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Effects of Intensification of the Amazon River Prawn, *Macrobrachium amazonicum*, Grow-out on Effluent Quality

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Abstract

Studies to determine suitable levels of intensification are essential for developing sustainable aquaculture. The objective of this study was to evaluate the quality of effluents discharged from ponds stocked with 10 (D10), 20 (D20), 40 (D40), and 80 (D80) postlarvae of *Macrobrachium amazonicum*/m^2. Intake and effluent water samples were taken throughout a 5.5-mo grow-out cycle. In that study, twelve 0.01-ha earthen ponds were stocked postlarvae with 0.01 g. Average water exchange rate was 15%/d; water was discharged from the bottom of the ponds. Prawns were fed a commercial feed with 38% crude protein according to their biomass (3–10%) and the concentration of dissolved oxygen (DO). In our research, temperature, turbidity, total suspended solids, conductivity, DO, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), *N*-ammonia, *N*-nitrite, *N*-nitrate, *N*-Kjeldahl nitrogen, total phosphorus, and soluble orthophosphate were measured every 15 d throughout the experiment in the early morning (0630 to 0730 h). Turbidity was lower in D10 than in D20 and D40 and total phosphorus was higher in D80 than in D10 and D20. An analysis of principal components comparing treatments and intake water showed three groups: intake, D10 and a cluster of D20, D40, and D80. On the basis of the water characteristics found in our study it appears that the farming of *M. amazonicum* is likely to have a low environmental impact, at least up to a stocking density of 80 prawns/m^2.

The increasing demand for aquatic animal products has led world aquaculture to the intensification of production systems and to the diversification of cultured species. The intensification normally means an increase in stocking density, and consequently an increase of energy and materials used as fertilizers, allochthonous feed and aeration. Thus, production may increase at the expenses of greater use of natural resources and the discharge of nutrient-rich effluents, which can damage the surrounding environment. Currently, the concept that aquaculture should be developed according to sustainability principles is totally accepted (Costa-Pierce 2010; FAO 2010). Thus, intensification may be limited by the capacity of the pond to assimilate inputs and to cause

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minimal wastes to be discarded. In addition, the maximum biomass that an aquaculture pond can produce is dependent upon water quality (Boyd and Tucker 1998). Intensification may prejudice water characteristics if the system is not managed properly. Therefore, studies to determine the suitable level of intensification are essential for developing aquaculture.

The key to managing and monitoring the environmental impacts of aquaculture pond effluents is the accurate estimation of the quality of the discharge from ponds (O'Bryen and Lee 2003). Minimizing the impact of aquaculture entails making changes in management (Pusceddu et al. 2011) or setting up efficient methods of effluent treatment. Many aquaculture facilities discharge their effluents with no previous treatment, which may cause severe environmental impacts on surrounding areas (Naylor et al. 2000; Burford and Lorenzen 2004; Islam and Tanaka 2004; Sàra et al. 2004; Anh et al. 2010; Serrano-Grijalva et al. 2011). In this context, many governmental authorities have initiated regulations for effluent discharge (Boyd 2003). In addition, the economic effect of effluent treatment is being studied (Engle et al. 2005) and guidelines for marine shrimp farm certification, for example, have been developed (GAA-BAP 2011). Considering that intensification is one of the most important factors that affect pond waste production and – consequently – receiving water bodies, studies on the effects of intensification on aquaculture systems are critical to match these goals.

As a factor in sustainability, it is essential to develop technologies to facilitate the production of native species, such as the Amazon River prawn, *Macrobrachium amazonicum*. This freshwater prawn is an important species native to South America (Moraes-Riodades and Valenti 2004) that shows favorable production characteristics (Moraes-Valenti and Valenti 2010) and good market acceptance (Maciel and Valenti 2009; Marques and Moraes-Valenti 2012). Recent research has demonstrated that *M. amazonicum* may be farmed in ponds filled with nutrient-rich water (Kimpara et al. 2010) at densities as high as 40–80 prawns/m^2 (Moraes-Valenti and Valenti 2007; Moraes-Valenti et al. 2010; Preto et al. 2010, 2011). Culture in such densities does not deteriorate pond water for aquaculture purposes (Moraes-Riodades et al. 2006). However, no information on the characteristics of the effluent produced has yet been published. Considering the above rationale, the objective of our study was to evaluate the quality of effluents discharged from *M. amazonicum* ponds stocked with various densities of postlarvae.

Materials and Methods

Twelve 0.01-ha^{-1} earthen ponds were stocked at with 10 (D10), 20 (D20), 40 (D40), and 80 (D80) postlarvae (PL) of *M. amazonicum*/m^2 with mean weight of 0.01 g. Rearing continued for 5.5 mo in a study on the effect of intensification on productivity parameters, as described in full by Moraes-Valenti and Valenti (2007). The postlarvae were reared at the Crustacean Sector, Aquaculture Center (Caunesp), located at São Paulo State University, Jaboticabal, SP, Brazil. An experimental design in blocks with four treatments and three replicates was used. These blocks corresponded to pond sites, to avoid possible interference caused by insolation, slope, and surrounded vegetation. Hydrated lime and cattle manure at rates of 1.0 and 3.0 t/ha, respectively, were applied to the ponds before they were filled. Intake water was obtained from an upstream dam located near the facility and water was continuously exchanged at a mean rate of 15%/d. Water exchange rate was determined using a graduated container and a chronometer. The quantity of effluent released from the ponds was evaluated according to the same methodology. Prawns were fed according to their biomass and the concentration of dissolved oxygen (DO). Feeding rates commenced at 10% and ended at 3% of prawn biomass. Adjustments were made considering 1% mortality and 10% weight gain per week. Animals were fed the total portion when the DO was higher than 5 mg/L or a half portion at 2.5 to 5 mg/L; at values below 2.5 mg/L feeding was suspended. The animals were fed a commercial pelletized feed that contained 40% crude protein during the first

month, and 38% for the remaining months when the effluent samples were being taken.

In our part of this research, intake and effluent water was sampled every 15 d in the early morning (0630 to 0730 h). Temperature was measured daily, using maximum and minimum index thermometers installed at the surface and the bottom of one pond, as no differences among ponds were previously observed. Temperature was measured at the surface and at the bottom of the ponds to verify possible thermal stratification. Other physical and chemical parameters of water quality were also recorded according to the methods of analysis shown in Table 1.

An Aquahobby B-500 model (Bernauer Aquacultura, Blumenau, SC, Brazil) aerator was used when low oxygen values were observed (<1 mg/L). After 5.5 mo, the ponds were drained and the prawns were harvested, and productivity and survival were determined (Moraes-Valenti and Valenti 2007). The variables measured in effluents were compared between treatments using univariate statistics and between treatments and the inlet water using multivariate statistics as an exploratory method. Effluent data were subjected to an analysis of variance (two-way ANOVA) according to a repeated measures procedure. Normality and homoscedasticity of data were tested using Kolmogorov–Smirnov and Brown–Forsythe tests, respectively. When differences were significant ($P < 0.05$), mean values were compared by the Duncan test. Later, a principal components analysis (PCA) was applied to the water variables to compare effluents and intake water. Multivariate analysis has been used as an exploratory analysis in water quality data (Güler et al. 2002; Milstein et al. 2003; Milstein et al. 2005; Muendo et al. 2006), which generally present a large number of variables. PCA is useful for data reduction and the assessment of continuity/overlap of clusters or clustering/similarities in it (Güler et al. 2002).

Results and Discussion

Significant differences were detected for variables throughout the rearing cycle. However, limnological parameters of effluents showed random variation over time. All parameters presented a wide variation in all treatments and large standard deviations (Table 2). There was no observed difference ($P = 0.3484$) in the quantity of effluent released from ponds among treatments (Table 3). The mean temperatures observed at the water surface of experimental ponds were always higher than the mean temperatures registered at the bottom of the ponds. The mean maximum and minimum pond temperatures observed during the study were 30 C and 28.8 C at the water surface and 28.6 C and 27.2 C at the bottom.

The minimum mean turbidity value (Table 2) was found in the effluent from D10 (17 NTU) and differed statistically from treatments D20 and D40. The maximum mean turbidity value was 24 NTU and was found in treatments D20 and D40 but there was no significant difference between treatments D20, D40, and D80. Total phosphorus ranged from 10.1 in D10 and D20 to 12.1 µg/L in D80. These values were significantly different. However, even at the highest stocking density, water was still oligotrophic; in warmwater tropical environments values of up to 39.6 µg/L are considered mesotrophic (Salas and Martino 1991). There was no significant difference among treatments for the other water variables. Therefore, stocking ponds at up to 80 prawns/m^2 did not cause a high environmental impact.

The PCA permits condensing the maximum original information from the measured variables into two latent orthogonal variables denominated principal components, that are the linear combination of the original variables, thus accounting for as much of the variation contained in the samples as possible (Milstein et al. 2003). The second factor is the second such function that accounts for most of the remaining variability, and so on (Milstein et al. 2003). Therefore, the initial set of 13 variables becomes characterized by two new latent variables which, according to the principal component ordination, can be plotted in bi-dimensional figures (Val et al. 2008). In our analysis of principal components, 83.36% of the total variability was accounted for by

TABLE 1. *Physical and chemical parameters of water quality and methods of analysis used to evaluate the loads of organic matter of* Macrobrachium amazonicum *experimental ponds.*

Parameter	Method of analysis/Apparatus	Reference
Dissolved oxygen (DO)	YSI model 55	Yellow Springs Instruments, Yellow Springs, OH, USA
pH	YSI model 63	Yellow Springs Instruments, Yellow Springs, OH, USA
Conductivity (COND)	YSI model 63	Yellow Springs Instruments, Yellow Springs, OH, USA
Turbidity (TURB)	Colorimetric	APHA (2005)
Total suspended solids (TSS)	Gravimetric	Boyd and Tucker (1992)
Biochemical oxygen demand (BOD)	5 d Incubation at 21 C	APHA (2005)
Chemical oxygen demand (COD)	Closed reflux, colorimetric	APHA (2005)
N-total ammonia (TAN)	Phenate, colorimetric	APHA (2005)
N-nitrite (NIT)	Colorimetric	Benschneider and Robinson (1952)
N-nitrate (NAT)	Hydrazine sulfate reduction	APHA (2005)
N-Kjehdahl nitrogen (N-NTK)	Micro-Kjeldahl	Mackereth et al. (1978)
P-total phosphorus (TP)	Stannous chloride, colorimetric	Boyd and Tucker (1992)
P-soluble orthophosphate (SP)	GF/C Filtration, Stannous chloride, colorimetric	Boyd and Tucker (1992)

the first two principal components (Fig. 1). Conductivity, pH, and *N*-total ammonia (TAN) were positively correlated to both components. DO and COD were positively correlated with the first principal component but negatively correlated with the second. Turbidity, TSS, NIT, SP, and TP were negatively correlated to the first principal component and positively correlated to the second. BOD, *N*-nitrate (NAT), and *N*-Kjehdahl nitrogen (*N*-NTK) were negatively correlated with both principal components. Three groups were formed (Fig. 2): Group A corresponded to inflow water; Group B to the treatment D10; and Group C clustered treatments D20, D40, and D80.

No significant statistical difference for prawn survival was observed during this experiment, as previously reported (Table 4). However, productivity increased significantly with increased stocking density. As the quantity of feed provided was based on the estimated prawn biomass, the amount varied in parallel to stocking density (Moraes-Valenti and Valenti 2007).

Multivariate analysis was used as an exploratory analytical tool to complement ANOVA analysis. This showed that the farming of *M. amazonicum* modified the water quality characteristics of the effluents compared to intake water. However, increasing intensification from 20 to 80 prawns/m^2 had little effect.

In our PCA of water quality in the intake and effluent water (Fig. 1) Factor 1 indicates that pond effluents had lower values of conductivity, DO, pH, COD, and TAN than intake water, but higher values of turbidity, TSS, BOD, *N*-nitrite, *N*-nitrate, organic nitrogen (indicated by *N*-NTK), and phosphorus. The changes in effluent water quality shown may be due to the large addition of allochthonous feed and its fragmentation. The decomposition of this organic matter and the assimilation of nutrients by phytoplankton are additionally important. A large quantity of particles is added to the water by the fragmentation of uneaten feed. This increases turbidity, suspended solids, and particulate organic matter, which contains nitrogen and phosphorus and causes high BOD. The decomposition of the organic matter liberates inorganic nitrogen and phosphorus, increasing their concentration in the effluents. The primary nitrogen product of decomposition is ammonia, which can be converted into nitrite and nitrate by nitrifying bacteria or assimilated by phytoplankton (Moss 2010). As samples were taken in the early morning, the lower values of DO and pH reflect the decomposition

TABLE 2. *Results of two-way ANOVA and Duncan mean multicomparisons of effluent water characteristics variables.*

	TURB (NTU)	TSS (mg/L)	COND (μS/cm)	DO (mg/L)	pH	BOD (mg/L)	COD (mg/L)
Model *P* value	0.0323	0.0001	<0.0001	0.2159	<0.0001	<0.0001	<0.0001
r^2	0.5906	0.7552	0.7629	0.5018	0.7373	0.8256	0.8138
Variance source							
Block	0.1350	0.1863	0.0002	0.4047	0.0050	0.2894	0.2894
Treatment	0.0045	0.0698	0.4993	0.7213	0.3894	0.5806	0.4357
Block × Treatment	0.3248	0.2314	0.0739	0.4369	0.3826	0.1351	0.1351
Time	0.0213	<0.0001	<0.0001	0.0102	<0.0001	<0.0001	<0.0001
Treatment × Time	0.4133	0.1107	0.8379	0.5242	0.9895	0.3192	0.3761
Mean grouped by treatment							
D10	17 ± 2^{b}	10.7 ± 7.5	96.7 ± 7.3	3.31 ± 0.85	6.72 ± 0.22	7.18 ± 4.51	18.62 ± 15.62
D20	24 ± 5^{a}	14.4 ± 12.8	98.9 ± 9.1	3.12 ± 0.79	6.79 ± 0.27	5.54 ± 3.48	14.44 ± 6.82
D40	24 ± 5^{a}	11.2 ± 3.5	97.0 ± 6.7	3.08 ± 0.49	6.82 ± 0.27	6.15 ± 3.63	13.63 ± 5.01
D80	21 ± 4^{ab}	13.4 ± 5.2	99.0 ± 5.4	2.94 ± 0.65	6.74 ± 0.21	6.82 ± 4.54	14.63 ± 6.52
Mean multicomparison by time							
1	19 ± 5^{b}	0.0076 ± 0.0036^{c}	91.08 ± 3.36^{c}	3.45 ± 1.08^{ab}	6.99 ± 0.19^{a}	2.13 ± 1.20^{d}	15.26 ± 6.40^{ab}
15	24 ± 7^{a}	0.025 ± 0.0099^{a}	89.12 ± 8.31^{c}	3.45 ± 0.97^{a}	$7.02 \pm .19^{a}$	11.44 ± 2.34^{a}	16.24 ± 5.93^{ab}
30	21 ± 8^{ab}	0.0093 ± 0.004^{bc}	102.98 ± 5.96^{a}	2.29 ± 0.58^{c}	6.64 ± 0.15^{b}	10.28 ± 5.13^{a}	12.39 ± 7.71^{b}
45	24 ± 9^{a}	0.0126 ± 0.0057^{b}	106.39 ± 12.04^{a}	2.94 ± 1.30^{abc}	6.76 ± 0.31^{b}	3.17 ± 1.79^{cd}	21.04 ± 19.89^{a}
60	21 ± 6^{ab}	0.0100 ± 0.0039^{bc}	96.47 ± 1.97^{b}	3.43 ± 0.80^{ab}	6.38 ± 0.069^{c}	4.54 ± 2.46^{c}	16.38 ± 4.69^{ab}
75	19 ± 4^{b}	0.00907 ± 0.0028^{bc}	101.49 ± 1.82^{a}	2.8 ± 0.87^{bc}	6.81 ± 0.18^{b}	6.95 ± 1.05^{b}	11.39 ± 5.07^{b}

	TAN (μg/L)	NIT (μg/L)	NAT (μg/L)	N-NTK (mg/L)	TP (μg/L)	SP (μg/L)
Model *P* value	0.0050	<0.0001	0.0163	0.3903	<0.0001	0.0001
r^2	0.6642	0.7457	0.8322	0.4935	0.7557	0.7285
Variance source						
Block	0.9541	0.6619	0.0600	0.8683	0.0061	0.0977
Treatment	0.6063	0.2074	0.5748	0.8291	0.0325	0.2432
Block × Treatment	0.0685	0.2294	0.2462	0.3455	0.1326	0.2462
Time	<0.0001	<0.0001	0.0003	0.3200	<0.0001	<0.0001
Treatment × Time	0.2721	0.1136	0.1896	0.2416	0.2716	0.3551
Mean grouped by treatment						
D10	110 ± 21	49.6 ± 13.8	1098.0 ± 388.3	0.35 ± 0.19	10.1 ± 3.8^{b}	1.6 ± 0.6
D20	127 ± 48	56.0 ± 16.3	1014.7 ± 726.0	0.24 ± 0.08	10.1 ± 4.1^{b}	2.1 ± 1.4
D40	141 ± 67	55.3 ± 10.0	1093.7 ± 912.3	0.24 ± 0.07	10.9 ± 3.2^{ab}	1.6 ± 0.8
D80	134 ± 65	61.6 ± 30.9	835.0 ± 548.1	0.27 ± 0.09	12.1 ± 3.5^{a}	1.6 ± 0.9
Mean multicomparison by time						
1	192 ± 72.27^{a}	46.65 ± 4.23^{bc}	662.05 ± 337.66^{cd}	0.29 ± 0.12	0.010 ± 0.0016^{bc}	0.0006 ± 0.0005^{c}
15	109.08 ± 72.07^{c}	51.93 ± 12.18^{b}	756.64 ± 410.44^{cd}	0.28 ± 0.12	0.015 ± 0.004^{a}	0.0021 ± 0.0005^{ab}
30	66.50 ± 42.83^{d}	41.27 ± 12.16^{c}	1406.10 ± 674.73^{ab}	0.21 ± 0.14	0.009 ± 0.004^{c}	0.0008 ± 0.0004^{c}
45	136.58 ± 49.64^{abc}	52.96 ± 24.05^{b}	1081.03 ± 794.32^{bc}	0.25 ± 0.12	0.012 ± 0.006^{b}	0.0022 ± 0.0007^{ab}
60	161 ± 65.25^{ab}	88.39 ± 22.65^{a}	1675.13 ± 742.26^{a}	0.29 ± 0.082	0.006 ± 0.002^{d}	0.0027 ± 0.0016^{a}
75	113.75 ± 33.79^{bc}	52.51 ± 10.39^{b}	343.01 ± 190.73^{d}	0.21 ± 0.09	0.011 ± 0.001^{bc}	0.0016 ± 0.0008^{b}

[1]Mean multi-comparisons: superscript letters in a column indicate a significant difference at the 0.05 level. a > b > c. Data refer to mean ± SD. r^2 is the coefficient of determination.

that occurred during the night; this consumes oxygen and liberates CO_2, decreasing the pH (Boyd and Tucker 1998). Thus, our data indicate that the load of organic matter due to the feed supplied to prawns is the main factor that drives the biological dynamic of the ponds, thus affecting effluent water quality. Kimpara et al. (2010), using factor analysis, also demonstrated the importance of organic load on the pond ecosystem.

The lower *N*-ammonia concentrations and higher *N*-nitrite and *N*-nitrate levels found in effluents in the morning may have occurred due to primary community assimilation during the day before sampling and/or the nitrification process. The assimilation and incorporation of ammonia by phytoplankton consumes less energy than the use of nitrate (Hargreaves 1998). Thus, ammonia is utilized first and the levels in the water column are normally low.

TABLE 3. *Quantity of effluents by treatment released from the system during the rearing cycle and harvest (mean ± SD)*

Treatment	Liters of effluent released
D10	3,470,109.33 ± 2,744,941.20
D20	4,089,228.00 ± 3,342,417.22
D40	3,563,413.08 ± 3,122,667.50
D80	2,994,545.53 ± 2,985,482.04

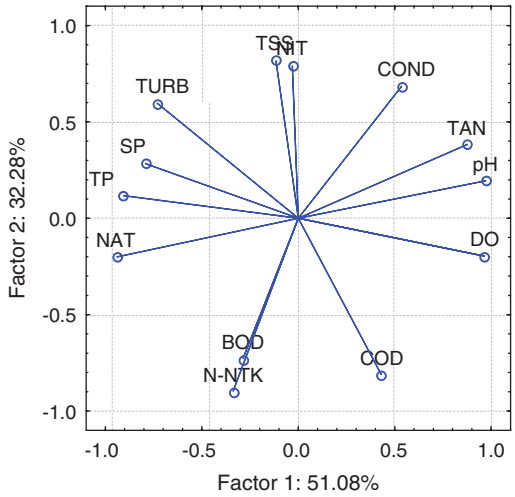

FIGURE 1. *Principal components analysis: water quality in intake and effluent water. TURB = turbidity; TSS = total suspended solids; COND = conductivity; DO = dissolved oxygen; BOD = biochemical oxygen demand; COD = chemical oxygen demand; TAN = total ammonia nitrogen; NIT = nitrite nitrogen; NAT = nitrate nitrogen; N-NTK = total Kjeldahl nitrogen; TP = total phosphorus; SP = soluble orthophosphorus.*

Tucker et al. (1984), Hopkins et al. (1994) and Pusceddu et al. (2011) have observed an inverse relationship between ammonia concentration and phytoplankton density in fish ponds. Dense phytoplankton populations are often developed in semi-intensive ponds due to a high rate of nutrient input (Hargreaves 1998). Jackson et al. (2003) found a relatively close relationship between chlorophyll-*a* and *N*-particulate concentrations, suggesting that the main fraction was phytoplankton. Thus, the increase in the level of TNK-N in the effluents observed in our study may have been caused by allochthonous diet or phytoplankton.

In ponds, nitrogen originates mainly from food protein (Mires 1995) and its concentration in the water column is also related to feeding strategy (Jiménez-Montealegre et al. 2005). The application of formulated feeds may constitute more than 90% of nitrogen input in semi-intensive ponds (Hargreaves 1998). Thus, further attention should be paid to feeding management in *M. amazonicum* ponds. Future research is necessary to define better-balanced and more water-stable diets. Determining optimum feeding rates to avoid leaching and the consequential excess of organic matter, which can deteriorate water quality and generate high impact effluents are also important avenues for further studies.

Low release of soluble orthophosphate and total phosphorus in the effluents were found in this study. Similar results were observed by Keppeler and Valenti (2006) in ponds stocked with 20 juveniles/m^2 of *M. amazonicum*. Ziemann et al. (1992) also observed low values of orthophosphate in effluents from freshwater prawn, *Macrobrachium rosenbergii*, ponds in Hawaii (1.8 µg/L). Despite the fact that concentrations were low, mean soluble orthophosphate levels in the effluents in our study were higher than in the inflow, which may indicate an effect of feeding on this parameter. Only a fraction (generally about 30%) of the phosphorus contained in the feed and fertilizers added to ponds is converted to harvested prawns and/or fish (Boyd and Tucker 1998). Thus the remaining phosphorus may cause eutrophication when effluent water is released into the environment (Cloern 2001; Porrello et al. 2003).

In the experiment of which our study formed an ancillary, the amount of feed supplied increased during the culture period (Moraes-Valenti and Valenti 2007) and could have led to an increase in the quantity of nutrients in the water column caused by the decomposition of uneaten feed, feces, and leaching losses. However, inorganic nitrogen and soluble orthophosphate in the effluents did not increase over time. Thus, nutrients were probably assimilated by live organisms or were deposited on the pond bottom. Nutrients were incorporated into prawn tissue, but a substantial part may have entered

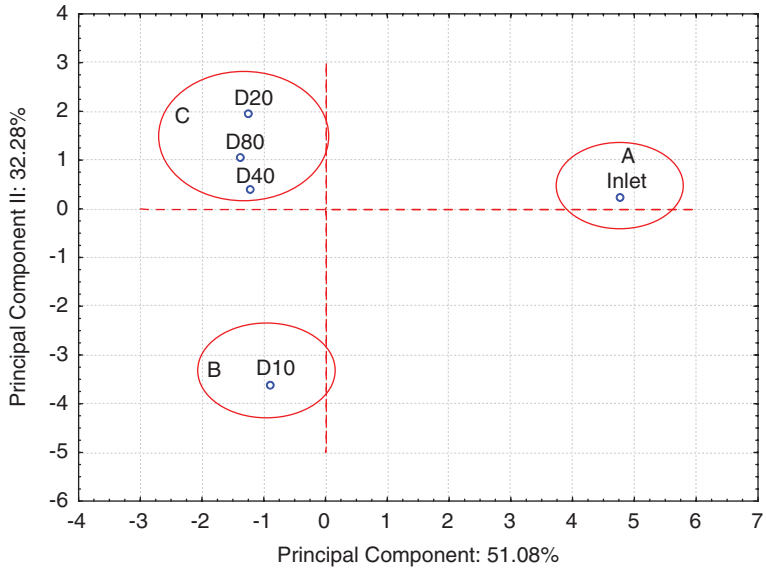

FIGURE 2. *Principal components analysis of effluents and intake water variables.*

TABLE 4. *Mean of survival, productivity, and total food supplied observed and provided during the culture of* Macrobrachium amazonicum *stocked with different densities.*[1] [2]

Stocking density (PL/m^2)	Survival (%)	Productivity (kg/ha)	Food (kg/ha/d)
10	72.2	508[a]	45
20	72.8	875[b]	53
40	65.6	1283[c]	63
80	71.4	2051[d]	102

[1]Table reproduced from Moraes-Valenti and Valenti (2007).

[2]Mean values followed by different superscript letters in the same column differ statistically ($P < 0.05$).

the water column after decomposition and been taken up by phytoplankton, which settle in the sediment after they die (Lin and Yi 2003; Burford and Lorenzen 2004). Regardless of the level of intensification, effluent data suggest that ponds assimilate allochthonous feed rather than being potential discharge pollutants. Similar results were observed by Trott and Alongi (2000) and Wahab et al. (2003) in marine shrimp culture ponds. The uptake of inorganic nitrogen and subsequent sedimentation of dead phytoplankton have been described in shrimp ponds operated at low water exchange rates (Lorenzen et al. 1997; Burford and Lorenzen 2004). The pond system appears to have some capacity to assimilate or transform nutrients, such as mineralization and subsequent dissipation by food webs or sediment accumulation. Semi-intensive earthen ponds may have internal mechanisms to preserve their stability, as occurs in natural aquatic ecosystems.

Factor 2 (Fig. 1) in our PCA of water quality in the intake and effluent water indicates that the effluent of ponds stocked at 10 PL/m^2 showed higher values of BOD, COD, and NKT-N than from ponds stocked at 20, 40, and 80 PL/m^2. However, lower values of conductivity, turbidity, suspended solids, and nitrite were found in effluents from D10 than from ponds stocked at 20, 40, and 80 PL/m^2. This suggests a higher sedimentation of organic matter, which can be formed by allochthonous food or dead phytoplankton. The settlement of organic matter in bottom layers decreases turbidity, suspended solids and decomposition. Decomposition is reduced because of the lower concentration of DO at the pond bottom and the reduction of the contact surface for microorganism action produced by the sedimentation of particles. Reducing decomposition increases BOD, COD, and organic nitrogen (as NKT-N) levels.

On the other hand, it decreases the ions resulting from the decomposition, decreasing conductivity. The higher sedimentation observed in D10, may be due to the reduction in bioturbation of the sediment by the smaller number of prawns at this low density. Kimpara et al. (2010) emphasized the important role played by the bioturbation of prawns in the biological processes of *M. amazonicum* ponds.

Despite our observations that water quality differed in some parameters between the effluents and intake water, it appears that *M. amazonicum* intensification can be characterized as having a low environmental impact, at least up to a stocking density of 80 prawns/m^2. Ponds appear to have the capacity to retain and process the major quantities of added food instead of releasing pollutants to the environment. Thus, *M. amazonicum* may be farmed in earthen ponds in high densities in order to maximize productivity while causing minimal impact on the surrounding environment. Our findings also corroborate the concept that *M. amazonicum* may be farmed in high densities in all phases of its culture cycle (Moraes-Valenti and Valenti 2010).

Acknowledgments

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