Effect of Different Feeding Strategies on Production and Economic Returns for Freshwater Prawn, *Macrobrachium rosenbergii*, Raised in Earthen Ponds in a Temperate Climate

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ABSTRACT. This study compared the current recommended technology of "phase-feeding" diets, increasing in nutrient density as the relative prawn, *Macrobrachium rosenbergii*, biomass increased, compared to feeding a steam-pelleted, practical diet containing 32% protein throughout the entire production period. Two treatments were evaluated. Treatment 1 was phase-feeding where prawn were fed unpelleted distillers grains with solubles (DDGS) for the first four weeks; fed a steam-pelleted prawn diet containing 28% protein for weeks 5-12; and fed an extruded marine shrimp diet containing 40% protein for weeks 13-18. In Treatment 2, prawn were fed a 28%-protein, steam-pelleted diet throughout the entire 18-week production period. Feeding rates in both treatments were based on a feeding table. There were three replicate 0.02-ha ponds for each treatment. All ponds were stocked at 87,500/ha and were provided with artificial substrate in the form of polyethylene "safety fence" oriented vertically at a rate to increase available surface area 50%. After 97 culture days, there was no significant difference ($P >$ 0.05) between treatments in terms of production, average individual

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weight, FCR, or survival which averaged 2,272 kg/ha, 28.4 g, 2.2, and 92%, overall. However, the percentage of prawns which reached over 30 g was increased approximately 20% in the phase-fed treatment. The added expense of the marine shrimp diet resulted in approximately a US $1.00/kg increase in the break-even price in the phase-treatment compared to feeding the diet containing 28% protein exclusively. There appears to be little benefit to feeding expensive marine shrimp diets to freshwater prawn; however, if the market being addressed requires, or pays, more for large animals, some added expense may be justified.

KEYWORDS. Freshwater prawn, feeding strategies

INTRODUCTION

The commercial culture of the freshwater prawn, *Macrobrachium rosenbergii*, in the United States has increased considerably in recent years, reaching an estimated 1,000 ha of ponds devoted to production. In the temperate United States, the production season is limited to 100-150 days by suitable water temperature. Under these conditions, maximizing production per unit is essential for this industry to reach commercial viability.

Recent developments in prawn production practices (i.e., added substrate, higher stocking densities, size grading, and higher feeding rates) have increased production from 900-1,000 kg/ha to over 2,500 kg/ha (Tidwell et al. 1999). While prawns can obtain substantial nutritional benefit from natural foods at relatively low biomass densities (< 1,000 kg/ha; Tidwell et al. 1997), at higher levels of biomass are likely to be more dependant on prepared diets, especially larger higher value individuals (Tidwell et al. 1999). Phase-feeding increasingly nutrient-dense diets throughout the production cycle, was initiated to compensate for the reduced nutritional contribution of natural food items as prawn biomass densities increase (Tidwell et al. 2000). While phase-feeding appears to be nutritionally effective, its economic impact has not been fully evaluated.

A recent study compared the effect of feeding a 40% protein diet formulated for marine shrimp throughout the production period relative to that of a phase-feeding regime. After 106 days, no benefit was observed for prawn fed the marine shrimp diet exclusively. It was concluded that, the use of supplemental diets, rather than more expensive, higher protein diets, during the first 12 weeks of prawn pond production was sufficient (Coyle et al. 2003).

The objective of this study was to compare the effect of phase feeding of increasingly nutrient dense diets to that of exclusively feeding a 28% protein steam-pelleted diet on prawn production, survival, and average size.

MATERIALS AND METHODS

Pond Preparation and Stocking

Two weeks prior to the anticipated stocking date, six ponds located at the Aquaculture Research Center (ARC), Kentucky State University, Frankfort, Kentucky, were drained and allowed to dry. Less than one week prior to stocking, ponds were filled with water from a reservoir filled by run-off from the surrounding watershed. The water-surface area of each experimental pond was 0.02-ha and average water depth was approximately 1.1 m. A 1/2-hp vertical pump surface aerator (Airolator, Kansas City, Missouri[1]), modified with a "deep-draw" tube, operated continuously at the surface of the deepest area of each pond to aerate and prevent thermal stratification. After filling the ponds, two applications of liquid fertilizer (NPK, 10:34:0) were added to each pond one week apart, at a rate of 9.0 kg phosphorous/ha, to achieve an algal bloom. Water to replace evaporative losses was obtained from a water-shed reservoir.

Post-larval prawn were shipped by air from a commercial hatchery (Aquaculture of Texas, Weatherford, Texas), nursed in a greenhouse at ARC for 60 days, and stocked on June 7, 2001. The mean stocking weight was determined from a sample of 100 prawn that were blotted free of surface water and individually weighed. Individual mean stocking weight ($\overline{X}$±SD) was 0.84±0.65 g. Prawn were hand-counted and stocked into six ponds to achieve a density of 87,500/ha. There were three replicate ponds per treatment.

1. Use of trade or manufacturer's name does not imply endorsement.

Ponds were provided with artificial substrate that consisted of 120-cm wide panels of polyethylene "safety fence" with a mesh opening (length × width) of 7.0-cm × 3.5-cm at a rate sufficient to increase the surface area of the pond bottom by 50%. The substrate stretched the length of the pond between metal fence posts, positioned vertically approximately 30-cm above the pond bottom with a 30-cm separation between layers. Surface area of the substrate was calculated based on dimensions of one side of the mesh (length × width), minus the total open area.

Samples

A 3.2-mm mesh seine was used to collect a sample of prawn (50-150 individuals/pond) from each experimental pond every three weeks. Substrate was not removed restricting seine capture to open areas in the pond. The sample was group-weighed (drained weight) to the nearest 0.1 g, counted, and returned to the pond. For the last two samples prior to harvest, prawn 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 Cohen et al. (1981) and modified by D'Abramo et al. (1989). For data presented here, BE and OP females were combined into one group of females termed reproductive females (RF).

Diets and Feeding

During the first four weeks of the phase-treatment, prawn were fed unpelleted distiller's grains with solubles (DDGS) (22% protein) (Tidwell et al. 1997). For weeks 5-12, a 28%-protein, steam-pelleted diet (2.4 mm; Bagdad Roller Mills, Bagdad, Kentucky) as described in Tidwell et al. (1997) was fed; and for weeks 12-16, a 40%-protein marine shrimp diet (2.4 mm; Rangen Inc., Buhl, Idaho) was fed. Prawns in the single food treatment were fed a 28%-protein steam-pelleted diet exclusively. One-half of the daily ration was distributed over the entire surface of each pond twice daily, between 0900 and 1000 hours and 1500 and 1600 hours.

Prawn in both treatments were initially fed at a set rate of 25 kg/ha/day until an average individual weight of 5 g was achieved in all ponds assigned to each of the treatments. For weights greater than 5 g, prawn were fed according to a percentage of body weight based on a feeding schedule modified from D'Abramo et al. (1995) through an increase in daily allotments by 20% above table values (Coyle et al. 2003). Feeding rates were adjusted weekly based on an assumed feed conversion ratio of 2.5 and an assumed survival of 100%. Feeding rates within a treatment were based on the average weight for the respective ponds assigned to that treatment. FCR values were based on the total amount of feed inputs, including DDGS in this calculation, as direct consumption of DDGS has been demonstrated (Coyle et al. 1996).

Water Quality Management

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

Harvest

Prawn were cultured in the experimental ponds for 97 days. One day prior to harvest, the water level in each pond was reduced to approximately 0.5 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 prawn were manually harvested from the pond bottom and purged of mud by holding in tanks with flowing water. Total bulk weight and number of prawn from each pond were recorded. A random sample of ≥500 prawn from each pond were then individually weighed and classified into one of the six previously described sexual morphotypes. As in sample data, open (OP) and berried (BE) morphotypes were later combined into a composite group of sexually mature reproductive females (RF).

Statistical Analyses

Treatment effects were evaluated by a two sample t-test using Statistix version 4.1 (Analytical Software, Tallahassee, Florida) to compare water quality and harvest data. Production/Size Index (PSI), was calculated as PSI = production (kg/ha) × average weight (g) ÷ 1,000 (Tidwell et al. 2000). Percentage and ratio data were converted to arc sin values prior to analysis but are presented in the untransformed form.

RESULTS AND DISCUSSION

There was no significant difference ($P > 0.05$) between treatments in measured water quality variables, either monthly or overall. Overall means (±SE) for water quality variables were: temperature, 26.9±0.3°C; dissolved oxygen, 6.9±0.3 mg/L; pH, 8.8±0.1; total ammonia-nitrogen, 0.50±0.1 mg/L; un-ionized ammonia-nitrogen, 0.08±0.01 mg/L; total nitrite-nitrogen, 0.01±0.00 mg/L. These values represent suitable conditions for prawn culture (Boyd and Zimmerman 2000).

One replicate pond in the phase-fed treatment had 43% survival as a result of copper toxicity after spot treatment (< 0.3 mg/L) with copper sulfate for algae control. This pond was not included in the statistical comparison. There was no significant difference ($P > 0.05$) in average weight between treatments at any of the sample dates. After 97 culture days, overall production, average individual weight, FCR, and survival, averaged 2272 kg/ha, 28.4 g, 2.2, and 92%, respectively, and did not differ significantly among treatments ($P > 0.05$; Table 1). However, production of prawns which reached an average size greater than 30 g in the phase-fed treatment (1,097 kg/ha) was significantly higher ($P < 0.05$) than that of prawn fed the 28%-protein diet throughout the production period (827 kg/ha) (Table 1).

At harvest, there was no significant difference ($P > 0.05$) in number or size of males classified into any of the three male morphotypes between treatments (Table 2). For female morphotypes, reproductive females from the phase-fed treatment had significantly higher ($P < 0.05$) average weights than for those fed only the 28%-protein diet (Table 2). The percentage of females reaching sexual maturity was greater ($P < 0.05$) in the 28%-protein treatment than that of the phase fed treatment. Conversely, the percentage of virgin females were higher ($P < 0.05$) in the phase-fed treatment compared to that of the 28%-protein diet treatment (Table 2). The differences ($P < 0.05$) in the number and size of female morphotypes were of relatively small magnitude and have not been demonstrated in previous studies evaluating different diets in

TABLE 1. Mean[1] (±SE) harvest weight, total yield, survival, feed conversion ratio (FCR), and daily yield of prawn cultured in ponds for 97 days and either fed unpelleted distillers grains with solubles (DDGS) for the first four weeks, a 28% protein diet for weeks 5-12, and a 40% protein marine shrimp diet for weeks 13-18 (Phase) or a 28% protein diet throughout the entire 14-week season (Prawn).

	Phase	Prawn
Avg. Wt. (g)	29.1±0.4a	27.7±2.7a
Survival (%)	93.1±5.5a	89.9±3.2a
Production (kg/ha)	2370.0±110.3a	2175.6±152.9a
FCR	2.1±0.1a	2.3±0.1a
PSI[2]	68.9±2.3a	60.6±10.0a
Production > 30g (kg/ha)	1061.6±8.9a	804.9±177.9b

[1] Values are means ±SE of two replicate ponds for the phase-fed treatment and three replicate ponds for the Prawn treatment. Treatment means within a row followed by a different letter are significantly different ($P \leq 0.05$) by two sample t-test.
[2] PSI = production (kg/ha) × average weight (g) ÷ 1,000.

TABLE 2. Mean[1] (±SE) for average weight (g) and percent distribution (% of sex) of each male and female morphotype for prawn cultured in ponds for 97 days and either fed unpelleted distillers grains with solubles (DDGS) for the first four weeks, a 28%-protein diet for weeks 5-12, and a 40%-protein marine shrimp diet for weeks 13-18 (Phase) or a 28%-protein diet throughout the entire 14 week season (Prawn).

Average weight (g)	Phase	Prawn
Blue Claw (BC)	55.6±5.3a	53.9 ±6.1a
Orange Claw (OC)	38.2±0.6a	38.3 ±0.2a
Small Male (SM)	9.6±0.7a	9.4 ±1.5a
Reproductive Female (RF)	35.4±3.0a	32.4 ±0.8b
Virgin Female (VF)	24.2±0.7a	22.3 ±1.4a
Percent of sex (%)		
BC as % of males	5.5±1.8a	5.0 ±2.6a
OC as % of males	64.8±1.1a	60.6 ±10.4a
SM as % of males	29.6±0.7a	34.4 ±8.3a
RF as % of females	24.2±0.5b	29.6 ±9.3a
VF as % of females	75.8±0.4a	69.7 ±8.8b

[1] Values are means ±SE of two replicate ponds for the phase-fed treatment and three replicate ponds for the Prawn treatment. Treatment means within a row followed by a different letter are significantly different ($P \leq 0.05$) by two sample t-test.

prawn stocked at similar densities (Tidwell et al. 1994; Coyle et al. 2003).

Due to the relatively high cost of the marine shrimp diet (US $0.84/kg), feeding cost in the phase-fed treatment were approximately 28% higher than the other treatment. The added expense of the marine shrimp diet in the phase-fed treatment resulted in approximately a US $1.00/kg increase in the break even price compared to feeding a 28%-protein diet throughout the growing season. As a result, the 28%-protein diet treatment generated greater net returns due to substantially lower diet and production costs, while total prawn output was not significantly different across the two feeding regimes. Previous research had indicated no benefit to using higher protein diets throughout the growing season when compared to the phase-feeding technology (Coyle et al. 2003). This study indicated that using higher protein diets during even just the last 4 weeks is not economically justified. These data indicate that there appears to be little benefit to feeding expensive marine shrimp diets to freshwater prawn.

Phase feeding did not increase total production or mean average weight; although did increase the percentage of the large, high value individuals (> 30 g) by approximately 20%. It is speculated that the larger, faster-growing individuals in the population may benefit from feeding higher protein diets as a "finishing feed." This may be due to a lesser ability of the larger animals to utilize natural food items or a reduction in the availability of natural foods as the prawn biomass increases, as suggested by Tidwell et al. (2000). As in previous studies (Tidwell et al. 2000; Coyle et al. 2003), feeding rates were increased approximately 20% above table values recommended by D'Abramo et al. (1995) to ensure that quantity of diet was not a limiting factor on production. At lower feeding rates, phase-feeding of increasingly nutrient-dense diets may be more important. Additionally, the higher volume of large prawn (> 30 g) in the phase-fed treatment may justify some increases in diet costs in a differentially-priced market-place which requires, or pays more, for larger prawn.

In pond-based, semi-intensive growout-systems, the natural biota of the ponds contributes significantly to satisfying nutrient requirements for cultured prawn (D'Abramo and New 2000). Prepared diets likely serve as both a direct source of supplemental nutrients as well as an indirect source of nutrition by enhancement of the natural productivity of the pond (Tidwell et al. 1997; D'Abramo and New 2000). The role of natural productivity complicates the determination of the most economical commercial diet or combination of diets for semi-intensive pond culture of the freshwater prawn as enhancement of natural food organisms in the pond may be as important nutritionally as providing properly formulated prepared diets. Additional research is needed to determine the most economical combination of diets, feeding techniques, and natural food enhancement practices for maximum profitability under different management regimes. These will likely differ depending on whether extensive or intensive production techniques are being utilized.

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REFERENCES

Boyd, C., and S. Zimmerman. 2000. Grow-out systems–Water quality and soil management. Pages 221-238 *in* M.B. New and W.C. Valenti, eds. Freshwater Prawn Culture–The Farming of *Macrobrachium rosenbergii*. Blackwell Science, Oxford, United Kingdom.

Cohen, D., Z. Ra'anan, and T. Brody. 1981. Population profile development and morphotypic differentiation in the giant freshwater prawn *Macrobrachium rosenbergii*. Journal of the World Mariculture Society 12:213-234.

Coyle, S., T. Najeeullah, and J. Tidwell. A preliminary evaluation of naturally occurring organisms, distillery by-products, and prepared diets as food for juvenile freshwater prawn *Macrobrachium rosenbergii*. Journal of Applied Aquaculture 6(2): 57-66.

Coyle, S., J. Tidwell, A. VanArnum, and L. Bright. 2003. A comparison of two feeding technologies in freshwater prawns, *Macrobrachium rosenbergii*, raised at high biomass densities in temperate ponds. Journal of Applied Aquaculture 14(1/2):125-135.

D'Abramo, L.R., and M.B. New. 2000. Nutrition, feeds and feeding. Pages 203-220 *in* M.B. New and W.C. Valenti, eds. Freshwater Prawn Culture–The Farming of *Macrobrachium rosenbergii*. Blackwell Science, Oxford, United Kingdom.

D'Abramo, L.R., W.H. Daniels, M.W. Fondren, and M.W. Brunson. 1995. Management practices for culture of freshwater shrimp (*Macrobrachium rosenbergii*) in temperate climates. Bulletin 1030. Mississippi Agricultural Forestry Experimental Station, Mississippi State University, Starkville, Mississippi.

D'Abramo, L.R., J.M. Heinen, H.R. Robinette, and J.S. Collins. 1989. Production of the freshwater prawn *Macrobrachium rosenbergii* stocked as juveniles at different densities in temperature zone ponds. Journal of the World Aquaculture Society 20:81-89.

New, M.B. 2000. Commercial freshwater prawn farming around the world. Pages 290-325 *in* M.B. New and W.C. Valenti, eds. Freshwater Prawn Culture–The Farming of *Macrobrachium rosenbergii*. Blackwell Science, Oxford, United Kingdom.

Tidwell, J.H., S.D. Coyle, J.D. Sedlacek, P.A. Weston, W.L. Knight, S.J. Hill, L.R. D'Abramo, and M.J. Fuller. 1997. Relative prawn production and benthic macroinvertebrate densities in unfed, organically fertilized, and fed pond systems. Aquaculture 149: 227-242.

Tidwell, J.H., S.D. Coyle, A. VanArnum, and C. Weibel. 2000. Production response of freshwater prawns *Macrobrachium rosenbergii* to increasing amounts of artificial substrate. Journal of the World Aquaculture Society 31:452-457.

Tidwell, J.H., S.D. Coyle, C. Weibel, and J. Evans. 1999. Effects and interactions of stocking density and added substrate on production and population structure of freshwater prawns *Macrobrachium rosenbergii*. Journal of the World Aquaculture Society 30:174-179.

Tidwell, J.H., C.D. Webster, L. Goodgame-Tiu, and L.R. D'Abramo. 1994. Population characteristics of *Macrobrachium rosenbergii* fed diets containing different protein sources under coolwater conditions in earthen ponds. Aquaculture 126: 271-281.