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Intensificação do cultivo de *Macrobrachium amazonicum*: efeito das estratégias de estocagem e despesca na água dos viveiros, efluentes e sedimentação em viveiros de crescimento final

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Resumo

O objetivo do estudo foi avaliar o efeito de diferentes estratégias de estocagem e despesca nas variáveis da água, efluentes e sedimentação em viveiros de crescimento final do camarão-da-amazônia *Macrobrachium amazonicum*. Doze viveiros de 0,01 ha foram estocados na densidade de 40 juvenis.m^{-2}. Parte dos juvenis foi submetida a aleatorização para gradeamento em caixas com abertura de 5-6 mm, com o objetivo de obtenção de duas subpopulações mais homogêneas a partir de uma população heterogênea. Os tratamentos foram: 1= estocagem de juvenis gradeados "upper"; 2= estocagem de juvenis gradeados "lower"; 3= estocagem de juvenis não-gradeados + despesca-seletiva; 4= estocagem de juvenis não-gradeados (cultivo tradicional). Foram realizadas três réplicas por tratamento. Temperatura, transparência, turbidez, sólidos totais em suspensão, pH, oxigênio dissolvido, N-amônia, N-nitrito, N-nitrato, N- Nitrogênio total Kjeldahl, demanda bioquímica de oxigênio, demanda química de oxigênio, clorofila-*a*, P-ortofosfato solúvel e P-fósforo total foram avaliados na água dos viveiros. As mesmas variáveis, exceto transparência e clorofila, foram mensuradas nos efluentes dos viveiros. A camada acumulada de sedimento e a concentração de matéria orgânica foram determinados no sedimento dos viveiros. O tratamento upper apresentou valores significativamente mais elevados de sólidos totais em suspensão na água do viveiro. As características da água dos viveiros dos tratamentos despesca-seletiva e tradicional não diferiram significativamente entre si. Os efluentes dos viveiros upper apresentaram maiores médias de turbidez. A água de abastecimento apresentou menores médias de pH e maiores teores de oxigênio dissolvido em comparação com os efluentes de todos os tratamentos. Valores superiores de demanda bioquímica de oxigênio foram encontrados nos efluentes dos tratamentos upper, lower e despesca-seletiva. Valores de nitrato foram significativamente superiores no efluente do tratamento tradicional e na água de abastecimento. A concentração de ortofosfato solúvel foi menor nos tratamentos upper e lower. O tratamento despesca-seletiva apresentou a maior concentração de fósforo total. Os resultados permitiram concluir que a aquicultura conduzida sob estas condições estudadas alterou a água captada em alguns parâmetros (turbidez, pH, oxigênio dissolvido, demanda bioquímica de oxigênio, nitrato, ortofosfato solúvel e fósforo total).

Palavras-chave: Despesca-seletiva, gradeamento, efluentes, qualidade da água, *Macrobrachium amazonicum*.

Intensification of *Macrobrachium amazonicum* grow-out system: effects of stocking and harvesting strategies on water, effluents and sedimentation.

Abstract

The aim of this study was to evaluate the characteristics of water, effluent and sedimentation in freshwater prawn ponds stocked and harvested according to different strategies. Twelve 0.01-ha earthen ponds were stocked at 40 juveniles.m^{-2}. Part of juveniles was randomized and graded in 5-6 mm bar grader, in order to obtain two more homogeneous subpopulations from a heterogeneous initial population. Treatments were: 1= stocking upper graded juveniles; 2= stocking lower graded juveniles; 3= stocking non-graded juveniles + culled-harvest; 4= stocking non-graded juveniles + total harvest (traditional culture). Three replicates per treatment were performed. Temperature, total suspended solids, turbidity, pH, dissolved oxygen, N-ammonia, N-nitrite, N-nitrate, N-Total Kjeldahl nitrogen, biochemical oxygen demand, chemical oxygen demand, P-soluble orthophosphate and P-total phosphorus were monitored in pond water. The same variables except transparency and clorophyll-*a* were measured in eflluents. Accumulated sediment layer and organic matter concentration were determined in ponds sediment. Upper ponds presented significantly higher total suspended solids values. Pond water characteristics in culled-harvest and traditional treatments did not differ. Efluents from upper ponds presented higher turbidity mean values. Inlet showed lower mean values of pH and higher dissolved oxygen concentration in comparison to all treatments. Higher biochemical oxygen demand values were found in upper, lower and culled-harvest treatments. Nitrate values were significantly higher in traditional effluents and inlet water. Soluble orthophosphate concentration was lower in upper and lower treatments. Culled-harvest treatment showed the higher P-total phosphorus concentration. According to the results, aquaculture conducted under these studied conditions changed inlet water in some parameters (turbidity, pH, dissolved oxygen, biochemical oxygen demand, N-nitrate, P-soluble orthophosphate and P-total phosphorus).

Keywords: Culled-harvest, grading, effluents, water quality, sedimentation

1. INTRODUÇÃO

A intensificação consiste basicamente na busca pela maior produtividade. O aumento da produção na mesma unidade de área geralmente envolve um maior aporte de energia externa sob a forma de fertilizantes, alimento alóctone, aeração, mão-de-obra, entre outros.

Sistemas intensificados de cultivo podem ou não atender aos princípios de sustentabilidade. A sustentabilidade econômica, social e ambiental dos sistemas de cultivo pode ser alcançada porque possibilita aumentar a produção nas mesmas instalações. Isto evita os gastos e o impacto ambiental decorrentes da ampliação do número de viveiros, além da possibilidade de emprego de maior número de funcionários no manejo mais intenso. No entanto, muitas vezes ocorre o inverso porque os gastos com a implantação e manutenção de um sistema mais intensivo ultrapassam o aumento da receita gerada e/ou a carga de efluentes apresenta maior impacto ambiental negativo. Assim, estudos acurados devem ser realizados para possibilitar a identificação do nível de intensificação adequado para atingir a sustentabilidade do sistema.

O cultivo de camarões de água doce tem sido reportado como uma atividade de baixo impacto ambiental (Valenti, 2002). O sistema mais utilizado na carcinicultura de água doce é o semi-extensivo, que é caracterizado principalmente pela obtenção de produtividade intermediária em relação aos sistemas extensivo e intensivo, utilização de viveiros com baixa renovação diária de água, dependência de alimento natural e alóctone, utilização de mão-de-obra permanente e controle das condições de cultivo. O cultivo tradicional consiste basicamente na preparação dos viveiros (calagem e fertilização), povoamento com pós-larvas ou juvenis, e despesca total ao final do período de cultivo. Em áreas de restrição climática, geralmente realiza-se um ciclo anual de 4-6 meses. Ao final deste período, os camarões podem ser comercializados vivos, abatidos inteiros ou sem o cefalotórax (cauda). O tamanho comercial médio de *Macrobrachium amazonicum* é de 7 g (Moraes-Riodades & Valenti, 2004). No entanto, no momento da despesca final são encontradas várias classes de tamanho do camarão. Segundo Moraes-Riodades & Valenti (2004), este fato pode ser devido à presença de quatro grupos de machos que apresentam taxas de crescimento diferentes: “Translucid Claw” (TC), “Cinnamon Claw” (CC), “Green Claw 1” (GC1) e “Green Claw 2” (GC2) (Figura 1). Dentre as características que os diferencia estão: os quelípodos são translúcidos em TC, cor de canela em CC, verdes e maiores em GC1 e GC2; os dois primeiros morfotipos apresentam poucos espinhos, enquanto os últimos possuem espinhos longos e robustos; GC2 apresenta o comprimento do quelípodo superior à distância pós-orbital e angulação dos espinhos mais aberta, enquanto GC1 apresenta o comprimento do quelípodo inferior à distância pós-orbital e angulação dos espinhos mais fechada (Moraes-Riodades & Valenti, 2004). A existência desses morfotipos tem implicações diretas para a aqüicultura, pois o manejo dos viveiros de engorda deve minimizar o crescimento heterogêneo dos machos para maximizar a produção e uniformizar o produto a ser comercializado.

Tecnologias têm sido desenvolvidas nos últimos anos para permitir a intensificação da produção de camarões de água doce (Tidwell et al., 2004). Técnicas como o gradeamento de juvenis, a prática de despesca-seletiva e o uso de substrato são utilizadas no cultivo de *Macrobrachium rosenbergii* para reduzir a variabilidade de tamanho. O gradeamento de juvenis para obter populações com tamanho mais homogêneo e o uso de despescas-seletivas reduziu os efeitos negativos do crescimento heterogêneo em *Macrobrachium rosenbergii* (Karplus et al., 2000; Tidwell & D'Abramo, 2000). O gradeamento de juvenis consiste em aleatorizar parte da população inicial e submetê-la a seleção em diferentes classes de tamanho, geralmente utilizando-se caixas com barras paralelas de abertura ajustável ao tamanho da população inicial (Tidwell & D´Abramo, 2000), conforme Figura 2. Os animais retidos na caixa gradeadora são chamados de "uppers", e os que passam pelas barras da caixa, de "lowers". Deste modo, obtem-se populações com tamanho mais homogêneo (Figura 3), e evita-se a inibição do crescimento dos indivíduos com tamanhos reduzidos por parte dos animais dominantes. Deste modo, obtêm-se camarões com taxas de crescimento mais elevadas e peso final mais homogêneo na despesca final. A despesca-seletiva (Figura 4) refere-se à retirada de machos dominantes que já apresentam tamanho comercial, contribuindo para a regularidade do produto no mercado, e das fêmeas maduras, que como os machos dominantes apresentam reduzidas taxas de crescimento (Valenti & New, 2000) (Figura 5). Outra vantagem da despesca-seletiva é que com a retirada dos animais dominantes, podem-se obter maiores taxas de crescimento dos camarões de castas sociais inferiores. Portanto, a despesca-seletiva inicia-se a partir da ocorrência de machos dominantes ou com peso comercial (aproximadamente 7 g para *Macrobrachium amazonicum*), e é realizada geralmente a cada 14-21 dias. Utilizam-se redes de arrasto com a abertura de malha adequada para a retirada dos animais maiores (aproximadamente 12 mm para *Macrobrachium amazonicum*). Os animais retidos são abatidos em água clorada e gelo, e os demais eventualmente capturados, devolvidos ao viveiro. O uso de substrato artificial (Figura 6) consiste na ampliação da área do viveiro para possibilitar o aumento do peso médio individual, da densidade de estocagem, diminuir a competição entre os animais e melhorar a conversão alimentar devido ao desenvolvimento de alimento natural na superfície do material adicionado (Tidwell et al., 1998; Tidwell et al., 2000). Esses métodos de manejo elevam significativamente produtividade (Karplus et al., 2000; Tidwell et al., 1998) e podem ser úteis no cultivo de *M. amazonicum.* Entretanto, o uso destas técnicas de cultivo no ecossistema do viveiro deve ser avaliado.

Conforme Funge-Smith & Briggs (1998), os fatores que influenciam o ambiente de cultivo são a água de abastecimento, os sedimentos depositados no fundo dos viveiros e o manejo empregado, respectivamente. O manejo inclui diversas estratégias de estocagem e despesca, métodos de alimentação, fertilização e calagem, o uso ou não de aeradores e a taxa de renovação da água. Portanto, viveiros sob diferentes estratégias de estocagem e tipo de despesca podem ter funcionamento distinto daquele encontrado nos viveiros sob cultivo tradicional. Estudos sobre a influência do tipo de manejo adotado no ambiente de cultivo de camarões de água doce são escassos (Keppeler & Valenti, 2006; Moraes-Riodades et al., 2006).

A estocagem de juvenis com tamanho superior pode provocar a bioturbação, que é a erosão causada pela atividade natatória do camarão. Como consequência, pode ocorrer principalmente o aumento da turbidez e da concentração de sólidos totais em suspensão, além de disponibilizar nutrientes do fundo do viveiro para a coluna d´água e gerar efluentes mais eutrofizados devido ao maior fornecimento de alimento alóctone. A despesca-seletiva, de maneira similar, parece ter o efeito benéfico de disponibilização de nutrientes contidos nos sedimentos dos viveiros. Além disso, esta estratégia de despesca permite aumentar a sustentabilidade social do cultivo, pois maior quantidade de mão-de-obra é empregada. Por outro lado, o revolvimento do fundo do viveiro pode provocar um aumento da turbidez e da concentração de sólidos totais em suspensão nos viveiros submetidos a este manejo. Este fato pode prejudicar o desenvolvimento da comunidade fitoplanctônica (devido à redução da entrada de luz), da comunidade bentônica (Keppeler & Valenti, 2006), inclusive dos camarões (por obstrução das brânquias), além da possibilidade de gerar efluentes com características distintas da água de abastecimento e do corpo de água receptor.

Os viveiros possuem uma notável capacidade de assimilar nitrogênio e fósforo por meio de processos físicos, químicos e biológicos (Schwartz & Boyd, 1994a). Contudo, os viveiros freqüentemente apresentam maiores concentrações de nutrientes, plâncton, sólidos em suspensão e demanda de oxigênio em comparação com o corpo de água que recebe os efluentes (Schwartz & Boyd, 1994b). Como exemplo, alimentos e fertilizantes são adicionados aos viveiros para promover a produção de camarões e peixes, e normalmente, apenas 25% a 30% do nitrogênio e fósforo contidos nos fertilizantes e alimentos é revertido em camarão e/ou peixe na despesca (Boyd & Tucker, 1998).

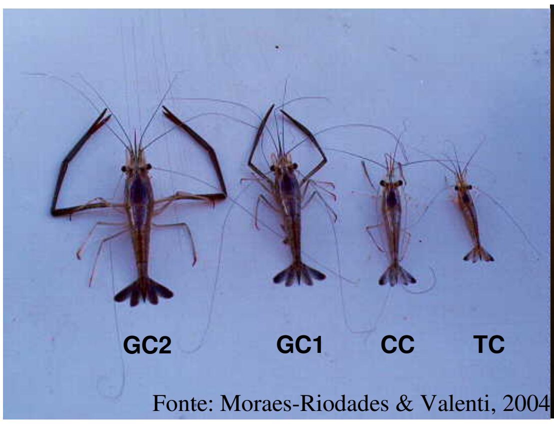
Os viveiros geram efluentes após chuvas severas, quando são drenados (Boyd & Queiroz, 2001) e em função da renovação da água (Boyd, 2003). Boyd (2003) afirma que, apesar de haver um interesse considerável no reuso da água, ou nos sistemas de produção em ciclo fechado, geralmente não é tecnicamente e/ou economicamente viável realizar aqüicultura sem descarga de efluentes.

De acordo com Boyd (2003), a aqüicultura tem crescido o suficiente para ter impacto significante no ambiente e recursos naturais, e um número significativo de ativistas ambientais e cientistas têm se preocupado com essa situação (Dierberg & Kiattisimukul, 1996; Goldburg & Triplett, 1997; Naylor et al., 1998, 2000; Jegatheesan et al., 2006). A poluição resultante dos efluentes dos viveiros tem atraído a atenção oficial de várias nações (Boyd & Gautier, 2000; Boyd & Tucker, 2000) que iniciaram a elaboração de regulamentos para os efluentes gerados pela aqüicultura, como por exemplo, países da Comunidade Européia, os Estados Unidos, Belize, Brasil, Equador, Índia, México, Oman, Tailândia e Venezuela (Boyd, 2003). As associações de aqüicultores estão preocupadas com os possíveis efeitos da não-aprovação por parte dos consumidores, pois há uma crescente conscientização ecológica (Boyd, 2003). Atualmente há uma crescente demanda pela implantação de sistemas de produção ambientalmente responsáveis e um interesse nas vantagens econômicas dos produtos certificados como “ambientalmente corretos” (Boyd, 2003).

Os regulamentos para efluentes impostos pelos governos freqüentemente requerem submissão aos padrões da qualidade da água dentro de um critério numérico (Gallagher & Miller, 1996; Mackenthun, 1998 *apud* Boyd, 2003), como ocorre no Brasil. (Brasil, 2005). Os aquicultores deverão adequar os métodos de produção para atender aos critérios de qualidade de água permitidos (Boyd, 2003). Além disso, a preservação ambiental é um componente da aqüicultura moderna (Valenti, 2002). Portanto, quando se pretende implantar novas técnicas de manejo, deve-se estudar o seu impacto sobre o ambiente de cultivo, pois os efluentes gerados podem impactar o meio ambiente receptor.

Dentro desse contexto, o objetivo deste trabalho foi avaliar o efeito do gradeamento de juvenis e da despesca-seletiva nas características da água do viveiro e efluentes, e nos sedimentos na fase de crescimento final de *M. amazonicum*. Este projeto insere-se dentro de um Programa para o Desenvolvimento de Tecnologia de Cultivo de *M. amazonicum*, envolvendo o Centro de Aqüicultura da UNESP, a Universidade de São Paulo, a Secretaria Executiva de Agricultura do Estado do Pará, a Universidade Estadual do Pará, a Universidade Federal Rural da Amazônia, a Universidade Estadual do Mato Grosso do Sul, a Embrapa Meio-Ambiente e o Instituto de Pesca da Secretaria de Agricultura do Estado de São Paulo.

Optou-se por apresentar a dissertação em forma de dois artigos científicos: o primeiro enfoca as características da água do viveiro e os sedimentos, e o segundo, os efluentes.



Fonte: Moraes-Riodades & Valenti, 2004

Figura 1. Morfotipos de *M. amazonicum*.

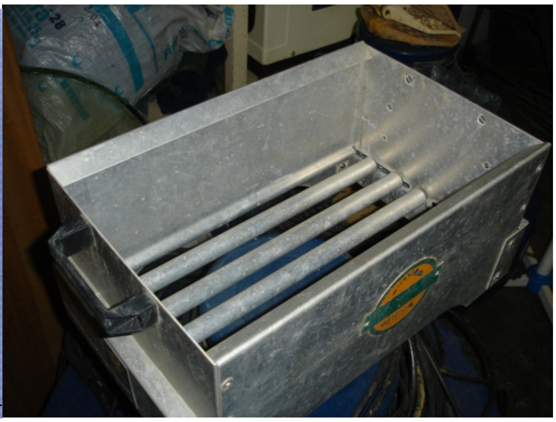


Figura 2. Caixa gradeadora.

Figura 3. A= juvenis não-gradeados; B= juvenis gradeados (“upper”).

Figura 5. Machos GC2 e fêmea retirados na despesca-seletiva.

Figura 4. Despesca-seletiva.

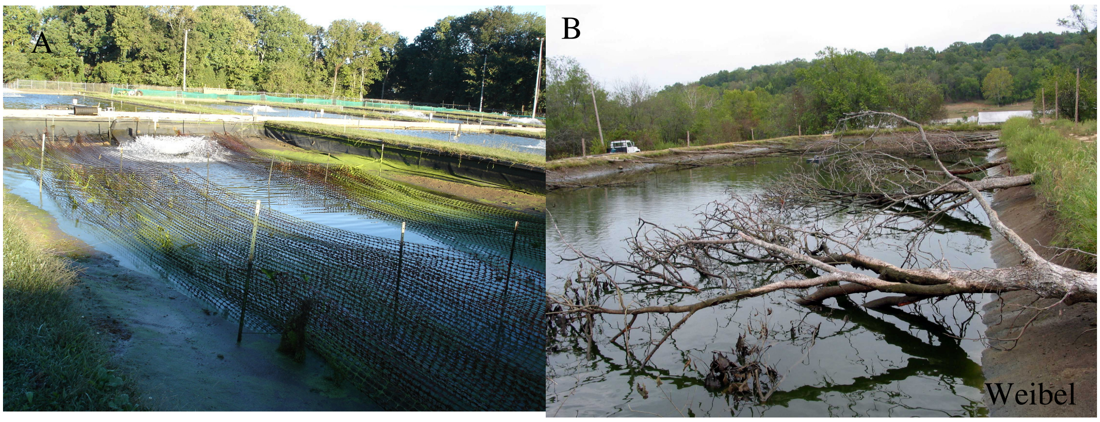


Figura 6. Substratos. A= polietileno; B= troncos de árvore.

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Intensification of *Macrobrachium amazonicum* grow-out system: effects of stocking and harvesting strategies on water quality and sediment characteristics in rearing ponds

Abstract

This study evaluated the effect of two different stocking and harvesting strategies on water quality and sediment in *Macrobrachium amazonicum* rearing ponds. Twelve 0.01-ha earthen ponds were stocked at 40 post-larvae.m^{-2} with three replicates per treatment. Treatments were: 1= stocking upper graded juveniles; 2= stocking lower graded juveniles; 3= stocking non-graded juveniles + culled-harvest; 4= stocking non-graded juveniles + total harvest (traditional culture). Temperature, transparency, turbidity, pH, dissolved oxygen, N-ammonia, N-nitrite, N-nitrate, N-Total Kjeldahl nitrogen, total suspended solids, biochemical oxygen demand, chemical oxygen demand, clorophyll-*a*, P-soluble orthophosphate and P-total phosphorus were determined in pond water. Accumulated sediment layer and the concentration of organic matter in sediments were determined. Ponds stocked upper animals presented significantly higher values of total suspended solids, which may be a result of higher feding input and/or an erosion consequence of their swimming activity. Culled-harvest did not differ from traditional culture in terms of water quality, but in sediment accumulation. Pond water differed slightly from inlet water indicating the effect of aquaculture practices, while the effect of treatments were negligible in this studied condition.

Keywords: *Macrobrachium amazonicum*, culled-harvest, grading, water quality, sedimentation

Introduction

The freshwater prawn *Macrobrachium amazonicum* is a native species from South America (Bialetzki et al., 1997) and presents great potential for aquaculture (Kutty, 2005; New, 2005). This prawn is largely distributed in the continent, is resistant, omnivorous, presents a relatively short grow-out phase, its hatchery technology is well defined, and has a huge market interest. However, males are divided in four distinct groups with different growth rates: "Translucent Claw" (TC), "Cinnamon Claw" (CC), "Green Claw 1" (GC1) and "Green Claw 2" (GC2) (Moraes-Riodades and Valenti, 2004). Due to this characteristic, some management practices might be used to minimize the negative effect of these morphotypes and raise productivity while ensuring the uniformity of production. The most practiced techniques for *Macrobrachium rosenbergii* are: use of substrates, culled-harvest and grading juveniles (Karplus et al., 2000; Tidwell and D'Abramo, 2000; Tidwell et al, 2003; Tidwell et al., 2004). These management practices may be useful in *M. amazonicum* culture. However, the impact of these intensifying techniques on water pond and sedimentation is unknown. In addition, papers with focus on water quality in grow-out ponds of *M. amazonicum* are scarce (Keppeler & Valenti, 2006; Moraes-Riodades et al., 2006).

Freshwater prawn culture is mainly conducted under semi-intensive systems. Post-larvae or juveniles are stocked after regular pond preparation (liming and fertilization), and general management consists in daily feeding and monitoring a few water parameters; after some months ponds are drained and prawns are totally harvested. Intensifying this basic management through grading juveniles or culled-harvest implies in higher labor requirements, and thus, higher energy input in the system. It may contribute to social, environmental, and economic sustainability. Social sustainability may be reached by direct labor increase; improving nutrients dynamic through bioturbation and seining resuspension may contribute to environmental sustainability, and productivity enhance leads to economic sustainability.

However, it is known that aquaculture may not convert energy input efficiently. Feed and fertilizers are added into ponds to promote prawn and fish production, and generally, only 25% to 30% of nitrogen and phosphorus from them are reverted in prawn and/or fish at harvest (Boyd and Tucker, 1998). Ponds frequently present higher nutrients, plankton, suspended solids, and oxygen demand (BOD) in comparison to receiving environments (Schwartz and Boyd, 1994). In this case, intensification may cause negative impacts and decrease sustainability.

Studies on *Macrobrachium* production generally does not focus on ponds ecology. However, understanding these ecosystems dynamics may contribute to a better nutrient utilization, reducing waste production within ponds (Jackson et al., 2003), highlights the importance of an integrated approach to waste reduction involving the disciplines of production management, nutrition, ecology (Burford et al., 2001), and thus attending sustainable principles.

In this context, the objective of this study was to evaluate the effects of size-grading juveniles and culled-harvest on water and sedimentation of *M. amazonicum* grow-out ponds.

Material and Methods

The study was carried out at the Crustacean Sector, Aquaculture Center, Sao Paulo State University, Jaboticabal, Sao Paulo, Brazil (21°15’22’’S and 48°18’48’’W). Twelve 0.01-ha earthen ponds were drained and allowed to air-dry. Then, they were filled via dam after passing through a mechanic filtering system. Emergency aerators were used when dissolved oxygen fell below 2.0 $mg.L^{-1}$ in the morning. Chemical fertilization was necessary when transparency value was above 50 cm. Urea and simple superphosphate were added in the proportion of 2 kg $N.ha^{-1}$ and 8 kg $P_2O_5.ha^{-1}$, respectively (Boyd & Zimmermann, 2000). Post-larvae for stocking were produced in the facility, stocked in nursery tanks for 15 days, and transferred to secondary nurseries for 30 days more. Randomized samples were taken and juveniles were graded in a 5-6 mm bar grader (Bernauer Aquacultura, SC, Brazil). Two populations were obtained: uppers (“top-grade”), or the animals that were retained by the grader, and lowers (“bottom-grade”), which corresponded to the juveniles that passed through the grader. Ponds were stocked in the density of 40 $juveniles.m^{-2}$, according to the treatments: T1 = graded-juveniles from population "upper"; T2 = graded-juveniles from population “lower”; T3 = non-graded juveniles + culled-harvest; T4 = non-graded-juveniles (traditional culture).

A completely randomized experiment design with four treatments and three replicates was used. T1 consisted of stocking the biggest animals, or “upper” graded-juveniles. After 3.5 months, ponds were drained for total harvest. T2 constituted ponds stocked with the population formed by prawns that presented minor initial growth, called "lowers". The objective was to stock ponds with either smaller or larger prawn to allow faster growth of smaller individuals that normally would be inhibited by the presence of bigger animals (Karplus et al., 2000). After 3.5 months, ponds were drained for total harvest. T3 ponds were stocked with non-graded juveniles. When part of population reached commercial sizes (approximately 7 g), culled-harvest was initiated, using a 12 mm mesh net. Three culled-harvests were carried out during the experimental period. At the end of rearing cycle (3.5 months), ponds were totally harvested. T4 was the traditional culture, or stocking non-graded juveniles, and, after 3.5 months, ponds were drained for harvest (total harvest).

Prawns were fed a pelletized commercial diet (30% crude protein) at a rate of 9 to 3% of prawn biomass according to development phase. Prawn biomass was estimated by monthly samples and was corrected weekly, considering 1% mortality and 10% weight gain. Feed was divided in two equal portions and distributed at 0800 and 1600 h daily. Total quantity of added feed is shown in Table 2. Water was daily monitored for temperature and dissolved oxygen concentration, in the morning and in the afternoon. Daily water exchange rate was measured weekly, using a graduated bucket. Water samples were taken for analysis according to Table 1.

Table 1. Water variables and methods of analysis.

Variable	**Method of analysis/apparatus**	**Sample frequency/ Time of sampling**	**Reference**
Temperature	Digital oxygen meter	Daily (0630h/1600h)	Yellow Springs Instruments, Yellow Springs, OH, USA
Transparency	Secchi disk	Weekly (1600h)	
Turbidity	Hach DR/2000	Weekly (1600h)	Hach, Loveland, CO, USA
Total suspended solids	Gravimetric	Biweekly (1600h)	APHA, 1998
pH	Digital pH meter	Weekly (1600h)	Yellow Springs Instruments, Yellow Springs, OH, USA
Dissolved oxygen	Digital oxygen meter	Daily (0630h/1600h)	Yellow Springs Instruments, Yellow Springs, OH, USA
BOD	5 days	Weekly (0630h)	APHA, 1998
COD	Closed reflux, colorimetric	Weekly (1600h)	APHA, 1998
Clorophyll-*a*	Colorimetric	Biweekly (1600h)	APHA, 1998
N- ammonia	Phenate, colorimetric	Weekly (0630h/1600h)	APHA, 1998
N-nitrite	Colorimetric	Weekly (0630h/1600h)	APHA, 1998
N-nitrate	Hydrazin sulphate reduction	Weekly (0630h/1600h)	APHA, 1998
N-Kjehdahl nitrogen	Semi-micro Kjeldahl	Biweekly (1600h)	APHA, 1998
P-soluble orthophosphate	Stanous cloride, colorimetric	Biweekly (1600h)	APHA, 1998
P-total phosphorus	GF/C Filtration, Stanous cloride, colorimetric	Biweekly (1600h)	APHA, 1998

Water samples were taken and *in situ* measurements were made in approximately 10 cm from the bottom of ponds, due to prawns habitat, except for chlorophyll-*a*, when samples were taken in the surface of ponds.

Pond bottom was marked at the beginning of the rearing cycle so after harvest accumulated layer was measured. Five sediment samples per pond were taken and pooled together for organic matter (gravimetric method, 24 hours at 70°C) determination.

Treatment effects were evaluated by normality and homocedasticity analysis using the Shapiro-Wilk and Brown-Forsythe tests, respectively (SAS version 8.2). Normal and homocedastic data were compared by analysis of variance (ANOVA) by F test (parametric) followed by Duncan test. Heterocedastic and/or non-normal data were analysed by Friedman test (non-parametric). A principal components analysis of pond water variables was made using Statistica (version 6.0).

Results

Water exchange rate was 29.0±1.6%.day^{-1}. Temperature in ponds was 27.1±0.1°C in the morning and 28.9±0.2°C in the afternoon. No significative difference among treatments was observed for transparency and clorophyll-*a* in pond water (Table 2). Turbidity was significatively lower in inlet water than in traditional, upper and lower pond treatments (Table 2). Higher concentration of total suspended solids was found in upper ponds (Table 2). Inlet pH mean value was inferior and dissolved oxygen values superior to pond values in all treatments (Table 2). Mean biochemical oxygen demand value was significatively lower in inlet water than in lower and culled-harvest ponds (Table 2).

N-ammonia concentration did not differ significantly among treatments neather in the morning nor in the afternoon (Table 2). N-ammonia was higher in lower and traditional treatments in the morning in comparison with the values in the afternoon (Table 2). N-nitrite concentration in ponds did not differ among treatments and inlet water (Table 2). N-nitrate was higher in inlet and upper treatment in the morning (Table 2). Inlet water showed higher value of N-nitrate than pond water in the afternoon (Table 2). No temporal variation trend was observed for N-nitrite and N-nitrate values (Table 2). N-Total Kjeldahl nitrogen did not differ among treatments (Table 2). There was no difference in P-soluble ortophosphate concentration among treatments while P-Total phosphorus concentration was higher in upper ponds (Table 2).

Higher accumulation layer was found in culled-harvest ponds than in traditional and upper treatments (Table 3). There was no difference among treatments for organic matter contend, which ranged from 83.5 to 84.2% of dry matter (Table 3).

Feed addition to ponds varied from 2988 $kg.ha^{-1}$ in lower treatment to 4077 $kg.ha^{-1}$ in upper treatments (Table 4). Culled-harvest presented 23.14% of feeding redution in comparison to traditional treatment (Table 4). Total nitrogen and phosphorus input by fertilization and feeding in $kg.ha^{-1}$ is shown in Table 5.

The principal components analysis resumed 91.33% of total variability in the first two components for pond water variables (Figures 1 and 2). Dissolved oxygen in the afternoon, temperature, pH and N-nitrate in the afternoon were positively correlated with principal components 1 and 2 (Figure 2). Turbidity and total suspended solids were positively correlated with principal component 2, and negatively correlated with principal component 1

(Figure 2). P-total phosphorus and P-soluble orthophosphate, N-total Kjeldahl nitrogen, chlorophyll-*a* and N-ammonia in the afternoon were negatively correlated with components 1 and 2 (Figure 2). Biochemical oxygen demand, chemical oxygen demand, N-ammonia in the morning, N-nitrate in the aftrnoon, dissolved oxygen in the morning, transparency and nitrite were positively correlated with the first component, and negatively correlated with component 2 (Figure 2). Measured factors grouped all treatments in a distinct quadrant (Figure 1).

Table 2. Mean values and standard deviation of water quality variables analyzed in inlet and pond water.

	Inlet water	**Upper**	**Lower**	**Culled-Harvest**	**Traditional**
Transparency (cm)		46±11^{a}	50±7^{a}	55±11^{a}	49±8^{a}
Turbidity (UNT)	15±6^{b}	26±5^{a}	24±2^{a}	21±3^{ab}	25±4^{a}
Total suspended solids (mg.L^{-1})	10.89±2.84^{b}	16.98±7.15^{a}	10.41±3.02^{b}	11.14±5.95^{b}	11.67±5.92^{b}
pH	7.04±0.47^{b}	7.83±0.45^{a}	7.97±0.40^{a}	7.85±0.42^{a}	7.88±0.35^{a}
Dissolved oxygen (mg.L^{-1}) morning	6.10±0.61^{Aa}	4.22±1.32^{Bb}	4.35±0.64^{Bb}	4.35±1.29^{Bb}	4.43±0.97^{Bb}
Dissolved oxygen (mg.L^{-1}) afternoon	7.41±0.46^{Ab}	8.14±3.06^{Aab}	9.94±1.96^{Aa}	7.75±2.53^{Aab}	8.24±2.28^{Aab}
BOD (mg.L^{-1})	2.58±2.27^{b}	3.45±1.81^{ab}	4.08±2.04^{a}	3.90±1.85^{a}	3.71±1.90^{ab}
COD (mg.L^{-1})	12.4±1.0^{a}	22.8±4.1^{a}	25.9±2.7^{a}	24.7±1.9^{a}	24.3±2.2^{a}
Clorophyll-*a* (mg.L^{-1})		0.187±0.180^{a}	0.049±0.021^{a}	0.143±0.146^{a}	0.153±0.125^{a}
N-Ammonia (μg.L^{-1}) morning	193.89±33.23^{Aa}	121.17±76.02^{Aa}	260.44±72.74^{Aa}	222.56±112.06^{Aa}	266.69±122.95^{Aa}
N-Ammonia (μg.L^{-1}) afternoon	130.19±34.63^{Aa}	77.72±49.32^{Aa}	56.51±39.86^{Ba}	115.46±84.40^{Aa}	92.24±38.01^{Ba}
N-Nitrite (μg.L^{-1}) morning	29.63±8.15^{Aa}	24.22±6.98^{Aa}	25.25±7.37^{Aa}	27.21±10.12^{Aa}	26.40±4.53^{Aa}
N-Nitrite (μg.L^{-1}) afternoon	26.82±6.11^{Aa}	26.61±5.60^{Aa}	27.01±7.72^{Aa}	29.03±7.55^{Aa}	28.64±4.69^{Aa}
N-Nitrate (mg.L^{-1}) morning	0.87±0.60^{Aa}	0.47±0.33^{Ab}	0.72±0.55^{Ab}	0.57±0.51^{Ab}	0.63±0.36^{Ab}
N-Nitrate (mg.L^{-1}) afternoon	1.30±0.99^{Aa}	0.22±0.13^{Ab}	0.32±0.25^{Ab}	0.32±0.24^{Ab}	0.31±0.15^{Ab}
N-Kjeldahl nitrogen (mg.L^{-1})	0.19±0.01^{a}	0.34±0.10^{a}	0.19±0.02^{a}	0.30±0.07^{a}	0.20±0.03^{a}
P-Soluble ortophosphate (μg.L^{-1})	46.80±56.80^{a}	38.27±26.11^{a}	25.25±19.01^{a}	31.18±14.61^{a}	30.53±16.22^{a}
P-Total phosphorus (mg.L^{-1})	0.101±0.021^{b}	0.155±0.028^{a}	0.104±0.013^{b}	0.133±0.023^{ab}	0.106±0.028^{ab}

Mean values followed by different lower case letters in the same row differ statistically ($p<0.05$). Capital letters refer to morning and afternoon comparisons ($p>0.05$).

Table 3. Sediment characteristics at harvest. Results are expressed as mean of 5 analyses ± SD.

	Traditional	Upper	Lower	Culled-harvest
Accumulated layer (cm)	0.87±0.42^{b}	0.84±0.63^{b}	1.11±0.77^{ab}	1.65±0.81^{a}
Organic matter (%DM)	83.7±0.7^{a}	83.7±4.3^{a}	83.5±2.5^{a}	84.2±4.8^{a}

Mean values followed by different letters in the same row differ statistically ($p<0.05$).

Table 4. Quantity of added feed (kg.ha^{-1}) per treatment.

Upper	4077±1870
Lower	2988±500
Culled-harvest	3284±512
Traditional	4044±1220

Table 5. Quantity of nitrogen and phosphorus added to ponds by fertilization and feeding* (kg).

	Upper		Lower		Culled-harvest		Traditional	
	N	P	N	P	N	P	N	P
Fertilization	0.021±0.003	0.08±0.01	0.021±0.002	0.08±0.01	0.019±0.001	0.08±0.01	0.021±0.003	0.09±0.01
Feeding	1.88±0.86	0.29±0.13	1.52±0.24	0.23±0.04	1.38±0.23	0.21±0.03	1.87±0.56	0.28±0.09

*Considering a diet with 30% crude protein and 0.70% phosphorus.

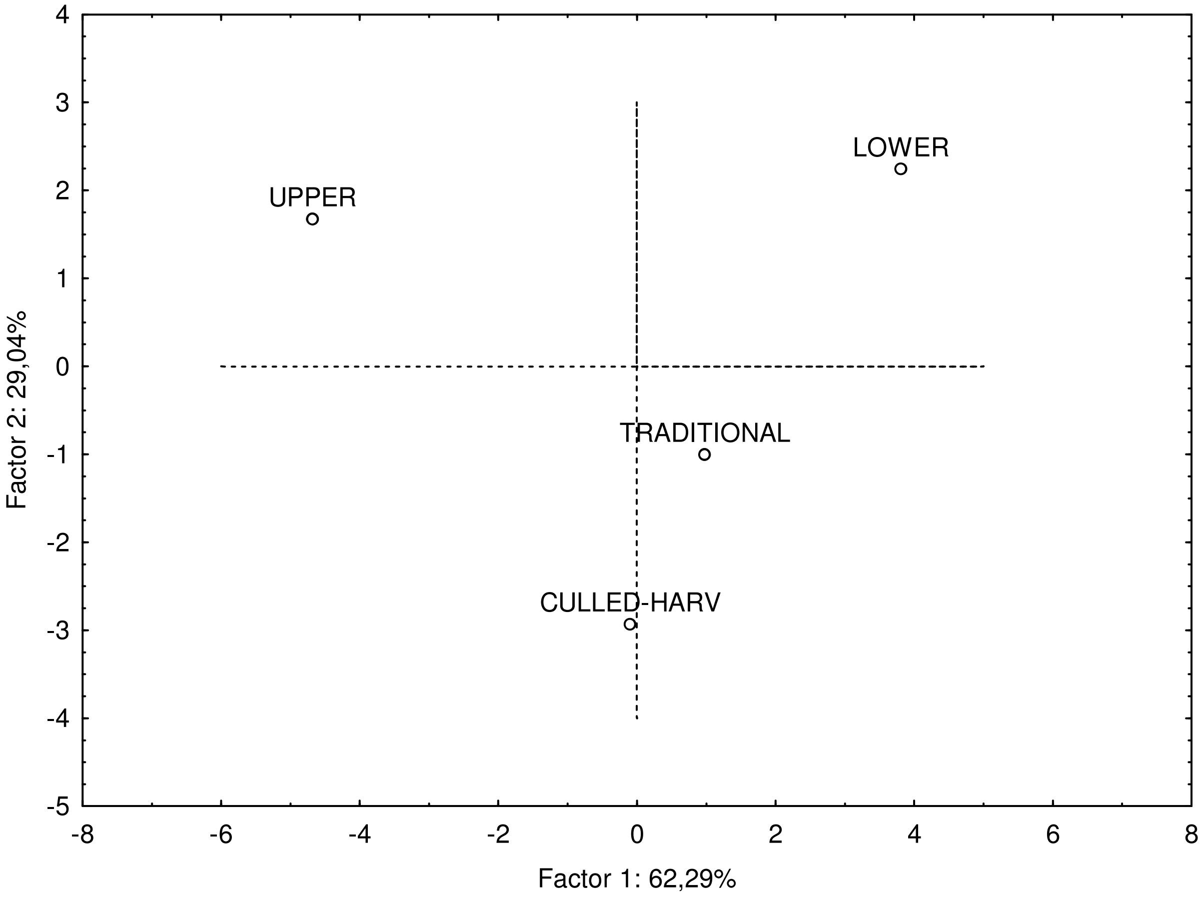

Figure 1. Principal components analysis: inlet and water from *M. amazonicum* rearing ponds under different management techniques. Upper= stocking upper-graded juveniles treatment; Lower= stocking lower-graded juveniles treatment; Culled-harvesr= stocking non-graded juveniles + culled-harvest; Traditional= stocking non-graded juveniles.

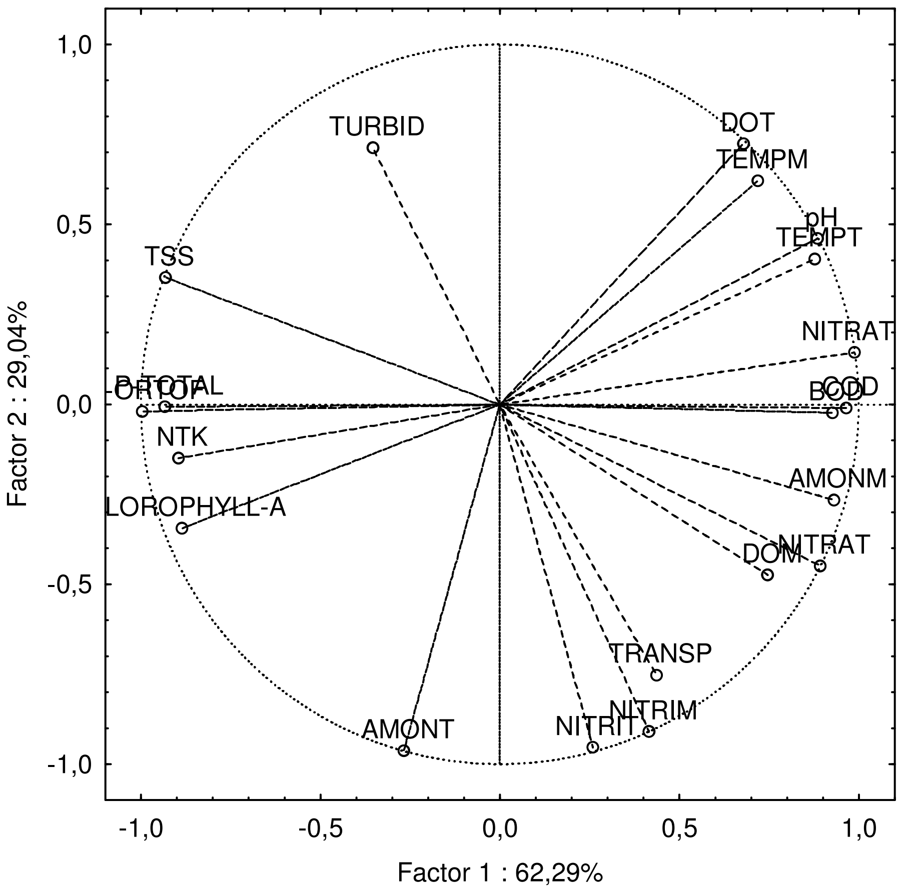

Figure 2. Principal components analysis: pond water from *M. amazonicum* culture under different management techniques. TURBID=turbidity; TSS= total suspended solids; DOM=dissolved oxygen in the morning; DOT=dissolved oxygen in the afternoon; BOD=biochemical oxygen demand; COD=chemical oxygen demand; AMONM= N-ammonia in the morning; AMONT= N-ammonia in the afternoon; NITRIM=N-nitrite in the morning; NITRIT=N-nitrite in the afternoon; NITRAM=N-nitrate in the morning; NITRAT=N-nitrate in the afternoon; NTK=N-total Kjeldahl nitrogen; P-ORTO=P-soluble orthophosphate; P-TOTAL=P-total phosphorus.

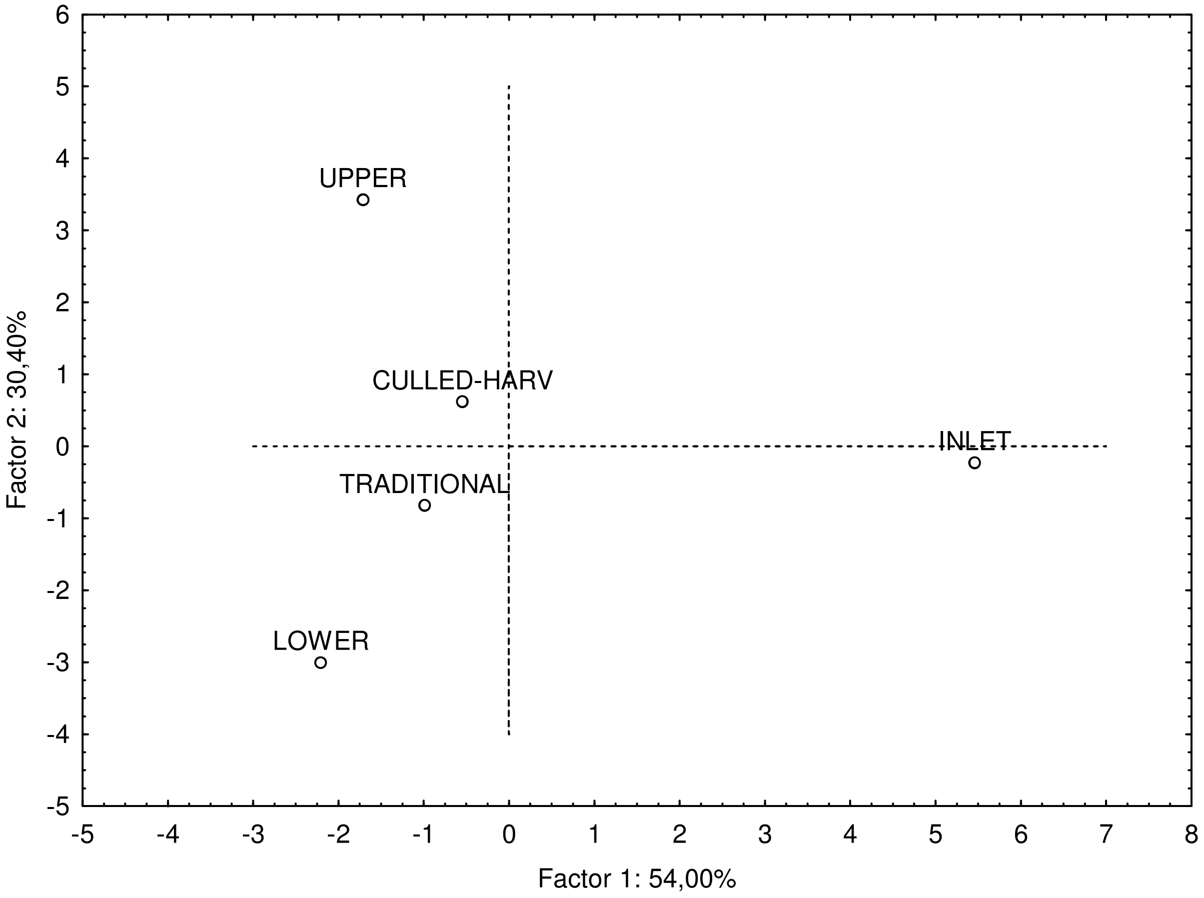

Figure 3. Principal components analysis: inlet and pond water from *M. amazonicum* culture under different management techniques. Inlet= inlet water; Upper= stocking upper-graded juveniles treatment; Lower= stocking lower-graded juveniles treatment; Culled-harvesr= stocking non-graded juveniles + culled-harvest; Traditional= stocking non-graded juveniles.

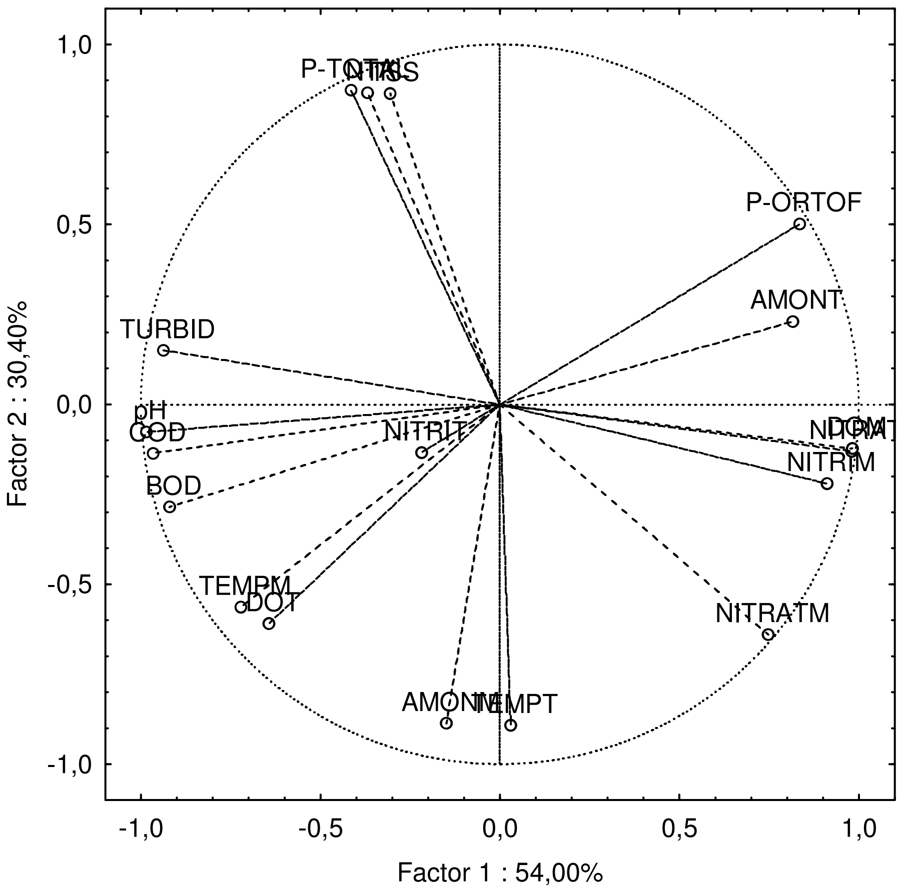

Figure 4. Principal components analysis: inlet and water from *M. amazonicum* rearing ponds under different management techniques. TURBID=turbidity; TSS= total suspended solids; DOM=dissolved oxygen in the morning; DOT=dissolved oxygen in the afternoon; BOD=biochemical oxygen demand; COD=chemical oxygen demand; AMONM= N-ammonia in the morning; AMONT= N-ammonia in the afternoon; NITRIM=N-nitrite in the morning; NITRIT=N-nitrite in the afternoon; NITRAM=N-nitrate in the morning; NITRAT=N-nitrate in the afternoon; NTK=N-total Kjeldahl nitrogen; P-ORTO=P-soluble orthophosphate; P-TOTAL=P-total phosphorus.

For inlet and pond water variables, a variability of 84.40% was resumed in the two first principal components (Figures 3 and 4). P-soluble orthophosphate and afternoon N-ammonia were positively correlated with both components (Figure 4). P-total phosphorus, total suspended solids, N-total Kjeldahl nitrogen and turbidity were positively correlated with principal component 2 (Figure 4). Biochemical oxygen demand, chemical oxygen demand, pH, N-nitrite in the afternoon, morning temperature, dissolved oxygen in the afternoon and N-ammonia in the morning were negatively correlated with the two principal components (Figure 4). Temperature in the afternoon, N-nitrate, N-nitrite in the morning and dissolved oxygen in the morning were positively correlated with principal component 1 and negatively correlated with component 2 (Figure 4). Two main groups could be observed: the first one corresponded to inlet water, and the other grouped all treatments (Figure 3).

Discussion

Management strategy slightly influenced pond dynamics. Although mean values of water variables generally did not differ among treatments, multivariate analysis showed that ponds subjected to different stocking and harvest strategies presented different characteristics. The effect was more pronounced in ponds stocked with upper graded population.

Higher biomass through stocking upper graded juveniles required more feeding input, which corresponded to 36.45% of increase in comparison to the amount added in lower treatment ponds. The increase in total suspended solids and turbidity in upper treatment ponds is probably a consequence of this higher feeding. Moreover, it is supposed that shrimps appear to cause ponds erosion by their swimming activity (Martin et al., 1998). Bioturbation may enhance nutrients availability to water column, improving primary production and avoiding anaerobic conditions in pond bottom (Haertel-Borer et al., 2004; Ritvo et al., 2004). Animal size may influence also the amount of nitrogen and phosphorus contends inside ponds (Haertel-Borer et al., 2004). However, no nutrients enhancement in water column was observed in this study after stocking larger animals. This fact may suggest that the material suspended by upper prawns may have been mainly inorganic particles such as clay from the bund of ponds, or that nutrients were adsorbed to these particles and were in an unavailable form for water column.

Harvesting can be considered a periodic ecological factor that substantially modifies pond ecosystem (Valenti, 1995). Seining activity disturbs ponds bottom, resuspends the sediment and possibly makes nutrients and organic material available for biological processes that occur in water column (Keppeler and Valenti, 2006). It may cause stress to benthic communities (including prawns) and alter water characteristics, the processes of organic carbon fixation by photosynthesis and decomposition by microorganisms (Keppeler and Valenti, 2006). The suspended material is expected to serve as a substrate for detritivorous organisms and thus, increase nitrogen and phosphorus in water column and decrease their concentrations in the sediment (Keppeler and Valenti, 2006). However, Ohle (1937 apud Esteves, 1998) and Einsele (1938 apud Esteves, 1998) studies showed that there are many variations of this general pattern of nutrients cycling. For example, Ohle (1958 apud Esteves, 1998) demonstrated that great proportion of the released phosphate from detritus occurs before sedimentation. Although accumulated sediment layer, total suspended solids and turbidity were higher in culled-harvest treatment, water column did not present higher values of nutrients. They may have been rapidly assimilated by phytoplankton after resuspension and/or were absorbed before being sedimentated. As water variables positively correlated with phytoplankton contend (transparency, turbidity, chlorophyll-*a*) were not different among treatments, it may be suggested that a high proportion of inorganic material was suspended, and/or that no difference could be detected because the concentration of nutrients in water was not limitant, as inlet water is hypereutrophic (Wetzel, 2001). This fact may lead to a mask effect of treatments as nutrients are not the limitant effect on primary production development. It was previously assumpted by a series of studies that the phytoplankton population was stimulated from an oligotrophic to a mesotrophic environment, but a limit to the stimulation existed before fully eutrophic conditions were reached (Higashi et al., 1998).

The high chemical oxygen demand:biochemical oxygen deman ratio (6.48±0.13) denoted that a huge non-biodegradable fraction had been accumulated in ponds probably due to feed (Boyd, 1985), organic matter production by photosynthesis (Boyd, 1985) and accumulation of chitin from prawns exuviae. About 300 kg.ha^{-1} of fiber was added to ponds through feeding, and in addition to phytoplankton senescence, it may mean an increase in the accumulation of non-readly biodegradable material such as cellulose. Moreover, molting process may accumulate chitin which is a structural polysaccharide that has poor solubility due to its crystalline structure (Jang et al., 2004). It is insoluble in water at neutral pH (Kurita, 2001) and also in all other usual solvents (Rinaudo, 2006). Stankiewicz et al. (1998) reported that there was no evidence of structural degradation of chitin prior to eight weeks.

It was observed that independently of adopted stocking and harvesting strategies, aquaculture changed water variables. It may have occurred mainly due to the presence of phytoplankton in ponds. Dissolved oxygen, pH and N-ammonia are affected by photosynthesis, decomposition and nitrification processes (Moraes-Riodades et al., 2006). Phytoplankton produces organic matter, takes N-ammonia and CO_2 up from the system, and releases oxygen; therefore, observed variations reflect the metabolism of pond communities (Moraes-Riodades et al., 2006). In this study, the dynamic of pond water variables throughout the day indicated the presence of phytoplankton and its photosynthetic and respiration processes. Moreover, it may be concluded from sediment data that feeding and fertilizing input caused an organic matter accumulation in ponds.

Stocking upper animals required more feeding input, which may have contributed to total suspended solids enhancement. In addition, bioturbation may also have been occurred in this treatment. Culled-harvest did not cause any alteration in pond water, but in sediment accumulation. Aquaculture did change some water characteristics and led to an accumulation of organic matter in ponds bottom, and thus, it is necessary to adopt management practices that minimizes these impacts, such as improving feed quality and feeding strategy and minimizing water exchange rate.

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Intensification of *Macrobrachium amazonicum* grow-out system: effects of stocking and harvesting strategies on effluents.

Abstract

The aim of this study was to evaluate the effluents from freshwater prawn ponds stocked and harvested with different strategies. Twelve 0.01-ha earthen ponds were stocked at 40 post-larvae.m^{-2}. Treatments were: 1= stocking upper juveniles; 2= stocking lower juveniles; 3= stocking non-graded juveniles + culled-harvest; 4= stocking non-graded juveniles + total harvest. Three replicates per treatment were performed. Temperature, total suspended solids, turbidity, pH, dissolved oxygen, N-ammonia, N-nitrite, N-nitrate, N-Total Kjeldahl nitrogen, biochemical oxygen demand, chemical oxygen demand, P-soluble orthophosphate and P-total phosphorus were measured in effluent water. Efluents from stocking upper-graded juveniles (T1) ponds presented higher turbidity mean values (25±10 NTU). Inlet showed lower mean values of pH (7.04±0.47) and higher dissolved oxygen concentration in comparison to all treatments. Higher biochemical oxygen demand values were found in upper (T1), lower (T2) and culled-harvest (T3) treatments (3.82±2.20; 4.18±2.25 and 3.86±2.03 mg.L^{-1}, respectively). Nitrate values were significantly higher in traditional treatment (T4) effluent (0.80±0.50 mg.L^{-1}) and inlet water (1.30 mg.L^{-1}). Soluble orthophosphate concentration was lower in upper (T1) and lower (T2) treatments (28.30±9.82 and 28.43±20.79 µg.L^{-1}, respectively). Culled-harvest (T3) treatment showed the higher P-total phosphorus concentration (0.196±0.023 mg.L^{-1}). According to the results, aquaculture conducted under these studied conditions changed the characteristics of the water used in prawns farming in some parameters: turbidity, pH, dissolved oxygen, biochemical oxygen demand, N-nitrate, P-soluble orthophosphate and P-total phosphorus. There were no differences among treatments.

Key-words: Culled-harvest, grading, effluents, water quality, *Macrobrachium amazonicum*.

Introduction

Macrobrachium amazonicum is largely distributed in natural waters in South America, form Venezuela to Argentina (Holthuis, 1952; Bialetzki et al., 1997). This species presents a great potencial for aquaculture (Kutty, 2005; New, 2005) and an important market in some regions of Brazil suppplied by artisanal fishery (New et al., 2000). Recently, a large multidisciplinar program to develop a sustainable technology for the culture of this specie has started in Brazil. One of the major subjects to be investigated is how management practices in rearing *M. amazonicum* may impact effluents from ponds and consequently, the surrounding environment.

Due to the presence of four groups of males that present different growth rates: "Translucent Claw" (TC), "Cinnamon Claw" (CC), "Green Claw 1" (GC1) and "Green Claw 2" (GC2) (Moraes-Riodades and Valenti, 2004), several management practices that intensify culture systems are being studied to minimize heterogeneous males’ growth and maximize production to obtain uniformity in product size. Among these practices, size-grading juvenile subpopulations before stocking ponds and implementation of the culled-harvest technique reduced negative effects of heterogeneous growth in *M. rosenbergii* (Karplus et al., 2000; Tidwell and D'Abramo, 2000; Tidwell et al, 2003; Tidwell et al., 2004a; Tidwell et al., 2004b). These management methods may significantly raise productivity (Karplus et al., 2000) and may be useful in *M.*

amazonicum culture. However, the effects of intensifying management practices on ponds and effluents must be evaluated.

There are three external main factors that may influence ponds ecosystem, and they include inlet water quality, settled sediments in the pond bottom and adopted pond management (Funge-Smith and Briggs, 1998). Management includes stocking and harvesting strategies, feeding, fertilization and liming, use of aerators and water exchange rate. General management should be conceived in order to produce water characteristics inside ponds according to target species requirements. Feed and fertilizers are added into ponds to promote prawn and fish production, and generally, only 25% to 30% of nitrogen and phosphorus from fertilizers and feed are reverted in prawn and/or fish at harvest (Boyd and Tucker, 1998). Ponds seem to have a notable capacity to assimilate nitrogen and phosphorus by physical, chemical, and biological processes (Schwartz and Boyd, 1994a). However, ponds frequently present higher nutrients concentration, plankton biomass, suspended solids, and biochemical oxygen demand concentrations (BOD) in comparison to effluent-receiving bodies of water (Schwartz and Boyd, 1994b). It may affect surrounding environment when effluents are produced. Ponds generate effluent after severe rains, after draining for harvest (Boyd and Queiroz, 2001), and due to water exchange (Boyd, 2003).

Stocking animals from different size and harvesting strategy may cause changes in pond water and consequently in effluents. Bioturbation due to the more intensive swimming activity of upper animals and culled-harvest may probably increase turbidity and total suspended solids in water. However, it may also enhance oxygen concentration in pond bottom, and turn adsorbed phosphorus available to water column. The adoption of these practices implies in more energy input, and thus characterizes an intensive culture. The main advantage of intensifying traditional systems is to contribute to social sustainability. However, environmental and economic aspects must be also evaluated. Effluents often present characteristics that differ from inlet water, which may cause an impact on receiving environment and negative externality generated by the production system.

As aquaculture has become a large enough industry to have significant impacts on environment and natural resources (Boyd, 2003), a number of concerns have been expressed by both environmental activists and scientists (Dierberg and Kiattisimukul, 1996; Goldburg and Triplett, 1997; Naylor et al., 1998, 2000; Jegatheesan et al., 2006). Resultant pollution by ponds effluent has attracted official attention in some nations (Boyd and Gautier, 2000; Boyd and Tucker, 2000), which have initiated regulations for effluent release generated by aquaculture. There is also a growing trend of environmental awareness by aquaculture associations, and they are promoting environmentally responsible production methods (Boyd, 2003). There is widespread interest in the economic advantages of products certified "environmentally friendly" (Boyd, 2003). Therefore, aquaculture producers will find it necessary to improve production methods in order to comply with water quality criteria in permits (Boyd, 2003).

When it is intended to implant new management techniques, impacts on water quality, sediments and effluent must be known. Therefore, the objective of this study was to evaluate the effects of stocking and harvesting strategies on effluent characteristics of *M. amazonicum* grow-out ponds.

Material and Methods

The study was carried out at the Crustacean Sector, Aquaculture Center, Sao Paulo State University, Jaboticabal, Sao Paulo (latitude 21° 15'S, longitude 48° 18'W). Twelve 0.01-ha earthen ponds were drained and allowed to air-dry. Ponds were filled via dam after passing through a mechanic filtering system. Emergency aerators were used when dissolved oxygen fell below 2.0 mg.L^{-1} in the morning. Chemical fertilization was necessary when transparency value was above 50 cm. Urea and simple superphosphate were added in the proportion of 2 kg N.ha^{-1} and 8 kg P_2O_5.ha^{-1}, respectively (Boyd and Zimmermann, 2000). Post-larvae for stocking were produced in the facility, stocked in nursery tanks for 15 days, and transferred to secondary nurseries for 30 days. Randomized samples were taken and juveniles were graded in a 5-6 mm bar grader. Two populations were obtained: uppers ("top-grade"), and lowers ("bottom-grade"). Upper juveniles corresponded to the animals that were retained by the grader, and lower juveniles were the ones that passed through the grader. Ponds were stocked in the density of 40 juveniles.m^{-2} following a completely randomized experimental design with four treatments and three replicates. Treatment 1 (T1) consisted of stocking the biggest animals, or "upper" graded-juveniles ("top-grade"). After 3.5 months, ponds were drained for total harvest. T2 ponds were stocked with the population formed by prawns that presented minor initial growth, called "lowers" ("bottom-grade"). The objective was to stock ponds with either smaller or larger prawn to allow faster growth of smaller individuals that normally would be inhibited by the presence of bigger animals (Karplus et al., 2000). After 3.5 months, ponds were drained for total harvest. T3 ponds were stocked with non-graded juveniles. When part of population reached commercial size (approximately 7 g), culled-harvest was initiated. This management was carried out three times throughout this experiment using a 12 mm mesh net. At the end of rearing cycle (3.5 months), ponds were totally harvested. T4 constituted traditional culture, or stocking non-graded juveniles, and, after 3.5 months, ponds were drained for harvest (total harvest).

Prawns were fed a pelletized commercial diet (30% crude protein) at a rate of 9 to 3% of prawn biomass according to development phase. Prawn biomass was estimated by monthly samples and ration was corrected weekly, considering 1% mortality and 10% weight gain. Total quantity of feed, nitrogen, and phosphorus added to ponds by feed is showed in Tables 3 and 4. Feed was divided in two equal portions and distributed at 0800 and 1600 h daily. Effluent was sampled in the afternoon (1530 to 1600 h) for analysis of the variables contained in Table 1. Dissolved oxygen was measured in the morning (0630 to 0700 h). The pH was measured in the afternoon (1530 to 1600). Temperature was daily monitored using a meter (Yellow Springs Instruments, Yellow Springs, OH, USA). Daily water exchange rate was determined using a 20-L graduated bucket. Water samples were taken inside the external monk.

Table 1. Water variables and methods of analysis.

Variable	Method of analysis/apparatus	Sample frequency/ Time of sampling	Reference
Turbidity	Hach DR/2000	Weekly	Hach, Loveland, CO, USA
Total suspended solids	Gravimetric	Biweekly	APHA, 1998
pH	pH meter	Weekly	Yellow Springs Instruments, Yellow Springs, OH, USA
Dissolved oxygen	Oxygen meter	Daily	Yellow Springs Instruments, Yellow Springs, OH, USA
BOD	5 days	Weekly	APHA, 1998
COD	Closed reflux, colorimetric	Weekly	APHA, 1998
N- ammonia	Phenate, colorimetric	Weekly	APHA, 1998
N-nitrite	Colorimetric	Weekly	APHA, 1998
N-nitrate	Hydrazin sulphate reduction	Weekly	APHA, 1998
N-Kjehdahl nitrogen	Semi-micro Kjeldahl	Biweekly	APHA, 1998
P-soluble orthophosphate	Stanous cloride, colorimetric	Biweekly	APHA, 1998
P-total phosphorus	GF/C Filtration, Stanous cloride, colorimetric	Biweekly	APHA, 1998

Data were subjected to analysis of normality using the Shapiro-Wilk test, and of homocedasticity using the Brown-Forsythe test (SAS version 8.2). Normal and homocedastic data were compared by analysis of variance (ANOVA) by F test (parametric) followed by Duncan test to compare the differences of mean values among treatments and between inlet water and treatments. Heterocedastic and/or non-normal data were analyzed by Friedman test (non-parametric). Analysis of principal components was made using Statistica version 6.0

Results

Water exchange rate was 29.0±1.6%.day^{-1}. Temperature in effluents was 27.2±0.1°C in the morning and 28.3±0.4°C in the afternoon. There was no significative difference between treatments and inlet water for temperature, total suspended solids, chemical oxygen demand, N-ammonia, N-nitrite and N-Kjeldahl nitrogen (Table 2). Turbidity was significatively lower in inlet water than upper effluent (Table 2). Inlet pH and biochemical oxygen demand mean values were inferior to effluent values in all treatments (Table 2). Dissolved oxygen and N-nitrate were significatively higher in inlet than in effluents (Table 2).

Higher concentration of P-soluble ortophosphate was found in inlet water, but it did not differ from traditional and culled-harvest effluents (Table 2). Culled-harvest effluent presented the highest concentration of P-total phosphorus and differed from inlet (Table 2). No temporal variation pattern was observed for any of the studied variables.

Total nitrogen and phosphorus input by fertilization and feeding in kg.ha^{-1} is shown in Table 3. Feed addition to ponds varied from 2988 kg.ha^{-1} in lower treatment to 4077 kg.ha^{-1} in upper treatments (Table 4). Culled-harvest presented 23.14% of feeding redution in comparison to traditional treatment (Table 4).

Table 2. Mean values and standard deviation of water quality variables analyzed in inlet water and effluent from ponds at different treatments.

	Inlet water	**Upper**	**Lower**	**Culled-harvest**	**Traditional**
Turbidity (NTU)	15±6^{b}	25±10^{a}	21±6^{ab}	18±7^{ab}	23±9^{ab}
Total suspended solids (mg.L^{-1})	10.89±2.84^{a}	13.43±4.6^{a}	10.75±5.14^{a}	14.91±10.86^{a}	10.41±6.24^{a}
pH	7.04±0.47^{b}	7.62±0.34^{a}	7.59±0.39^{a}	7.64±0.39^{a}	7.65±0.33^{a}
Dissolved oxygen (mg.L^{-1})	6.10±0.61^{a}	3.43±1.07^{b}	3.55±1.18^{b}	3.43±0.94^{b}	3.77±0.97^{b}
BOD (mg.L^{-1})	2.58±2.27^{b}	3.82±2.20^{a}	4.18±2.25^{a}	3.86±2.03^{a}	3.67±2.19^{ab}
COD (mg.L^{-1})	12.4±1.0^{a}	23.6±3.6^{a}	25.0±10.6^{a}	25.4±9.0^{a}	30.2±10.1^{a}
N-Ammonia (µg.L^{-1})	130.19±34.63^{a}	183.26±85.93^{a}	139.86±49.46^{a}	204.60±113.68^{a}	164.55±97.54^{a}
N-Nitrite (µg.L^{-1})	26.82±6.11^{a}	27.75±8.09^{a}	27.64±5.06^{a}	27.70±8.89^{a}	28.94±5.28^{a}
N-Nitrate (mg.L^{-1})	1.30±0.99^{a}	0.57±0.47^{b}	0.64±0.70^{b}	0.54±0.43^{b}	0.80±0.50^{ab}
N-Kjeldahl nitrogen (mg.L^{-1})	0.19±0.01^{a}	0.29±0.09^{a}	0.28±0.04^{a}	0.39±0.20^{a}	0.24±0.04^{a}
P-Soluble orthophosphate (µg.L^{-1})	46.80±56.80^{a}	28.30±9.82^{b}	28.43±20.79^{b}	38.70±19.77^{ab}	41.20±26.71^{ab}
P-Total phosphorus (mg.L^{-1})	0.101±0.021^{b}	0.108±0.008^{ab}	0.138±0.027^{ab}	0.196±0.023^{a}	0.122±0.024^{ab}

Mean values followed by different letters in the same row differ statistically ($p<0.05$).

Table 3. Quantity of nitrogen and phosphorus added to ponds by fertilization and feeding* (kg).

	Upper		**Lower**		**Culled-harvest**		**Traditional**	
	N	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Fertilization	0.021±0.003	0.08±0.01	0.021±0.002	0.08±0.01	0.019±0.001	0.08±0.01	0.021±0.003	0.09±0.01
Feeding	1.88±0.86	0.29±0.13	1.52±0.24	0.23±0.04	1.38±0.23	0.21±0.03	1.87±0.56	0.28±0.09

*Considering a diet with 30% crude protein and 0.70% phosphorus.

Table 4. Quantity of added feed (kg.ha^{-1}) per treatment.

Upper	4076.90±1870.07
Lower	2987.89±499.82
Culled-harvest	3284.19±512.03
Traditional	4044.29±1220.30

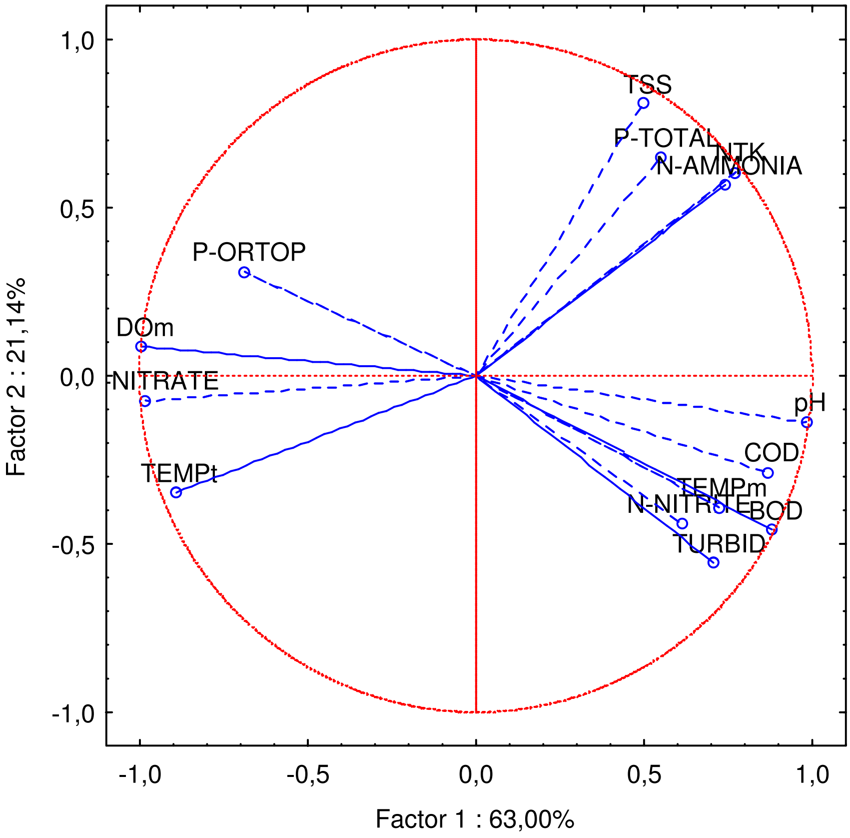

Figure 1. Principal components analysis: inlet and effluents from *M. amazonicum* rearing ponds under different management techniques.

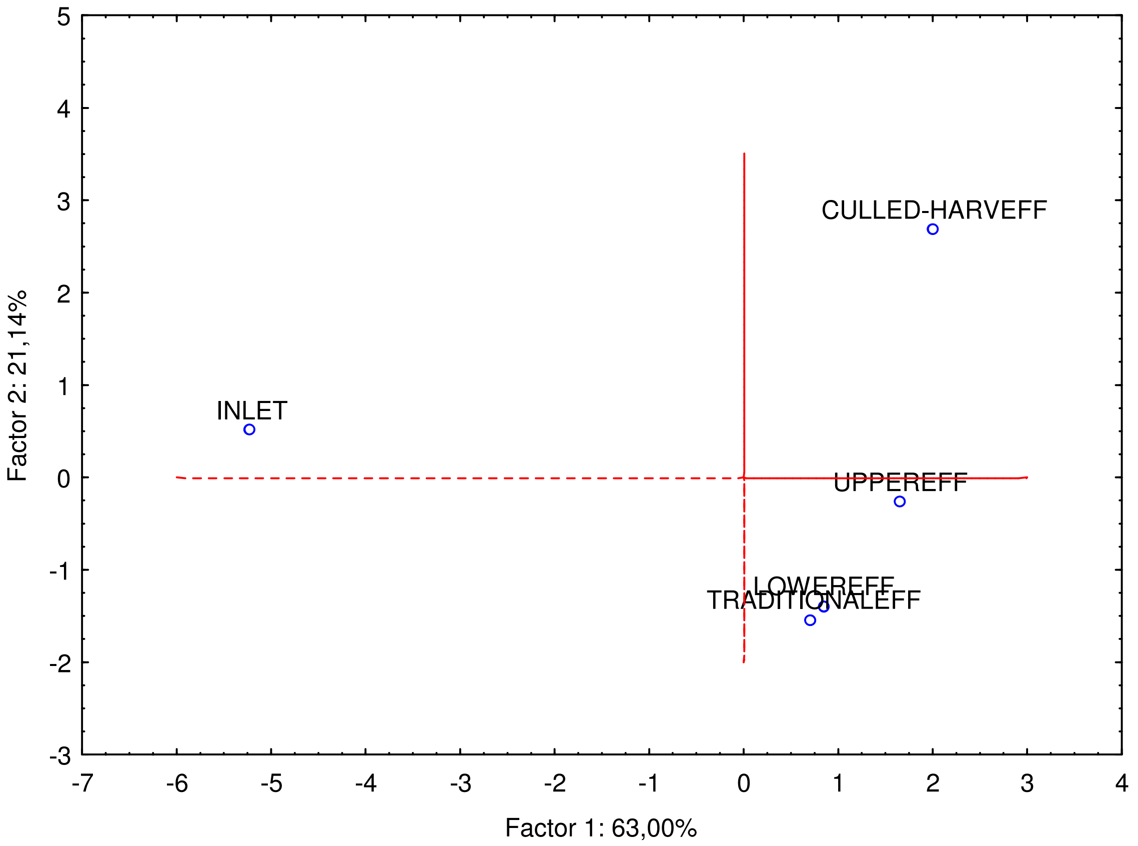

Figure 2. Principal components analysis: inlet and effluents from *M. amazonicum* rearing ponds under different management techniques. Inlet= inlet water; Upper= stocking upper-graded juveniles treatment; Lower= stocking lower-graded juveniles treatment; Culled-harvesr= stocking non-graded juveniles + culled-harvest; Traditional= stocking non-graded juveniles.

The analysis of principal components resumed 84.14% of total variability in the first two components (Figures 1 and 2). The analysis showed three distint groups (Figure 2): 1- inlet; 2- culled-harvest and 3- upper + lower + traditional. Total suspended solids, P-total phosphorus, N-Kjeldahl nitrogen and N-ammonia were highly and positively correlated to the first principal component (Figure 1). P-soluble orthophosphate and dissolved oxygen were positively correlated to component 2 but negatively correlated to component 1 (Figure 1). N-nitrate and afternoon temperature were negatively correlated to components 1 and 2 (Figure 1). Chemical oxygen demand, biochemical oxygen demand, pH, morning temperature, N-nitrite and turbidity were positively correlated to component 1 and negatively correlated to component 2 (Figure 1).

Discussion

Management techniques to improve productivity may contribute to changes in water and sediment characteristics, and consequently in discharged effluents. Seining frequency and the effect of animals size and their natatory effect (bioturbation), generally tend to elevate the concentration of total suspended solids, turbidity and phosphorus, among other elements, in pond water. In addition, aquaculture itself may change inlet water characteristics independently of management techniques.

Culled-harvest did act on resuspension of sediments, increasing total suspended solids discharge in effluents. Moreover, higher P-total phosphorus and N-Kjeldahl nitrogen concentration in effluents and the high positive correlation with the first principal component indicate that seining seem to influence these nutrients availability. During harvesting, agitated shrimp, wading workers, and rapidly ouflowing water resuspend sediment resulting in high concentrations of nitrogen, phosphorus, suspended solids, and biochemical oxygen demand (Boyd and Gautier, 2000).

Bioturbation activity generated by fish is known to have the potential to increase oxygen supply to a greater depth in aquaculture pond bottom (Ritvo *et al.*, 2004; Haertel-Borer *et al.*, 2004). Ritvo *et al.* (2004) showed that degradation of the sedimenting organic matter was accelerated by carp bioturbation, especially so in the upper layer, as reflected by the reduction in organic carbon. Burrowing activity of macrofauna may also enhance ammonia concentration (Hargreaves, 1998). Martin *et al.* (1998) suggested that an increase in the level of pond floors during *Penaeus stylirostris* rearing cycle appeared to have been related neither to input and sedimentation of solids (seston or feed pellets), nor to hydraulic erosion of the pond banks, but to an erosion produced by the swimming activity of the shrimps. In our study, stocking upper prawns did not present such effects, but higher turbidity was found in this treatment effluent. As feeding strategy was a function of prawns biomass, obviously upper animals were fed a higher amount of peletized commercial feed, which may have leached nutrients and other materials and thus contributed to this variable. Moreover, these nutrients may have been led to a denser phytoplankton community, which may also be concluded from higher pH values.

Some water quality parameters have changed from inlet water to ponds water and their effluents as a consequence of aquaculture practices. Apart from treatments, pH and dissolved oxygen values were significantly different in inlet and effluents. This fact can be clearly observed in the principal components, where inlet water was classified in an apart group. Adding commercial feed and fertilizers, and using aerators seemed to have caused a higher turbidity in pond water. Both these addition and prawns presence resulted in lower dissolved oxygen concentrations in pond water comparing to inlet water. Similarly, lower biochemical oxygen demand mean concentration in inlet water was probably found as a consequence of higher organic matter input in rearing ponds. Higher nitrate concentrations in inlet water were also obtained by Ziemann *et al.* (1992) comparing effluents from *Macrobrachium rosenbergii* ponds. It may have been a consequence of phytoplankton uptake, ammonification or denitrification processes inside ponds. P-soluble orthophosphate concentrations decreased probably as a result of primary producers assimilation. The high chemical oxygen demand:biochemical oxygen demand ratio indicates the predominance of non-biodegradable particles. Inlet water presents high chemical oxygen demand, but the ratio increased in treatments. This fact suggests that aquaculture management is probably accumulating materials such as fiber, humic acid and chitin, and thus biological treatment for effluents from these rearing ponds is not possible. Therefore, it is necessary to add alternative physical treatments to these effluents.

Stocking upper animals increased significantly turbidity in effluents, which may be an erosion consequence of prawns swimming activity. Multivariate analysis showed that culled-harvest presented higher total suspended solids, P-total phosphorus, N-Kjeldahl nitrogen and N-ammonia concentration, which characterized a distinct group among all treatments. Effluents differed from inlet water in many variables, specially in dissolved oxygen, pH and P-soluble orthophosphate, evidencing the effect of aquaculture practices on water quality. Variable values did fit most of effluents regulation developed by several countries, except for dissolved oxygen. Best management practices might be adopted to fit legislation and improve the assimilation of nutrients in these aquaculture systems.

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3. CONSIDERAÇÕES FINAIS

- A estratégia de povoamento e despesca apresentou reduzida influência sobre as características da água de viveiros e efluentes de engorda do camarão *Macrobrachium amazonicum*;
- Os viveiros estocados com juvenis gradeados “upper” apresentaram maiores concentrações de sólidos totais em suspensão, provavelmente pelo maior aporte de alimentação e/ou devido à bioturbação;
- O tratamento despesca-seletiva não diferiu do tratamento tradicional em relação às características hidrobiológicas do viveiro, mas apresentou maior acúmulo médio de sedimento;
- Os efeitos dos tratamentos sobre as características da água podem ter sido reduzidos devido ao estado trófico da água de abastecimento (hipereutrófica);
- Observou-se acúmulo de material pouco biodegradável, que provavelmente refere-se à quitina proveniente da exúvia dos camarões;
- A água de abastecimento diferiu da água dos viveiros quanto a turbidez, pH, oxigênio dissolvido, demanda química de oxigênio e nitrato, indicando que as práticas aquícolas alteram as características da água captada.
- A água dos efluentes diferiram quanto a água de entrada quanto ao pH, oxigênio dissolvido e demanda bioquímica de oxigênio e nitrato.