PRODUCTION OF LIVE BAIT-SHRIMP (*Farfantepenaeus paulensis*) IN CAGES AT VARYING STOCKING DENSITIES

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ABSTRACT

In Brazil's southern and southeastern coast, sport fisheries have a large demand for live bait-shrimp that is usually not met by local fishermen. The production of 4-5 g shrimp in cages may therefore provide a promising alternative to fill this gap. Unfortunately, studies defining adequate management guidelines for the production of live bait-shrimp in cages are as yet not available. In this study, the influence of stocking density on the survival, growth and food conversion ratio (FCR) of the shrimp *Farfantepenaeus paulensis* reared in cages was evaluated. The trial lasted 42 days and assessed three stocking densities (50, 100 and 200/m²) of *F. paulensis* juveniles (mean initial weight of 1.04 g). Final survival and weight of shrimp reared at 50, 100 and 200/m² were 94.1, 94.6 and 59.2%, and 6.0, 5.0 and 4.3 g, respectively. Survival and final weight of shrimp were negatively related to density. FCR was not significantly different between treatments but tended to increase at higher densities. The present results indicate that the production of *F. paulensis* in cages is feasible at all densities tested, but as rearing 200/m² will produce a larger number of bait-sized juveniles, this stocking density may be recommended when a rearing site presenting optimal environmental conditions is available. The production of live bait-shrimp in cages may become an interesting source of income for artisanal fishermen and farmers living near estuarine areas in Brazil and elsewhere.

Key Words: bait; shrimp; cage; *Farfantepenaeus paulensis*; stocking density.

PRODUÇÃO DE ISCA-VIVA DE CAMARÃO (*Farfantepenaeus paulensis*) EM GAIOLAS COM DIFERENTES DENSIDADES DE ESTOCAGEM

RESUMO

No litoral sul e sudeste do Brasil, a forte demanda da pesca esportiva por camarões vivos, para serem utilizados como isca, não é atendida pela pesca artesanal. O cultivo em gaiolas de juvenis de camarão (peso de 4-5 g) pode, portanto, ser uma alternativa interessante para atender este mercado. Infelizmente, estratégias de manejo adequadas à produção de camarões em gaiolas ainda não foram devidamente estabelecidas. Neste estudo, avaliou-se a influência da densidade de estocagem sobre a sobrevivência, crescimento e taxa de conversão alimentar (TCA) do camarão-rosa *Farfantepenaeus paulensis* cultivado em gaiolas. O experimento durou 42 dias e considerou três densidades de estocagem (50, 100 e 200/m²) de juvenis com peso médio inicial de 1,04 g. Ao final do período, as médias de sobrevivência e peso dos camarões cultivados a 50, 100 e 200/m² foram 94,1, 94,6 e 59,2%, e 6,0, 5,0 e 4,3 g, respectivamente. A sobrevivência e o peso final se correlacionaram negativamente à densidade. A TCA, porém, não se diferenciou significativamente entre os tratamentos, mas apresentou uma tendência de aumento nas densidades mais altas. Os resultados indicam que a produção de isca-vivas de *F. paulensis* em gaiolas é tecnicamente viável em todas as densidades testadas. Entretanto, como o cultivo de 200 camarões/m² resulta na produção de um maior número de juvenis, esta densidade de estocagem pode ser recomendada para utilização em áreas que apresentam boas condições ambientais. A produção de iscas-viva de camarão em gaiolas pode se tornar uma interessante fonte de renda alternativa para as comunidades de pescadores artesanais e agricultores que habitam o entorno de áreas estuarinas no Brasil e em outros países.

Palavras-chave: isca-viva; camarão; gaiola; *Farfantepenaeus paulensis*; densidade de estocagem.

Artigo Científico: Recebido em: 11/07/2007 - Aprovado em: 22/04/2009

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INTRODUCTION

The farming of penaeid shrimp is considered an alternative source of income for artisanal fishermen and farmers living near estuarine areas in southern Brazil (CAVALLI *et al.*, 2008). However, shrimp farming is commonly carried out in earthen ponds that demand relatively high levels of investments for their construction and management. For instance, in southern Brazil the implantation of one hectare for shrimp farming is estimated to cost more than US$ 12,000 dollars (SOUZA FILHO *et al.*, 2002). It is thus practically impossible for communities with limited economic resources to farm shrimp in conventional, pond-based culture systems. On the other hand, the farming of penaeids in cages placed within natural water bodies has been proposed by several authors (WALFORD and LAM, 1987; SINGH and MATTAI, 1990; SAMARANAYAKE, 1990; PAQUOTTE *et al.*, 1998; ZARAIN-HERZBERG *et al.* 2006) as a possible way to reduce implantation costs.

In the last few years, several attempts to culture penaeids in cages have had varying levels of success in Brazil. Despite good zootechnical results with the Pacific white shrimp *Litopenaeus vannamei* (PAQUOTTE *et al.*, 1998; COSTA *et al.*, 2000; OSTRENSKY and PILCHOWSKY, 2002), the culture of exotic species is a point of public debate in Brazil. For instance, cage culture of *L. vannamei* has been somehow restricted in southern Brazil (ROUBACH *et al.*, 2003) because of the danger of accidental introduction in natural waters. As an alternative, *Farfantepenaeus paulensis*, an endemic species to the southwestern Atlantic, has produced promising results when reared in cages (WASIELESKY *et al.*, 1995; BALLESTER *et al.*, 2003; CAVALLI and WASIELESKY, 2003; LOMBARDI *et al.*, 2003; VAZ *et al.*, 2004; PRETO *et al.*, 2005).

Along the southern and southeastern Brazilian coast, sport fisheries, particularly of the snook (*Centropomus* sp.), have a large demand for live bait-shrimp (4 to 5 g) that is not met by local fishermen. For instance, in the municipality of Cananéia, São Paulo, in certain months the demand for live bait-shrimp is estimated to vary between 270,000 to 300,000 individuals, with bait shrimp fetching from US$ 0.05 to US$ 0.45 a piece (MENDONÇA, Instituto de Pesca do Estado de São Paulo, pers. com.). Furthermore, the supply of native shrimp species to bait dealers is subject to natural availability in coastal estuaries and bays with each species having a peak availability. The production of bait-sized shrimp in cages may therefore provide a promising alternative to fill this gap. Live bait-shrimp trade is also common in the southern coast of the United States, where the culture of *Litopenaeus setiferus* in ponds has been proposed as an alternative to cater for the market (SAMOCHA *et al.*, 1998; McKEE *et al.*, 1989).

Despite an earlier study suggesting the possibility of producing bait-sized *F. paulensis* in cages (CAVALLI and WASIELESKY, 2003), appropriate management guidelines for the production of live bait-shrimp in cages are as yet not available. For instance, although it is well-known that stocking density affects the growth of pond-reared penaeids (SANDIFER *et al.*, 1994; COMAN *et al.*, 2004), optimal density for cage culture has not been determined. Determining the optimal stocking density in this alternative culture system is a key factor to maximize economic return as cage material responds for 80% of initial installation costs (ABDALLAH *et al.*, 2003). In this study we evaluated the influence of stocking density on the survival, growth and apparent food conversion ratio of *F. paulensis* cultured to bait size (4-5 g) in cages.

MATERIAL AND METHODS

This study was carried out in Justino Bay (32° 03′ 55″S; 52° 12′ 30″W), an estuarine inlet of Patos Lagoon, Brazil. Shrimp juveniles were reared from postlarvae (PL) produced by the University of Rio Grande's Marine Aquaculture Center. During the nursery period, PL were kept in 10-ton tanks and fed *ad libitum* a commercial shrimp diet containing 40% crude protein (Camaronina, Purina) supplemented with waste from shrimp processing (mainly fresh frozen shrimp heads).

At the beginning of the trial, juveniles (1.04 ± 0.56 g) were stocked in 2 x 2 x 2 m (4m² bottom area) PVC-coated polyester mesh cages with a 5 mm mesh opening. Twenty days before stocking the shrimp, cages were placed 40 cm distant from each other and the distance to the bottom of the lagoon was at least 30 cm. The experimental design consisted of three stocking densities (50, 100 and 200/m²) with three replicates each.

Shrimp were fed a commercial diet (Vanamar, Purina) containing 35% crude protein twice a day (8:00 and 18:00 h). Feeding amount was initially set at 7% of the biomass and adjusted according to consumption. One feeding tray was placed in each cage to estimate the apparent food conversion ratio (FCR) in the different treatments, which was calculated by FCR = Wd / (Wf - Wi), where Wd = total amount of feed supplied, Wf = shrimp final weight, and Wi = shrimp initial weight. When deemed necessary, fouling organisms were rubbed off the outer side of the cages.

Temperature and salinity were measured daily at 8:00 h with a mercury thermometer and an optic refractometer, respectively. Temperature was also measured daily at 18:00 h. Dissolved oxygen (Handylab oxymeter OXI/Set SCHOTT) and pH (pHmeter Handylab 2 BNC SCHOTT) were periodically measured at 8:00 h and 18:00 h in each cage and in a control point distant 100 m from the cages. Total ammonia concentrations (UNESCO, 1983) were also measured at the same locations at 18:00 h.

The experimental period lasted 42 days. At the end, surviving shrimp from each cage were hand counted and 30 of them were individually weighed. Results of survival, final weight, FCR and water quality were submitted to Levene's test and the K-S test to check their homogeneity and normal distribution, respectively. Results of survival, final weight and water quality were then submitted to one-way ANOVA (α = 0.05). Data presenting significant differences were submitted to Tukey's test, while the results of FCR were analyzed with Kruskal-Wallis's test.

RESULTS

Salinity, temperature, dissolved oxygen (DO), pH and total ammonia concentrations are shown in Table 1. Although no significant differences in salinity, temperature, DO concentrations and pH levels were observed between treatments, significantly lower levels of DO and pH were observed in the experimental cages than at the control point ($p<0.05$). There were no significant differences in the concentrations of total ammonia between treatments or between the cages and the control point.

Table 1. Mean (± SD), minimum and maximum values of salinity (ppt), temperature (°C) at 8:00 and 18:00 h, and dissolved oxygen (mg/l), pH, total ammonia (mg/l) in the experimental cages and the control point.

	Mean	Minimum	Maximum
Salinity	18.8 ± 3.6	12.0	23.0
Temperature (8:00 h)	22.5 ± 3.4	11.0	26.0
Temperature (18:00 h)	25.1 ± 3.0	16.0	29.0
DO – Cages	8.65 ± 2.95	4.01	14.78
DO – Control	9.57 ± 2.83	7.00	16.01
pH – Cages	8.36 ± 0.39	7.53	8.95
pH – Control	8.45 ± 0.40	7.67	9.07
Ammonia – Cages	0.04 ± 0.19	0.00	1.20
Ammonia – Control	n.d.	n.d.	n.d.

n.d. = not detected

No significant differences in survival were observed between treatments (Table 2). However, a large mortality occurred in one replicate of treatment 200/m², where only 18% of the initial population survived until the end of the study when total ammonia concentrations in this particular cage reached 1.2 mg/L. It is noteworthy that this cage was placed in the shallowest part of the lagoon where a comparatively lower water circulation was observed throughout the study period.

Table 2. Mean (± SD) survival, final weight and apparent food conversion ratio (FCR) of *Farfantepenaeus paulensis* reared in cages at 50, 100 and 200 shrimp/m² during 42 days.

	50/m²	100/m²	200/m²
Survival (%)	94.1 ± 7.9 ^{a}	94.6 ± 4.5 ^{a}	59.2 ± 36.4 ^{a}
Final weight (g)	6.00 ± 1.32 ^{a}	5.00 ± 1.43 ^{b}	4.30 ± 1.49 ^{c}
FCR	0.68 ± 0.00 ^{a}	0.88 ± 0.09 ^{a}	2.77 ± 2.92 ^{a}

Within a row, different superscript letters represent significant differences (P<0.05).

Final weight of shrimp reared at 50/m² was significantly higher (p<0.05) than those cultured at 100/m², which in turn was significantly higher than those reared at 200/m² (Table 2). FCR tended to increase at higher stocking densities, but no significant differences were detected between treatments (p>0.05).

DISCUSSION

Prevailing abiotic conditions during the experimental period were considered suitable as temperature, salinity, DO and pH values in the experimental cages varied within the tolerance ranges estimated for most penaeids (BOYD, 1990) as well as for *F. paulensis* (POERSCH and MARCHIORI, 1992; CORLETO *et al.*, 1993; HENNIG and ANDREATTA, 1998; WASIELESKY, 2000; TSUZUKI *et al.*, 2003). On the other hand, DO levels were higher in the control area than in the cages. This suggests that the rearing structures affected water circulation, which, in turn, negatively affected DO levels. Although the exterior of the net cages was periodically cleaned, it did not prevent the attachment of algae and detritus (fouling) on the netting material, which may have compromised further water flow through the cages. Additionally, oxygen consumption by the shrimp stock and fouling organisms attached to the cage walls may also have affected DO levels. Nevertheless, DO levels within cages were still high as they remained above 4.0 mg/l.

Total ammonia concentrations in this study were low (0.04 mg/l on average), except for one replicate of the treatment with 200/m², where a concentration of 1.2 mg/l was observed probably because this particular cage was located in a low water circulation area. Although safe levels of total ammonia for *F. paulensis* juveniles are much higher than the values observed here (OSTRENSKY and WASIELESKY, 1995), WASIELESKY (2000) reported that juveniles exposed to ammonia for longer periods of time may be affected by levels as low as 0.9 mg/l.

Growth was negatively affected by increasing stocking densities. Similar results were obtained in a previous study of the production of bait-sized *F. paulensis* in cages, where final weight at the densities of 15, 30, 60 and 90/m² were 5.1, 4.2, 3.6 and 3.4 g, respectively (CAVALLI and WASIELESKY, 2003). Likewise, ARAVINDAKSHAN *et al.* (1980) observed a 60% decrease on the final weight of *Fenneropenaeus indicus* reared in cages at 40/m² in comparison to shrimp reared at lower (5-10/m²) densities. From the present results, it is clear that rearing 100 to 200 shrimp/m² will produce a larger number of bait-sized juveniles with lower final weights (4.3 – 5.0 g). Although comparatively smaller shrimp are produced, according to our experience shrimp in this size range will be accepted by sport fishermen to be used as live bait.

Final survival and weight of shrimp in the present study were comparatively higher than in previous studies where penaeids were cultured in cages (MARTINEZ-CÓRDOVA, 1988; CAVALLI and WASIELESKY, 2003). Although management practices and species-specific differences may make within study comparisons difficult, natural productivity of the different environments certainly plays an important role in the final results. For instance, the high productivity (hence a large availability of natural food items) and good water quality that characterizes the Patos Lagoon estuary may partially explain the high survival and growth. The importance of natural productivity is also emphasized when FCR values from the present study are analyzed. FCR values of shrimp reared at 50-100/m² varied from 0.68 to 0.88, which are well below conversion rates usually obtained in most commercial shrimp farms. Comparison of FCR values from this study to those from commercial farms must be done with caution. Several reasons may help explain the low FCR obtained in this study: small (≤ 5g) juvenile shrimp present a higher relative growth and a better feed transformation than larger animals (individual weight > 8 g), a shorter rearing period (42 days in this study and minimum 110 days in commercial culture), feeding carried out exclusively on trays which optimizes consumption, and, as stated above, contribution of the natural productivity. For instance, epibiont and epiphytes growing on cage walls are known to improve growth performance of *F. paulensis* (BALLESTER *et al.*, 2003; ABREU *et al.*, 2007).

F. paulensis is known to spend most of the daytime burrowed in the sediment (IWAI, 1978) as a strategy to avoid potential predators (DALL *et al.*, 1990). The absence of sediment has been shown to affect negatively the growth of cage-reared shrimp (WASIELESKY *et al.*, 1999; VAZ *et al.*, 2004). Nevertheless, it is interesting to notice that growth of cage-cultured *F. paulensis* in this study is comparable to that of juvenile populations in the natural environment (D'INCAO, 1984) and pond-reared shrimp (PEIXOTO *et al.*, 2003). This is likely the result of a larger availability of food and, in comparison to natural populations, protection from potential predators.

Under the conditions of the present study, it is concluded that the production of live bait-sized *F. paulensis* in cages is viable at the densities of 50, 100 and 200/m². Nonetheless, the high mortality observed in one replicate of the 200/m² treatment illustrates the need for careful selection of potential rearing sites. Therefore, as stocking 200/m² will produce a larger number of bait-sized shrimp, this density may be recommended as long as the water quality in the cage can be sustained. Rearing conditions in the cage depend mostly on the water quality of the site and on the water renewal directly influenced by water flow through the cage net.

To ensure a constant supply of live bait-sized shrimp, commercial farmers may just restock cages at a given density or they may opt to stock cages with varying densities. By choosing low stocking densities (e.g. 50/m²), farmers may obtain bait-sized (4-5 g) shrimp after 4 weeks of culture, while higher densities (100 to 200/m²) will produce 5 g shrimp after 6 to 7 weeks. This may allow the staggered production of 4-5 g shrimp throughout spring, summer and autumn to provide a continuous supply of live bait, an important asset if such a venture is to succeed.

While our results demonstrate the technical feasibility of producing live bait-sized *F. paulensis* in cages, further research should focus on the refinement of production techniques to improve survival at high densities, as well as on the analysis of the economic feasibility of this culture system. If proven profitable, the culture of native species in cages to supply gaps in recreational demand of live bait shrimp is likely to increase in the coming years.

ACKNOWLEDGEMENTS

The present study was partially funded by Secretaria da Ciência e Tecnologia – RS, Polo de Modernização Tecnológica (Secretariat for Science and Technology – State of Rio Grande do Sul). A.L. Preto and T.L. Pissetti acknowledge grants from the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq (Brazil's National Council for Technological and Scientific Development). R.O. Cavalli and W. Wasielesky are research fellows of this agency.

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