C during the experimental period (Table 2).

Table 2. Results of analysis of water limnological characteristics at P_1 and P_2 – P_4, where: mn= median value, md= average value, var= variance, F= value of variance homogeneity test, Z= value of reduce score, t= t test value, *= significant and ns= non-significant

Limnological Characteristics	P_1	$P_2 - P_3 - P_4$	F	Z,t
Alkalinity	mn= 104.2 var= 801.7	mn= 63.8 var= 83.5	9.6*	4.54 ($P<0.01$)*
Chlorophyll ***a***	mn= 12.0 var= 88.2	mn= 39.9 var= 4660.4	52.9*	4.7 ($P<0.01$)*
Total CO_2	mn= 153.1 var= 711.6	mn= 138.3 var= 217.2	3.27*	-1.62 ($P<0.05$)*
Conductivity	mn= 120.0 var= 287.8	mn= 87.0 var= 56.7	5.07*	-4.7 ($P<0.00003$)*
Nitrite	mn= 6.87 var= 4.48	mn= 7.69 var= 5.51	1.23 ns	1.22 ($P>0.05$) ns
Dissolved Oxygen	mn= 4.8 var= 1.3	mn= 0.96 var= 0.5	2.54*	-5.81 ($P<0.00003$)*
Temperature	mn= 26.1 var= 0.6	mn= 25.6 var= 0.22	2.64*	-1.97 ($P<0.02$)*
Orthophosphate	mn= 49.8 var= 457.6	mn= 28.1 var= 531.3	1.16 ns	11.2 ($P<0.05$)*
Total Phosphorus	mn= 59.9 var= 494.1	mn= 43.1 var= 5833.7	11.8*	-5.09 ($P<0.00003$)*
pH	mn= 7.2 var= 0.09	mn= 6.36 var= 0.007	12.7*	-16.3 ($P<0.00003$)*
Nitrate	mn= 494.2 var= 67284.2	mn= 53.9 var= 1721.7	39.1*	5.34 ($P<0.00003$)*
Ammonia	mn= 85.5 var=1451.1	mn= 91.2 var= 5334.9	3.68*	0.74 ($P>0.23$) ns
Carbonate	mn= 0.1 var= 1.1	mn= 0.01 var= 0.021	51.7*	-2.29 ($P<0.01$)*
Free CO_2	mn= 14.1 var= 339.8	mn= 57.48 var= 115.8	2.93*	4.84 ($P<0.01$)*
Bicarbonate	mn= 130.0 var= 24.9	mn= 82.1 var= 84.7	3.59*	4.87 ($P<0.01$)*

DO decreased markedly inside the pond varying from 0.87 to 1.12 mg/L, when compared to P_1 probably due to the slope at the water inlet, the concentrations increased to an average of 5.24 mg/L (Table 3).

At the water inlet (P_1) pH was alkaline and for the other sampling points was acid, varying from 6.32 to 6.64, with the lowest values inside the pond (P_2, P_3, P_4), influencing directly free CO_2 concentrations in the fishpond. The high concentrations of free CO_2 inside the pond may be associated with the acid pH of the medium (Table 3).

Among inorganic carbons, bicarbonate was the most abundant and displayed behavior similar to alkalinity, that is, higher concentrations at the inlet (P_1) and lower at P_2, (Table 3).

Conductivity displayed behavior similar to alkalinity and bicarbonate, high concentrations at the fishpond inlet (P_1) and markedly reduction at P_2, while oscillating inside the fishpond between 84.78 and 95.30 μS/cm (Table 3).

TP concentrations inside the pond varied slightly, with higher values at P_1 the inlet, average of 65.43 μg/L. Inside the fishpond, the highest average concentration was found for P_4, average of 61.05 μg/L and lower values at points P_2 and P_3, average values were 42.18 and 42.09 μg/L (Tables 2 and 3).

As for $P\text{-}PO_4$, the available form of phosphorus in the water, the behavior was similar to TP, displaying high concentrations at the inlet (P_1), average of 56.82 μg/L tending to decrease further on and increasing again. The lowest average value was observed at P_3 with 19.03 μg/L and highest values in fishpond was at P_4 an average of 43.14 μg/L (Tables 2 and 3).

An inverse relationship was observed between TP and $P\text{-}PO_4$ with chlorophyll ***a*** during the period. The lowest value of chlorophyll ***a*** was observed for the water inlet, increased markedly at P_2 and P_3 and decreased at P_4. P_2 and P_3 presented average values six times higher than P_4, 64.02, 69.79 and 20.82, respectively (Table 3).

Among nitrogen compounds, ammonia displayed the highest concentrations and nitrite the lowest. However, nitrate peaked at the inlet (P_1) with a value of 513.33 μg/L while ammonia was 82.62 μg/L. Nitrate levels decreased markedly inside the pond, with the highest average value at P_2, 126.94 μg/L and the lowest at P_3, 38.49 μg/L (Tables 2 and 3).

Ammonia and nitrite displayed higher concentrations at P_2, 155.15 and 10.38 μg/L, respectively. Nitrite displayed the lowest concentrations at inlet (P_1) 6.87 μg/L (Tables 2 and 3).

Table 3. Results of analysis of water limnological characteristics inside the pond, where: mn= median value, md= average value, var= variance, F= value of variance homogeneity test, F_2= ANOVA test value, x^2_r= Friedman test value, *= significant (P<0.05) and ns= non-significant (P>0.05)

Limnological characteristics	P_2	P_3	P_4	F	F, x^2_r
Alkalinity	mn= 58.4 var= 8.26	mn= 62.4 var= 11.68	mn= 75.4 var= 96.32	11.66 (P<0.05)*	28.43 (P<0.05)*
Chlorophyll **a**	mn= 45.52 var= 2817.1	mn= 49.6 var= 3112.35	mn= 20.4 var= 176.37	17.65 (P<0.05)*	16.7 (P<0.05)*
Total CO_2	mn= 132.85 var= 227.06	mn= 147.03 var= 137.6	mn= 158.38 var= 473.32	3.44 (P<0.05)*	15.74 (P<0.05)*
Conductivity	mn= 79.0 var= 43.03	mn= 85.0 var= 9.72	mn= 95.0 var= 7.22	5.96 (P<0.05)*	34.7 (P<0.05)*
Nitrite	mn= 10.10 var= 1.74	mn= 6.7 var= 5.11	mn= 6.8 var= 8.56	4.92 (P<0.05)*	55.33 (P<0.05)*
Dissolved Oxygen	mn= 0.87 var= 0.31	mn= 1.12 var= 0.81	mn= 1.01 var= 0.48	2.67 (P>0.05) ns	0.068 (P>0.05) ns
Temperature	mn= 25.75 var= 0.20	mn= 25.49 var= 0.14	mn= 25.78 var= 0.15	1.44 (P>0.05) ns	3.02 (P>0.05) ns
Orthophosphate	mn= 29.55 var= 633.51	mn= 19.03 var= 398.2	mn= 23.76 var= 428.92	1.59 (P>0.05) ns	1.26 (P>0.05) ns
Total Phosphorus	mn= 42.19 var= 16.5	mn= 42.01 var= 32.28	mn= 42.1 var= 24.75	1.96 (P>0.05) ns	0.003 (P>0.05) ns
pH	mn= 6.36 var= 0.01	mn= 6.33 Var= 0.004	mn= 6.43 var= 0.005	0.44 (P>0.05) ns	0.065 (P>0.05) ns
Nitrate	mn= 126.93 var= 1504.1	Mn= 38.49 Var= 515.03	mn= 51.94 var= 633.41	2.92 (P>0.05) ns	59.09 (P<0.05)*
Ammonia	mn= 141.1 var= 7128.9	Mn= 88.1 Var= 3363.3	mn= 64.9 var= 1014.9	6.84 (P<0.05)*	15.91 (P<0.05)*
Carbonate	mn= 0.01 var= 0.021	Mn= 0.01 Var= 0.001	mn= 0.02 var= 0.57	629.8 (P<0.05)*	8.43 (P<0.05)*
Free CO_2	mn= 54.56 var= 213.46	Mn= 60.67 Var= 74.32	mn= 52.22 var= 160.67	2.87 (P<0.05) ns	2.95 (P>0.05) ns
Bicarbonate	mn= 79.56 var= 39.63	Mn= 82.88 Var= 51.88	mn= 94.64 var= 158.31	4.00 (P<0.05)*	26.17 (P<0.05)*

Table 3 shows the points located inside the pond and indicates differences among average concentrations for alkalinity, nitrite, nitrate, ammonia, carbonate and bicarbonate.

In the studied ponds, the space covered by *E. crassipes* presented lower average concentration for P-PO_4, total CO_2, bicarbonate, alkalinity, conductivity and DO. In general, the space covered by *Salvinia* sp. presented higher average values of limnological characteristics with exception chlorophyll ***a*** and nitrogen compounds (Table 3).

Discussion

The culture systems at Aquaculture Center, Unesp, are equipped with continuous water flow, that is, water flows from one pond to another without any previous treatment. However, the studied pond is the only one to present a bank of emerging macrophytes at the pond entrance (P_1), which worked as a biofilter, decreasing the values of limnological characteristics at P_2 inside the pond, besides being the only point covered by *E. crassipes*. The limnological variables that presented this reduction were nitrate, DO, TP, P-PO_4, conductivity, alkalinity, bicarbonate, carbonate and further on they presented fluctuations inside the pond.

The variable that reduced markedly inside the pond and remained at critical level was DO, probably due to excess breathing of the plants and fauna associated with macrophytes and fish breathing as well.

According to Gopal (1999) floating plants may eliminate completely oxygen from the water column, promoting, thus, reduction processes in the medium.

Results of pond monitoring showed that ponds with wetlands had dampened daily fluctuations in dissolved oxygen and reduced levels of photosynthetic pigments, compared to control ponds (Maussaut, 1999).

Chlorophyll ***a*** in the pond, contrary to the observations cited above by the author, presented high concentrations at P_2 and P_3 and an abrupt reduction further on at P_4.

The low DO levels in the medium reduced nitrate inside the pond, when DO concentrations are below 0.2 mg/L, as seen here, aerobic bacteria use nitrate as electron final acceptor in the denitrifying process (Bratvold and Browdy, 2001). The denitrifying process also influences pH and, if proteins are metabolized by the fish, breathing final products after amino acid hydrolysis are ammonia and bicarbonate (Boely *et al*., 2000).

Probably, this explains higher ammonia concentrations inside the pond and lower nitrite, as well as the dominance of bicarbonate among inorganic carbons present.

Ammonia is used by aquatic plants. However, in this study they tended to present higher concentrations inside the pond probably due to low pH, favoring, thus, the appearance of NH_4^+, which is not toxic to aquatic plants (McMurtry *et al*., 1997).

Generally, the floating plants can obtain inorganic nutrients from the water column, displaying an inverse relationship with pH, that is, increasing pH decreases plant density in the medium (Forchhammer, 1999).

According to Kioussis *et al.* (2000) to reach equilibrium among nitrogen compounds in the medium at least 0.03 mg/L of nitrite, less than 1.1 mg/L of nitrate and 2.6 mg/L of $P\text{-}PO_4$ is recommended. In this study all compounds were below the limits recommended by this author.

During the period, there was no nitrogen compound reduction at P_2, which was covered with *Eichhornia crassipes*. This plant displays great ability to absorb high nutrient concentrations from the medium, and absorption levels are related to plant growth conditions (Gopal, 1999).

In this study the low efficiency of nitrogen compound absorption in the local covered by *E. crassipes* was probably associated with plant size and space, since a large number of plants was in state of leaf decomposition. In addition, macrophytes have the capacity to store nitrogen and phosphorus in reserve organs after fruiting stage, which varies according to species, local and season (Ennabili *et al*., 1998).

Boyd and Queiroz (1997) verified that aquatic plants in biofilter systems were capable of removing 94% of nitrite and 97% of phosphorus. However, the soil was responsible for higher removal of phosphorus from the water.

Environmental education is one of the main factors for adequate management of farming systems of aquatic organisms, leaving aside old practices and customs that lead to eutrophication and deterioration of the water quality, due to lack of understanding of how such systems work. Aquatic plants impact negatively the fishpond if precautions are not observed such as total coverage of the fishpond by the plants. However, if well managed, native aquatic plants work as a great ally in such fish farming systems, and may become a support in modern aquaculture through new technologies.

According to Maussaut (1999) a fishpond with 25% of covered area and a residence time of two days presented good water quality inside and at the pond outlet.

Our data suggest that due to sudden reduction of DO, medium acidification and increasing levels of ammonia, chlorophyll ***a*** e free CO_2 in the water column, macrophytes caused an adverse effect although no fish death was observed during the period. However, these plants reduced efficiently levels of nitrate, conductivity, TP and $P\text{-}PO_4$ thus indicating that when *E. crassipes* and *Salvinia* sp. are used in a controlled way, that is, below the limit of 25% of the total area of the pond, they may avoid the negative impact on the water quality and consequently, will favor fish production.

Suggestions for application of best management practices (BMPs) regarding the appearance floating of aquatic plants in fish farming systems

1. In the studied system, it was observed that aquatic plants close to water inlet acted as a biofilter and therefore had a positive impact on the studied limnological variables.
2. When macrophyte covers the pond surface, the water flow should be increased during 3 to 4 days in order to maintain the water quality and further on.
3. Frequent management should be realized at the water inlet and outlet of the ponds, mainly in systems where the water passes from one pond to another to avoid the eutrophication of the medium.
4. Utilization of floating aquatic plants inside the fishpond should be controlled by using wood frames, PVC, bamboo or tapes to avoid random spreading in the pond and consequently sudden reduction of DO and poor water quality.

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