Effects of selective harvest of the amazon river prawn, Macrobrachium amazonicum on pond water, sediment and effluent.

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ABSTRACT: Effects of selective harvest of amazon river prawn, Macrobrachium amazonicum on pond water, sediment and effluent. In freshwater prawn grow-out phase, the harvest can be total, selective or combined. The harvest can be considered as a periodic antropic factor that greatly modifies the pond ecosystem. Thus, the effect of harvest type (with seining or not) on pond water variables, sediment and effluents was investigated. Six 0.01-ha ponds were stocked with 20 M. amazonicum juveniles per m². Three ponds were seined fortnightly from 12th week on (selective harvest), while the other three were non-seined. Certain variables of water and effluent were monitored weekly, that is, dissolved oxygen, biochemical oxygen demand, pH, total alkalinity, electrical conductivity, nitrate-N, nitrite-N, ammonia-N, soluble phosphate, total phosphate, chlorophyll a, chlorophyll b, chlorophyll c, pheophytin, total dissolved solids and turbidity. The concentrations of organic carbon, total nitrogen and total phosphorus in sediment were also determined. Variables were compared between the treatments and day periods, for Student Test t . Temporal variation presented similar pattern in both treatments. Selective harvest did not alter pond water characteristics or the sediment. However, daily differences were seen for dissolved oxygen, pH, soluble phosphate and total dissolved solids in seined and non-seined ponds due to community metabolism. Data indicated that selective harvest does not impact pond water and sediments as well as effluents.
Key-words: pond water quality and sediment, effluents, selective harvest, Macrobrachium amazonicum.

RESUMO: Efeitos das despescas seletivas sobre as características limnológicas da água, sedimento e efluentes no cultivo do camarão-da-amazônia, Macrobrachium amazonicum. Na carcinicultura de água doce, a despesca pode ser total, parcelada (seletiva) ou mista. A despesca pode ser considerada como um fator antrópico periódico que modifica bastante o ecossistema. Assim, investigaram-se os efeitos do tipo de despesca (aplicação de despescas seletivas ou não) nas variáveis da água e sedimentos em viveiros, bem como dos efluentes. Utilizaram-se seis viveiros com cerca de 0,01 ha povoados com 20 juvenis de M. amazonicum.m^{-2}, dos quais somente três viveiros foram submetidos a arrastos com redes (despesca seletiva) a cada duas semanas, antes da despesca final. Semanalmente, foram determinadas as variáveis da água: oxigênio dissolvido, demanda bioquímica de oxigênio, pH, alcalinidade total, condutividade elétrica, nitrato, nitrito, nitrogênio amoniacal, ortofosfato solúvel, fósforo total, clorofila a, clorofila b, clorofila c, feofitina, sólidos totais dissolvidos e turbidez. Adicionalmente, avaliaram-se as concentrações de carbono orgânico, nitrogênio total e fósforo total no sedimento. As variáveis foram comparadas entre os tratamentos e períodos do dia, pelo teste t de Student. A variação temporal dos parâmetros analisados para a água foi similar nos dois tratamentos. As despescas seletivas não alteraram as características da água e do sedimento e do efluente. Por outro lado, diferenças ao longo do dia no oxigênio dissolvido, pH, ortofosfato solúvel e sólidos totais dissolvidos ocorreram nos viveiros de ambos os tratamentos, devido ao metabolismo da comunidade aquática.
Palavras-chave: Características da água e sedimento, efluentes, despescas seletivas, Macrobrachium amazonicum.

Introduction

Grow-out of freshwater prawns is performed in earthen ponds, which resemble natural bodies of continental waters (Valenti, 1995; Valenti & New, 2000). In general, ponds are stocked with post-larvae or juveniles prawns and, after some time, adults are harvested. The harvest can be total, selective or a combination of the two (Valenti & New, 2000). These techniques are described in detail by Valenti (1998), Valenti & New (2000) and New (2002). Briefly, total harvest involves total draining of the pond and collection of all prawns, whereas selective harvest (or cull harvest) comprises the use of a seine to collect only prawns of commercial size. In combined harvest, ponds are seined periodically to catch big prawns and drained at the end of culture to remove the leftover ones.

The harvest can be considered a periodic ecological factor that modifies pond ecosystem substantially (Valenti, 1995). Seining process disturbs the bottom, resuspending the sediment and possibly making nutrients and organic material available for biological processes that occur in the water column. It is believed that seining ponds cause stress to benthic communities including the prawns, and can alter the characteristics of the water and the processes of organic carbon fixation by photosynthesis and of decomposition by microorganisms.

Amazon river prawn, Macrobrachium amazonicum occurs widely in Brazil, namely in Acre, Amazonas, Amapá, Pará, Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Goiás, Mato Grosso, Mato Grosso do Sul (Young, 1998), Paraná (Bialetzki et al., 1997; Porto, 2004) and São Paulo (Magalhães et al., 2005). Traditional prawn fishing is practiced in Amazonia and Northeast States for local consumption (New et al., 2000). However, this species presents great potential for commercial farming (New, 2005) with low environmental impact (Moraes-Riodades & Valenti, 2001). Therefore, a multidisciplinary program aiming to obtain technology for M. amazonicum culture has been developed since 2000 (Valenti et al., 2003).

The objective of the present study was to test the hypothesis that seining periodically the ponds (selective harvest) produces permanent alterations in their limnological characteristics. The following aspects were investigated: a) effect of the type of harvest (with and without seining) on the limnological variables of the water column and effluent; b) effect of the type of harvest on the deposition of organic carbon, nitrogen and phosphorus on pond bottom, and consequently on the benefit of these nutrients.

Material and methods

Description of culture

The 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 (Fig. 1). Climate is Cwa type according to the Koepen classification, where there are a dry and a rainy alternating seasons (Koeppen, 1944). The annual mean precipitation and air temperature are greater 1350mm and 21/22°C, respectively. Precipitation and air temperature during experiment are presented in Figure 2.

Twelve earthen ponds of approximately 0.01 ha and about 1 m deep were used (Fig. 1). They were constructed on red latosol sediment with a sandy texture. The bunds were protected with grass to prevent erosion. Before filling, ponds were drained and air-dried, and the bottom sediment was removed. Then, they were limed using dolomitic limestone at 1 t/ha, and fertilized by the addition of 3 t/ha chopped cattle manure. Ponds were supplied with water from two dams that recycle the effluent of other experimental ponds and contain fish. These dams present hypertrophic characteristics, and their limnology is described by Macedo (2004). Water exchange rate was 5-10% of pond volume per day. Therefore, the retention time was 10 to 20 days. Sporadically, when a pond showed a dissolved oxygen level below 2 mgL^{-1}, an emergency aerator was turned on in the morning.

Ponds were stocked with 20 juveniles II (according to Austin & Sampaio, 2000) of M. Amazonicum per m^2 (50 days after metamorphosis and 0.36 ± 0.09 g). The animals fed extruded 37% crude protein commercial diet. Feeding rate varied between 7 and 9% of the total prawn biomass in each pond up 9th week. This biomass was estimated by means of monthly biometry and corrected monthly in the first two months. In the following two months, it was 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. After adoption of selective harvest

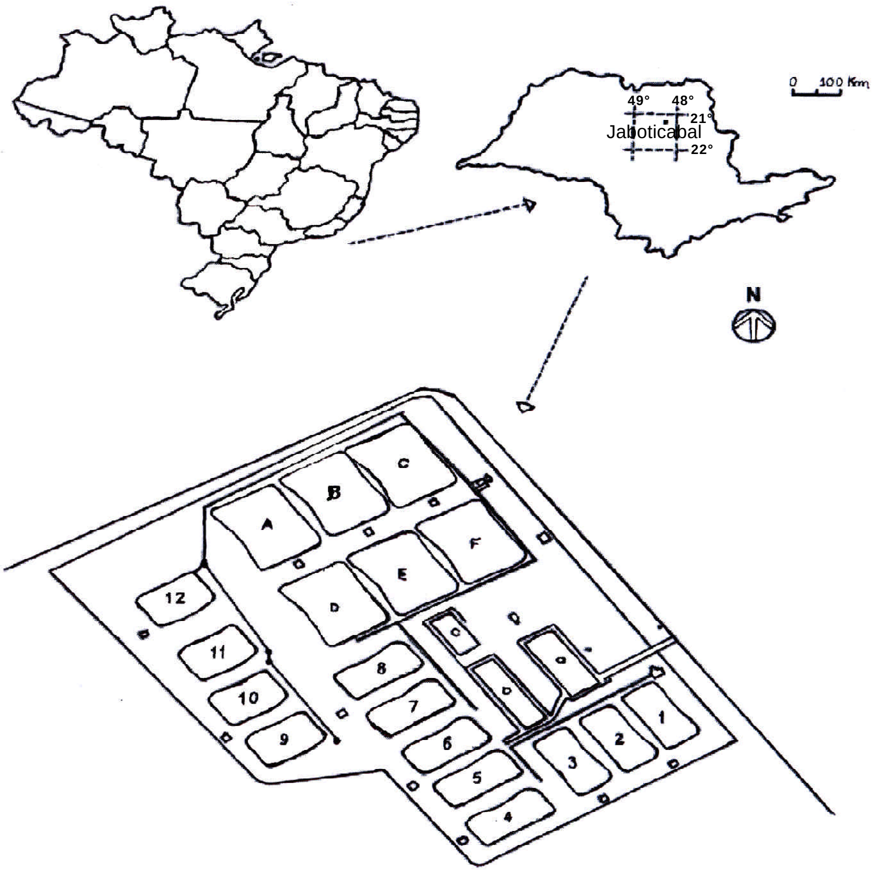

Figure 1: Location of the area of study. (Legend. 1 to 12 Grow-out ponds of Macrobrachium amazonicum; A to F – Ponds used as Broodstock of Macrobrachium amazonicum, Macrobrachium rosenbergii and sporadically used as secondary nursery; A – Laboratory of Larviculture and water quality; B – Nursery; C – Laboratory of Biometry).

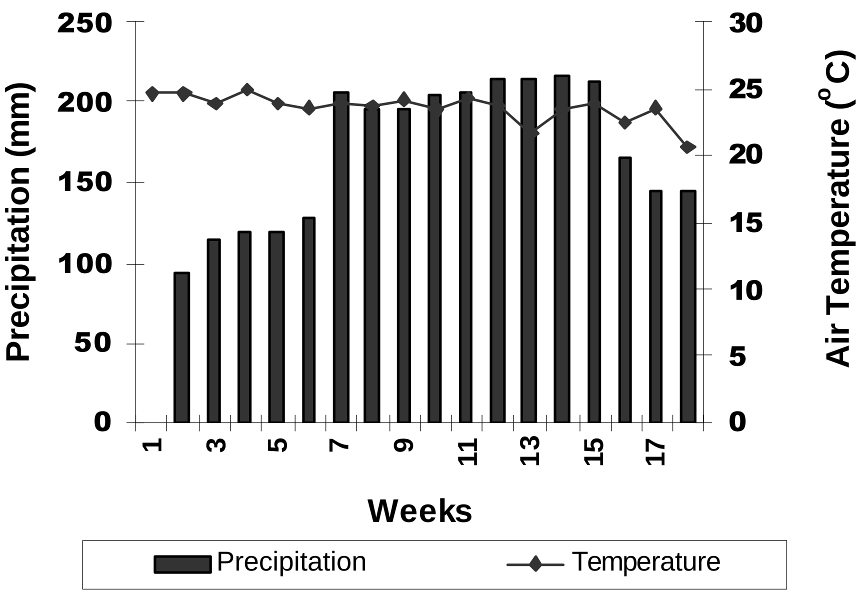

Figure 2: Air temperature (°C) and precipitation (mm) during the cultivation of Macrobrachium amazonicum (December 2004 to May 2005)

management 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 and 0.68 to 4.2 Kg/ha, respectively. General management followed the semi-intensive system in freshwater prawn farming (New, 2002).

Three ponds sorted randomly were submitted to the combined harvest system (selective plus total harvest), while three others were submitted to total harvest system (they were not seined) (Tab. I). Selective harvest was initiated on 12th week, when part of the population reached commercial size. This consisted of fortnight seining using 15 and 18 mm mesh seines to remove larger animals (Valenti & New, 2000). Both presented polyester bottom lines filled with lead weights (300 g.m^{-1} sinker). The seines were extending across the pond and drawing along the buds two times each one. The purpose of this process was to accelerate the growth of smaller prawns, which is inhibited by the presence of large animals. Selective harvests were carried out on weeks 12, 14 and 16, 0 to 3 days before water sampling. In the middle of May, after 145 days of stocking, a total harvest was performed in all ponds. After that, production for each pond was determined by sum of individual weight of all prawns harvested (Tab. I).

Table I: Pond size, number of individuals stocked, production and harvest treatment for each pond.

Pond	Size of pond (m^2)	No. Individuals Stocked	Production (kg.ha^{-1})	Treatment
9	89	1780	717.93	Combined harvest
2	92	1840	637.03	Combined harvest
3	100	2000	642.53	Total harvest
4	100	2000	666.27	Total harvest
5	120	2400	500.70	Combined harvest
6	98	1960	630.29	Total harvest

Water analyses

Each week, measurements and sampling of the ponds inlet water and effluent were performed during morning (7-9h) and afternoon (15-17h). Temperature (surface and bottom), 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, 1992). Total alkalinity was assessed according to Boyd & Tucker (1992). pH and electrical conductivity were determined in the bottom of the ponds using a YSI pH conductivity meter model 63.

Different forms of nitrogen and phosphorus were determined in whole samples collected from both the photic and aphotic zones following methods presented in APHA (1992) for nitrate, Strickland & Parsons (1960) for nitrite, Solorzano (1969) for ammonia nitrogen, Valderrama (1981) for total nitrogen, Adams (1990) and Boyd & Tucker (1992) for total phosphorus and soluble phosphate. Turbidity was assessed according to Wetzel & Likens (1991) by spectrophotometry, and total suspended solids by a gravimetric method as described by Boyd & Tucker (1992). The pigments chlorophyll a, b, c and pheophytin were determined according to the APHA (1992) method. A Hach model 2000 spectrophotometer was used in these analyses. All determinations were performed in duplicate. 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.

Sediment analyses

Sampling of the sediment (about 10 cm deep) was carried out on 18th week of culture (six weeks after selective harvest had started). Samples were obtained randomly in the ponds, using a shovel. Next, the samples were air-dried and stored in Styrofoam containers. Before the laboratory analysis, the samples were strained through a 2-mm mesh and homogenized. The South Dakota methods (modified for the determination of organic matter) were used (Cantarella et al., 2001). The determination of total nitrogen was carried out based on the method described by Tedesco et al. (1985). This method consists basically of the digestion of the samples at a temperature up to 330 °C, in the presence of oxidants and catalysts. Subsequently, the extract was distilled in a micro Kjeldahl apparatus and N was quantified by acid-base titration. The concentrations of total phosphorus were determined based on the colorimetric method described by Kuo (1996).

Experimental design and Statistical analysis

The experiment was set up as a one-way, completely randomized design with two treatments (harvest types) and three replicates (ponds). Data obtained after selective harvest start (from 12th week on) in the morning and afternoon were pooled by treatment and presented as means ± standard deviation. Shapiro-Wilk and Levene's tests were used to verify data normality and homocedasticity between treatments, respectively. The Student's t - test was applied to detect differences in means between two harvest techniques and between morning and afternoon. When assumptions of this parametric test were violated, the non-parametric Mann-Whitney U – test was used. All the data were analyzed using Statistica software version 6.0 from Statsoft Company (Statsoft, 1996) and SAS version 8.2 (Sas Institute, 2001). The results were considered statistically significant where $p < 0.05$.

Results

Figures 3 to 5 show the temporal variation of the limnological variables of the ponds water and inlet water during weeks 12 to 18, that is, after the start of selective harvest. Apparently, both treatments showed the same pattern of variation along culture. Table II presents the means of pond water limnological variables obtained from 12th week on, pooled by treatment, in the morning and afternoon. There was no statistically significant difference between combined harvest and total harvest (p›0.05)

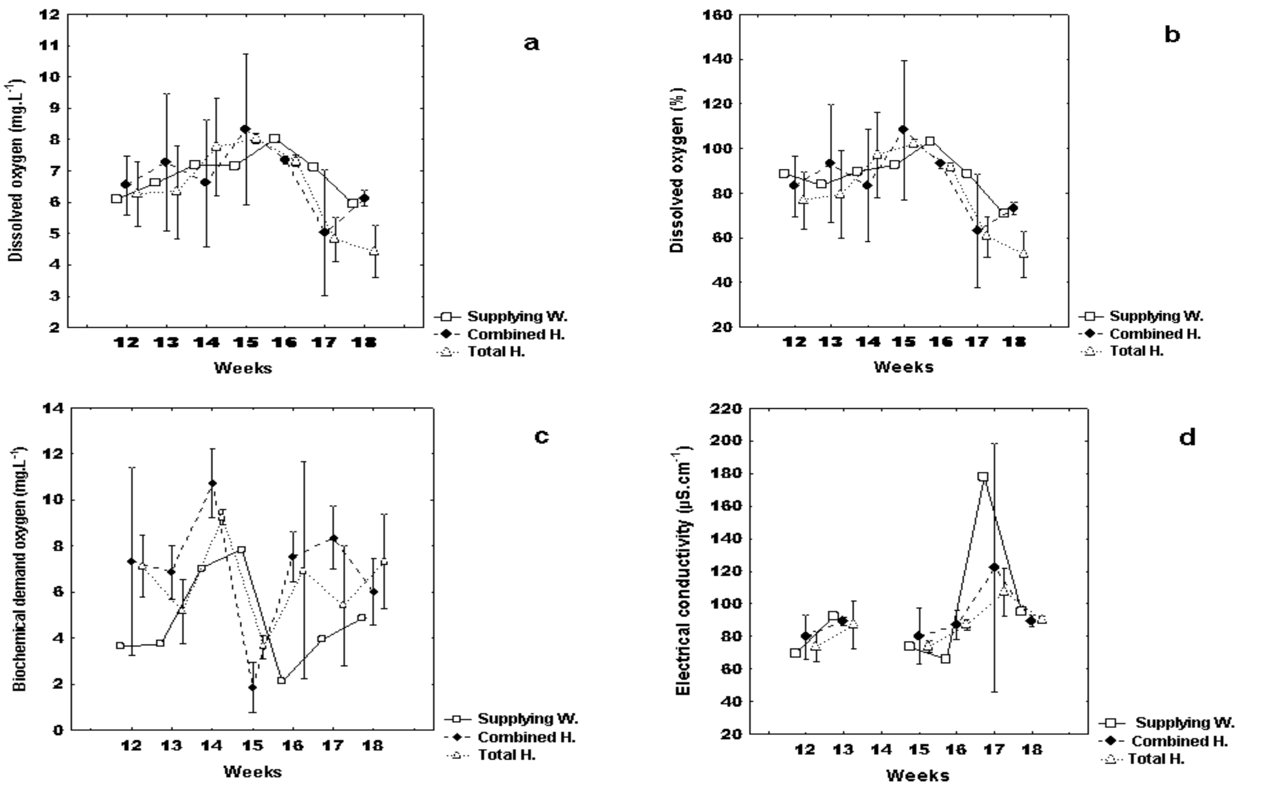

Figure 3a: Temporal variation of means and standard deviations of dissolved oxygen in mg.L-1 (a), dissolved oxygen in % (b), biochemichal demand oxygen (c) and electrical conductivity (d) after selective harvest. W= Water; H= Harvest

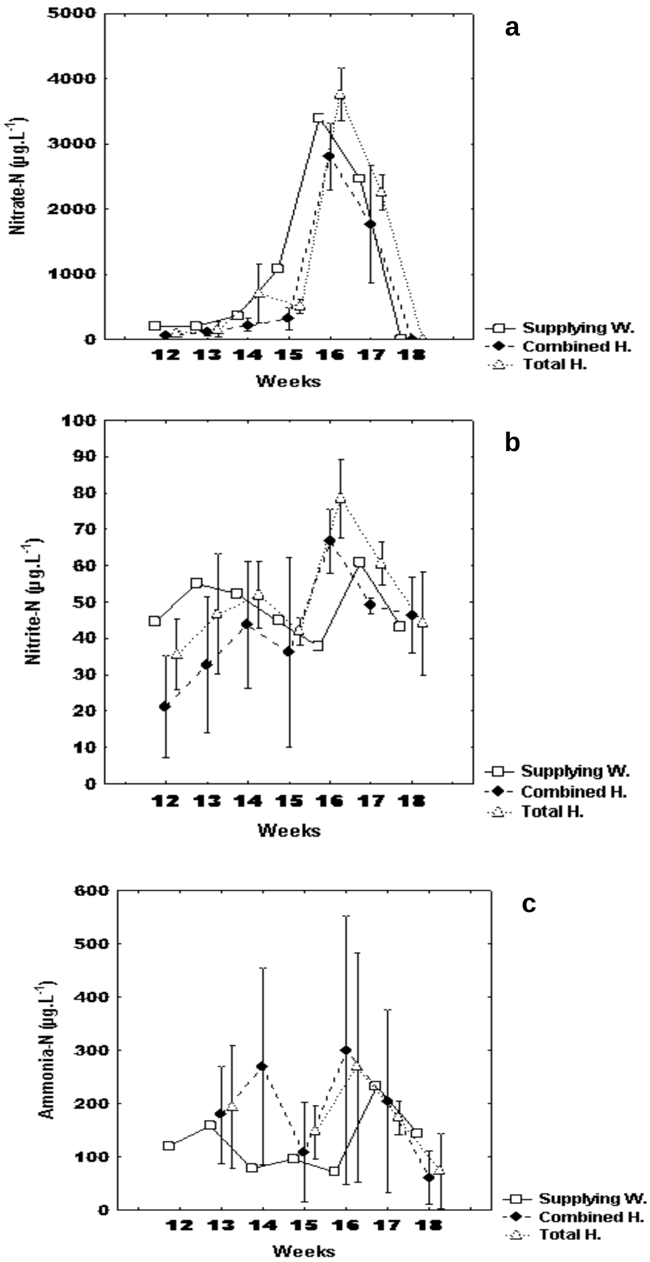

Figure 4a: Temporal variation of means and standard deviations of nitrate-N (a), nitrite-N (b) and ammonia-N (c) after selective harvest. W= Water; H= Harvest

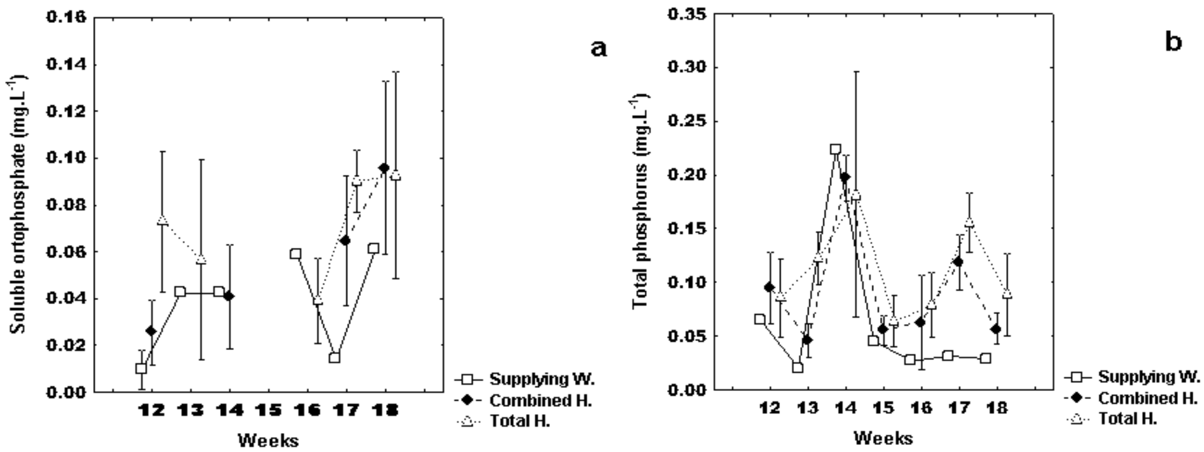

Figure 4b: Temporal variation of means and standard deviations of soluble ortophosphate (a) and total phosphorus (b) after selective harvest. W= Water; H= Harvest

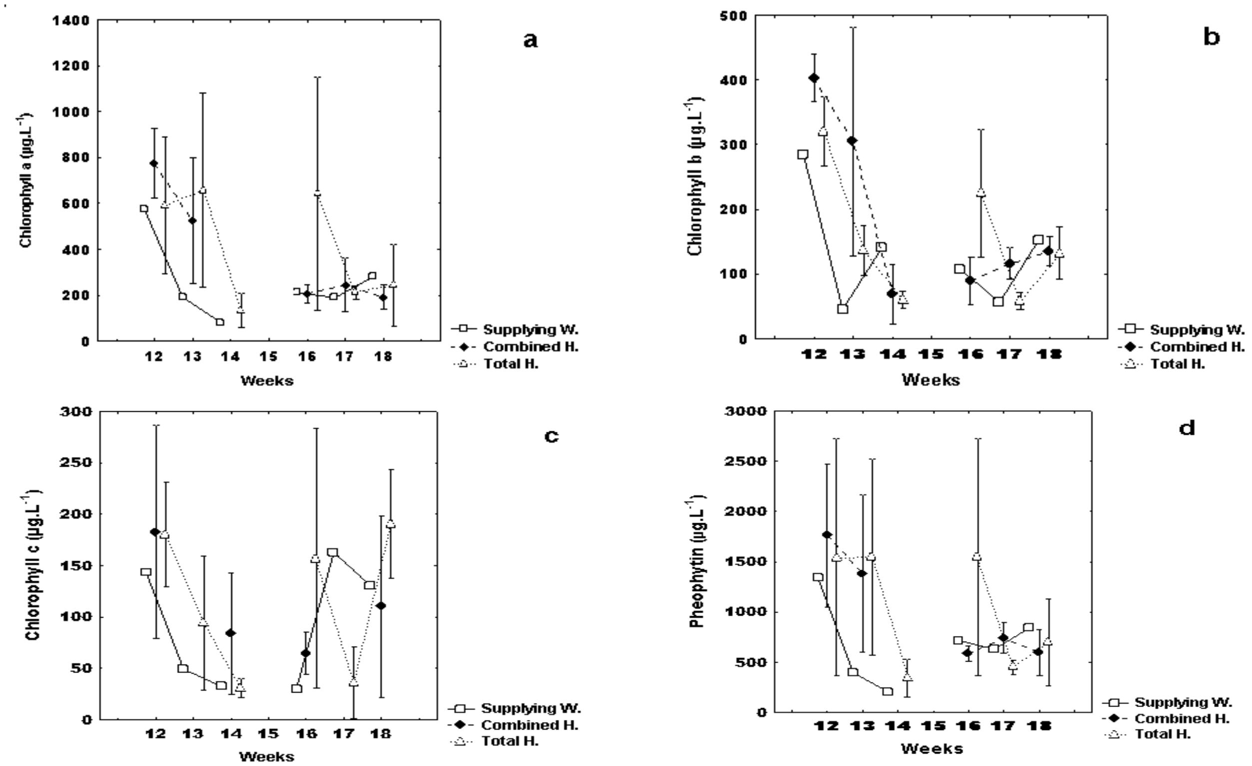

Figure 5: Temporal variation of means and standard deviations of chlorophyll a (a), chlorophyll b (b), chlorophyll c (c) and pheophytin (d) after selective harvest. W= Water; H= Harvest

Table II: Means (± standard deviation) of limnological variables of the ponds water, obtained in the morning and afternoon. Each mean represents the pooled value obtained for the three ponds of the same treatment. Means followed by different letters in the same row of the same treatment differ between day period

Variable	**Total harvest (no seined)**		**Combined harvest (seined)**	
	Morning	**Afternoon**	**Morning**	**Afternoon**
Dissolved oxygen (mgL^{-1})	5.63±1.67 **a**	6.99±2.62 **b**	6.30±2.05 **a**	7.08±2.13 **b**
Dissolved oxygen (%)	68.85±21.20 **a**	89.01±35.35 **b**	77.58±26.05 **a**	91.29±29.44 **b**
BOD ($mg.L^{-1}$)	5.92±3.67	6.98±3.14	7.02±2.84	7.02±3.59
pH	7.09±0.44 **a**	7.92±0.64 **b**	7.18±0.40 **a**	7.94±0.67 **b**
Total alkalinity($mg.L^{-1}$ $CaCO_3$)	45.42±3.95	44.58±5.61	46.54±4.57	44.86±5.40
Electrical conductivity ($mS.cm^{-1}$)	91±15	88±9.00	95±27	89±9
Nitrate ($mg.L^{-1}$)	1220±1238	1239±1696	1059±1332	707±1085
Nitrite ($mg.L^{-1}$)	54±18	53±18	45±16	47±21
Ammonia nitrogen ($mg.L^{-1}$)	208±99	149±84	201±97	172±155
Soluble phosphate ($mg.L^{-1}$)	0.041±0.046 **a**	0.066±0.031 **b**	0.045±0.039 **a**	0.084±0.073 b
Total phoshorus ($mg.L^{-1}$)	0.112±0.087	0.086±0.086	0.086±0.056	0.112±0.095
Chlorophyll a ($mg.L^{-1}$)	359±512	343±413	278±197	264±246
Chlorophyll b ($mg.L^{-1}$)	102±101	136±129	181±304	95±73
Chlorophyll c ($mg.L^{-1}$)	89±103	93±101	98±84	62±57
Pheophytin ($mg.L^{-1}$)	902±1199	836±863	830±557	712±593
Total suspended solids ($mg.L^{-1}$)	0.050±0.052 **a**	0.014±0.014 **b**	0.026±0.025 **a**	0.024±0.028 b
Turbidity (TNU)	20±10	21±19	23±12	25±11

(Tab. II). On the other hand, dissolved oxygen ($mg.L^{-1}$ and %S), pH, soluble phosphate and total dissolved solids differed ($p < 0.05$) between morning and afternoon in both treatments.

The mean values for the limnological variables of pond effluent obtained from 12th week on, pooled by treatment, in the morning and afternoon are described in Table III. In general, no difference was noted between the two treatments, except for dissolved oxygen ($p < 0.01$) in the morning. Comparison of values for the morning and afternoon did not show a statistically significant difference. Table IV presents data on pond sediment. Organic carbon, total nitrogen and total phosphorus did not differ between the two treatments ($p > 0.05$).

Table III: Means (± standard deviation) of limnological variables of the effluent water, obtained in the morning and afternoon. Each mean represent the pooled value obtained for the three ponds of the same treatment. Means followed by different letters differ between harvest types. ($P<0.05$). No difference were observed between morning and afternoon.

Variable	Total harvest (no seined)		Combined harvest (seined)	
	Morning	**Afternoon**	**Morning**	**Afternoon**
Dissolved oxygen ($mg.L^{-1}$)	5.14±1.73 a	5.09±1.74	5.93±2.65 **b**	5.46±1.57
Dissolved oxygen (%)	66.11±23.58	61.07±20.28	75.36±27.36	64.21±22.47
BOD($mg.L^{-1}$)	5.63±3.39	4.69±2.49	5.72±2.63	4.90±2.41
pH	7.26±0.75	7.48±0.59	7.40±0.61	7.34±0.59
Total alkalinity($mg.L^{-1}$ $CaCO_3$)	44.77±7.87	44.18±4.19	45.56±4.48	44.21±6.88
Electrical conductivity ($mS.cm^{-1}$)	89±10	89±10	92±13	96±10
Nitrate ($mg.L^{-1}$)	1181±1302	1424±2259	1162±130	1362±2011
Nitrite ($mg.L^{-1}$)	61±26	57±20	54±25	58±33
Ammonia nitrogen ($mg.L^{-1}$)	197±128	234±153	215±118	158±121
Soluble phosphate ($mg.L^{-1}$)	0.044±0.049	0.064±0.061	0.059±0.085	0.076±0.058
Total phoshorus ($mg.L^{-1}$)	0.122±0.075	0.077±0.073	0.113±0.111	0.097±0.096
Chlorophyll a ($mg.L^{-1}$)	266±194	271±170	247±294	347±304
Chlorophyll b ($mg.L^{-1}$)	91±71	101±59	74±59	109±64
Chlorophyll c ($mg.L^{-1}$)	58±40	80±65	54±34	88±65
Pheophytin ($mg.L^{-1}$)	673±494	678±411	632±729	828±797
Total suspended solids ($mg.L^{-1}$)	0.027±0.042	0.011±0.007	0.018±0.014	0.015±0.011
Turbidity (NTU)	19±12	23±9	24±13	27±12

Table IV: Concentration of organic carbon, total nitrogen and total phosphorus in the sediment of ponds submitted to combined (seined) and total harvest (non-seined). No difference were observed between treatments ($P > 0.05$)

	Combined harvest	**Total harvest**	**P**
Organic carbon ($g.dm^{-3}$)	12.00±2.00	11.66±2.51	0.86
Total nitrogen ($g.Kg^{-1}$)	1.56±0.50	2.06±0.95	0.46
Total phoshorus ($g.Kg^{-1}$)	1.60± 0.17	1.63±0.73	0.94

Discussion

Selective harvests carried out fortnightly did not alter pond water characteristics, effluent or the deposition of organic material, total nitrogen and total phosphorus in the sediment. Seining operation turns up the sediment, and resuspends a large quantity of material, which can be, observed visually at time of selective harvest (W. Valenti, pers. obs.). Therefore, the material suspended in the water column would be expected to serve as a substrate for detritivorous organisms, bacteria and fungi, increasing the concentrations of nitrogen and phosphorus compounds in the water column, and also decreasing their concentrations in the sediment. In addition, certain nutrients (as phosphorous) may be available to the phytoplankton. Such effect may be momentary, disappearing thereafter, or may alter permanently the limnological characteristics of the water and sediment. These alterations were not detected in the samples collected 0 to 3 days after harvest indicating none enduring modification in water or sediment produced by seining management. It may be due to the hypertrophic characteristics of the ponds, the large amount of feed and added fertilizers, the rapid sedimentation of suspended sediment or a combined effect of all these factors.

Generally, aquaculture ponds are hypertrophic ecosystems, in which is added artificial feed and fertilizers daily or weekly (W. Valenti, Pers. Com.). The high values of nitrogen and phosphorous in water column obtained in the present experiment indicate that the ponds really presented hypertrophic condition. Therefore, material suspended during seining may not be significant compared to the amount permanently suspended or dissolved in water column. On the other hand, feeding and fertilizers added to the tanks weekly were high. Each kg of commercial diet used adds about 60 g of nitrogenous and 10g of phosphorous. Therefore, added organic matter and nutrients may be higher than the amount spread in water column or subtracted from bottom as suspended material by seining management, which would mask the effect of selective harvest. In addition, the action of microorganisms on organic matter or ions certainly depends on the time in contact. In the present study, suspended sediment matter might settled rapidly after seining before undergoing significant exploitation by phytoplankton or other organisms.

No papers focus on the effects of selective harvest on limnological characteristics of aquaculture ponds were found. However, some authors have studied the effect of total harvest on pond water and effluent (Tepe & Boyd, 2002; Schwartz & Boyd, 1994; Lin et al., 2001; Hargreaves et al., 2005). On the contrary of we obtained in this work, Tepe & Boyd (2002) stated that phosphorous contained in the sediment increased the levels of phosphorus in water column, making it available for phytoplankton populations and causing algal "blooms" in bait minnow ponds, at Arkansas, USA. Consequently, it deteriorates pond water quality for aquaculture. Schwartz & Boyd (1994) point out that resuspension of the pond bottom during drainage can increase the concentrations of total suspended solids and turbidity in the effluent. In the present study, these were observed.

In general, temporal variation was similar in the two treatments for all variables. However, turbidity was higher in ponds with selective harvest in the majority of weeks. Probably some variables, as nitrate, were more affected by the supply water than by the seining pond, while the other variables might be more influenced by other processes that occurred in the ponds. In addition, community metabolism could be responsible for daily differences observed for dissolved oxygen, pH, soluble phosphate and total dissolved solids in seined and non-seined ponds (Esteves, 1988).

Seining ponds did not alter the deposition of carbon, ammonia nitrogen and phosphorus in the sediment. Similarly, it has a very slight effect on the quality of the water in the ponds and effluents. Therefore, the semi-intensive cultivation of M. amazonicum, using selective harvest, does not damage limnological pond characteristics by altering it in a significant manner. The choice of the use or not selective harvest should be based on production and economic features, as no important effect is produced on pond water, sediment and effluent characteristics.

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