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Production strategies for short term grow-out of the Amazon River prawn *Macrobrachium amazonicum* (Heller 1862) in ponds

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Abstract. The aim of this study was to evaluate the effect of stocking ponds using graded and ungraded juveniles and performing drained and combined harvesting on the production of *M. amazonicum*. A randomized completed-blocks design with 4 treatments (farming strategies) and 3 replicates was used. Treatments were: Upper size-graded juveniles, Lower size-graded juveniles, Ungraded juveniles, all with total drained harvesting, and Combined Harvesting (ungraded juveniles). Twelve earthen ponds were stocked at 40 juveniles.m^{-2}, according to the treatment. After 3.5 months prawns were completely harvested. Lower size-graded prawns showed smaller average weight (3.37 ± 0.25 g) than upper size-graded (4.03 ± 0.40 g) and ungraded ones (3.80 ± 0.16 g). Survival percentage varied from 68 ± 9 to 76 ± 10, productivity was slightly higher than 1,000 kg.ha^{-1} and apparent feed conversion rate varied from 3.0 ± 0.7 to 3.7 ± 1.3. These parameters did not differ among the farming strategies. The best strategy for short term grow-out *M. amazonicum* in earthen ponds is stocking ungraded juveniles and performing total harvesting by draining ponds at the end of rearing cycle. Grading juveniles before stocking and selective-harvesting managements are not advantageous because they increase costs and do not improve any production parameter.

Keywords: *Macrobrachium*, Amazon River prawn, grow-out, selective harvesting, grading juveniles

Resumo. Estratégias de produção para engorda do camarão-da-amazônia *Macrobrachium amazonicum* em curto período. O objetivo deste estudo foi avaliar o efeito das estratégias de povoamento e despesca sobre a produção de camarões *M. amazonicum*. O delineamento experimental foi em blocos casualizados com 4 tratamentos (estratégias de cultivo) e 3 repetições. 12 viveiros de fundo natural foram estocados com 40 juvenis.m^{-2} de acordo com os tratamentos: Upper = estocagem de juvenis retidos na gradeadora, Lower = estocagem de juvenis que passaram pela gradeadora, NG = estocagem de juvenis não gradeados e DC = estocagem de juvenis não gradeados mais o uso de despesca combinada (seletivas e total). Após 3,5 meses os camarões foram despescados. Os camarões do tratamento Lower apresentaram peso médio menor (3,37 ± 0,25 g) que os uppers (4,03 ± 0,40 g) e não gradeados (3,80 ± 0,16 g). A sobrevivência variou de 68 ± 9 a 76 ± 10%, a produtividade foi ligeiramente superior a 1000 kg.ha^{-1} e a conversão alimentar aparente variou entre 3,0 ± 0,7 e 3,7 ± 1,3. Estes parâmetros não diferiram entre as estratégias de cultivo. A melhor estratégia para o crescimento de *M. amazonicum* durante curto período é a estocagem de juvenis não gradeados seguida de despesca total. O gradeamento de juvenis e o uso das despescas seletivas aumentam o custo e não melhoram a produtividade.

Palavras chave: *Macrobrachium*, camarão-da-amazônia, engorda, despesca seletiva, gradeamento de juvenis

Introduction

Strategies to farm freshwater prawns include variations in the rearing cycle period, the stocking and the harvesting managements (Valenti & Tidwell 2006, Valenti *et al*. 2010). Prawns can be farmed for short (3-4 months), medium (4-6 months) and long (6-9 months) periods. Farming juveniles in grow-out earthen ponds for 3-4 months is particularly valuable because it optimizes land use and maximizes productivity. This strategy allows performing one profitable rearing cycle in temperate regions, two in subtropical and three in tropical areas (Valenti & Tidwell 2006). Stocking strategies include the use of newly-metamorphosed post-larvae or 0.5-2 month juveniles, which can be graded by size before stocking (Tidwell & D´Abramo 2010, Karplus & Sagi 2010). Harvest may be performed by seining ponds periodically, draining the ponds at the end of culture or by a combined method, in which ponds are seined once some prawns attain the commercial size and finally are drained to catch all remaining prawns (New 2002, Valenti *et al*. 2010).

Prawns of the genus *Macrobrachium* generally show territorial and aggressive behavior, as was demonstrated for *Macrobrachium rosenbergii* (De Man 1879) (Peebles 1977, 1979a,b, Cohen *et al*. 1981) and *Macrobrachium iheringi* (Ortmann 1897) (Volpato & Hoshino 1984, 1987). For this reason, dominant males inhibit growth of the others and productivity can not be managed only by increasing density and feeding input. Hence, research on strategies to increase final mean weight and productivity have been carried out (Karplus *et al*. 1986, 1987, Daniels & D'Abramo 1994, Daniels *et al*. 1995, Tidwell *et al*. 2003, 2004a,b, 2005). These studies have been concentrated on the most common farmed species around the world, *M. rosenbergii*. Productivity above 2 $t.ha^{-1}$ has been obtained in temperate regions, in 3-4 months of culture preceded by a 60-days nursery (Tidwell *et al*. 2003, 2004a, b). Moreover, in tropical regions, the use of these techniques allows 3 rearing cycles per year and productivity may reach 7-8 $t.ha^{-1}.yr^{-1}$ (Valenti 2002a, Valenti & Moraes-Riodades 2004).

Grading juveniles before stocking consists in separating fast growing juveniles from the laggard ones and stocking the two fractions in different ponds (Tidwell & D'Abramo 2010). Then, the social interactions that affect prawns growth are reduced (Tidwell *et al*. 2005). The "upper" fraction of graded prawns may overcome the performance of ungraded animals from 20 to 50% (Karplus *et al*. 1986, Daniels & D'Abramo 1994). On the other hand, "lower" graded fraction show different results, according to the size of juveniles stocked, the grow-out period, and the use of substrates inside the ponds (Karplus *et al*. 1986, Karplus & Sagi 2010).

Selective harvesting consists in removing dominant males and mature females throughout the rearing cycle by seining ponds (Valenti 2002b, Valenti *et al*. 2010). The removed animals show reduced growth rate and may be sold before total harvesting enlarging the time in which product is available for commercialization. In addition, density inside pond decreases and dominant males are removed allowing the growth of small animals. This management can decrease the negative results of the heterogeneous growth and contributes to the regularity in offering the product in the market. Nevertheless, scientific-based studies focusing on the effects of selective harvesting on production of any *Macrobrachium* species are scarce.

The Amazon River prawn *Macrobrachium amazonicum* (Heller 1862) is a hard South American species which shows great potential for aquaculture (Kutty 2005, New 2005). It is smaller than *M. rosenbergii*, which permits stocking densities 5-10 times higher. In both species size variation occurs, causing negative effects on farming. Alike *M. rosenbergii*, the variability in size of *M. amazonicum* is a result of the heterogeneous growth due to the existence of different males morphotypes (Moraes-Riodades & Valenti 2004). Therefore, stocking and harvesting strategies used to reduce heterogeneous growth may be useful in *M. amazonicum* farming.

As stated above, some studies have demonstrated the feasibility of different production strategies for *M. rosenbergii*. However, no information is available for the Amazon River prawn. Thus, the aim of this research was to evaluate the effect of stocking ponds using graded and non-graded juveniles and performing drained or combined harvesting on the production of *M. amazonicum* raised in ponds for 3.5 months.

Material and methods

This study was conducted in the Crustacean Sector, Aquaculture Center at the São Paulo State University, Brazil (21°15'22''S and 48°18'48''W). Post-larvae of *M. amazonicum* were obtained from broodstock formed by wild animals captured in Northeast Para, Brazil (01°14'30"S 48°19'52"W) in 2001. Newly-metamorphosed post-larvae (PL) were stocked for 15 days in indoor nursery tanks at 7 $PL.L^{-1}$ and after that, for 30 days in outdoor nursery ponds at 200 $PL.m^{-2}$. Part of these animals was graded using a 5 mm mesh grader box (Bernauer model D6001). As a result, two subpopulations were obtained: "uppers" (1/3 of total), which were trapped in the bars, and "lowers" (2/3 of total) which passed through the bars.

A randomized completed-blocks design with four treatments (farming strategies) and three replicates was used. Upper treatment consisted in stocking ponds with the subpopulation of larger juveniles (0.59 ± 0.02 g). In Lower treatment, ponds were stocked with the smallest juveniles (0.39 ± 0.03 g). In the Ungraded treatment, ponds were stocked non-graded juveniles (0.51 ± 0.03 g). In all these treatments total harvesting was performed by draining ponds at the end of the trial. In the Combined-harvesting treatment, ponds were stocked non-graded juveniles (0.50 ± 0.04 g) and two intermediate selective harvests were performed at 10 and 13 weeks after stocking using a 12 mm-mesh seine. In all treatments, pods were drained at 15th week and total harvests were performed.

Twelve 0.01 ha-earthen ponds (1m deep) were stocked at 40 juveniles.m^{-2}, according to the relevant treatment. Prawns were fed a commercial pelletized diet (35% crude protein) supplied in two daily portions at 08:00 and 16:00 h. Prawn biomass inside ponds was estimated every 3 weeks by weighing a sample of prawns using a Marte A 500 scale (0.01 g). At the beginning, daily feeding rate was 9% of biomass. This rate was reduced in 2% in each biometry, reaching 3% at the 13th week. In addition, the amount of feed was weekly corrected, considering 1% mortality and 20% weight gain per week. Daily quantity was reduced by half when dissolved oxygen was between 2.5 and 3.5 mg.L^{-1} in the morning.

Water temperature and dissolved oxygen were daily monitored at 07:00 and 17:00 h, whereas water exchange rate, transparency, pH and N-total ammonia were measured weekly at 15:00 to 17:00 h. For temperature and dissolved oxygen determination, an YSI model 55 oxygen/temperature meter was used. Water exchange rate was determined by measuring flow rate in the entrance of ponds, using a graduated bucket. Transparency was measured using a Secchi disk. The pH was determined using an YSI model 63 pH meter. N-total ammonia concentrations were determined according to Solorzano (1969), using a Hach DR 2000 spectrophotometer.

There were no significant differences ($\underline{P}$ > 0.05) in water quality variables among treatments. Overall treatment means (± S.D.) range were: daily water exchange rate, from 27 ± 12 to 31 ± 18%; temperature, from 27.1 ± 1.0 to 29.1 ± 1.0 C; transparency, from 46 ± 11 to 55± 11 cm; dissolved oxygen, from 4.22 ± 1.32 to 9.94 ± 1.96 mg.L^{-1}; pH, from 7.83 ± 0.45 to 7.97 ± 0.40; total ammonia-nitrogen, from 56 ± 40 to 116 ± 84 μg.L^{-1}. These values were similar to conditions formerly used in culture of *M. amazonicum* in ponds (Moraes-Riodades *et al*. 2006, Keppeler & Valenti 2006) and generally match the results obtained in the natural habitats of the this species (Maciel & Valenti 2009). Therefore, we presumed that the water quality was suitable for *M. amazonicum* culture.

In the first selective harvesting of Combined Harvesting treatment, all animals were individually counted and weighted. In the second one, all animals were counted and a randomized sample was taken (N≥50) from each pond for individual weight determination. After 3.5 months of culture, total harvesting was done in all ponds. Animals were counted and a random sample of 10% of total prawns was taken from each pond to determine the individual weight. Data of animals removed at the selective harvests were added to those harvested at the end of culture and the mean weight, survival, productivity and apparent food conversion rate were determined for each pond. For each treatment, weight data of all animals were separated into classes of 1g. After that, the weights in each class were added and converted to kg.ha^{-1}, to determine the amount produced per size class. Then, the percentage of production and the productivity of prawns larger than or equal to 7 g were determined. This reference weight was chosen because of the higher market prices of such prawns (Moraes-Valenti & Valenti 2007). Considering that in a commercial farming all individuals (uppers and lowers) would be used for stocking, the weighted average between the "upper" (1/3) and "lower" (2/3) treatments was calculated for prawns larger than or equal to 7 g.

The normality and homocedasticity of data were evaluated by the Shapiro-Wilk and Brown-Forsythe tests, respectively. As both conditions were satisfied, means were compared by two-way ANOVA, $\underline{F}$ test, performed as a mixed model, in which production strategy is the fixed factor and block is the random factor; the null hypothesis of equal means on all production strategies was tested. When significant differences were obtained, Fisher-LSD test was used to compare the mean values. Survival data were previously subjected to arcsin√x transformation, but the original values are presented to facilitate the interpretation. Statistical analyses were performed in the "Statistica 6.0" software, by StatSoft. In all cases, it was considered that means differ when the probability to obtain the statistical calculated value was inferior or equal to 5%.

Results

Mean weight of harvested prawns varied between 3.37 and 4.03 g (Table I). Animals from Lower treatment were significantly smaller than those from Upper and Ungraded treatments were, whereas those from Combined Harvesting were intermediate (Table I). Survival, productivity and apparent feed conversion rate did not differ among treatments. Survival percentage varied from 68 ± 9 to 76 ± 10, productivity was slightly higher than 1000 $kg.ha^{-1}$ and apparent feed conversion rate varied from 3.0 ± 0.7 to 3.7 ± 1.3 (Table I).

The distributions of production in classes of weight followed a slightly bimodal pattern in all treatments (Figure 1). The highest productivity was obtained for the 4 g class, which contains mainly stunted males and females. In the Combined-Harvesting treatment, the productivity of animals above 11 g was negligible. The fraction of production containing larger prawns (≥ 7 g) varied from 17 to 31% and did not differ among treatments (Table II). This large group is composed by the dominant males. The weighted average between Upper and Lower treatments showed the intermediate value of 24%.

Table I. Mean (± standard deviation) weight, survival, productivity and apparent feed conversion rate.

	Mean weight (g)	Survival (%)	Productivity ($kg.ha^{-1}$)	Apparent feed conversion rate
Upper	4.03 ± 0.40[a]	70 ± 12[a]	1,140 ± 292[a]	3.6 ± 1.5[a]
Lower	3.37 ± 0.25[b]	76 ± 10[a]	1,026 ± 184[a]	3.2 ± 0.7[a]
Ungraded	3.80 ± 0.16[a]	68 ± 9[a]	1,032 ± 166[a]	3.7 ± 1.3[a]
Combined Harvesting	3.59 ± 0.29[ab]	73 ± 5[a]	1,049 ± 145[a]	3.0 ± 0.7[a]

Mean value followed by the same letter in the same column does not differ significantly at 5%.

Table II. Percentage of production and productivity (± standard deviation) of prawns in different treatments and the weighted average between "upper" and "lower" treatments.

	% of production		Productivity ($kg.ha^{-1}$)	
	< 7 g	≥ 7 g	< 7 g	≥ 7 g
Upper	71	29	804 ± 186	336 ± 112
Lower	79	21	810 ± 159	217 ± 80
Ungraded	69	31	716 ± 102	316 ± 69
Combined Harvesting	83	17	868 ± 97	181 ± 48
Upper and Lower	76	24	808	257

There was no significant difference among treatments.

Discussion

Stocking graded or ungraded juveniles with total harvesting and stocking ungraded juveniles with combined harvesting showed similar performance for the culture of *M. amazonicum* during 3.5 months. Harvested prawns were slightly smaller in Lower treatment, whereas survival, productivity and apparent feed conversion rate were not significantly different. Growth of stunted prawns was not improved by separating them from the larger ones at juvenile phase by grading or at maturity by selective harvesting.

Besides, although no significant difference was observed, combined - harvesting management decreased the production fraction of large marketable prawns by almost a half. Karplus *et al*. (1986, 1987), observed that the lower-fraction of juveniles of *M. rosenbergii* showed smaller mean weight than upper-fraction and ungraded. However, there is a time demanding compensatory shift from the small males (SM) to the large Orange Claw (OC) and Blue Claw (BC) morphotypes in the absence of the dominants (Karplus & Sagi 2010). The proportion of SM in the lower fraction of graded population was higher than in ungraded after 97 days grow-out (Karplus *et al*. 1987). However, the performance of lower-fraction may overcome ungraded performance after 120 to 140 days of culture (Daniels & D' Abramo 1994, Tidwell *et al*. 2004a) and a dramatic increase in the performance occurs after 165 days grow-out (D'Abramo *et al*. 1991). Our results showed that 105 days grow-out was not enough time for smaller *M. amazonicum* develop and reach weight equivalent or superior to ungraded animals.

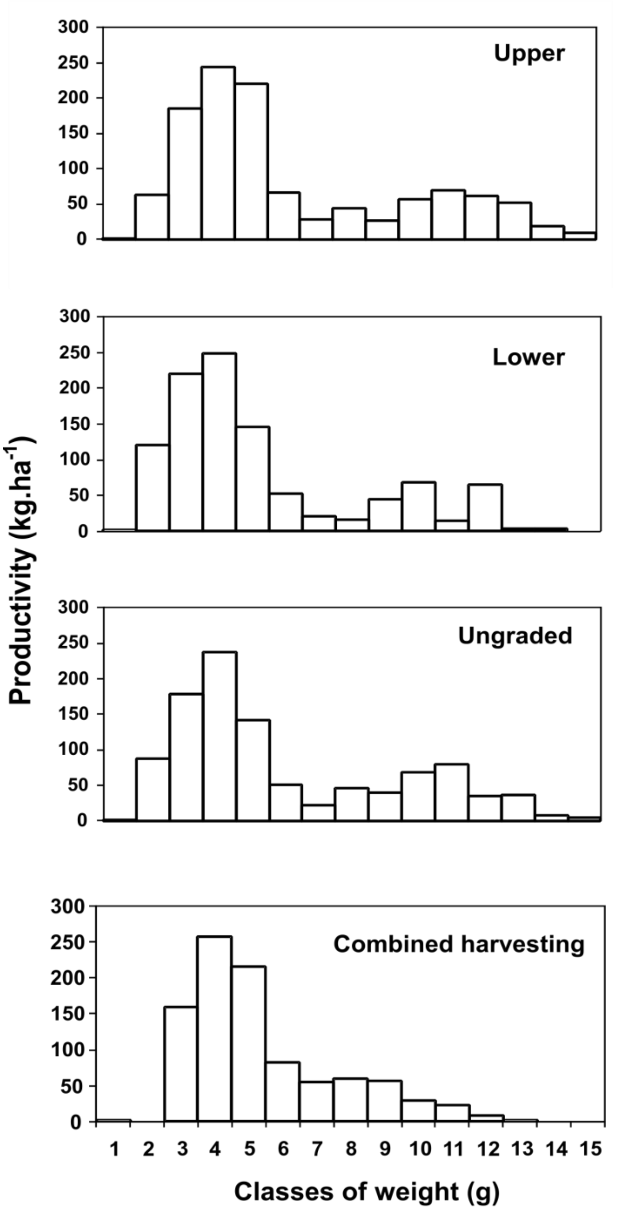

Figure 1. Distribution of prawn productivity in classes of weight.

Therefore, grading juveniles before stocking is not a good practice for short term culture of *M. amazonicum*. Separating larger and smaller animals before stocking or after maturation did not affect survival. This suggests that the intraspecific competition and/or social interactions are processes that have evolved to maintain the population size. The reduction of growth may be advantageous to diminish the use of resources in crowding situations such as those found in aquaculture ponds. Survival rates obtained in the present work were similar to those obtained by Moraes-Valenti & Valenti (2007) raising *M. amazonicum* at the same density in ponds stocked with post-larvae during 5.5 months. However, the farming period in that study was 2 months longer, and so, results did not confirm the hypothesis that higher survival may be obtained in ponds stocked with juveniles. Expected survival in *Macrobrachium* prawn farming after a 3-5 month culture period is 40-60%, whereas penaeid survival reaches 60-80% during a 3-4 month culture (Wickins & Lee 2002). Therefore, we can consider that *M. amazonicum* raised for short term in ponds showed high survival rates.

M. amazonicum is a high productivity species (Moraes-Valenti & Valenti 2010). Productivity obtained in the present work is ~1,000 $kg.ha^{-1}.3.5^{-1}$ months and stoking graded juveniles or performing selective harvesting did not increase productivity. This productivity is similar to those obtained in previous studies, in which prawns were stocked at 40 $individuals.m^{-2}$ (Moraes-Valenti & Valenti 2007, Nogueira 2008). In tropical regions, it is possible to perform 3 grow-out cycles of 3-4 months during the year, and productivity may reach more than 3,000 $kg.ha^{-1}.yr^{-1}$. However, productivity may reach 6,000 $kg.ha^{-1}.yr^{-1}$ at stocking densities as high as $80.m^{-2}$ (Moraes-Valenti & Valenti 2007). The value obtained in the present work is within the range of annual productivity observed for *M. rosenbergii* in commercial cultures, which generally varies between 1,000 and 4,500 $kg.ha^{-1}$ (Wickins & Lee 2002, Valenti & Moraes-Riodades 2004). It should be emphasized that productivity decreases as the pond size increases (Malecha 1983). Therefore, results reported for small experimental ponds are not always achieved in commercial farm conditions. Hence, pilot scale studies, in larger ponds, must be conducted to verify results.

The expected compensatory growth of stunted males from the lower graded population and of small prawns that remained inside ponds after selective harvesting did not occur in *M. amazonicum* grow-out stocked at 40 $juveniles.m^{-2}$. Animals from the Upper treatment showed performance similar to that of the ungraded prawns. Values of weighted mean production between Upper and Lower treatment were close to the means obtained in Ungraded and Combined-Harvesting treatments. The distribution of productivity in classes of weight in the Combined-Harvesting treatment showed a reduction in larger prawns. They were removed from the ponds generally below 9 g and the majority below 6 g. This may have caused the lower in productivity of animals above 7 g compared to treatments with complete harvsting . This suggests that the dominant males remain growing inside the ponds in contrast to dominant males of *M. rosenbergii*, which show reduced or zero growth rate (Karplus 2005, Karplus & Sagi 2010). Maybe, in a period longer than 3.5 months of rearing cycle and larger interval between harvests, the combined harvesting management would result in a higher productivity.

Grading *M. amazonicum* juveniles and performing selective harvesting is a hard and labor-intensive work (Preto *et al*. 2010), because this specie is small and is stocked at high densities (Moraes-Valenti & Valenti 2010). In addition, the difference in size between the dominant and the dominated prawns after maturation is small. Thus, these practices increase labor and certainly production cost without increasing prawn size or productivity. Hence, other management techniques to decrease heterogeneous growth, as the use of artificial substrates (Tidwell & D'Abramo 2010), should be evaluated for short-term farming of *M. amazonicum*.

In conclusion, the best strategy for short term grow-out of *M. amazonicum* in earthen ponds is stocking ungraded juveniles and performing total harvesting by draining ponds at the end of the rearing cycle. Grading juveniles before stocking and selective-harvesting managements are not advantageous because they increase costs and do not improve any production parameter. However, studies should be carried out to evaluate the effects of these strategies in 6 to 9 months cultures, which are used to get 1 or 2 annual cycles in subtropical and tropical regions (Valenti & Tidwell 2006). Perhaps in these cases, juveniles of lower fraction and population remaining in the ponds after selective harvesting have time to develop, increasing the final productivity of large prawns and total productivity.

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