Production of Nile Tilapia *Oreochromis niloticus* and Freshwater Prawn *Macrobrachium rosenbergii* Stocked at Different Densities in Polyculture Systems in Brazil

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**Abstract.**—The effect of stocking prawns *Macrobrachium rosenbergii* at increasing densities in ponds with Nile tilapia *Oreochromis niloticus* reared at low density was evaluated. Twelve 0.01-ha earthen ponds were stocked with 1 tilapia/m² and 0, 2, 4, or 6 postlarvae prawn/m². Three replicates were randomly assigned to each prawn density. Postlarval prawns were stocked a week prior to tilapia juveniles and both were harvested 175 d after the beginning of the experiment. Tilapia final average weight, survival, production, and food conversion rates did not differ significantly among treatments ($P > 0.05$); the averages were 531 g, 67%, 3,673 kg/ha, and 1.91, respectively. Prawn survival rates did not differ for the three stocking densities (mean 90%). However, final weight and production were significantly different ($P < 0.05$) as follows: 34.0, 23.0, and 14.7 g and 639, 909, and 818 kg/ha, respectively for 2, 4, and 6 prawns/m² densities. Stocking densities up to 6 prawns/m² did not affect tilapia production and required neither additional feeding nor significant changes in management. The polyculture system allowed an increase in total production with the same amount of supplied feed, thus improving the system sustainability.

A polyculture system consists of simultaneously rearing two or more species in the same pond in order to maximize production by using organisms with different feeding habits and space distribution (Zimmermann and New 2000). According to New (2000) freshwater prawns are good candidates for polyculture systems because they allow fish farmers to increase productivity and profits with a small additional cost and no environmental impact. Tilapia characteristics favor polyculture systems with freshwater prawns. They both require similar temperatures to obtain high productivity, reach commercial size within about 5 mo, tolerate low quality water, and present few problems regarding diseases (Rouse and Kahn 1998). Tilapia is one of the most important species for 21st century aquaculture and is produced in more than 100 countries (Fitzsimmons 2000). In 1998, world production of tilapia *Oreochromis niloticus* reached 793,931 tons (FAO 2000) in systems varying from extensive to super intensive. World production of the freshwater prawn *Macrobrachium rosenbergii* reached almost 130,000 tons with US$ 800 million in revenues (FAO 2000).

Ponds are underutilized when farmers cultivate only tilapia or prawn. While fish occupy mainly the water column rarely exploring the bottom, prawns live along the substrate and efficiently utilize the benthic production. Therefore, pond based monoculture systems of both species leave significant part of the installations unused. Monocultured tilapia may cause significant waste deposition on the bottom, which will be released to the environment. Meanwhile, monocultured prawns leave the water column empty, thus favoring plankton instability (Cohen et al. 1983). Polyculture systems have been recognized by the efficient occupation of pond physical space and use of different trophic niches (Malecha et al. 1981; Costa-Pierce et al. 1987; Zimmermann and New 2000).

According to Zimmermann and New (2000) polyculture systems of prawn and fishes are a very common practice in farms, but scientific studies are incomplete and fragmented. Although, several papers have been published on polyculture systems of crustaceans and fishes (Cohen and Ra’an-
1983; McGinty and Alston 1987; Mires 1987; Hulata et al. 1990; Garcia-Perkz et al. 2000; Tidwell et al. 2000), important aspects such as stocking density, carrying capacity, and profitability of these systems still need to be clarified. Moreover, specific research concerning polyculture of O. niloticus and M. rosenbergii are even more scarce.

Recently, tilapia culture has intensified, due mainly to high prices of the export market to the USA and growth of internal markets in American countries (Costa-Pierce 1997). However, this is originally a subsistence activity with low productivity (Engle 1997). Until today, farmers stocked at low densities to take advantage of natural food present in the ponds and generally, no manufactured feed was supplied. Many of these culture systems were not profitable (Engle 1997). Therefore, polyculture systems incorporating high market value species, such as freshwater prawns, may be important to optimize these enterprises.

In this context, this study was designed to evaluate the effect of stocking prawns Macrobrachium rosenbergii at increasing densities in ponds with Nile tilapia Oreochromis niloticus stocked at low density.

Materials and Methods

The experiment was carried out in 12 100-m² earthen, rectangular ponds (average depth 1 m), located at Aquaculture Center, UNESP (CAUNESP), Jaboticabal, SP, Brazil (25°15'S, 42°19'W). Tilapia was considered, in general, as the major species.

The ponds were drained, air dried and excess sedimentation was scraped off. Then, they were limed (1,000 kg/ha) and organically fertilized using cattle manure (1,500 kg/ha). No lime or fertilizer was further applied during the experiment. The ponds were filled with water from a dam, previously filtered by a stone mechanical filter. Water renewal was kept at 3% daily during the culture.

The experiment consisted of four treatments (monoculture of fish and polyculture of fish and prawns, at three prawn stocking densities) with three replicates using a completely randomized design. The ponds were stocked with M. rosenbergii postlarvae (pl) (0.014 ± 0.005 g) at 0, 2, 4, and 6/m² during the last week of September, when the minimum water temperature recorded was 21.9 °C. A week later, all the ponds were stocked with Oreochromis niloticus (Chitalada strain) juveniles at 1/m² density. The postlarvae were produced at the CAUNESP hatchery. Tilapia fingerlings were supplied by Estação de Piscicultura Aquabel Ltda and kept in nursery ponds inside a greenhouse for 48 d at CAUNESP. Tilapia fry were produced using artificial incubation in a closed system. After yolk absorption, fingerlings (7–12 d old) were sexually reverted to male by oral administration of the synthetic androgen 17α methyltestosterone at a rate of 60 mg/kg feed for a period of 4 wk.

Daily feeding was adjusted according to monthly estimates of tilapia biomass, determined in samples of 10% of the fish in each pond, considering 100% final survival. Prawns were not considered in the daily feeding. In the first 60 d, a floating extruded commercial diet, produced by Nutremix, was supplied at the rate of 5% of fish biomass per day. Diet composition was crude protein (32%), ash (12%), moisture (13%), crude fiber (6%), and crude fat (4%). From day 61, feeding was reduced to 3% of fish biomass per day until the end of the experiment. In this period the feed had the following composition: crude protein (28%), ash (10%), moisture (13%), crude fiber (8%), and crude fat (2%). Daily feeding was divided into two portions and distributed between 0800-0900 h and 1500-1600 h.

The experiment lasted from September to March, approximately 175 ± 2 d. Aeration was not used. At the end, the ponds were completely drained and prawn and fish were harvested. Fish were collected and weighed individually using a Filizola Model L plate scale (Indústrias Filizola S.A.,
**Table 1.** Average values for initial and final weight, survival, and estimated production of prawns and fish (average ± SD). Average values followed by different letters in the same row are different by Tukey test (P < 0.05).

<table>
<thead>
<tr>
<th>Organism</th>
<th>Parameters</th>
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<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilapia</td>
<td>Initial weight (g)</td>
<td>2.9 ± 1.0</td>
<td>2.9 ± 0.6</td>
<td>2.2 ± 0.7</td>
<td>2.1 ± 0.7</td>
</tr>
<tr>
<td></td>
<td>Final weight (g)</td>
<td>526.2 ± 88.0</td>
<td>540.5 ± 103.9</td>
<td>536.0 ± 71.9</td>
<td>519.6 ± 31.4</td>
</tr>
<tr>
<td></td>
<td>Survival (%)</td>
<td>62 ± 9</td>
<td>64 ± 2</td>
<td>72 ± 4</td>
<td>71 ± 6</td>
</tr>
<tr>
<td></td>
<td>Production (kg/ha)</td>
<td>3,445 ± 315</td>
<td>3,671 ± 938</td>
<td>3,857 ± 372</td>
<td>3,721 ± 474</td>
</tr>
<tr>
<td></td>
<td>Feed conversion rate</td>
<td>1.89 ± 0.12</td>
<td>1.94 ± 0.16</td>
<td>1.94 ± 0.21</td>
<td>1.86 ± 0.25</td>
</tr>
<tr>
<td>Prawn</td>
<td>Initial weight (8pl)</td>
<td>—</td>
<td>0.016 ± 0.005</td>
<td>0.016 ± 0.005</td>
<td>0.016 ± 0.005</td>
</tr>
<tr>
<td></td>
<td>Final weight (g)</td>
<td>—</td>
<td>34.0 ± 2.6 a</td>
<td>23.0 ± 4.8 b</td>
<td>14.7 ± 1.5 c</td>
</tr>
<tr>
<td></td>
<td>Survival (%)</td>
<td>—</td>
<td>88 ± 9</td>
<td>92 ± 5</td>
<td>91 ± 2</td>
</tr>
<tr>
<td></td>
<td>Production (kg/ha)</td>
<td>—</td>
<td>639 ± 98 b</td>
<td>909 ± 109 a</td>
<td>818 ± 96 ab</td>
</tr>
</tbody>
</table>

* pl = postlarvae.

São Paulo, São Paulo, Brazil), with 20-g precision. Prawns were killed in cold water (0°C), according to Madrid and Phillips (2000), sorted by size, counted and individually weighed using a Marte Model AS 2000 C digital scale (Marte Balanças e Aparelhos de Precisão Ltda., São Paulo, São Paulo, Brazil), with 0.01-g precision. After harvest, total production, survival, feed conversion rate, and average final weight of prawns and fish were determined.

Dissolved oxygen, pH, ammonia, nitrite, and total alkalinity levels in the water were monitored weekly in all ponds twice a day, between 0630 and 0700 h and 1630 and 1700 h. Oxygen samples were collected on the bottom, while all the other samples were on the surface. Dissolved oxygen and pH were determined by a YSI Model 55 oxygen meter (Yellow Springs Instruments Company, Yellow Springs, Ohio, USA) and a KROLL-LABORBEDARF Model pH96-A/SET-1 electronic pH meter (KROLL-LABORBEDARF, Germany), respectively. Ammonia and nitrite were determined according to Solorzano (1969) and Bend-schneider and Robinson (1952), respectively, using a Hach Model DR 2000 spectrophotometer (Hach Company, Ames, Iowa, USA). Alkalinity was determined following the method described by Boyd (1979). Water temperature was monitored daily at 1700 h using thermometers of maximum and minimum, for surface and bottom. Average values were calculated for maximum and minimum temperatures, at each depth.

Data on growth, survival, production, feed conversion rate, and water quality were analyzed statistically by ANOVA (Steel and Torrie 1980). Survival data were transformed by arc sin prior to analysis, but unmodified values are presented. If significant differences were indicated by ANOVA (P < 0.05), means were compared by Tukey test.

**Results and Discussion**

Tilapia final average weight, survival, production, and feed conversion rates were not significantly different for all four treatments (Table 1). Therefore, prawns present at densities of 2, 4, and 6 pl/m² did not affect fish production.

Tilapia weight, survival rate, and productivity were 531 g, 67%, and 3,673 kg/ha, respectively (mean values of the 12 groups). Tilapia with weights above 500 g are suitable for fillet marketing. The low survival rates observed were due to birds that predated on fish schools while feeding
on the surface. This predation occurred until the fish attained 50 g. Rouse and Kahn (1998) using the same density for tilapia in polyculture with red claw crayfish *Cherax quadricarinatus* reported 403 g fish average weight, 84% survival rate, and 3,623 kg/ha productivity in 135 d. However, García-Pérez et al. (2000) also while stocking 1 tilapia/m² in polyculture with *M. rosenbergii*, reported 2,769 kg/ha productivity, 331 g average weight, and 84% survival rate at the end of 145 d. A comparison of the results suggests that the low survival rate obtained in this experiment was compensated by a longer culture period (171 d) and consequently higher fish average weight, thus reaching productivity similar to Rouse and Kahn (1998) and higher than that reported by Garcia-Pérez et al. (2000).

Prawn average survival rate was 90% and did not differ for the three culture densities (Table 1). This value is higher than the survival rate obtained for monoculture, which generally varies between 50 and 80% (New and Singholka 1985; Lee and Winkins 1992; Valenti 1996). This improvement may be attributed to better water quality caused by tilapia filtering action or lesser predation. *O. niloticus* is an omnivore species with great ability to filter plankton particles (Hassan et al. 1997). Perschbacher and Lorio (1993) observed that tilapia stocked at densities higher than 0.5/m² promoted a very effective biological control over phytoplankton. During culture, the birds predated mainly on tilapia since they feed on the surface, instead of diving to capture prawns on the bottom. This fact certainly reduced prawn mortality due to predation. Similar survival rates were reported for *M. rosenbergii* in polyculture systems with several carp and tilapia species, by Cohen and Ra’anan (1983, 89%), Hulata et al. (1988, 88%), Karplus et al. (1986, 89%), Karplus et al. (1987, 88%), and Karplus et al. (1990, 84%). On the other hand, McGinty and Alston (1987) and García-Pérez et al. (2000) reported survival rates of 65 and 39%, respectively, for prawns stocked in polyculture with Nile tilapia. These authors attributed high mortality rates to bird predation that occurred during culture and harvest. Therefore, high mortality was caused by external factors and not by the fish. It should be noted that the studies cited above were conducted under very different conditions and comparisons should be made with caution.

Prawn production and final weight were significantly different among treatments. Final weight was inversely proportional to density (Table 1). This is a well known trend in monoculture (Valenti and New 2000). Prawn biomass increased 42% when density increased from 2 to 4 pl/m²; however, when density increased from 4 to 6 pl/m² biomass decreased 10%. This fact suggests that available food was not enough to sustain adequate prawn development at 6 pl/m² density. It is known that freshwater prawns feed on benthic organisms (Tidwell et al. 1995), detritus (Valenti 1996), and feces (Zimmermann and New 2000). Therefore, energy and nutrients vital for prawn development might be supplied by benthic organisms, formulated feed residues, and tilapia feces. Observations conducted in the lab showed that prawns ingest significant amounts of tilapia feces when they are available. Since tilapia density was the same for all treatments, there was less food available at higher densities.

Tidwell et al. (1997), while studying ponds stocked with 4 prawns/m² in Kentucky, USA, observed that benthic macrofauna sustained a production of 426 kg/ha of prawns in unfed ponds, which corresponded to 34% of the biomass produced in ponds using formulated feed, performed simultaneously. In this study, prawn production at 4/m² density was 909 kg/ha, that is, twice the above biomass. Although the experiments were conducted in different regions, the data in the present work, suggest that half of the prawn production from the polyculture may be supported by tilapia feces and supplied feed not consumed by the fish. Probably, a significant portion of the
residues that otherwise would accumulate on the bottom of the ponds or be discarded to the environment in monoculture effluents are being converted into prawn biomass in polyculture systems. This fact contributes to make the system more environmentally friendly and sustainable.

*M. rosenbergii* productivity in monoculture systems performed in southern Brazil (latitudes above 20°S) generally varies between 1,000 and 1,500 kg/ha per yr, with a production cycle of 8 mo (Valenti 1993). In this research, productivity reached 909 kg/ha within a period of less than 6 mo. This indicates that prawn productivity obtained in polyculture systems is similar to that of monoculture, with the additional advantage of saving on feed costs. These data suggest that Nile tilapia did not cause a negative impact on the prawns and corroborates the hypothesis that the latter grew using by-products from tilapia culture as food (leftover ration and feces).

Prawn production distributed over weight classes, for tested densities, is shown in Fig. 1. Considering the commercial average weight of 20 g for prawns, it can be seen that 95% of prawns produced at 2/m² density reached commercial weight and 40% were over 40 g. At a density of 4/m², 67% of the prawns reached commercial weight and 10% were over 40 g. At 6/m² density, only 22% of the prawns reached 20 g and none were over 40 g. Density increase affected prawn weight. Although the highest productivity was observed for stocking density of 4/m², the 2/m² density allowed the production of larger prawns, which are required by certain markets. Therefore, the stocking strategy should consider the target market.

Average water temperature in the ponds was 28.0 ± 2.6 °C on the surface and 27.4 ± 1.3 °C on the bottom. Ammonia, pH, nitrite, and total alkalinity did not show significant differences between mono and polyculture systems (Table 2). Only dissolved oxygen showed a small difference between the treatments 0 and 4 prawns/m² in the afternoon, which cannot be attributed to the presence of prawns. In addition, dissolved oxygen levels remained high throughout the experiment. These data indicate that the introduction of prawns, in general, did not change the water quality. Therefore, the system is capable of sustaining the biomass increase resulting from the polyculture, and it is not necessary to introduce any management change to maintain the water quality in the ponds. All the evaluated parameters remained within the acceptable levels for prawn (Boyd and Zimmermann 2000) and tilapia culture (Kubitza 2000).

The results presented here indicate that
density up to 6 prawns/m² in polyculture with tilapia stocked at 1/m² does not affect fish production. This practice allows perfect synchronization of the two species cycles and does not require important alterations in tilapia management. It allows an increase of pond total production compared to monoculture of tilapia with the same amount of supplied feed.

Tilapia culture has intensified in the last few years. However, there are thousands of hectares of ponds operating in semi-intensive systems with low productivity. The use of the bottom of these ponds to produce freshwater prawn in polyculture may increase produced biomass at very low cost, thus increasing profits. In addition, polyculture systems rationally use the energy available in the system. Food residues and tilapia feces are consumed by the prawns and transformed into valuable biomass that reduces environmental impact.

**Acknowledgments**

We thank Dr. L. E. Pezzato, D. J. Carneiro, J. B. K. Fernandes, and W. M. Furuya for the important suggestions during project design. We also thank the support from the technicians Jose Roberto Polacchini and Valdecir Fernandes de Lima, for all their help during the experiment.

**Literature Cited**


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**Table 2. Values recorded for dissolved oxygen (DO), pH, ammonia (NH₄⁺), nitrite (NO₂⁻) and total alkalinity, (average ± SD), during the experiment, morning (M) and afternoon (A). Average followed by the same letter in the same row are different by Tukey test (P < 0.05).**

<table>
<thead>
<tr>
<th>Parameters</th>
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<tr>
<td>DO—bottom (mg/L)</td>
<td>M</td>
<td>4.81±1.46</td>
<td>4.60±1.26</td>
<td>4.62±1.34</td>
<td>4.66±1.18</td>
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<td></td>
<td>A</td>
<td>7.70±1.02 a</td>
<td>7.38±1.17 ab</td>
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<tr>
<td>pH</td>
<td>M</td>
<td>7.64±0.46</td>
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<td>7.65±0.45</td>
<td>7.72±0.36</td>
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<td>A</td>
<td>8.46±0.56</td>
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<td>NH₄⁺ (µg/L)</td>
<td>M</td>
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<td>58±43</td>
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<tr>
<td></td>
<td>A</td>
<td>32±17</td>
<td>33±17</td>
<td>32±17</td>
<td>30±17</td>
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<tr>
<td>NO₂⁻ (µg/L)</td>
<td>M</td>
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<td>47.4±13.9</td>
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<td>41.6±14.3</td>
<td>47.7±17.5</td>
<td>46.2±14.8</td>
<td>43.7±15.6</td>
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<tr>
<td>Total alkalinity (mg/L)</td>
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<td>34.07±7.78</td>
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<td>A</td>
<td>34.43±5.30</td>
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<td>34.10±5.78</td>
<td>34.86±6.26</td>
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</table>

* pl = postlarvae.
POLyculture of Tilapia and Prawn


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