Limnological parameters and plankton community responses in Nile tilapia ponds under chicken dung and NPK (4-14-8) fertilizers.

SIPAÚBA-TAVARES[1], L.H.* BACCARIN[1], A.E. & BRAGA[2], F.M. de S.

[1] Laboratório de Limnologia e Produção de Plâncton, Centro de Aqüicultura, UNESP, 14884-900, Jaboticabal-SP, Brazil. e-mail: sipauba@caunesp.unesp.br

[2] Departameno de Zoologia, Instituto de Biociências, UNESP, 13506-900, Rio Claro-SP, Brazil. e-mail: fmsbraga@ms.rc.unesp.br

ABSTRACT: Limnological parameters and plankton community responses in Nile tilapia ponds under chicken dung and NPK (4-14-8) fertilizers. Two types of fertilizers, organic (chicken dung) and inorganic (NPK), were used in three Nile tilapia fishponds to evaluate the influence of enrichment on plankton community and water quality, during the dry period, namely, in July, August, and September. Inlet water was also analyzed. A sampling site was assigned to each pond to measure water quality parameters. Water pH, temperature, residence time, nitrate, and orthophosphate were not significantly different ($p>0.05$) when temporal variations and pond interactions were taken into account. Comparison between ponds and inlet water showed that free CO_2, nitrite and ammonia in water were not significantly different ($p>0.05$). On the other hand, total phosphorus and chlorophyll-a were significantly different ($p<0.05$) in ponds and in inlet water. Fish growth rate was higher and planktonic organisms, such as green algae (Chlorophyta) and Copepoda-Calanoida, were more abundant in fertilized fishponds. Rotifera and Chaoborus sp densities increased only in fertilized ponds. Results indicate benefits when inorganic fertilizers were added.

Key-words: Phytoplankton, zooplankton, water quality, organic and inorganic fertilizers, fishpond.

RESUMO: Respostas das variáveis limnológicas e da comunidade planctônica em relação ao uso de fertilizantes de esterco de frango e NPK (4-14-8) em viveiros de criação de tilápia do Nilo. Dois tipos de fertilizantes, um orgânico (esterco de frango) e outro inorgânico (NPK) foram utilizados em viveiros de criação de tilápia do Nilo a fim de avaliar a influência destes fertilizantes na comunidade planctônica e qualidade da água dos viveiros, durante os meses de julho, agosto e setembro, correspondente ao período de seca. A água de abastecimento também foi analisada. Um ponto de amostragem de água foi colhido em cada viveiro. Considerando as variações entre período e as variações entre viveiros o pH, temperatura, tempo de residência, nitrato e ortofosfato não foram significativamente diferentes ($p>0,05$). Comparando os viveiros e a água de abastecimento não foram observadas diferenças significativas ($p>0,05$) entre a variável CO_2 livre, nitrito e amônia. Já o fósforo total e clorofila-a foram significativamente diferentes ($p<0,05$) entre os viveiros e água de abastecimento. Nos viveiros contendo fertilizantes, houve maior crescimento dos peixes e maior abundância de organismos planctônicos, representados principalmente pelas algas verdes (Chlorophyta) e Copepoda-Calanoida. Rotifera e Chaoborus sp foram encontrados somente nos viveiros fertilizados. Os resultados obtidos indicaram que as proporções de fertilizantes utilizadas foram benéficas, com os melhores resultados para o fertilizante inorgânico.

Palavras-chave: Fitoplâncton, zooplâncton, qualidade da água, fertilizante orgânico e inorgânico, viveiro.

Introduction

Whereas inorganic and organic fertilizers may be used in fishponds, inorganic fertilizers present certain advantages when compared to organic ones. Inorganic fertilizers are widely available, require low application rates, dilute easily in water, have a well-defined composition and high nitrogen contents. Some are potentially less harmful than organic ones because they dissolve slowly in water and increase bacterial and algal productivity. Therefore, the use of organic fertilizers to improve soil organic matter level and long term soil fertility and productivity is gaining importance (Goyal et al., 2005).

Chicken dung, extensively used in Brazil, is a very common fertilizer. The mixture of excrements, feathers, broken eggs, feed remains and fly larvae forms a fertilizer which is rich in organic matter, calcium and phosphorus. In fact, approximately 30% of crude protein of chicken dung is made up of amino-acids (Vilela, 1983). On the other hand, inorganic fertilizers contain sources of nitrogen and phosphorus (rather more than organic fertilizer) and maintain high water quality, i.e., high dissolved oxygen and moderate water pH (Tew et al., 2006).

General fertilization recommendations for ponds in the southeastern Brazil include much higher rates than those found in inorganic fertilizer combined with organic applications (Arana, 1997; Kubitza, 2003). Whereas the amount of nitrogen and phosphorus released from organic fertilizers and the timing of their release are difficult to predict, the direct use of inorganic nitrogen and phosphorus as fertilizers facilitates control of nitrogen and phosphorus amounts in ponds and prevents over-fertilization (Tew et al., 2006).

So that the system and biological productivity may be maintained in equilibrium, about 50% of nutrients should have inorganic sources and the other 50% should come from organic sources. However, an excess of organic or inorganic fertilizer may deplete dissolved oxygen concentrations in the water (Qin et al, 1995; Boyd & Tucker, 1998).

One of the most important problems concerning fishponds fertilization is to determine the best fertilizer dose to be added to the pond system. Optimal requirement of fertilizers with regard to different types of soil conditions and their interactions with various factors of pond ecosystem are still unknown (Feng et al, 2005). According to Bhakta et al. (2004), optimal fertilization rates are the amount of organic matter that may be cost-effective and utilized in a pond ecosystem without any harmful effects on water quality and fish growth. This is one of the most important aspects of pond management since excess in fertilizers is not only expensive but is also the cause of nutrient enrichment in water bodies.

Fertilization of ponds to enhance algal growth and to promote the production of zooplankton suitable for larval fish is a common practice in fishponds. Current study evaluates water quality and phytoplankton and zooplankton responses to organic and inorganic fertilization in Nile tilapia ponds. Oreochromis niloticus (Nile tilapia) is one of the most popular species cultivated in Brazil. Although most production of Nile tilapia is realized in cages; some producers cultivate it in semi-intensive systems with inorganic and organic fertilizer inputs in earthen ponds.

Study Area

Research was carried out at the Aquaculture Center (21° 15'S; 48° 18'W) at the Universidade Estadual Paulista (UNESP) in Jaboticabal SP Brazil, in three fishponds (area $45m^2$; depth 1.2m), with continuous water flow, provided by a 5% daily exchange rate of the rearing volume, during the dry period (July to September).

Material and methods

Three treatments were analyzed: T_1 was fertilized only at the beginning of the trial, by the addition of 300 g of inorganic fertilizer (NPK; 4-14-8), directly mixed in the water; T_2 was the control, without any addition of fertilizer; T_3 was fertilized with organic fertilizer (chicken dung), by adding 12 kg of chicken dung to the empty pond, 15 days before the start of the study.

All fishponds were populated with juvenile tilapia (Oreochromis niloticus), length 5.2 cm and weight 10.2 cm, at a density of 2-fish/m^2, fed daily with ration (25% crude protein) at 3% of their mean live weight.

Water samples were taken with a Van Dorn bottle (5 L) at four sites: one in the inlet water (IW) and at three different sites in each pond (T_1, T_2, and T_3), during ten consecutive days in July and September, and during five consecutive days in August, during the dry period. Dissolved oxygen was determined by Winkler method (Golterman et al., 1978). Variables, such as water pH, temperature and electrical conductivity, were measured with a Corning (PS 15) pH meter, Corning (PS 16) temperature meter and Corning (PS 17) electrical conductivity meter. Total phosphorus, orthophosphate, ammonia, nitrite and nitrate were determined following techniques by Golterman et al. (1978) and Koroleff (1976). Residence time was measured by difference in water volume between inlet and outlet water. Alkalinity and inorganic carbons were determined according to Mackereth et al. (1978), and chlorophyll-a according to Nush (1980). Secchi disk transparency was also measured daily.

For quantitative and qualitative analysis of phytoplankton and zooplankton, the samples were obtained with a 25 mm and 58mm mesh net, and preserved in a lugol solution and formalin (4%), respectively. Data were expressed in relative abundance.

About ten fish in each fishpond were measured for total length with a graded scale and weighed with a 1g precision balance. Weight and length were registered at the beginning and at end of the study.

Two-way ANOVA analysis was applied to limnological variables to compare treatments between ponds and periods and the interaction between them (Fowler et al., 1998). Analysis of variance homogeneity was applied between the limnological variables and, in the case of homogeneous variance, the non-parametric test of Kruskal-Wallis (Siegel, 1975) was applied, followed by Dunn's test (Vanzoline, 1993).

Results

Whereas concentrations of nitrogen compounds were lower, nitrate was the most abundant nitrogen compound during the experiment, with peak in August, ranging from 0.30 to 0.46 $mg.L^{-1}$ at T_1; from 0.28 to 0.41 $mg.L^{-1}$ at T_2; from 0.28 to 0.46 $mg.L^{-1}$ at T_3. At the end of the experiment it decreased by highest rates at T_3, ranging from 0.04 to 0.17 $mg.L^{-1}$. Nitrate, with initial average concentration between 0.40 and 0.55 $mg.L^{-1}$, was affected by inlet water, whereas ammonia and nitrate were, as a rule, below 0.09 $mg.L^{-1}$ (Tab. I).

Fertilizer increased chlorophyll-a concentrations in treatments T_1 and T_3, when compared to those at T_2. At the end of the experiment chlorophyll-a concentrations were very high and ranged from 24.2 to 243.7 $mg.L^{-1}$ at T_1 and from 90.2 to 163.2 $mg.L^{-1}$ at T_3 (Tab. I).

Table I: Average, minimum and maximum values (between parentheses) of nutrients, chlorophyll-a, residence time, and transparency in the different treatments (T_1= inorganic fertilizer, T_2= control, T_3= organic fertilizer, and IW= inlet water) during the dry period.

Parameters	T_1	T_2	T_3	IW
Ammonia ($mg.L^{-1}$)	0.10 (0.0-0.30)	0.10 (0.0-0.36)	0.05 (0.0-0.24)	0.003 (0.0-0.007)
Nitrate ($mg.L^{-1}$)	0.26 (0.0-0.45)	0.29 (0.07-0.47)	0.26 (0.0-0.40)	0.48 (0.30-0.66)
Nitrite ($mg.L^{-1}$)	0.01 (0.0-0.075)	0.007 (0.0-0.01)	0.008 (0.0-0.02)	0.003 (0.0-0.009)
Total-phosphorus ($mg L^{-1}$)	1.15 (0.09-3.1)	0.77 (0.06-1.86)	1.55 (0.10-3.7)	0.15 (0.0-0.18)
Orthophosphate ($mg.L^{-1}$)	0.07 (0.11-0.23)	0.04 (0.009-0.11)	0.10 (0.01-0.25)	0.007 (0.0-0.08)
Chlorophyll-a ($mg.L^{-1}$)	79.50 (6.14-237.93)	10.77 (1.67-32.9)	60.12 (5.02-163.2)	0.63 (0.0-7.81)
Residence time (days)	6.48 (2.8-10.97)	5.75 (2.25-9.68)	7.07 (2.6-20.0)	*
Transparency (cm)	106.0 (60-120)	117.33 (60-120)	106.2 (70-120)	*

* not measured

Whereas total phosphorus concentrations were highest in the fertilized ponds, there was no significant difference in orthophosphate ($p>0.05$) among treatments. Phosphorus concentrations tended to rise throughout the experiment and, excepting orthophosphate, reached their peak in the fertilized tanks in September. Concentrations of total phosphorus at the end of the experiment were over 2.4 $mg.L^{-1}$, with highest peak at T_3 with 3.67 $mg.L^{-1}$ (Tab. I, II and III).

There was no significant difference among inorganic carbon when treatments were compared ($p<0.01$), with the exception of carbonate ($p>0.05$), during the experimental period. Bicarbonate was the most abundant form of inorganic carbon during the experiment. A decrease of inorganic carbons has been reported throughout the experimental period. Alkalinity had the same fluctuating pattern as that of bicarbonate. Free CO_2 was lower in treatment T_3 owing to alkaline pH water, whereas the opposite occurred with high carbonate rate in T_3 (Tab. II; Figs. 2 and 3).

Electric conductivity rates at the start of current study were higher in the pond with organic fertilizers; a decline occurred and rate remained below 40 mS.cm^{-1}. Inorganic fertilizer treatment (T_1) and control (T_2) exhibited a similar pattern, ranging between 30 and 50 mS.cm^{-1}. Supply water affected conductivity rates of water in tanks with rates ranging between 20 and 60 mS.cm^{-1} (Tab. II; Figs. 1 and 3). Concentrations of dissolved oxygen tended to decrease throughout the experiment and were significantly different (p‹0.01) throughout the period and between treatments. As a rule, concentrations of dissolved oxygen at the start of current study were lower than 4 mg.L^{-1}, with lowest concentration in control (0.67 to 2.01 mg.L^{-1}). Supply water continued to exhibit concentrations over 4.86 mg.L^{-1} throughout the experiment. Dissolved oxygen was significantly different (p‹0.01) between periods and treatments (Tab. II; Figs. 1 and 3).

Table II: Results of two-way nested ANOVA (*P‹0.05; **P‹0.01).

Parameters	F (temporal)	F (treatments)	F (interactions)
Dissolved oxygen	62.87**	32.83**	7.83**
pH	47.79**	0.70	0.07
Temperature	27.72**	6.74**	0.46
Residence time	2.12	0.15	0.36
Carbonate	1.72	3.51**	24.26**
Bicarbonate	24.44**	29.68**	7.25**
Total CO_2	21.90**	20.08**	3.10*
Nitrate	57.00**	37.00**	2.60
Orthophosphate	6.40**	0.06	0.0007
Alkalinity	30.09*	34.27**	7.68**

Table III: Krulskal-Wallis results, and Dunn test applied between ponds (T_1, T_2, and T_3), and inlet water (IW), (*=P‹0.05; ***= P‹0.0001).

Parameters	H	T_3-T_1	T_3-T_2	T_1-T_2	T_1-IW	T_2-IW	T_3-IW
Free CO_2	0.20						
Nitrite	4.06						
Ammonia	1.21						
Total-phosphorus	38.47***	0.31	1.84	1.53	4.29***	2.76*	4.60***
Chlorophyll-a	25.83***	0.16	2.45	2.29	5.33***	3.04*	5.49***

Water pH was not different (p›0.05) between treatments and throughout the entire experiment (p‹0.01). Water pH was slightly acid to alkaline, with highest rates in September in the three treatments, respectively 8.3, 8.4, and 8.6 at T_1, T_2, and T_3 (Tab. II; Figs. 1 and 3).

Water pH, temperature, residence time, nitrate and orthophosphate were not significantly different (p›0.05) when seasonal variations and pond interactions were taken into account. When ponds and inlet water were compared, there was no significant difference in free CO_2, nitrite and ammonia in water (p›0.05). On the other hand, total phosphorus and chlorophyll-a were significantly different (p‹0.05) in ponds and in inlet water (Tab. II and III).

Chlorophyta comprised more than 91% of phytoplankton at the start of the experiment. In fact, in August, Chrysophyta was dominant and was mainly represented by Micrasterias sp with 52.4% and by Botryococcus sp. with 44.1% and 50.8% in treatments T_1, T_2 and T_3, respectively. With the exception of T_1, Chlorophyta, mainly represented in September by Scenedesmus bijugus with 52.1% and 55.3% of total Chlorophyta, was dominant. During this same period dominance of Chrysophyta in T_1 was due to Botryococcus sp (43.8%) and Micrasterias sp (42.3%) (Tab. IV; Fig. 4).

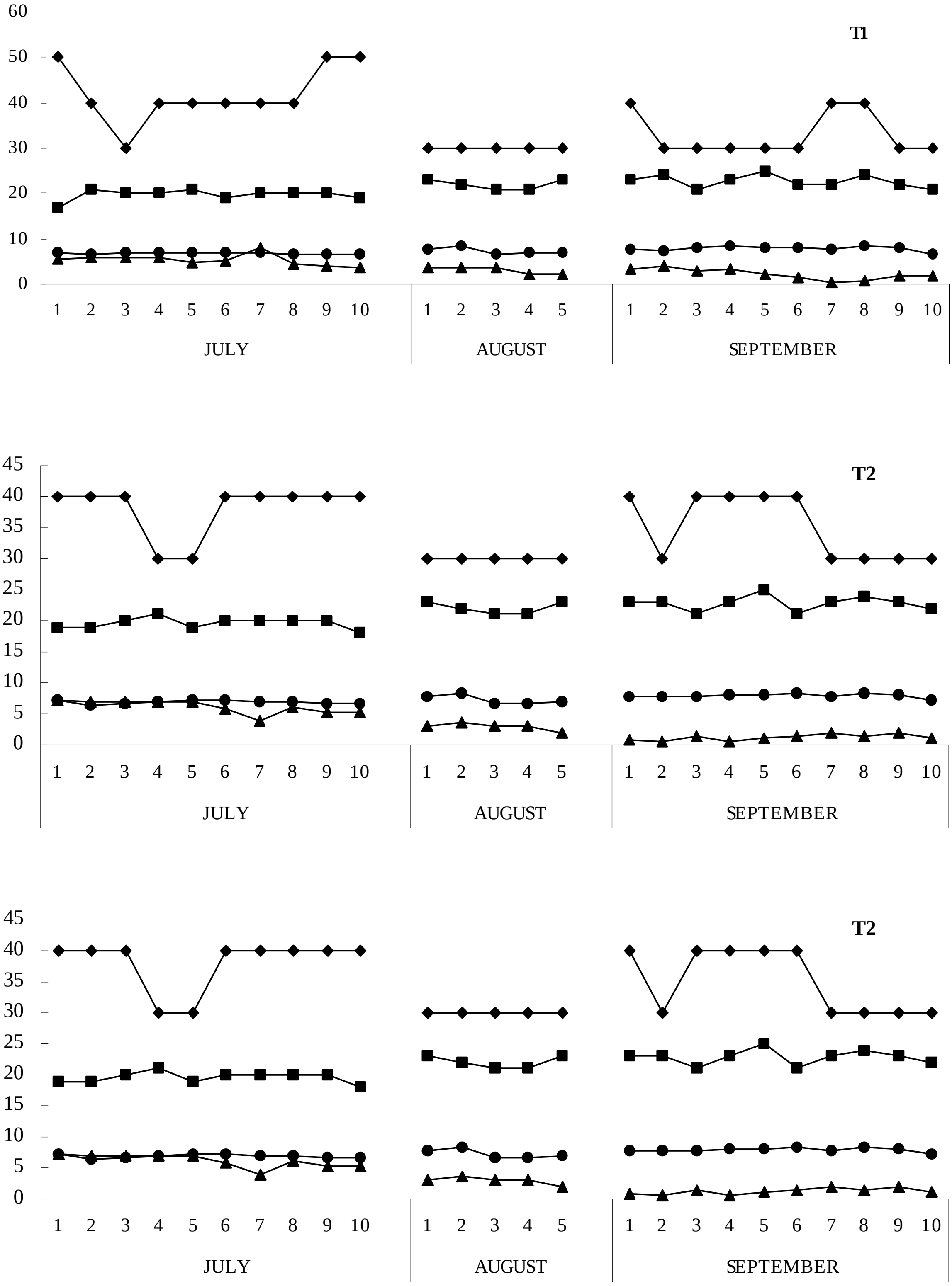

Figure 1: Conductivity ($mS.cm^{-1}$), water temperature (ºC), dissolved oxygen ($mg.L^{-1}$), and water pH in the different treatments (T_1= inorganic fertilizer, T_2= control, and T_3= organic fertilizer) during the dry period.

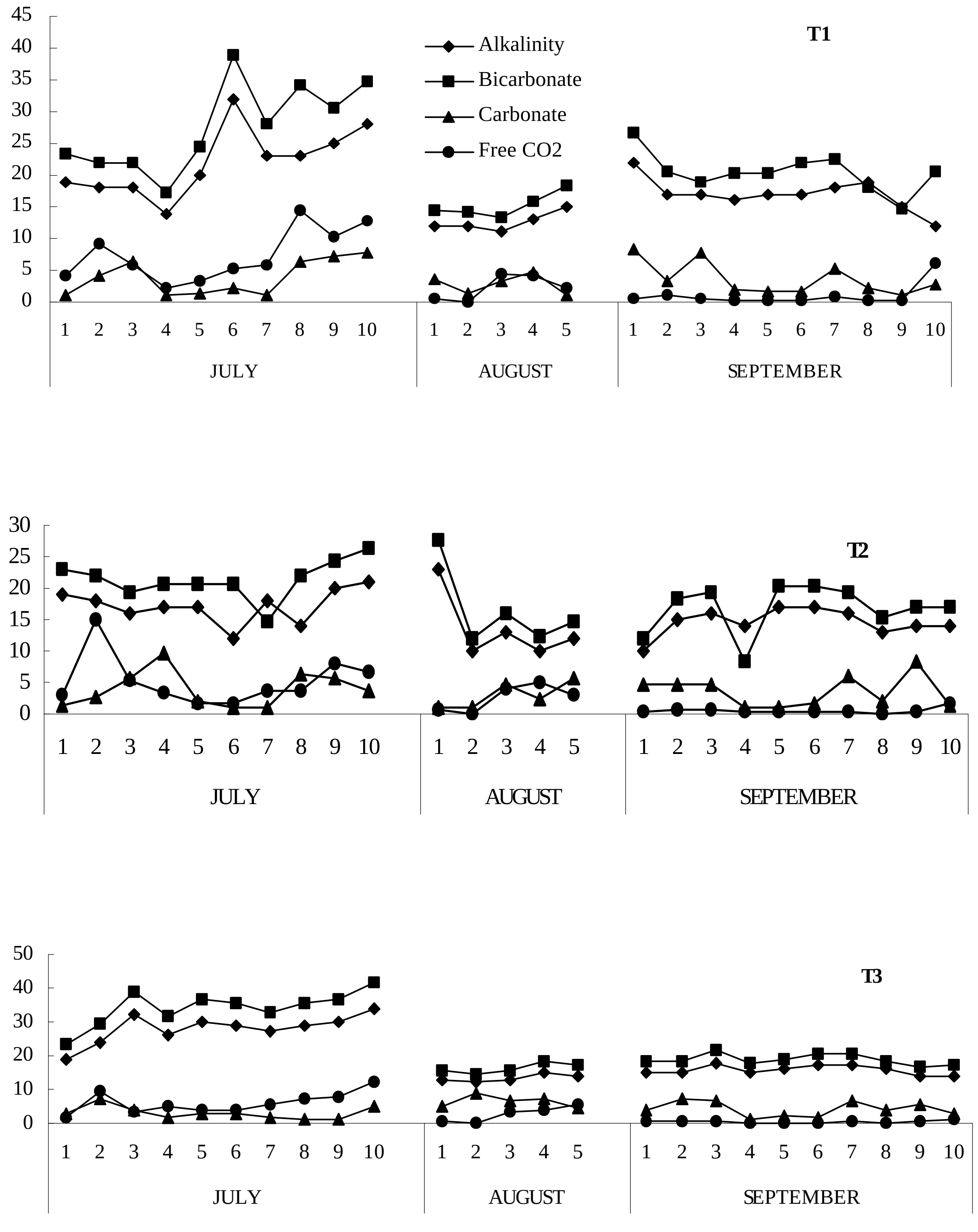

Figure 2: Alkalinity, bicarbonate, carbonate, and free CO_2 ($mg.L^{-1}$) in the different treatments (T_1= inorganic fertilizer, T_2= control, and T_3= organic fertilizer) during the dry period.

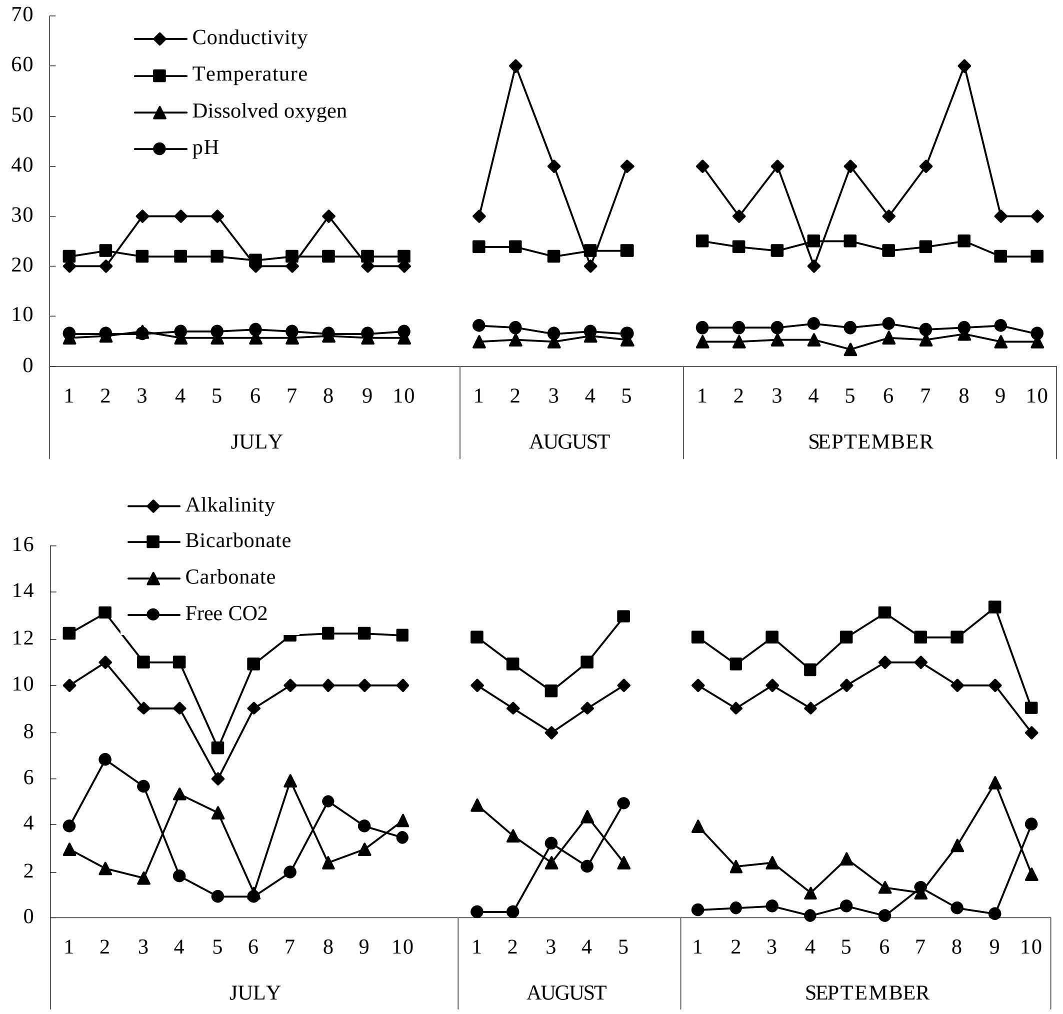

Figure 3: Conductivity ($mS.cm^{-1}$), water temperature (ºC), dissolved oxygen ($mg.L^{-1}$), water pH, alkalinity, bicarbonate, carbonate, and free CO_2 ($mg.L^{-1}$) in the inlet water (IW) during the dry period.

The highest number of phytoplankton in treatment T_3, corresponding to 38.0 and 82.4%, was reported in August and September, respectively. In June the highest number of phytoplankton was observed in T_1 with 39.5% (Tab. IV; Fig.4).

In the case of zooplankton, Copepoda were more representative throughout the experiment, excepting June in T_3 and September in T_2 and T_3, when Cladocera represented 59.5% and 53.8% of zooplankton, owing to Bosmina hagmani and Moina micrura. However, in June, Rotifera represented 91.2% of zooplankton in treatment T_3, with percentage zooplankton peak during the experimental period (Tab. IV; Fig. 4).

At the end of the study Cladocera were dominant in treatments T_2 and T_3, coinciding with green algae dominance. In T_2, Cladocera dominated in September owing to Bosmina sp, Moina micrura, Diaphanosoma birgei and Daphnia gessneri. On the other hand, Calanoida-Copepoda A. furcatus in treatment T_1 was more abundant and comprised approximately 73.2% of zooplankton in the pond. In this case, green algae, 13.4% of total, were less abundant when compared to Chrysophyta with 86.6%. As a rule, a higher abundance of zooplankton species was reported in treatment with organic fertilizer (T_3) than in T_2 with 57.8% of zooplankton, except in September (Tab. IV; Fig. 4).

In treatments with enrichment, final fish length and weight were higher in treatments T_1 and T_3, 14 cm long and, respectively, 106 and 111 g in length. Fish length and weight in treatment T_2 were 70g and 12 cm, respectively.

Table IV: Relative abundance (%) of phytoplankton and zooplankton in the fishponds (T_1, T_2 and T_3) during the three months of dry period.

Species/Genus	July			August			September		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Chlorophyta									
Actinastrum sp.	0.27	0.18	0.17	-	-	-	-	0.17	0.13
Ankistrodesmus gracilis	1.97	0.58	0.35	0.73	0.15	-	-	-	0.21
Chlorella vulgaris	20.13	5.41	7.48	2.24	4.60	-	0.36	-	2.35
Closterium sp	0.31	-	-	-	-	-	-	0.14	-
Gleocystis vesiculare	7.60	2.06	0.69	0.82	-	-	-	-	3.83
Pediastrum boryanum	1.31	1.79	1.09	0.50	0.43	0.29	021	0.17	1.03
Plankthosphaeria sp	0.31	1.52	4.14	0.41	0.57	-	024	0.03	0.21
Pleurotaenium sp	9.37	33.88	17.83	11.21	5.6	14.54	4.45	9.25	1.58
Scenedesmus bijugus	8.44	5.50	4.31	1.46	1.15	2.35	074	52.14	55.25
Scenedesmus quadricauda	41.63	3.69	53.48	9.26	9.05	6.90	4.81	6.20	18.32
Sphaerocystis schroeteri	0.29	1.88	-	1.22	-	-	-	-	2.70
Spirogyra sp	3.70	36.60	1.55	14.09	3.02	6.17	2.58	9.43	0.49
Tetrasporidium sp	-	3.67	0.06	-	0.14	-	-	-	-
Chrysophyta									
Botryococcus sp	-	-	-	5.64	44.11	50.84	43.79	3.26	10.71
Micrasterias sp	4.55	2.30	8.05	52.42	30.17	17.91	42.25	17.35	2.88
Navicula sp	0.12	0.94	0.86	-	1.01	1.03	0.57	1.89	0.31
Cladocera									
Bosmina hagmani	1.1	-	0.01	-	0.38	0.07	0.12	20.03	3.87
Echnischia paulineis	-	-	-	-	0.08	-	-	-	-
Daphnia gessneri	2.1	2.13	0.01	0.22	1.54	4.20	6.91	18.38	6.22
Diaphanosoma birgei	-	-	-	0.22	4.23	1.70	0.47	5.66	21.19
Moina micrura	52.02	36.17	8.60	0.65	19.23	8.80	4.62	15.40	24.51
Copepoda									
A. furcatus adult	7.97	14.89	0.03	29.59	34.92	44.30	66.86	23.47	18.00
Copepodid	3.57	21.28	0.07	7.00	10.08	17.50	2.93	15.07	10.75
Nauplii	11.26	19.15	0.05	25.00	27.46	16.10	2.69	1.26	9.86
T. decipiens adult	1.37	3.19	0.01	10.00	0.54	0.81	0.47	0.42	0.60
Copepodid	0.55	2.13	0.01	0.22	0.69	1.22	0.29	0.28	1.61
Nauplii	1.92	1.06	0.01	0.65	0.85	0.54	-	0.03	1.55
Rotifera									
Asplanchna sp	8.24	-	1.60	-	-	4.06	-	-	-
Brachionus calyciflorus	-	-	88.15	-	-	-	-	-	-
Brachionus. caudatus	-	-	0.60	-	-	-	-	-	-
Brachionus falcatus	-	-	0.20	-	-	-	-	-	-

Table IV: Cont.

Species/Genus	July			August			September		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Keratella cochlearis	8.25	-	-	-	-	-	-	-	-
Keratella cruciformis	-	-	0.20	-	-	-	-	-	-
Keratella lenzi	-	-	0.20	-	-	-	-	-	-
Lepadella ovalis	-	-	-	6.00	-	-	3.51	-	-
Lepadella patella	-	-	0.20	20.00	-	-	-	-	-
Proalis doliaris	-	-	-	-	-	-	10.54	-	1.72
Insecta									
Chaoborus sp.	1.65	-	0.05	0.45	-	0.70	0.59	-	0.12

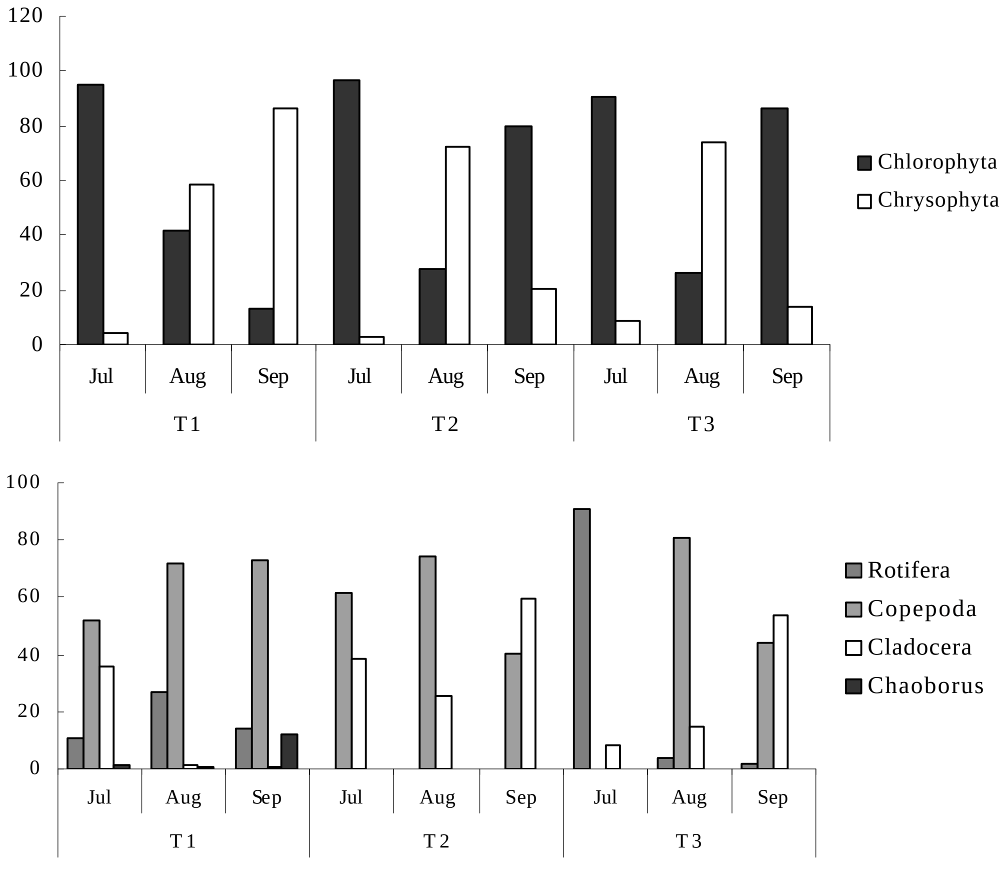

Figure 4: Relative abundance of phytoplankton and zooplankton in the different treatments (T_1= inorganic fertilizer, T_2 = control, and T_3 = organic fertilizer) during the dry period.

Discussion

Pond fertilization is a management protocol to enhance biological productivity by means of organic and inorganic fertilizers. The role of fertilizers in increasing fish production has been emphasized in many studies covering tropical and temperate conditions (Bhakta et al., 2004).

Treatments with organic and inorganic fertilizers caused greater fish length and weight when compared to same factors in control (T_2).

In current analysis alkalinity was low and, according to Boyd & Tucker (1998), adequate concentration for fish farming should reach 40 mg.L^{-1}. Carbonate concentrations were relatively high in this study, over 1 mg.L^{-1}, with maximum rate of 9 mg.L^{-1}. However, carbonate concentrations in fish farms of the Aquaculture Center were extremely low, or rather, less than 0.5 mg.L^{-1} (Sipaúba-Tavares & Colus, 1995).

According to Stickney (1994), pH rates up to 7.7 – 8.7, measured at 0900-1000h, are considered safe since ponds are relatively well buffered. Affected by inlet water, this was not reported in current study when pH ranged between 6.4 and 8.6 in the three treatments throughout the experiment.

Dissolved oxygen concentrations decreased throughout the period and continuous water flow did not promote higher oxygenation, probably due to decomposition of organic matter. Qin et al. (1995) verified that ponds with organic fertilizers showed lower oxygen contents when compared to those fertilized with inorganic material. Organic fertilizers function as an energy source for bacterial growth, which leads to aerobic decomposition, an important factor in decreasing oxygen supply in fishponds.

In our study the high transparency by Secchi disk in the fertilizer ponds indicated fertilizer adsorption by phytoplankton. According to Tepe & Boyd (2001), fertilizer application based on water transparency may be an appropriate procedure within a 40 to 60 cm range.

Doses of organic and inorganic fertilizers used in this study maintained nutrient concentrations at adequate conditions for fish ponds. Only nitrate was directly affected by inlet water, causing high concentrations and promoting more abundance of component in the ponds.

Although fertilization of the two ponds (T_1 and T_3) kept nitrogen compounds and conductivity similar to those of control pond (T_2), phosphorus concentrations were higher in treatments with fertilizers. The same has been reported in the case of chlorophyll-a. The highest conductivity rates observed in the treatments with fertilizers at the start of our study were related to a greater availability of phosphorus in the treatments with fertilizers. This fact favored an increase in zooplankton, namely 3.6% (T_1) and 95.8% (T_3) in July. The opposite has been reported at the end of the experiment when control comprised 57.8% of zooplankton.

According to Qin & Culver (1992), high zooplankton densities at the start of culture may result in the early exhaustion of phytoplankton populations, which in turn might result in the early decline of zooplankton populations prior to the rapid increase of larval fish and plankton consumption.

Culver et al. (1993) found that nitrogen and phosphorus in fertilizers enhanced the growth of small unicellular algae that provide food for zooplankton, thereby increasing the reliability of fish production.

Fertilizers with ammonium sulfate stimulate phytoplankton growth and zooplankton production (Dhawan & Laur, 2002). According to Yusoff & McNabb (1999), the combined action of nitrogen and phosphorus stimulates high production as well as dominance of Cyanobacteria in the fish ponds. The non-occurrence of Cyanobacteria in the fish ponds and the abundance of Chlorophyta and Chrysophyta may also be associated with low nitrogen and phosphorus ratios, since Cyanabacteria in general require a 16-3 N/P ratio (Das & Jana, 1996). Under both organic and inorganic fertilizer treatments, the percentage of unicellular green algae was high.

Phosphorus contents (>1mg.L^{-1}) in treatment T_3 favored species with a fast reproduction rate and a short life span of r-strategists organisms, such as Rotifera. Lack of fertilizers in treatment T_2 and the addition of a daily ration merely to feed the fish did not promote the appearance of Rotifera.

Cladocera, such as Moina micrura, Diaphonosoma birgei and Daphnia gessneri, were also reported by Chakrabarti & Jana (1998) in a fertilized pond with chicken dung. The inorganic fertilizer (T_1) favored an abundance of Copepoda, followed by Cladocera, Rotifera and Chaoborus sp. Dhawan & Laur (2002) and Mischke & Zimba (2004) also reported that organic and inorganic fertilizers also favored dominance of Rotifera, followed by Copepoda and Cladocera.

Availability and quality of food influenced too the diversity of zooplanktonic species. In the period of abundant Copepoda, the population of Chlorophyta decreased. Afterwards, Chrysophyta dominated the fish ponds. This fact was probably due to Calanoida grazing over the green algae, since these organisms select phytoplankton species (Sipaúba-Tavares et al., 2001).

Inverse relationship between the abundance of Cladocera and that of Chaoborus sp. occurred because of the latter's carnivorous behavior (Arcifa, 2000). In treatment T_1, when insect larvae were more abundant in September, Cladocera represented only 0.59% of the zooplankton. In the absence of Chaoborus sp., in treatment T_2, for instance, Cladocera were more abundant throughout the study and represented more than 25.75% of total zooplankton. Cladocera were actually the dominant group at the end of the experiment.

When excessive fertilizers are added, abundance of phytoplankton, benthic filamentous algae and aquatic vascular plants will also be enhanced (Tew et al., 2006). Optimal fertilization rate is the amount of organic matter that may be cost effective and utilized in a pond ecosystem without any harmful effect on water quality and on fish growth. The actual requirement of fertilizer dose in a pond system varies and depends upon the type of fish farming, agro-climatic conditions and productive history or the residual nutrients in the bottom sediment of the ponds (Bhakta et al., 2004).

Experiments suggest that inorganic fertilizers in the proportion of 300 g for a 45m^2 fish pond, produced adequate plankton (mainly Chlorophyta and Copepoda) with only slight water quality degradation. Inorganic fertilizer (NPK) favored the appearance of Calanoida-Copepoda, Argyrodiaptomus furcatus, which, together with nauplii, are easily preyed upon by fish larvae (Sipaúba-Tavares et al., 2001). Fertilizers favor the appearance of Rotifera and will also provide sufficient phytoplankton for zooplankton consumed by tilapia. It will also reduce the risk of extreme pH, low dissolved oxygen, and the potential infestation of Cyanobacteria which might cause water quality deterioration. Throughout the experiment temperature caused the establishment of phytoplankton and zooplankton. The use of inorganic fertilizer (NPK) is much better since it does not promote residue increase in the pond; rather it improves the quality and quantity of plankton and ecological and economic efficiencies. Moreover, fertilization of fish ponds promotes larger size increase and weight gain of fish.

Acknowledgments

Current paper was supported by FAPESP, ("Fundação de Amparo à Pesquisa do Estado de São Paulo"), protocol 95/1004-0. The authors are also grateful to Silvia R.L. de Laurentiz for technical assistance.

References

Arana, L.V. 1997. Princípios químicos da qualidade da água em aqüicultura. Editora da UFSC, Florianópolis. 166p.

Arcifa, M.S. 2000. Feeding habits of Chaoborus larvae in a tropical Brazilian reservoir. Rev. Bras. Biol., 60:591-597.

Bhakta, J.N., Sankar, D., Jana, S. & Jana, B.B. 2004. Optimizing fertilizer dose for rearing stage production of carps under polyculture. Aquaculture, 239:125-139.

Boyd, C.E. & Tucker, C.S. 1998. Pond aquaculture water quality management. Kluwer Academic Publishers, London. 700p.

Chakrabarti, R. & Jana, B.B. 1998. Effects on growth and water quality of feeding exogenous plankton compared to use of manure in the culture of mirgal, Cirrhinus mrigala, and rohu, Labeo rohita, fry in tanks. J. Appl. Aquacult., 8:87-95.

Culver, D.A., Madson, S. & Qin, J. 1993. Percid pond production technique: timing, enrichment, and stocking density manipulation. J. Appl. Aquacult., 2:9-31.

Das, S.K. & Jana, B.B. 1996. Pond fertilization though inorganic sources: an overview. Indian J. Fish., 43:155-173.

Dhawan, A. & Laur, S. 2002. Pig dung as pond manure: effect on water quality, pond productivity and growth of carps in poly-culture system. ICLARM Q., 25:11-14.

Feng, G.L., Letey, J., Chang, A.C. & Campbell-Mathews, M. 2005. Simulating dairy liquid waste management options as a nitrogen source for crops. Agric. Ecosyst. Environ., 110:219-229.

Fowler, J., Cohen, L. & Jarvis, P. 1998. Practical statistics for field biology. John Wiley & Sons, New York. 259p.

Golterman, H.L., Clymo, R.S. & Ohnstad, M.A.M. 1978. Methods for physical & chemical analysis of freshwaters. Blackwell Scientific Publication, London. 213p. (IBP Handbook, 8).

Goyal, S., Dhull, S.K. & Kappoor, K.K. 2005. Chemical and biological changes during composting of different organic wastes and assessment of compost maturity. Bioresour. Technol., 96:1584-1591.

Koroleff, F. 1976. Determination of nutrients. In: Grashof, K., Emhardt, M. & Kremling, E. (eds.) Methods of seawater analysis. Verlag Chemie, Wenhein.

Kubitza, F. 2003. Qualidade da água no cultivo de peixes e camarões. ESALQ/USP, Jundiaí. 229p.

Mackereth, F.J.H., Heron, J. & Talling, J.F. 1978. Water analysis: some revision methods for limnologists. Titus Wilson & Sons, Amblesie. 121p. (Scientific Publication, 36).

Mischke, C.C. & Zimba, P.V. 2004. Plankton community responses in earthen channel catfish nursery ponds under various fertilization regimes. Aquaculture, 233:219-235.

Nush, E.A. 1980. Comparison of different methods for chlorophyll and phaeopigments determination. Arch. Hydrobiol., 14:14-36.

Qin, J. & Culver, D.A. 1992. The survival and growth of larval walleye Stizostedion vitreum, and trophic dynamics in fertilized ponds. Aquaculture, 108:257-276.

Qin, J., Culver, D.A. & Yu, N. 1995. Effect of organic fertilizer on heterotrophs and autotrophs: implications for water quality management. Aquacult. Res., 26:911-920.

Siegel, S. 1975. Estatística não-paramétrica (para ciências do comportamento). McGraw-Hill do Brasil, São Paulo. 350p.

Sipaúba-Tavares, L.H. & Colus, D.S.O. 1995. Estudo da variação nictemeral em um viveiro de piscicultura no período de seca. Rev. Unimar, 17:225-236.

Sipaúba-Tavares, L.H., Bachion, M.A. & Braga, F.M.S. 2001. Effects of food quality on growth and biochemical composition of a calanoid copepod, Argyrodiaptomus furcatus, and its importance as a natural food source for larvae of two tropical fishes. Hydrobiologia, 453/454:393-401.

Stickney, R.R. 1994. Principles of aquaculture. John Wiley & Sons, New York. 502p.

Tepe, Y. & Boyd, C.E. 2001. A sodium-nitrate-based, water-soluble, granular fertilizer for sport fishponds. North Am. J. Aquacult., 63:328-332.

Tew, K.S., Conroy, J.D. & Culver, D.A. 2006. Effects of lowered inorganic phosphorus fertilization rates on pond production of percid fingerling. Aquaculture, 255:436-446.

Vanzolini, P.E. 1993. Métodos estatísticos elementares em sistemática zoológica. Hucitec, São Paulo. 130p.

Vilela, H. 1983. Utilização de excrementos de aves para ruminantes. Embrater, São Paulo. p.1-5. (Informação Técnica, 1).

Yusoff, F.M. & Mcnabb, C.D. 1999. The effects of phosphorus and nitrogen on phytoplankton dominance in tropical fish ponds. Aquacult. Res., 28:591-597.

Received: 13 March 2006
Accepted: 10 November 2006