Limnological variables and their correlation with water flow in fishponds

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ABSTRACT: Limnological variables and their correlation with water flow in fishs. In order to evaluate the effect of water flow on the physical, chemical and biological characteristics of fishs, an intensive sampling was carried out in two ponds and in a channel at CEPTA/IBAMA, in Pirassununga, SP, Brazil, during two months. The ponds had a water volume of 300m^3 and the mean depth of 1 m., receiving in a longitudinally opposite position water from the inlet and exporting by the outlet. Temperature, pH, Secchi disk visibility, electrical conductivity, dissolved oxygen, total organic nitrogen and total phosphorus, suspended material (total, organic and inorganic), chlorophyll-a and phaeophytin, as well as the zooplankton abundance, including the Cladocera, Copepoda, Rotifera and other organisms were determined. Our findings demonstrated the impact of fish cultivation on water quality (increased conductivity and nutrients concentration and, reduction of dissolved oxygen) and the effect that the water flow exerts on the physical and chemical characteristics and on the structure (composition and density) of the populations, by means of direct (wash-out) and indirect effects (alterations in water chemical composition and its relation with food availability).

Key-words: Fish culture; Water flow; Limnology, Zooplankton.

RESUMO: Efeito do fluxo de água nas características limnológicas em viveiros de piscicultura. Com o objetivo de avaliar os efeitos do fluxo da água nas características físicas, químicas e biológicas em viveiros de piscicultura, foi realizado no CEPTA/IBAMA, em Pirassununga - SP, um trabalho experimental durante dois meses, em viveiros de terra, com volume de 300 m^3 de água, profundidade média de 1 metro e sistemas de entrada e saída de água opostos longitudinalmente. As variáveis analisadas foram temperatura, pH, transparência da água, condutividade elétrica, oxigênio dissolvido, nitrogênio e fósforo total, material em suspensão (total, orgânico e inorgânico), clorofila a e feofitina, além do zooplâncton, considerando-se os grupos Cladocera, Copepoda, Rotifera e outros organismos. Os resultados obtidos demonstram não somente o impacto do cultivo de peixes na qualidade da água (aumento da condutividade e da concentração de nutrientes e redução de oxigênio dissolvido), mas também o efeito que o fluxo de água exerce nas características físicas e químicas da água, bem como na estrutura (composição e densidade) das populações, por meio do efeito direto (wash-out) e indireto (alterações na composição química da água e sua relação com a disponibilidade alimentar).

Palavras-chave: Piscicultura; Fluxo de água; Limnologia, Zooplâncton.

Introduction

Since the increase of food demand, intensive fish culture systems has been used aiming a high productivity. For this purpose, monoculture with high fish stocking density and water exchange has been used, because food is supplied in function of fish biomass, stocking density and water temperature. As water quality becomes a limiting factor, the continuous renewal is used for elimination of metabolic and alimentary residues (Sipaúba-Tavares, 1995). Therefore, water flow becomes a dilution factor of chemical and biological components, modifying the communities structure and internal processes of the system.

Fish farming ponds are shallow and dynamic ecosystems, with limited space, extremely susceptible to meteorological factors (mainly wind), besides the outflow and low water residence time. These environments present short-term stratification in the dependence of the period of the year, of the pond morphometry and of the implanted fish biomass (Costa Neto, 1990). The interactions of physical, chemical and biological factors, and the transformation of organic and inorganic substances in fish ponds must to be know in order to found solutions to increase the production of fish biomass and to generate knowledge about the causes of its decline (Mabaye & Taussig, 1973).

Among the several factors affecting ponds, biomass of cultivated fish and water flows are the main power functions (Krom et al., 1989; Pereira, 1998; Eler, 2000; Drapcho & Brune, 2000). Water flow acts as a controlling element of dissolved oxygen, nutrient concentration and autochthonous organic matter production. One of the main problems in fishponds is generated by the great amount of food that is not used by the fish, which is available to the growth of algae and bacteria (Sipaúba-Tavares, 1995).

Outflow effects on the residence time of water have become essential to the understanding of the internal processes of artificial systems. In the case of fish farming, Sipaúba-Tavares (1995) evidenced an effect on the fertilization and the calcium carbonate application since,in the dependence of the water flow, it can be lost even before the action on the dynamics of the aquatic ecosystem. Besides, the movement produced by the water inflow and outflow, as well as the wind, contributes to the organisms' distribution accounts variation of physical and chemical factors.

In fish farming ponds at the Center of Aquiculture of UNESP, Jaboticabal-SP, Yoshida (1996) compared systems without water renewal and a system with artificial aeration and concluded that the continuous water flow was a decisive factor in maintenance of water quality in Tilapia cultivation. According to Yoshida (1996) a large accumulation of organic matter, nutrients and chlorophyll a occurs in ponds without water renewal.

Although water flow is a decisive factor in the dynamics of fish farming ponds, most of the researches are still directed to the biomass production. Studies about ecological interactions and the impact of fish farming in the water resource, as well as the outflow effect on the limnological variables, are still scarce (Sipaúba-Tavares, 1995; Pereira, 1998; Eler, 2000). The aim of the present study was to evaluate the physical, chemical and biological changes in fish farming ponds and their relationship with water flow.

Material and methods

The experimental work was developed in at Center of Training and Research in Aquiculture (CEPTA/IBAMA), Pirassununga-São Paulo, in two rectangular ponds (Ponds 1 and 2) with $300m^3$ water volume and 1 m mean depth. The ponds were supplied by water from an 5 ha reservoir. Water supplied to the ponds was also sampled, at a station called "channel" .

In the fishponds, Brycon cephalus (matrinchã), from the Characidae family (an omnivorous feeding fish, having excellent conditions for rearing in captivity), was stocking with a mean weight of 400g (Coefficient of variation = 15%). The fishes were fed with pelletized meal (26% of protein and 2,600 Kcal of digestive energy estimated for each kg of ration), supplied daily "ad libitum", in the morning. The fish stocking density was 3 individuals / 2 m^3, and the water flows ranged from 60 to 173 L/min for the pond 1 and from 60 to 301 L/min for the pond 2. The outflow discharges (in liters per minute) were obtained through the time of filling of a bucket of a known volume.

The water sampling for physical, chemical and biological analyses (chlorophyll a and zooplankton) was carried out during two months (from December, 1996 to January, 1997), daily (during 12 days) in the period of pond filling and before the insertion of the fish, every other days. The samples were collected in channel and in the central area of the pond (at approximately 0.5m deep).

Temperature and dissolved oxygen (DO analyzer YSI, model 57), conductivity (conductivity analyzer YSI, model 33-SC T meter), pH (Micronal B278), transparency (Secchi disk), total, organic and inorganic suspended material (using a gravimetric technique, described in Teixeira et al., 1965), total organic nitrogen (Golterman et al., 1978), total phosphorus (APHA, 1995), chlorophyll-a and phaeophytin (Nusch, 1980), were measured. The abundance zooplankton (Cladocera, Copepoda and Rotifera), and the biomass of phytoplankton - the chlorophyll-a (gravimetric method according to Teixeira et al. (1965) and Wetzel & Likens, (1991) were also determined.

Daily values of the wind speed (measured with a anemometer Windwed of R. Fuess), air temperature and precipitation (data from the Meteorological Station of the Air Force Academy, in Pirassununga/SP), were obtained for the study period.

Results

Climatological variables

The mean air temperature ranged from 21 to 27°C, and the maximum, minimum and mean values were 33, 16 and 24.5°C, respectively, throughout the sampling period. The total precipitation from December 1996 to January 1997 was 566.4 mm and the daily values ranged from 0 to 76.4 mm. The highest and the lowest values for wind speed were 84.76 Km/h and 0.01 Km/h, respectively.

Physical, chemical and biological variables of the water

The water supply to the fish farming ponds was directly influenced by its availability at the inflow, depending on the rain occurrence in the area. The initial outflow was of 60 L/min from days 1 to 7, increasing to 120 L/min at day 8, and remained constant until the 19th day at the end of sampling (day 62). The outflows were 173 and 301 L/min in ponds 1 and 2, respectively (Fig. 1). Low content of dissolved oxygen (‹1.0 mg/L) was detected during the high outflow period in the two ponds (Fig. 2).

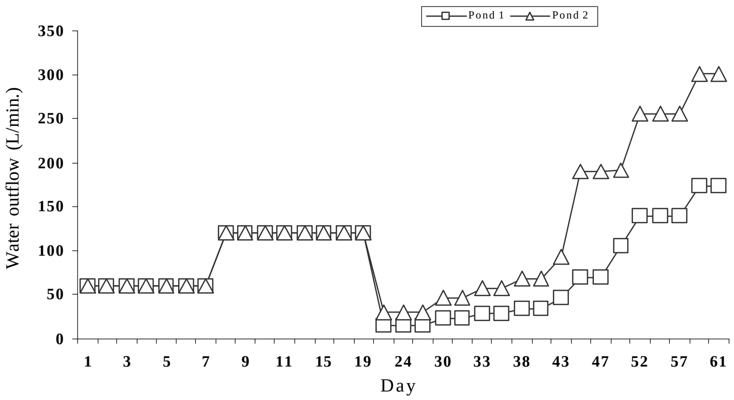


Figure 1: Water outflow (L/min.) in Ponds 1 and 2 during the sampling period.

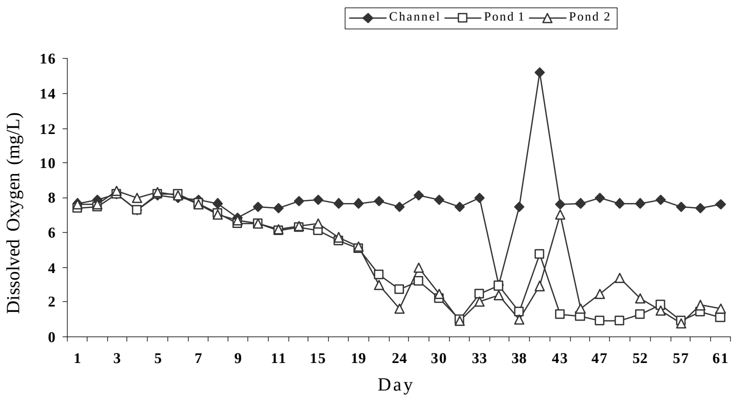


Figure 2: Temporal variation of dissolved oxygen (mg/L) in the Channel and Ponds 1 and 2.

No significant variation in the water temperature ranges was found in three studied sites (Tab. I)

The dissolved oxygen in channel varied between 6.8 and 14 mg/L, a typical lotic characteristic. In the two ponds, sharp reduction in oxygen concentration was recorded from 15th day, after the fish stocking (Fig.2).

Electrical conductivity in the channel ranged from 8 to 13 mS/cm in the major part of time and was smaller than in the ponds (Fig. 3). In the period of high concentrations of chlorophyll a (Fig. 4), and low outflow (between 15 and 60 L/min.), there was a decrease in the values of electrical conductivity. The ranges in ponds 1 and 2 were smaller than in channel (Tab. I).

The water from the channel and ponds was moderately acidic in almost the whole experimental period, except, on the 8th day in channel, that presented a pH close to neutral (7.5). The minimum recorded value of pH was 5.7 (channel and pond 2), and the maximum values were 7.5 (channel) and 6.9 (pond 1). The water transparency attained the bottom of the ponds.

Table I: Water temperature, dissolved oxygen, electrical conductivity, pH, total organic nitrogen, total phosphorus, chlorophyll a, phaeophytin, total suspended material (TSM), organic suspended material (OSM) and inorganic suspended material (IMS) in the channel (inlet), and pond 1 and 2 (maximum, minimum and mean values in the study period).

Variables	**CHANNEL**			**POND 1**			**POND 2**		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Temperature (°C)	26.5	24.0	24.9	28.6	23.0	26.5	28.5	24.0	26.4
Dissolved oxygen (mg/L)	15.2	3.0	7.7	8.2	0.9	4.2	8.4	0.8	4.5
Conductivity (mS/cm)	13.0	5.0	10.3	39.0	15.0	24.9	30.0	10.0	20.3
pH	7.5	5.7	6.4	6.9	5.9	6.3	6.8	5.7	6.1
Total Organic Nitrogen (mg/L)	3.4	0.4	1.7	2.5	0.5	1.5	2.2	1.2	0.4
Total Phosphorus (mg/L)	34.8	2.7	20.5	234.7	20.7	114.4	288.9	12.8	110.7
Chlorophyll a (mg/L)	11.1	1.1	5.2	55.8	0.7	7.8	97.7	1.1	20.3
Phaeophytin (mg/L)	9.0	0.6	3.9	28.2	0.7	5.2	11.0	0.4	4.2
T.S.M. (mg/L)	19.4	3.0	9.4	53.6	0.4	7.1	9.2	1.5	5.5
O. S. M. (mg/L)	7.5	1.5	4.5	49.4	0.0	5.1	8.0	0.5	3.3
I. S. M. (mg/L)	15.2	0.4	5.5	11.5	0.0	2.4	6.4	0.0	2.4

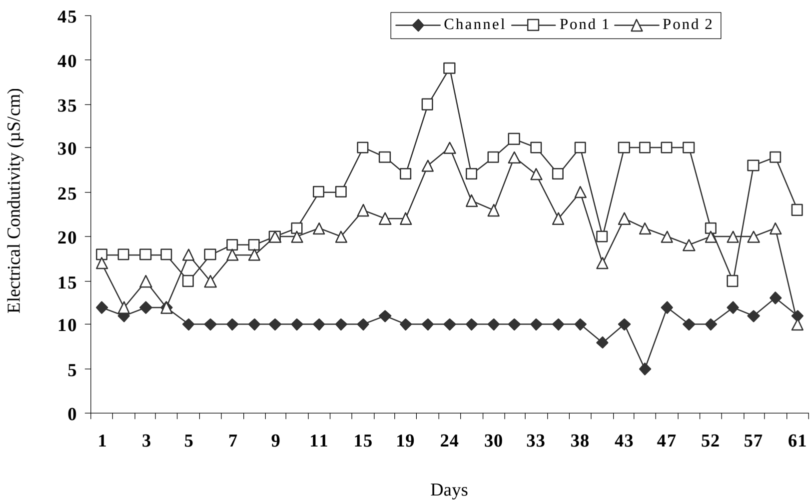


Figure 3: Temporal variation of electrical conductivity in the Channel and the Ponds 1 and 2.

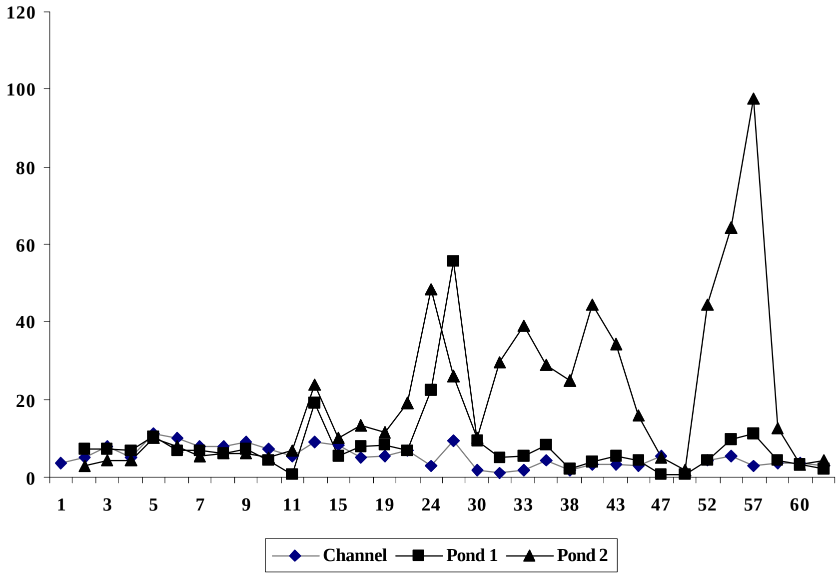


Figure 4: Temporal variation of Chlorophyll (mgL^{-1}) in the Channel and Ponds 1 and 2.

The highest contribution of inorganic material of suspended matter (Tab. I) was found in the channel (from 53 to 78%), while in the ponds the organic fraction predominates (from 35 to 100% in pond 1 and from 10 to 90% in pond 2).

The total organic nitrogen (Tab. I) ranged from 0.4 to 3.4 mg/L (channel); from 0.5 to 2.5 mg/L (pond 1), and from 0.4 to 2.2 mg/L (pond 2). The mean content of total phosphorus was higher in the two ponds, when compared with the channel.

The flow variations influenced directly the chlorophyll a concentrations (Tab. I), varying from 1.1 to 11.1 mg/L in the channel, from 0.7 and 55.8 mg/L in the pond 1 and from 1.1 to 97.7 mg/L in the pond 2. In relation to the phaeophytin, the variation was from 0.6 to 9.0 mg/L in the channel, 0.7 to 28.2 mg/L in the pond 1 and from 0.4 to 11 mg/L in pond 2.

The relative contribution of Rotifera, Cladocera and Copepoda, in the zooplankton assemblage for each site, besides other organisms (insect larvae, Bryozoa, Protozoa and Conchostraca) can be seen in Fig. 5. In the channel (inlet), Rotifera was the dominant group (64%) during the sampling period, while Cladocera, Copepoda and others organisms represented 19, 11, and 6%, respectively.

In the ponds, a low Rotifera density was observed, while those of Cladocera and Copepoda increased significantly after December 10. In pond 1, Rotifera represented only 7% of the total density in the sampling period, while Cladocera represented 47% and Copepoda 47%. In the pond 2, Cladocera represented 46% of the individuals, Copepoda 32% and Rotifera 22%.

The other organisms (mainly insect larvae) presented low contribution inside the ponds, being represented mainly by Protozoa (such as Tecameba).

Significant differences on the zooplankton biomass were found among the channel and the ponds. In channel, the biomass varied between 9.3 and 214.7 mg/L, while it ranged from 32.4 to 1,811.7 mg/L in the pond 1 and from 34.2 to 1,685.6 mg/L in the pond 2. The planktonic biomass in the ponds was larger, between December 24, 1996 and December 01, 1997, when the outflow is low (Fig.6)

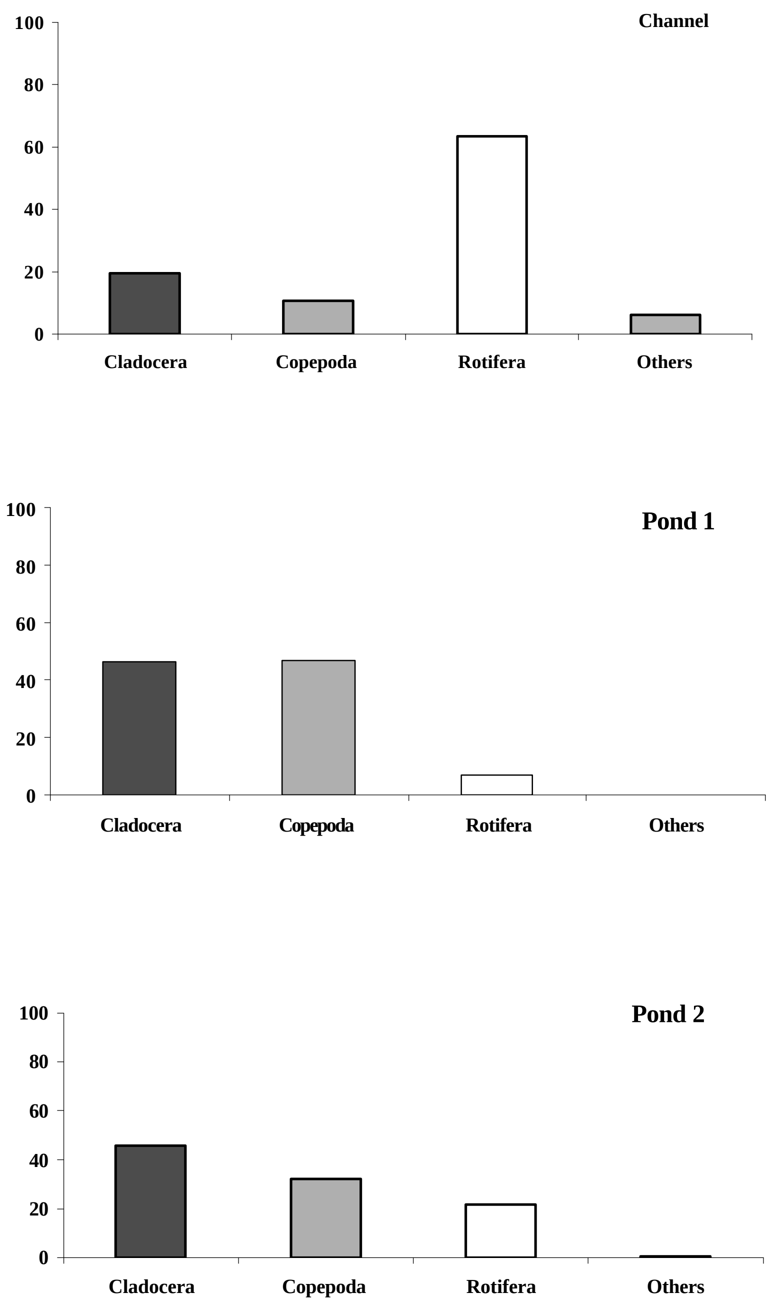
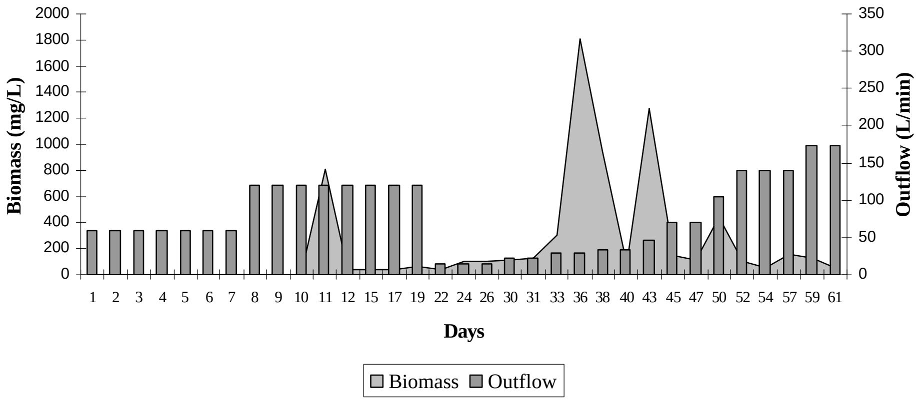


Figure 5: Temporal variation of relative abundance (%) of zooplankton in Channel and Ponds 1 and 2.



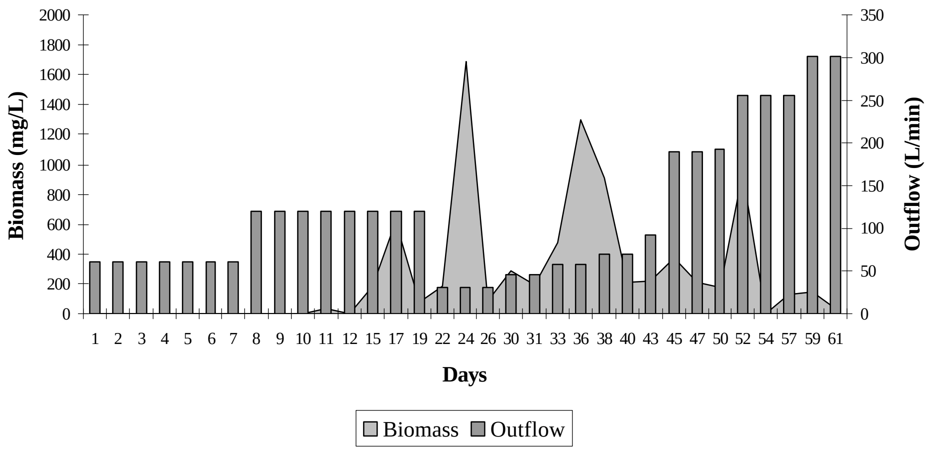


Figure 6: Relationships between the total biomass of zooplankton and the outflow in Ponds 1 and 2.

Discussion

Since water quality is one of the main limiting factors in fish culture, the continuous water renewal is used for the elimination of metabolic and alimentary residues (Sipaúba-Tavares, 1995). In this study, one of the pond variables with higher impact related to the continuous water flow was the dissolved oxygen concentration. Besides the influence of temperature and atmospheric pressure in the freshwater systems, turbulence affects the oxygen displacement. However, the biological processes are the mains responsible for the regulation of dissolved oxygen content in fish farming ponds (Boyd, 1998).

Water temperature is another controlling factor for the dynamics of aquatic environments, because interferes in the organisms metabolism, influencing the reproduction, accelerating the reactions' speed and increasing the degradation rate of organic matter (Bottrell et al., 1976). According to Tundisi (1977), in shallow artificial environments, like fish farming ponds, water temperature is mainly influenced by wind and precipitation.

The electrical conductivity in channel was low during the whole study period. Similar values were obtained for Barrinha stream (Nascimento, 2000) and the Velha reservoir, which supplies water to the CEPTA's fishponds and tanks. However, there was a significant increase of conductivity inside the ponds, and were due to the density of fish stocking.

Photosynthesis, respiration and the organic matter decomposition influence pH values. In this study, significant pH changes between the channel and ponds were detected, probably due to the fertilization during the experiments, besides the continuous water renewal. In another study (Eler, 1996), the pH increase was not related with the CO_2 buffer system or the photosynthesis, but with the water flow.

Mainly planktonic organisms and dead organic matter, besides also being a food source for organisms through debris food chain, represented suspended material, in fishponds. Thus, suspended matter can reduce water transparency. But in the ponds with a high water renewal, Secchi disk transparency was attained Zmax. Bottom ressuspension can also affect the Secchi disk transparency in pond (Eler, 1996), but in this study the water transparency was high in the period of continuous flow. The suspended matter is altered by the integrated action of fish biomass with physical, chemical and meteorological factors, influencing directly the amount and quality of the zooplankton and phytoplankton organisms (Costa-Neto, 1990). But, fish stocking density and water flow influenced the concentration of suspended material in this study.

The inflow and outflow are some of the main factors to understand the dynamics of the zooplankton populations in fish farming and in other artificial systems (Krom et al., 1989). The inlet and outlet flows in the ponds cause modifications in the environment, which can contribute to the success or failure of the communities. Eler (1996), evaluating the plankton communities in fishponds of CEPTA, concluded that both water flow and the fish stocking density affected the planktonic population dynamics. The effect of water flow caused a variation on the Cladocera population densities in this study.

Significant modifications in the community structure in the ponds and in the channel were evidenced, as well as the dominance and abundance of the Rotifera populations. These changes were associated to the water flow in the ponds, besides other factors such as amount of available food, chemical and physical changes of the environment and biological interactions, like predation and competition. Eler (1996) also verified the predominance of Cladocera and Copepoda over Rotifera populations and this was due the low pH values, alkalinity and conductivity in the ponds.

Therefore, the water flow influenced the physical and chemical characteristics of the ponds, as well as zooplankton populations, and the systems with larger water flow presented reduction in the density and biomass of the organisms. In the systems with smaller water flow, nutrient concentration, suspended material, and chlorophyll a were higher, while the oxygen content was low. Thus fish farming causes alterations in water quality and, depending on the cultivation extension (area and production), it can be considered as a impacting activity.

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