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Effects of Added Substrate on the Production and Population Characteristics of Freshwater Prawns *Macrobrachium rosenbergii* in Ponds

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Abstract

The effects of added substrate on the growth and population characteristics of freshwater prawns raised in ponds were evaluated. Juvenile prawns (0.3 ± 0.2 g) were stocked into six 0.04-ha ponds at a density of 59,280/ha. In three randomly selected ponds artificial substrate was added sufficient to increase available surface area approximately 20%. Three control ponds received no added substrate. Added substrate consisted of PVC frames with horizontal plastic mesh and vertical suspended seines. Prawns were fed a commercial diet (32% protein) twice daily according to a computer-generated feeding schedule. At harvest average individual weight, daily yield, and total yield were significantly higher ($P < 0.05$) in ponds with added substrate (37 g, 12.0 kg/ha per day, and 1,268 kg/ha, respectively). There was no significant difference in survival between treatments, averaging 59% overall. In ponds without substrate the number of small males (SM) was significantly higher and the number of orange claw males (OC) was significantly lower than in ponds with added substrate. Average individual weights of blue claw males, orange claw males, reproductive females, and virgin females were significantly higher ($P \leq 0.05$) in ponds with added substrate. Prawns raised in ponds containing added substrate had growth rates and population structures characteristic of prawns stocked at lower densities. Optimum relationships between stocking rates and amounts and types of added substrate should be evaluated as possible methods to increase production levels.

In temperate climates, production of freshwater prawns *Macrobrachium rosenbergii* is limited to a single seasonal crop. As a result, desired production characteristics must be maximized to achieve commercial viability. Several methods have been employed to increase per unit production (kg/ha) of prawns including increased size at stocking (Eble et al. 1977; D'Abramo et al. 1989), increased stocking densities (D'Abramo et al. 1989), grading animals prior to stocking (Daniels et al. 1995), and selective harvesting of the largest animals during the growing season (D'Abramo et al. 1995). Despite these efforts, expected mean yield for prawns (1,120 kg/ha) (D'Abramo et al. 1995) remain below the apparent carrying capacity of the pond based on other species such as channel catfish *Ictalurus punctatus* (> 5,000 kg/ha) (Busch 1985).

In their natural habitat, prawns spend much of their life in lotic and riverine environments (Raman 1967) which are characterized by water movement, high and uniform oxygen concentrations, and relatively complex benthic substrate (Cohen et al. 1983). As a primarily benthic animal, prawns are constrained by the availability of two dimensional space rather than three dimensional volume (as with many finfish species). This limitation on production is exacerbated by the territorial nature of male prawns (Cohen et al. 1981). Therefore, it may be possible to increase production of prawns from a pond by increasing the amount of surface area available within the pond. Sandifer and Smith (1977) reported that addition of substrate in nursery tanks allowed prawns to utilize the entire water column and reduced mortality. Cohen et al. (1983) reported that added substrate in

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ponds increased prawn production by 14% and average size by 13%. Ra'anan et al. (1984) reported that added substrate was more effective in intensively-stocked, aerated systems.

Prawns raised in coolwater regions have different population characteristics than those raised at comparatively higher temperatures (Tidwell et al. 1996). Since the positive effect of substrate is thought by some to be the result of a reduction in growth retarding encounters among certain segments of the population (Cohen et al. 1983), the effect of substrate could be different in coolwater regions. This research was designed to evaluate the effects of added artificial substrate on production and survival of freshwater prawns raised under coolwater conditions in earthen ponds.

Materials and Methods

Pond Preparation and Stocking

Two weeks prior to the anticipated stocking date, ponds located at the Aquaculture Research Center, Kentucky State University, Frankfort, Kentucky, USA were drained, allowed to dry, and raked to remove organic debris (dried leaves and algae). Less than one week prior to stocking, ponds were filled with water from a reservoir filled by runoff from the surrounding watershed. The water-surface area of all experimental ponds was 0.04 ha and average water depth was approximately 1.1 m. A 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 (NPK, 10:34:0) were added one week apart, at a rate of 9.0-kg phosphorous/ha, to each pond to achieve an algal bloom. Water to replace evaporative losses of the ponds was obtained from the reservoir.

Juvenile prawns were shipped by truck from a commercial hatchery (Aquaculture of Texas, Weatherford, Texas, USA) on 2 June 1996. Prawns were held in three 3,000-L tanks containing plastic netting to provide substrate. On the stocking date (4 June 1996), the mean stocking weight was determined from a sample of 50 prawns that were blotted free of surface water and individually weighed (0.33 ± 0.15 g). Prawns were hand-counted and stocked into each of six ponds at 59,280/ha. Three replicate ponds were randomly assigned to receive added substrate. Each pond in the added substrate treatment contained four multi-level habitat substrates measuring 2.1 m (l) × 1.2 m (w) × 0.9 m (h) constructed of a 1.9-cm PVC pipe frame. For each unit there were three separate horizontal levels, each 30 cm apart composed of 12.7-mm plastic mesh sheeting stretched within the PVC frame. The whole substrate unit was anchored and floated approximately 30 cm above the pond bottom so that four levels (including the pond bottom) were actually available. Within each pond, two 17.7-m long nylon seines composed of 8.0-mm mesh were also suspended vertically from the surface to the bottom. Calculated on dimensions of mesh (l × w), these additions increased available surface area in each pond approximately 20%. Open area within the mesh itself was not substracted from surface area calculations.

Samples

A 3.2-mm square mesh seine was used to collect a sample of prawns from each pond every 3 wk during the 106-d grow-out period. 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 (VG)—or one of three male morphotypes—blue-claw (BC), orange-claw (OC), and small (< 20 g; SM) as described by Cohen et al. (1981). For data presented here BE and OP females were combined into a composite group of mature females called reproductive females (RF).

TABLE 1. *Mean (± SD) harvest weight, survival, total yield, daily yield and feed conversion ratio (FCR) of prawns cultured at 59,280/ha with and without added substrate. Means within a row followed by different letters are significantly different* ($P < 0.05$).

Variable	Treatment: Without substrate	Treatment: With substrate
Harvest weight (g)	30.0 ± 3.2b	36.9 ± 3.4a
Survival (%)	59.3 ± 6.9b	57.3 ± 3.0b
Total yield (kg/ha)	1,060 ± 67b	1,268 ± 81a
Daily yield (kg/ha per day)	10.0 ± 0.6b	12.0 ± 0.8a
FCR[1]	2.48 ± 0.03a	2.33 ± 0.15a

[1] FCR = kg of feed as fed/kg weight gain.

Feeds and Feeding

Prawns were fed a 32% protein sinking commercial catfish diet (Nunn Milling, Evansville, Indiana, USA). 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. 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. (1989). Feeding rates were adjusted weekly based on a feed conversion ratio of 2.5 and survival was assumed to be 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 in water samples collected from each pond at approximately 1300 h were determined weekly, 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).

Harvest

Prawns were cultured for 106 d. One day prior to harvest, 20 September 1996, the water levels in each pond were lowered to approximately 0.9 m at the drain end. On the following day, 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.

Statistical Analyses

Water quality data, interim sample weights, and harvest data were compared using Student's *t*-test (Steel and Torrie 1980). Percentage and ratio data were converted to arc sin values prior to analysis (Zar 1984).

Results and Discussion

There were no significant differences ($P > 0.05$) in measured water quality variables for ponds within the two treatments. Overall means for water quality variables were: temperature, 26.9 C; dissolved oxygen, 7.5 mg/L; pH, 8.8; total ammonia-nitrogen, 0.81 mg/L; and nitrite-nitrogen, 0.04 mg/L.

There was no significant difference ($P > 0.05$) in prawn survivals in ponds with and without added substrate. However, addition of substrate had a substantial effect on prawn production (Table 1). Prawns provided with substrate were significantly larger

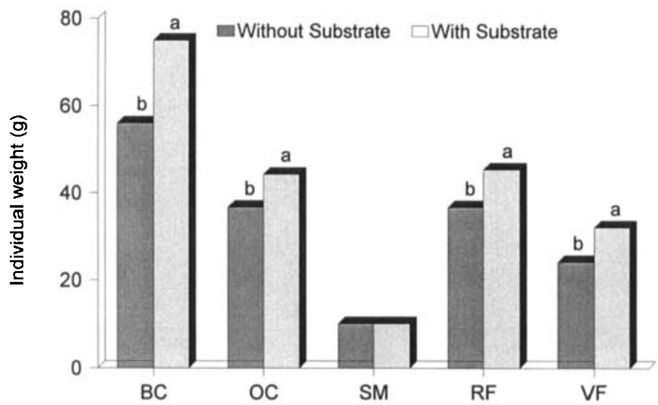

FIGURE 1. *Average weights (g) of the morphotypes blue claw males (BC), orange claw males (OC), small males (SM), reproductive females (RF), and virgin females (VF) in ponds stocked at 59,280/ha with and without added substrate. Different letters within morphotypes indicate significant difference* (P < *0.05) between treatments.*

($P < 0.05$) than those without substrate (37 and 30 g, respectively) (Table 1) as was total yield and average daily yield. These increases were very similar in magnitude (20–23%) to the magnitude of surface area increase (20%). There was no significant difference ($P > 0.05$) in feed conversion ratios (FCR) between the two treatments. Population structures were also profoundly impacted by added substrate. Average weights of BC, OC, RF, and VR were significantly greater ($P < 0.05$) in ponds with substrate than in ponds without substrate (Fig. 1). Addition of substrate also caused a significant increase ($P < 0.05$) in the number of OC and a significant decrease ($P < 0.05$) in number of SM (as % of sex) (Fig. 2). These changes were consistent with those expected of a reduction in stocking density (Karplus et al. 1986) or delayed sexual maturation (Tidwell et al. 1996).

The differences in growth and population structures of prawns stocked at the same density, with and without substrate, would seem to support the theory that it is primarily the two dimensional space available

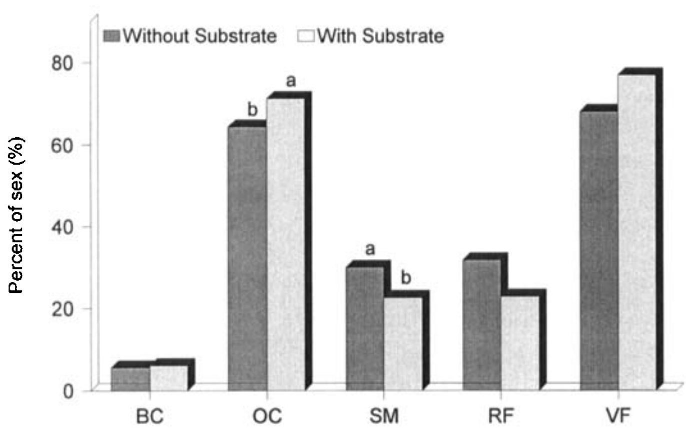

FIGURE 2. *Proportions (number as percent of sex) of the morphotypes blue claw males (BC), orange claw males (OC), small males (SM), reproductive females (RF), and virgin females (VF) in ponds stocked at 59,280/ ha with and without added substrate. Different letters within morphotypes indicate significant difference* (P < *0.05) between treatments.*

to each prawn which limits growth and influences morphotype ratios, not competition for food, or the presence of water borne metabolites or pheromones, as has been proposed (Karplus et al. 1986). However, food competition cannot be entirely eliminated if added substrate were found to increase production of natural food items, thereby decreasing food competition. Also, pheromones could still be a primary control mechanism, with their production being decreased by decreased prawn/prawn interactions in substrate ponds.

Ponds provided with substrate produced prawns 23% larger and production 20% greater than ponds without substrate (an increase of 208 kg/ha). Based on values of 22–26.5 US$/kg (live) (New 1995), added substrate would have increased gross income $4,576–$5,512/ha. However, low cost materials and installation methods must be developed and evaluated before a positive effect on net income can be realized.

These data would indicate that production rates may be able to be increased further by increasing stocking rates, if habitat is supplied at a proportional rate, without negatively impacting prawn size or marketable percentage. Further research should evaluate optimum relationships between stocking rates and amounts and types of added substrate. Cost of substrate materials and ease of installation and removal will be major considerations in applicability to commercial production.

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