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Production Response of Freshwater Prawns *Macrobrachium rosenbergii* to Increasing Amounts of Artificial Substrate in Ponds

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Abstract.—The response of freshwater prawns *Macrobrachium rosenbergii* to increasing amounts of artificial substrate was evaluated in ponds. Juvenile prawns (0.24 ± 0.13 g) were stocked into nine 0.04-ha ponds at 74,000/ha. Three control ponds received no artificial substrate while artificial substrate in the form of horizontal strips of polyethylene "construction fence" was added to the six treatment ponds to produce 40% or 80% increases in available surface area. Increasing availability of surface area produced a direct linear increase ($P < 0.05$, $r^2 = 0.89$) in total production with no significant change in average weight ($P > 0.05$). There was an inverse linear relationship between available surface area and feed conversion ratios ($P < 0.01$, $r^2 = 0.66$) likely indicating increased availability of natural foods or reduced stress among animals. There was a direct linear increase in the percentage of females which achieved sexual maturity ($P < 0.01$, $r^2 = 0.71$) as the amount of added substrate was increased. Size and number of other sexual morphotypes were not significantly affected. These responses are consistent with those that would be expected if stocking densities were decreased. These data indicate that prawn production increases in direct relation to the amount of added substrate while utilizing feed more efficiently. The effect of substrate orientation on its functionality should be evaluated to allow further increases in substrate inclusion amounts for additional production intensification.

Commercial production of freshwater prawns *Macrobrachium rosenbergii* has partially been constrained by low production levels relative to penaeid species. Semi-intensive production of farmed penaeids averages 600–2,000 kg/ha per crop of 16–36 g average weight (Lim and Persyn 1989) but 600–1,200 kg/ha of 28–36 g average weight for freshwater prawns (D'Abramo et al. 1995). Also, the fact that prawns are often raised in small-scale units (New 1995), and are limited to one seasonal crop in temperate regions, increases the need to intensify production. It is known that production can be increased by increasing stocking densities, however, this decreases average prawn size at harvest (D'Abramo et al. 1989). This can affect marketability as the greatest demand is for large individuals (> 30 g) (Riggins 1999). The ability to increase total production without decreasing average individual weight would be beneficial for prawn producers.

Cohen et al. (1983) reported that adding substrate to ponds allowed for an increase in prawn production of 14%, while average size was increased 13%. Tidwell et al. (1998) evaluated added substrate under temperate conditions and reported that in prawns stocked at relatively low densities (59,280/ha), production and average size were increased 20 and 23%, respectively. Ra'anan et al. (1984) reported that substrate was more effective in intensively-stocked systems. However, Tidwell et al. (1999) added a fixed amount of substrate to ponds stocked at different densities and found no significant interactions between stocking density and presence of substrate, though substrate did significantly increase production without decreasing average weights.

The present study was designed to quantify the response of prawns stocked at a fixed density to varying amounts of substrate. Ultimately, this series of studies should allow the relationships of substrate, production, and average prawn size to be modeled so that management systems can be developed to produce target levels of production at desired prawn sizes.

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Materials and Methods

Pond Preparation and Stocking

Two weeks prior to the anticipated stocking date, 15 ponds located at the Aquaculture Research Center (ARC), Kentucky State University, Frankfort, Kentucky, USA were drained and allowed to dry. Less than 1 wk prior to stocking, ponds were filled with water from a reservoir filled by runoff from the surrounding watershed. The water-surface area of each experimental pond was 0.04 ha and average water depth was approximately 1.1 m. A 0.37-kW (½- hp) aerator operated continuously at the surface of the deepest area of each pond to aerate and prevent thermal stratification. Two applications of liquid fertilizer ($N:P_2O_5:K_2O$ = 10:34:0) were added to each pond one week apart, at a rate of 9.0 kg P_2O_5/ha, to achieve an algal bloom. Water to replace evaporative losses was obtained from the reservoir.

Post-larval prawns were shipped by air from a commercial hatchery (Aquaculture of Texas, Weatherford, Texas, USA), nursed in a greenhouse at ARC for 60 d, and stocked on 1 June 1998. The mean stocking weight (0.24 ± 0.13 g; $\bar{x}$ ± SD) was determined from a sample of 50 prawns that were blotted free of surface water and individually weighed. Prawns were hand-counted and stocked into 12 ponds at 74,000/ha. Ponds were randomly assigned to receive different amounts of substrate based on treatment. Substrate consisted of 120-cm wide panels of polyethylene "construction/safety fence" with a mesh opening (length × width) of 7.0 cm × 3.5 cm, suspended horizontally across the pond. The substrate was positioned approximately 30 cm above the pond bottom with a 30 cm vertical separation between layers in the treatments receiving more than one layer. Substrate was held in position with stakes made from PVC pipe driven into the pond bottom. Based on dimensions of mesh (length × width), with open area within the mesh subtracted from surface area calculations, treatments effectively increased available surface area 0, 40, and 80%. There were three replicate ponds per treatment. Three ponds were also prepared to attempt a 120% increase in surface area. However, to achieve this five levels of substrate were needed. Layers could not be kept physically separated and were therefore unavailable to the prawns. These ponds were not included in statistical analyses. Three additional ponds were stocked at 37,000/ha with no added substrate. This represents current management practices in the region and was included for comparative purposes.

Samples

A 3.2-mm mesh seine was used to collect a sample of prawns from each pond every 3 wk. Structures were not removed and only open areas were seined. Prawns in the sample were group-weighed (drained weight) to the nearest 0.1 g, counted, and returned to the pond. Prawns in the last sample obtained prior to harvest were also individually weighed and classified into either one of three female morphotypes: berried (egg carrying; BE), open (previously egg carrying; OP), and virgin (VF); or one of three male morphotypes: blue claw (BC), orange-claw (OC), and small (< 20 g; SM) as described by D'Abramo et al. (1989) and modified from Cohen et al. (1981). For data presented here BE and OP females were combined into a composite group of mature females termed reproductive females (RF).

Feeds and Feeding

Prawns were fed a 32% protein prawn diet processed into 5-mm sinking pellets. The formulation is described in Tidwell et al. (1997). One-half of the daily ration was distributed over the entire surface of each pond twice daily between 0900 and 1000 h and between 1500 and 1600 h. Prawns were initially fed at a set rate of 25 kg/ha per day until an average individual weight of 5 g was achieved in samples. For weights greater than 5 g, prawns were fed a percentage of body weight based on a feeding schedule reported by D'Abramo et al. (1995). Feeding rates were adjusted weekly based on an assumed feed conversion ratio of 2.5 and an assumed survival of 100%.

Water Quality Management

Dissolved oxygen (DO) and temperature of all ponds were monitored twice daily (0900 h and 1530 h) using a YSI Model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio, USA). Levels of total ammonia-nitrogen (TAN) and nitrite-nitrogen were determined weekly from water samples collected from each pond at approximately 1300 h according to outlined procedures for a HACH DR/2000 spectrophotometer (Hach Co., Loveland, Colorado, USA). The pH of each pond was determined daily at 1300 h using an electronic pH meter (Hanna Instruments, Ltd., Mauritius). Sample data were compiled into monthly pond means for analysis.

Harvest

Prawns were cultured for 106 d. Beginning one day prior to harvest, 15 September 1998, the water levels in each pond were lowered to approximately 0.9 m at the drain end. On the following day, substrates were removed and each pond was seined three times with a 1.3-cm square mesh seine and then completely drained. Remaining prawns were manually harvested from the pond bottom and purged in clean water. Total bulk weight and number of prawns from each pond were recorded. All prawns in each pond were then individually classified into one of the six previously described sexual morphotypes. Prawns, in each morphotype within each pond, were bulk weighed and counted. As in sample data, open (OP) and berried (BE) morphotypes were later combined into a composite group of reproductive females (RF).

Statistical Analyses

Monthly water quality data, interim sample weights, and final harvest data were analyzed by ANOVA at a significance level of $P \leq 0.05$ (Steel and Torrie 1980) using Statistix Version 4.1 (Statistix Analytical Software 1994). Variables showing a significant response to addition of substrate were then regressed against the percentage increase in available surface area in the pond and tested for significance to evaluate if the relationship was linear (Neter and Wasserman 1974).

Results and Discussion

There were no significant differences in monthly means of total ammonia-nitrogen or nitrite-nitrogen ($P > 0.05$) in ponds with different amounts of substrate. Overall means (± SE) for water quality variables over the course of the study were: combined morning and afternoon temperature, 27.3 C, combined morning and afternoon DO, 7.8 mg/L, afternoon pH, 8.2, total ammonia-nitrogen, 0.58 mg/L, and nitrite-nitrogen 0.07 mg/L.

Survival averaged ≥ 90% in all treatments and did not differ significantly among treatments ($P > 0.05$). Addition of artificial substrate produced a positive linear response ($P < 0.01$, $r^2 = 0.89$) in total production (Fig. 1), resulting in a 24% increase in unit production from 1,460 kg/ha in control ponds to 1,816 kg/ha in ponds with an 80% increase in available surface area. This is similar to increases reported in earlier studies (Tidwell et al. 1998, 1999). Average harvest weights were not significantly different ($P > 0.05$) among the three treatments with an overall mean of 23 g. The significant increase in total production is explained by consistent increases in both average weight and survival as substrate amounts were increased. Although changes in average weight and survival were not statistically significant, increases were additive, producing statistically significant increases in total production.

Feed conversion ratios (FCR) demonstrated a significant ($P < 0.01$, $r^2 = 0.66$) inverse linear relationship (Fig. 2) to the amount of added substrate. FCR decreased from 2.8 in control ponds with no added substrate to 2.4 in ponds with an 80% in-

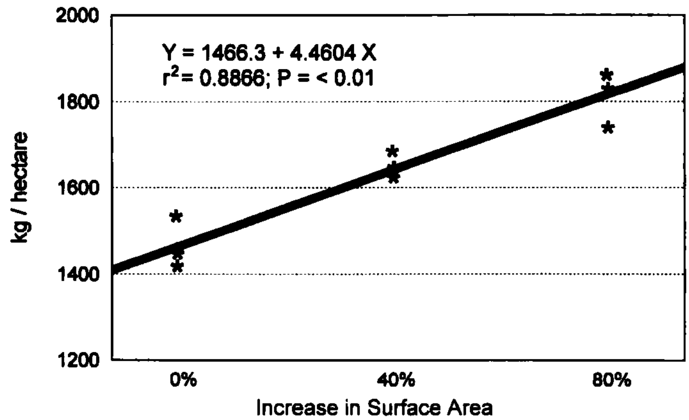

FIGURE 1. *Total pond production (kg/ha) of freshwater prawns provided with artificial substrate to achieve a 0, 40, or 80% increase in available surface area. There were three replicate ponds (*) per treatment.*

crease in surface area. Tidwell et al. (1999) reported that added substrate improved feed conversion efficiencies. This is probably due to increases in periphyton production and the resulting increases in natural food availability associated with the increased amount and complexity of benthic substrate (Tidwell et al. 1999). However, reductions in antagonistic interactions could also potentially reduce stress and improve feed conversion efficiency (Karplus et al. 1992).

Increasing availability of artificial substrate had no consistent impact on average weights or numbers within each male morphotype ($P > 0.05$). Average weights of female morphotypes were not significantly affected ($P > 0.05$) while the number of reproductive females (RF) (as a percentage of females) showed a significant linear response ($P < 0.01$, $r^2 = 0.71$) to added substrate (Fig. 3). This response would be consistent with that expected from a decrease in stocking density. Cohen et al. (1981) reported that relative proportion of male morphotypes did not vary with stocking density, while the number of reproductive females increases when density decreases. This would tend to support a visual or tactile mode of interaction controlling female morphotype ratios as the number of prawns and water volume did not differ between treatments. This could also affect marketing

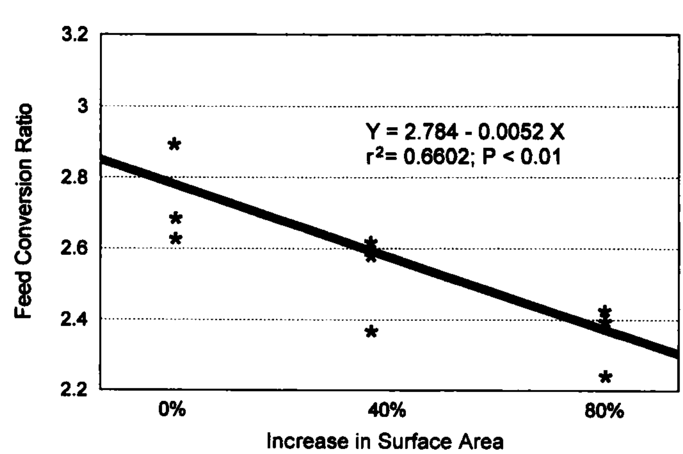

FIGURE 2. *Feed conversion ratios of freshwater prawns provided with artificial substrate to achieve a 0, 40, or 80% increase in available surface area. There were three replicate ponds (*) per treatment.*

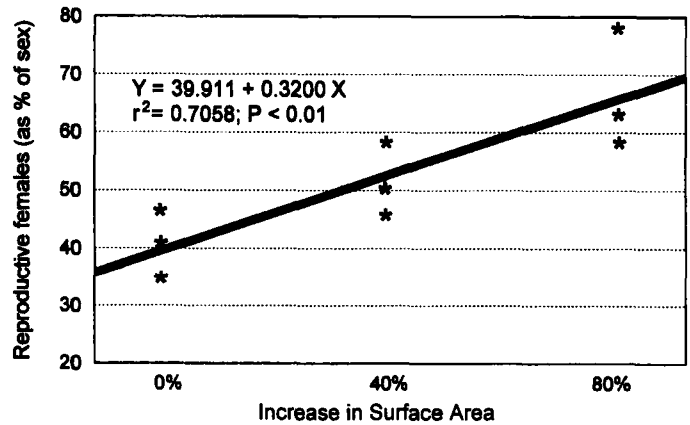

FIGURE 3. *Reproductive females as a percentage of total females in freshwater prawns provided with artificial substrate to achieve a 0, 40, or 80% increase in available surface area. There were three replicate ponds (*) per treatment.*

as mature females bearing eggs are not considered desirable in certain markets (Riggins 1999).

Comparisons of results between studies and among treatments within a study are complicated by the dynamic equilibrium of unit production and average size of the organism. If only production results are compared, their impact on average sizes may negate positive changes in production by decreasing average individual weights. If only average sizes are compared, increases may be at the expense of total production. Since the emphasis of this line of research is to increase production without decreasing average weights, some measure is needed which combines both to discern whether positive impacts on the combined factors are actually being made. This would allow significant comparisons to be made among and within studies on management variables which may impact total production and average weight. Treatments which simply shift the relationship between production and average weight would not produce a positive increase. We propose combining per unit production and average weight into a Production/Size Index (PSI), calculated as PSI = production (kg/ha) × average weight (g) ÷ 1,000.

To verify the potential validity of this index, it was applied to these data and data within several published studies. In the present study there was no significant difference ($P > 0.05$) in the PSI of ponds without substrate when stocked at 37,000 or 74,000/ha, although there were large and statistically significant ($P < 0.05$) differences in total production (1,052 and 1,460 kg/ha, respectively) and average size (33 g and 22 g, respectively). This indicates that although total production increased (38%) with increased stocking density, average weight decreased in direct proportion (33%). However, when substrate was added to ponds at a single stocking density (74,000/ha), PSI was significantly increased ($P < 0.05$) indicating a net positive shift in the entire production/size equilibrium, rather than just movement within the equilibrium relationship. Also, in this study PSI demonstrated a direct linear relationship ($P < 0.01$, $r^2 = 0.63$) to the amount of added substrate (Fig. 4). These data support the ability of artificial substrate to increase total production without producing a proportional decrease in average weight.

For further validation, PSI was calculated on data provided in D'Abramo et al. (1989). These data, over a wide range of stocking densities (39,536, 59,304, 79,072, and 118,608/ha), produced no significant differ-

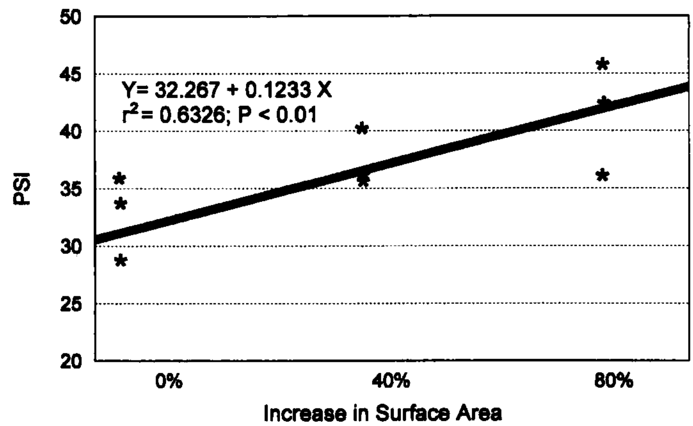

FIGURE 4. *Production/Size Index (PSI) calculated as PSI = production (kg/ha) × average weight (g) ÷ 1,000 for freshwater prawns provided with added artificial substrate at either a 0, 40, or 80% increase in available surface area. There were three replicate ponds (*) per treatment.*

ence ($P > 0.05$) in PSI within years indicating that these large changes only produced shifts within the production/size equilibrium. However, grading procedures presented by Daniels and D'Abramo (1994) produced significant improvements in PSI compared to ungraded controls indicating overall increases in one or both variables without concomitant decreases in the corresponding variable. We suggest that the calculation of PSI may be a useful tool in comparing management procedures in crustaceans and finfish species where it is desirable to increase production without compromising average weights.

In summary, addition of increasing amounts of artificial substrate produced a linear increase in total production without the normal decrease in average individual weights. An increase of approximately 80% of available surface area was the most that could be practically achieved with this material in a horizontal orientation due to the inability to keep multiple layers physically separated. To pursue this concept further will require the evaluation of new methods of suspending substrate materials within ponds. If the material could be vertically oriented and still serve as functional surface area for the prawns, much higher inclusion rates could be achieved. Future studies should evaluate the effect of physical orientation on substrate performance.

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