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Temporal variation in the water quality of ponds and effluent of grow-out ponds of Amazon River prawn *Macrobrachium amazonicum*

Variación temporal de la calidad del agua de los estanques y efluentes de los estanques de engorde del camarón de río *Macrobrachium amazonicum*

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Abstract

This study was conducted in the Crustacean Sector of the Aquaculture Center (CAUNESP) at the São Paulo State University, Jaboticabal (21˚15'22"S and 48˚18'48"W) São Paulo, Brazil, from December 2003 to May 2004. The aim was to examine the water quality parameters of importance to freshwater prawn culture, operated in a semi-intensive system in Amazon River. Nine 0.01-ha earthen ponds were stocked with 20 juveniles.m^{-2}. Prawns were fed commercial diet at a rate of 7 to 9% of biomass until the 14^{th} week. After 145 days of stocking, all ponds were drained and harvested. The following water parameters were determined weekly: dissolved oxygen, oxygen biochemical demand, pH, total alkalinity, electrical conductivity, suspended total solids and turbidity, N-nitrate, N-nitrite, N-nitrogen ammonia, N- total, soluble ortophosphate, total phosphorus, chlorophyll and pheophytin. In the semi-intensive culture system of *M. amazonicum*, there was no clear pattern of temporal variation in the limnological variables studied. Dissolved oxygen, pH, BOD, ammonia nitrogen and nitrate increased in the afternoon period while, the other variables did not change. In general, water quality is more dependent on the biological processes that occur in the pond than on the characteristics of the renewal water for some variable.

Keywords: *Macrobrachium amazonicum;* limnology; pond water; renewal water; temporal pattern.

Resumen

Este estudio se llevó a cabo en el Sector de Crustáceos del Centro de Acuicultura (CAUNESP) de la Universidad Estadual Paulista, Jaboticabal (21°15'22"S y 48°18'48"W) en São Paulo, Brasil; entre diciembre de 2003 y mayo de 2004. El objetivo fue evaluar los parámetros de calidad de agua con importancia para los cultivos de camarón de agua dulce, operado en un sistema semi-intensivo de estanques en río Amazonas. Nueve estanques de 0,01 ha, fueron sembrados a una densidad de 20 juveniles.m^{-2}, y alimentados con una dieta comercial a una tasa de 7 a 9% de la biomassa, hasta la semana 14. Después de 145 días de crianza, todos los estanques fueron drenados y cosechados. Se determinaron semanalmente los siguientes: oxígeno disuelto, demanda bioquímica de oxígeno, pH, alcalinidad total, conductividad eléctrica, sólidos totales en suspensión y turbidez, nitrato-N, N-nitrito, amoníaco-nitrógeno N, N-total, ortofosfato soluble, total fósforo, clorofila y feofitina. En el sistema de cultivo semi-intensivo de *M. amazonicum*, no hubo un patrón claro de variación temporal en las variables limnológicas estudiadas. Oxígeno disuelto, pH, DBO, nitrógeno amoniacal y nitratos aumentaron durante las tardes, mientras que las otras variables no cambiaron. En general, la calidad del agua es más dependiente de los procesos biológicos que se producen en el estanque, que de las características de la renovación del agua para alguna variable.

Keywords: *Macrobrachium amazonicum;* limnología; viveros; renovación del agua; patrón temporal.

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Introduction

Aquaculture provided nearly 50 percent of the annual world fisheries production of 110 million tons of food fish in 2006 (FAO 2010). Half of all aquaculture production is finfish, a quarter is aquatic plants and the remaining quarter is made up of crustaceans (such as shrimp, prawns, crabs) and molluscs (such as clams, oysters and mussels) (FAO 2010). Brazil stands out as one of the countries with a major potential for the development of aquaculture, because it shelters a large diversity of native freshwater species and because of its continental dimensions (Queiroz et al. 2005). Therefore, Brazil also has a large consumer market and the scientific knowledge for the sustainable use of aquatic ecosystems. However, studies are necessary to evaluate water quality in ponds, because species such as *Macrobrachium amazonicum* (Heller, 1862)*,* despite their small size, have a high survival rate and productivity, according to Moraes-Riodades andValenti (2007). Moraes-Riodades and Valenti also report that in tropical regions, if a preculture phase were introduced, as in this work, whereby postlarvae are grown for 45 – 60 d in nurseries, three grow-out cycles of 3.5 – 4 months would be possible, and productivity could reach 6000 kg/ha/yr. This value is within the range of productivity obtained for penaeid shrimps in intensive systems (5000 – 10000 kg/ha/yr) according to Wickins and Lee (2002). Such characteristics make it ideal for prawn culture in a semi-intensive system.

The ponds for semi-intensive culture of freshwater prawns are limnic ecosystems in the initial phase of ecological succession (Valenti & New 2000). They show biotic diversity, trophic structure and mineral nutrient cycling (Valenti & New 2000). When the ponds are full, a process of ecological succession begins, occurring at different serial stages of filling. This can be autotrophic or heterotrophic. Generally, freshwater prawn ponds receive initial organic fertilizing and feed is added over the course of the culture. Therefore, succession is mainly heterotrophic, and the detritus food chains predominate (Valenti & New 2000). The freshwater prawn ponds can be static or dynamic. In the former, there is no water input or output; where as in the latter water is continuously renewed. Static ponds function as lentic ecosystems, while dynamic ponds show intermediate characteristics between lentic and lotic systems (Valenti & New 2000).

Pond water quality is essential for the success of aquaculture (Boyd & Zimmermann 2000, Kubitza 2003), especially in ponds of freshwater prawns. In recent years, intensive studies have been carried out by Keppeler and Valenti (2006), Henry-Silva and Camargo (2008) considering ponds and effluents**.** The most important variables considered are dissolved oxygen and ammonia nitrogen. The importance of oxygen lies in the fact that the majority of the animals satisfy their need of energy by means of food oxidation, with the formation of carbon dioxide and water in the process (Schmidt-Nielsen 2002). Therefore, this is of basic importance for the maintenance of life (Margalef 1983).

Ammonia nitrogen is the main nitrogenous product excreted by the prawns, originating from the metabolic processes of transformation and oxidation of protein (amino acids) obtained from foods. In general, the consumption of foods high in protein and/or with an imbalance in its amino acid composition generally increases the excretion of ammonia nitrogen in prawns. Another important source of ammonia nitrogen in the culture is the microbial decomposition of proteins and amino acids eliminated in feces (Hargreaves 1998).

Ammonia nitrogen is toxic to prawns, and measure must be taking to prevent its extreme accumulation in the water during the culture. Besides nitrogenous compounds, other limnological characteristics involved in the dynamics of ponds affect the development of the prawns (Boyd & Zimmermann 2000).

Phosphorus is generally the main limiting factor in the development of phytoplankton in aquatic environments. Among all the forms or fractions of phosphate, orthophosphate is the most important as it is the main form assimilated by aquatic plants. Its concentration depends on the density and the activity of organisms in the water, especially phytoplanktonic organisms and aquatic macrophytes, which during photosynthesis can assimilate great amounts of these ions (Boyd 1979). In aquatic environments, high temperature increases the metabolic rate of organisms considerably, causing soluble phosphate to be more quickly assimilated and incorporated in its biomass (Boyd 1979).

This is one of the main reasons for very low concentrations of soluble phosphate. In short, biological, chemical and physical aspects of the water influence prawn culture with regard to growth, resistance to pathogens, reproduction and tolerance to extreme water temperature (Boyd & Zimmermann 2000).

These aquaculture ponds are ecosystems with great entrance and exit of energy and materials (Valenti & New 2000). The main entrances are the stocked prawns, organic fertilizer, managed feed and sunlight, while the main exits are the effluent and harvested prawns (Valenti & New 2000). With the growth of the prawns, the supplied feed is increasingly converted to biomass over the course of the culture. These factors, together with ecological succession, can result in modifications of the water variables of the culture.

The objective of this study was to examine the water quality parameters of importance to freshwater prawn culture, operated in a semi-intensive system in Amazon River prawn ponds. The following aspects were investigated: a) The temporal oscillations of the limnological variables, until to the 14th week of the culture; b) effect of water turnover time on the limnological variables in the interior of the freshwater prawn culture; c) variations of the limnological variables in the morning and afternoon in effluents.

Material and methods

Collection and rearing.- *Macrobrachium amazonicum* (Heller, 1862) juveniles collected in Amazonian rivers according to Moraes Riodades and Valenti (2004) were allowed to grow and mature in an earthen pond in Crustacean Sector of the Aquaculture Center at São Paulo State University (CAUNESP), Jaboticabal, São Paulo (21° 15'22"S, 48°18'48"W). According to Moraes-Riodades and Valenti (2007) ovigerous females with late embryonic eggs were selected from this set of wild animals and stocked in 50-L polyethylene tanks for hatching larvae. Larvae were cultured until metamorphosis in 120-L recirculating tank systems filled with brackish water (salinity: 10) for about 24 d. One week after metamorphosis, juveniles (0.01 g) were hand counted and randomly distributed in primary nurseries and later in secondary nurseries (New 2002). Ponds were stocked with 20 juveniles II of *M. amazonicum* per m^2 (50 days after metamorphosis and 0.36 ± 0.09 g).

Description of ponds.- The ponds were composed of 12 rectangular (~100 m2; ~7.5 × 14 m) earthen ponds with an average water depth of 1 m. Total water volume was about 100 m^3. The pond bottoms were limed (100 g.m^{-2}) and fertilized with cow manure (300 g.m^{-2}) to enhance development of the benthic and plankton communities. The ponds were then filled with mechanically filtered water from a reservoir. A continuous water flow was provided to roughly simulate lotic environments. Turnover rate was 5 – 10% of pond volume per day. Predators and competitors were excluded by means of 1 mm mesh screens set up at the inlet water pipe (Moraes-Valenti et al. 2010).

To study the dynamics of the ponds, the data of the nine ponds were used, in first 14 weeks. The data obtained for each water variable of the ponds, for each week in the nine ponds, were combined. The means and standard deviation were separately determined for the morning and afternoon. The values obtained were plotted versus time to determine the existence of a pattern of temporal variation.

Allochthonous feed input.- A commercial marine shrimp pelleted diet was supplied twice daily (Moraes-Valenti et al. 2010) at 07:30 to 08:30 and 16:00 to 17:00 h. The daily input in each pond was 2.5 g m^{-2} during the first 4 week. Thereafter, for weeks 5 to 12, 9% of prawn biomass was supplied daily; for weeks 13 to 14, the feed was reduced to 6% of prawn biomass. The amount of feed supplied, for the nine ponds, until the 14th week of culture reached 80 kg. ha^{-1}. day^{-1}, but the average, considering all the period of the culture was of 29 kg. ha^{-1}. day^{-1}, and from week 15 onward up to 3%.

This biomass was estimated by means of monthly biometry and corrected fortnightly, increasing it by 20% of the amount determined at the start of the month. In the last month, the correction was 10% each week. In the last two months. The weekly diet supply varied from 184 to 557.3 kg.ha^{-1}.

During culture, ponds were chemically fertilized with urea plus ammonium sulfate, NPK and urea plus simple superphosphate. The quantities of N and P applied each week varied from 1.98 to 8.8 kg.ha^{-1} and 0.68 to 4.2 kg.ha^{-1}, respectively. General management followed the semi-intensive system in freshwater prawn farming (New 2002).

Prawn biomass was estimated in each pond based on the individual mean mass obtained by monthly sampling and the expected survival and growth, assuming 1% mortality and 20% increase in mass per week. If the oxygen level was between 2.5 and 3.5 mg L^{-1} in the morning, the removal rate was increased. When these levels were recorded, a B-500 Aquahobby (Bernauer Aquacultura) emergency aerator was used. This arrangement maintained an adequate level of dissolved oxygen at all times.

Water quality.- Each week, measurements and sampling of the pond inlet water and effluent were performed during the morning (7 – 9 h) and afternoon (15 – 17 h). Dissolved oxygen (bottom) and biochemical oxygen demand (BOD) were measured using a model 52 oxygen meter from YSI (integrated sample). BOD was calculated as the difference between the final and initial level of dissolved oxygen during five days of incubation at 20 ± 1 °C, with water samples diluted generally to 40% (APHA 1998). Total alkalinity was assessed according to Boyd and Tucker (1992). pH and electrical conductivity were determined at the bottom of the ponds using a YSI pH conductivity meter model 63.

Turbidity in whole samples collected from both the photic and aphotic zones was assessed according to Wetzel and Likens (1991) by spectrophotometry, and total suspended solids by a gravimetric method as described by Boyd and Tucker (1992).

Different forms of nitrogen and phosphorus were determined in whole samples collected from both the photic and aphotic zones following methods described by APHA (1992) for nitrate, Strickland and Parsons (1960) for nitrite, Solorzano (1969) for ammonia nitrogen, Valderrama (1981) for total nitrogen, and Adams (1990) and Boyd and Tucker (1992) for total phosphorus and soluble phosphate. Turbidity was assessed according to Wetzel and Likens (1991) by spectrophotometry, and total suspended solids by a gravimetric method as described by Boyd and Tucker (1992). The pigments chlorophyll a and pheophytin were determined according to the APHA (1992) method. A Hach model 2000 spectrophotometer was used in these analyses. All determinations were performed twice. When the two values obtained were close, the average was taken as the result. If the values were discrepant, a third reading was taken and the extreme value was discarded. Student's t – test was applied to detect differences in means between morning and afternoon in effluents.

When assumptions for this parametric test were not accepted, the non-parametric Mann-Whitney U – test was used. Data were also submitted to Kendall coefficient analysis. Analyses were carried out using Statistica v6.0, (Statsoft, 1996) and SAS (2001). The results were considered statistically significant where $p < 0.05$.

Results

Means and standard deviation were determined for all variables. The temporal variation of each variable until the 14th week of culture is shown in Figure 1. It is noted that there was no differential pattern for variable behavior, in the different treatments. However, electrical conductivity and biochemical oxygen demand, chlorophyll and pheophytin showed a particular pattern of variation, fitting a polynomial curve. For the other variables, there was random variation in the means obtained throughout the study period.

Table 1. Means (±standard deviation) of limnological variables of the water supplying ponds, obtained in the morning and afternoon.

Variable	Morning	Afternoon
Dissolved oxygen (mg.L^{-1})	5.72 ± 1.39	7.52 ± 2.13
Dissolved oxygen (%)	70.97 ± 16.93	96.87 ± 28.93
Biochemical oxygen demand (mg.L^{-1})	4.84 ± 3.24	6.46 ± 4.22
pH	8.04 ± 0.78	7.73 ± 0.59
Total alkalinity (mg.L^{-1} $CaCO_3$)	45.86 ± 5.34	40.67 ± 6.77
Electrical conductivity (µS.cm^{-1})	102 ± 37	92 ± 18
Total suspended solids (mg.L^{-1})	0.030 ± 0.078	0.011 ± 0.008
Turbidity (TNU)	42 ± 105	13 ± 9
Nitrate-N (µg.L^{-1})	730 ± 861	1129 ± 1161
Nitrite-N (µg.L^{-1})	58 ± 25	44 ± 12
Ammonia nitrogen (µg.L^{-1})	140 ± 124	88 ± 62
Soluble orthophosphate (mg.L^{-1})	0.029 ± 0.032	0.022 ± 0.029
Total phosphorus (mg.L^{-1})	0.086 ± 0.113	0.104 ± 0.110
Chlorophyll a (µg.L^{-1})	388 ± 634	218 ± 175
Pheophytin (µg.L^{-1})	1017 ± 1666	556 ± 433

The means of the water quality variables of the supply water, analyzed during the experiment, in the periods of the morning and afternoon are presented in Table 1. The quality of the supply water showed some variations over the course of the culture. Kendall's coefficient of concordance (k) that correlated each variable with supplying water the pond water was significant for electrical conductivity, total alkalinity, nitrate-N ($p< 0.01$) and soluble orthophosphate ($p < 0.05$).

In the Table 2 presents the means of the limnological variables in the periods of the morning and afternoon in the nine ponds up to the 14th week in effluents. The standard deviation was high, indicating a great degree of variability in all variables. Significant differences were observed between the morning and afternoon to dissolved oxygen, pH, ammonia nitrogen, nitrate, soluble orthophosphate ($p< 0.05$). Total phosphorus showed substantial declines in the afternoon, and chlorophyll a increasing in afternoon, but a statistically significant difference was not observed ($p< 0.05$).

Discussion

Prawns grow during culture and their effect on the environment should increase greatly over time. Therefore, the daily feed added to the ponds continues to increase. In this study, it increased five times. Therefore, variations in the limnological variables during culture are expected, and these could follow a pattern conditioned by the above-mentioned processes. This, however, did not occur in the present work.

The majority of the variables studied showed a random pattern of changes during culture. Only BOD, electrical conductivity, chlorophyll and pheophytin showed a distinct pattern. The BOD increased, declined and then increased again, while

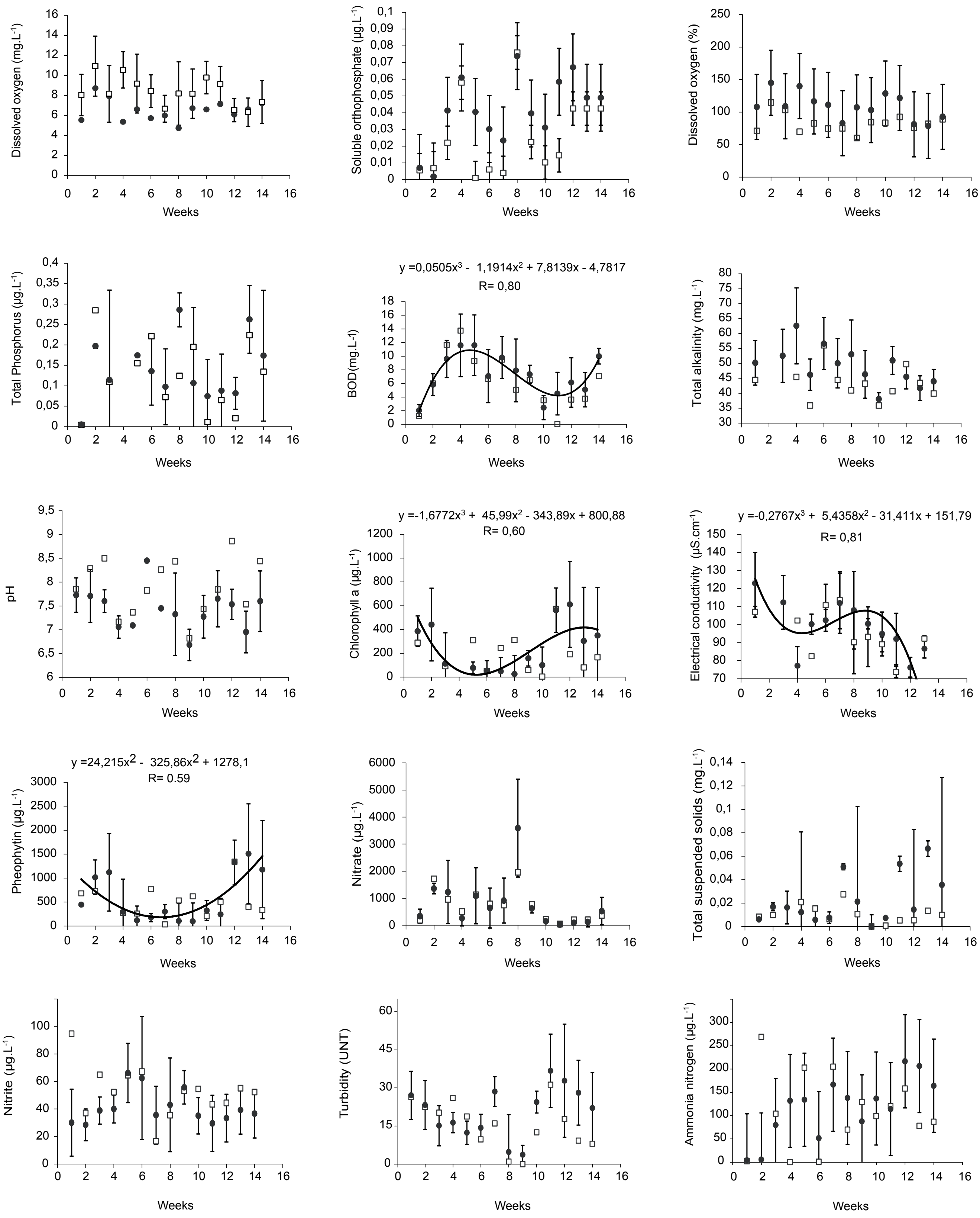

Figure 1. Temporal variation of limnological variables over the course of the culture. Supply Water: means between morning and afternoon; Ponds: Means ± standard deviation of the nine ponds studied. Curve polynomial represents the pattern of variation.(□)Supplying W.= Supplying water, and (●)Pond W =Pond Water.

Table 2. Means (±standard deviation) of limnological variables of the pond water and effluents, obtained in the morning and afternoon. T = Student's t test; U= Mann-Whitney test. Means followed by different letters in the same row differ at the 5% level of significance for morning and afternoon periods.

Variable	Morning	Afternoon	T
Dissolved oxygen (mg.L^{-1})	6.34±2.71**a**	7.45±2.81**b**	U
Dissolved oxygen (%)	90.15±41.47**a**	119.98±34.15**b**	T
Biochemical oxygen demand (mg.L^{-1})	6.57±3.54	6.42±3.38	T
pH	6.95±0.51**a**	7.24±0.52**b**	T
Total alkalinity (mg.L^{-1} $CaCO_3$)	50.89±9.51	49.58±9.69	T
Electrical conductivity (μS.cm^{-1})	100±17	100±17	T
Total suspended solids (mg.L^{-1})	0.016±0.023	0.015±0.011	T
Turbidity (TNU)	27±31	25±37	T
Nitrate-N (μg.L^{-1})	403±746**a**	898±1237**b**	U
Nitrite-N (μg.L^{-1})	49±24	49±32	T
Ammonia nitrogen (μg.L^{-1})	163±123^{a}	122±92**b**	T
Soluble orthophosphate (mg.L^{-1})	0.047±0.042**a**	0.035±0.029**b**	T
Total phosphorus (mg.L^{-1})	0.153±0.136	0.125±0.143	T
Chlorophyll a (μg.L^{-1})	264±369	308±372	U
Pheophytin (μg.L^{-1})	648±844	840±935	U

conductivity displayed an inverse pattern. BOD and electric conductivity followed the same pattern of variation in the ponds as in the water supply.

It is possible that the various factors, such as water supply, feeding rate, and pond position, acting on these variables are very great, and therefore, under the culture conditions practiced, no particular pattern of variation was observed. This is in accordance with the instability of the water variables observed in hypertrophic environments. However, aquaculture is a form of controlled eutrophication in which succession is controlled by management strategies, including aeration, water exchange, type of fertilizer and various feeds and feeding regimes (Pruder 1986), as carried out in this study, with control objectives the system.

In the present work, only alkalinity, conductivity, nitrate, and soluble ortophosphate showed a positive correlation between supplying water and pond water. Therefore, oxygen was not apparently influenced by water renewal in the range of 5 – 10% per day, value minimum recommended for New (2002), as was practiced in this work.

Moreover, in the ponds studied, pH, dissolved oxygen, dissolved material, nitrite, total phosphorus, chlorophyll, seemed to be more dependent on the biological processes that occur inside of the pond than on the supplying water. This could be due to the fact that both the supplying water and pond water show hypereutrophic characteristics (Keppeler & Valenti 2006), and therefore, in a semi-intensive system, the addition of a large amount of fertilizer and high feeding rate should reduce the effect of water renewal. The data indicate that the environments were hyperthrophic because they showed relatively high levels of phosphorus and chlorophyll according to Vollenweider (1968).

The biological and chemical processes that occur in the ponds produce changes in the values of the limnological variables throughout the day. In the present work, significant differences in effluents were observed between the morning and afternoon to dissolved oxygen, pH, ammonia nitrogen, nitrate, soluble orthophosphate. A significant difference in the other variables studied was not observed. These data must reflect the processes of photosynthesis that occur in limnic ecosystems. These, in turn, are mainly influenced by the variation in light intensity and temperature.

During the day, an increase in temperature occurred, which speeds up the decomposition of organic substances, leading to the formation of ammonia. This immediately is assimilated by phytoplankton or converted into nitrate by nitrifying bacteria. If the concentration becomes highly elevated and the pH strongly alkaline, there can be a loss of gaseous ammonia to the atmnosphere (Delincé 1992). In this work, there was a decrease in ammonia during the afternoon period, indicating that the processes photosynthesis and nitrification had predominated over the ammonification process. On the hand, by night, photosynthesis ceases and oxygen level declines, which inhibits nitrification (Kaiser & Wheaton 1983). The finding of more elevated levels of ammonia nitrogen in the morning indicates that ammonification was greater than nitrification during the night. As pH was always below 9, and the concentration of ammonia nitrogen low, there should not have been losses of this gas to the atmosphere.

In the morning period, the oxygen measured corresponded to the that remaining after aquatic processes of respiration by the prawns and other organisms, decomposition of organic substances and nitrification of ammonia to nitrate during the night in the absence of photosynthesis. With sunrise, photosynthesis begins, with the consumption of CO_2 and production of oxygen. Consequently, the oxygen measured in the afternoon represents the balance between what was produced by phytoplankton and what was expended in the processes described above. The absorption of phosphorus is also associated with primary production (Wetzel 1981). Therefore, throughout the day, there will be consumption of inorganic, phosphorus and ammonia nitrogen and the release of oxygen.

The variable nitrogen ammonia can supply an approximation estimate of the pollution potential of a pond. On the other hand, a great amount of oxygen can be used by nitrifying bacteria to oxidize ammonia nitrogen to nitrate. Moreover, the consumption of oxygen in five days represents only one fraction of the total oxygen that will be consumed in the processes of decomposition and nitrification. This represents about 35% of the BOD in the afternoon period.

Nitrate originates from the processes of nitrification of ammonia. This can accumulate in the system as nitrate, absorbed by phytoplankton (Hargreaves 1998), reconverted into ammonia by ammonification or converted into molecular nitrogen. These last two processes occur mainly at the sediment level in anaerobic conditions or low concentration of oxygen.

In the ponds studied, it was observed that the nitrate increased in the afternoon. This indicates that during the day there was an increase in the nitrification processes. Therefore, there was enough ammonia and oxygen. Nitrate absorption by phytoplankton only occurs when there is lack of ammonia, since nitrate must be reduced to ammonia in cells before being used, with an expenditure of energy, since during the day than at night. This must have been due to the higher temperature and greater oxygen availability. On the hand, at night there was a mean decrease in NO_3-N of 300 µg.L^{-1}. This must not have been converted into ammonia, because ammonia increased by only about 50 µg.L^{-1} of NH_3-N, on average. Therefore, at night, there must have occurred a process of denitrification and about 300 µg.L^{-1} of nitrogen must have been lost from the ponds of the atmosphere.

In the absence of photosynthesis during the night, pH declined by the morning. Sipaúba-Tavares et al. (1998a,b) also observed a relation between pH and dissolved oxygen in ponds. This is possibly related to the involvement of these variables in the processes of photosynthesis and decomposition. High pH, as encountered in this study, is mainly due to the presence of carbonate and bicarbonate ions, which together with CO_2 are the main forms of inorganic carbon available in the water.

Sipaúba-Tavares et al. (1998) found that the reduction in the concentration of ammonia nitrogen affected alkalinity, when studying the dynamics of some limnological variables in two fish ponds. In the ponds studied here, alkalinity did not vary between the periods of the day, but alkalinity was highest at the start of the experiment but tended to decrease at the end, with values similar those observed in studies carried out by Paggi and Sipaúba-Tavares (2006). Sipaúba-Tavares (2007) evaluated water quality through a limnological survey in a fish culture system in the Paranaíta region (Mato Grosso, Brazil), and found values similar to those obtained in the present study and also in other studies carried out by Moraes-Riodades et al. (2006) and Moraes-Riodades and Valenti (2007) when determining the effect of intensification of Amazon River prawn *Macrobrachium amazonicum* culture on pond hydrobiology. This indicates that the values for this culture are in accordance with those mentioned for aquaculture in general.

The efficiency of the nitrification process in ponds is evidenced by the low levels of nitrite which is an intermediate product in the nitrification process. Its presence in aquatic environments is always low but increases when nitrification reactions are blocked (Boyd & Tucker 1998). The low values obtained in this work indicate that the nitrification process occurred regularly in the ponds. This is corroborated by the high nitrate levels found in the afternoon.

Photosynthesis, occurring during the day, was possibly compensated by nitrification, since nitrate levels increased significantly in the afternoon, indicating the occurrence of nitrification. On the other hand, at night, respiration could have been compensated by denitrification.

The processes of photosynthesis, denitrification, and reduction of sulfate and dissolution of lime used in aquaculture can increase alkalinity, while respiration, nitrification and oxidation of sulfites can decline (Delincé 1992).

Alkalinity exerts little effect on aquatic organisms; fish and shrimp have been cultivated at very high levels of alkalinity without any apparent problem (Boyd & Tucker 1998). The main effect of alkalinity in culture ponds is the dampening of the variations in pH resulting from the processes of assimilation and CO_2 elimination by the organisms. The values obtained varied around 40 mg.L^{-1} of $CaCO_3$, which is considered by Boyd and Tucker (1998) and Boyd and Zimmermann (2000) adequate for aquaculture.

The daily variation can indicate a predominance of photosynthesis or decomposition, as the conductivity increases or declines. In the ponds studied, there was no difference between the morning and afternoon levels, suggesting that ions removed from the water for photosynthesis had been compensated by decomposition. In waters with low conductivity (<600 µS.cm^{-1}), calcium ions are the most important (Delincé 1992). The ponds studied had received an application of 100 g.m^{-2} of dolomite before filling. This certainly contributed significantly to the rise in conductivity. Moreover, it was observed that the renewal water influenced the variation in conductivity over time in the earthen culture ponds.

In general, water quality of aquaculture is influenced by the water supply (Macedo & Sipaúba-Tavares 2010). Electrical conductivity and total alkalinity was influenced by the supplying water, as observed in the study of Lachi and Sipaúba-Tavares (2008). These authors reported that variation in the limnological parameters was influenced by organic substances and nutrients in the water from other ponds that emptied directly into the studied freshwater prawn pond, producing annual average values of 6 mg.L^{-1} for dissolved oxygen, 124 µS.cm^{-1} for electrical conductivity and (93 mg.L^{-1}) for total alkalinity. In this study, dissolved oxygen level was not affected, but electrical conductivity and total alkalinity values were decreased (100 µS.cm^{-1} and 48 mg.L^{-1}, respectively).

Suspended total solids and turbidity reflect the materials dispersed or dissolved in the water column, be they living organisms or not, organic or inorganic. In this work, these variables did not change over the course of the day, indicating that the biological processes had little effect on the material in the water column, as detected by the methods used, or compensatory antagonistic processes could have occurred, that is, addition and subtraction of equivalent amounts of material in suspension and dissolved.

In the ponds studied, the levels of orthophosphate and total phosphorus declined in the afternoon, but the difference was not significant. In the ponds, bound phosphorus is converted to orthophosphate at a higher rate during the day than at night, due to the increase in temperature and consequent increase in rate of decomposition. Both orthophosphate and organic phosphate were absorbed by phytoplankton during the day, and therefore, their levels were lower in the afternoon. At night, if the conditions of the sediment become anaerobic, phosphorus can be released into the water column (Delincé 1992).

Moreover, prawns are animals that show greater activity during the night. The movement of the animals and the handling of materials contained in the substratum can resuspend the sediment, releasing phosphorus into the water column (Delincé 1992).

In this work, the concentration of chlorophyll did not vary between morning and afternoon, indicating that the density of phytoplankton must not have varied. However, it must be pointed out that the amount of chlorophyll in cells varies as an adaptation to light availability (Wetzel 1981).

In this work, pheophytin concentration did not differ between the morning and afternoon, and was very higher than that the chlorophyll, which indicates a high rate of degradation for chlorophyll, suggesting high rates of mortality and decomposition for phytoplankton. Thus, it appears that the renewal rate of phytoplankton was increased.

Therefore, the culture of freshwater prawns is an activity without impact, especially on effluents.

Conclusions

In the semi-intensive culture system of *M. amazonicum*, there was no clear pattern of temporal variation in the limnological variables studied.

- In general, water quality is more dependent on the biological processes that occur in the pond than on the characteristics of the renewal water for some variables.
- Dissolved oxygen, pH, BOD, ammonia nitrogen and nitrate increased in the afternoon period, while the other variables did not change.
- The culture of freshwater prawn has no substantial impact on the environment.

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