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Aquaculture 231 (2004) 123–134
Aquaculture
www.elsevier.com/locate/aqua-online

Effects of stocking different fractions of size graded juvenile prawns on production and population structure during a temperature-limited growout period

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Received 4 April 2003; received in revised form 15 July 2003; accepted 17 July 2003

Abstract

Size grading of juvenile prawns prior to pond stocking is used to disrupt negative social interactions. Animals graded off the upper end of the size range can outperform ungraded animals by 20–50%. However, reports differ on the performance of the lower grade fraction. Some studies indicate that lower grade prawns can out perform ungraded populations within a 120–140-day growing season while other studies indicate that >140 growing days are required. The objective of this study was to compare the growth of this lower grade fraction with the upper grade fraction and an ungraded fraction of the same population within a temperature-constrained growing season of 100–120 days. Prawn juveniles that had been nursed 60 days were separated into three groups. Approximately 50% of the population was maintained ungraded with the full range of size variation. The other 50% was separated into two fractions (large = upper grade; small = lower grade) using a #13 bar grader (0.5-cm spacing). Ponds were randomly assigned to receive one of the three treatments (ungraded controls, upper grade, and lower grade) with average stocking weights of 0.5 ± 0.3, 0.8 ± 0.4, and 0.2 ± 0.1 g ($\bar{x} \pm$ S.D.), respectively. There were three replicate 0.04-ha ponds per treatment. All ponds were stocked at 59,280 ha^{-1}. Artificial substrate was added to ponds at a rate to increase available surface area by 50%. After 104 days, there was no significant difference (P>0.05) in survival of prawns from the three fractions (overall average 88%). Total production, marketable production (>20, >30 g) and average individual weight was significantly greater ($P<0.05$) in prawns from the upper grade fraction. At harvest, there was no significant difference (P>0.05) in total production or average individual weight of prawns stocked from the ungraded or lower graded fractions. Impacts of grading procedures on population structures were much more pronounced in females than in males with upper graded animals having a significantly higher

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doi:10.1016/S0044-8486(03)00544-1

($P \leq 0.05$) percentage of sexually mature reproductive females. Compared to ungraded juveniles, projected net returns were lower for lower graded prawns, higher for upper graded, and higher for combined lower and upper under all model farm scenarios. In summary, stocking of the upper graded fraction increased total production, average weights, and marketable production. There was no difference in lower graded and ungraded animal production variables.

Keywords: Freshwater prawn; Size grading; Substrate

1. Introduction

Production of the freshwater prawn *Macrobrachium rosenbergii* has increased substantially in recent years. These increases are partially based on several positive production attributes which include resistance to the diseases which have severely impacted penaeid production (Wang et al., 1998), the potential of producing large average sizes (New, 2000a,b), and the recognition that prawn culture may be more environmentally sustainable than intensive penaeid shrimp production (Tidwell and D'Abramo, 2000). Though prawn production has greatly increased, it continues to lag behind the rapid growth of the penaeid industry. This is partially due to the lower production rates (kg ha^{-1}) of prawns compared to most penaeid shrimps. However, these lower production rates are also likely a positive factor in the environmental sustainability of prawn production (New, 2000a,b).

In recent years, technologies have been developed which allow the intensification of prawn production rates without sacrificing large average sizes or negatively impacting water quality. These technologies include adding substrate materials to the production ponds combined with increased stocking densities, increased feeding rates, and grading of prawns prior to pond stocking to disrupt negative social interactions (Tidwell and D'Abramo, 2000). During the nursery period, a dominance hierarchy develops which negatively impacts the subsequent growth of a large proportion of the population. Grading the juveniles during the process of transferring the animals from the nursery system to the growout ponds disrupts this hierarchy reducing growth suppression in subdominant animals. While studies in Israel, Mississippi, and Kentucky have consistently shown that stocking animals graded off the upper end of the size range can outperform ungraded animals by 20–50% (Daniels and D'Abramo, 1994; Karplus et al., 1986; Tidwell et al., 2002), reports on the performance of the lower grade fraction of the population differ. D'Abramo et al. (1991) reported that stocking the lower graded portion increased total yields 11%; while Karplus et al. (1986) reported that stocking the lower grade animals decreased yields 10% when compared to ungraded controls. Daniels and D'Abramo (1994) found no difference in final yields when ponds were stocked with lower grade animals or ungraded controls.

Since the cost for stocker juveniles can represent over 50% of pond production costs, it is impractical to waste large numbers of lower grade juveniles. However, if the performance of a large portion of the seedstock is actually decreased, the documented positive impacts of upper grade animals could be severely compromised. According to

Karplus et al. (2000), yields from lower grade animals can eventually equal or surpass ungraded animals if the growing season is sufficiently long and that this limited the positive impacts of grading procedures to tropical regions. Since the growing season in the temperate region is limited to 100–140 days, it is essential that these conflicting reports on the performance of lower grade animals be clarified to access the applicability of these management procedures to temperate zone culture.

2. Materials and methods

2.1. Pond preparation and stocking

Two weeks prior to the anticipated stocking date, nine ponds located at the Aquaculture Research Center (ARC), Kentucky State University, Frankfort, KY, USA were drained and allowed to dry. Less than 1 week 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 1/2 hp vertical pump surface aerator (Airolator, Kansas City, MO, USA) modified with a "deep-draw" tube was 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 to each pond 1 week apart, at a rate of 9.0 kg phosphorous ha^{-1}, 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, TX, USA) and stocked into eleven 1900-l tanks housed in a temperature-controlled greenhouse at the Aquaculture Research Center, Kentucky State University, Frankfort, KY. Artificial substrate, in the form of horizontally layered sheets of 0.625-cm (10 mm) black plastic mesh supported by a PVC frame, was added to each tank to provide 20.5 m^2 of total surface area. Prawn were fed a #2 crumble (42% protein and 8% lipid) commercial trout diet (Silver Cup, Murray, UT) according to rates and schedules recommended by D'Abramo et al. (1989). The daily ration was divided into two equal feedings (0900 and 1500 h). All experimental units received approximately 8 l/min of tempered water from an outside reservoir pond. Water temperatures in all tanks were maintained at 28 °C by flowing water through a common heat pump unit. Each tank was aerated by an air stone supplied with air from a regenerative blower. Total length of the nursery period was 60 days.

Prior to pond stocking, juveniles were moved into holding tanks which were provided with artificial substrate and a constant flow of reservoir water. Animals were then separated into three groups. One group was not graded (Controls) and retained the original size distribution which had developed during the nursery period. This is the current technology used in the region. The other group of 60-day juveniles was passively graded into two approximately equal groups using a #13 bar grader (0.5-cm spacing). Those which were retained by the grader were used as the "upper grade" treatment and those which passed through the grader were used as the "lower grade" treatment.

The mean stocking weight for each of the three treatment groups was determined from a sample of 100 prawns from each group. Juveniles were blotted free of surface water and individually weighed. Individual mean stocking weight ($\bar{x} \pm$ S.D.) for each treatment was: (1) Controls (ungraded juveniles), 0.46 ± 0.29 g; (2) upper grade juveniles, 0.75 ± 0.44 g; and (3) lower grade juveniles, 0.19 ± 0.11 g. Ponds were randomly assigned to receive juveniles from one of three grading treatments with three replicate ponds per treatment. Prawns were hand-counted and stocked into each pond at a density of 59,280 ha^{-1} on June 6, 2001.

Added substrate for the growout ponds consisted of 120-cm wide panels of polyethylene "construction/safety fence" with a mesh opening (length × width) of 7.0 × 3.5 cm. Substrate was hung in vertical orientation and stretched the length of the pond between metal fence posts. The substrate was positioned approximately 30 cm above the pond bottom with a 30-cm separation between layers. The surface area contributed by the artificial substrate was calculated to increase available surface area by 50% compared to the bottom area in ponds without substrate (Tidwell et al., 2000). Surface area of the substrate was calculated based on dimensions of one side of the mesh (length × width), with open area within the mesh subtracted from surface area calculations.

2.2. Samples

A 3.2-mm mesh seine was used to collect a sample of ≥ 50 prawns from each pond every 3 weeks. Substrate materials were not removed and only open areas in the pond were seined. The sample was group-weighed (drained weight) to the nearest 0.1 g, counted, and returned to the pond. On the last two sample dates prior to harvest, prawns 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 a composite group of mature females termed reproductive females (RF).

2.3. Feeds and feeding

For the first 4 weeks, prawns were fed unpelleted distiller's grains with solubles (DDGS) (Tidwell et al., 1997), for weeks 5–12, a 32% prawn diet (as described in Tidwell et al., 1997) was fed, and for weeks 12–16, prawns were fed a 40% protein penaeid diet (Rangen, Buhl, ID). 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^{-1} day^{-1} of DDGS 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 modified from D'Abramo et al. (1995) by increasing daily allotments 20% above table values. Feeding rates were adjusted weekly based on an assumed feed conversion ratio of 2.5 and an assumed survival of 100%. Rates for all ponds within a treatment were based on the treatment average, not on individual pond sample weights.

2.4. Water quality management

Dissolved oxygen (DO) and temperature of all ponds were monitored twice daily (0900 and 1530 h) using a YSI Model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, OH, 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, Loveland, CO, USA). The pH of each pond was determined daily at 1300 h using an electronic pH meter (Hanna Instruments, Mauritius). Sample data were compiled into monthly pond means for analysis.

2.5. Harvest

Prawns were cultured for 104 days. One day prior to harvest, September 16, 2001, 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. A random sample of ≥ 500 prawns from each pond was 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).

2.6. Statistical analyses

Treatment effects were evaluated using ANOVA (Steel and Torrie, 1980) to compare water quality and harvest data. If significant differences were indicated by ANOVA ($P \leq 0.05$), means were separated using the least significant difference (LSD) test. Feed conversion ratio (FCR) was calculated as FCR = total weight of feed fed (kg) ÷ total live weight gain (kg) during the study. Production/Size Index (PSI) was calculated as PSI=[production (kg ha^{-1}) × average weight (g)] ÷ 1000 (Tidwell et al., 2000). To test the overall effect of grading, production parameter values were also averaged over upper grade and lower grade treatments and compared to the ungraded treatment based on the null hypothesis H_0: $\mu_{\mathrm{Upper}} + \mu_{\mathrm{Lower}} - 2 \times \mu_{\mathrm{Ungraded}} = 0$, where μ = treatment average of any one of the production parameters. Null and alternative hypotheses were tested using contrasts developed from ANOVA on production parameters for which the null hypotheses of equality of treatment means were rejected (Montgomery, 1991). Effect of grading on individual size variation was evaluated using a one-factor ANOVA of the coefficient of variation (CV) against treatment type, followed by multiple comparison tests.

2.7. Economic analyses

To evaluate the effects of these management procedures on economic returns, four economic scenarios were developed based on fixed ($0.10 each) or variable prices ($0.08 lower grade; $0.10 ungraded; $0.12 upper grade) for stocker juveniles and fixed or variable prices (based on weight) for harvested animals. Since size-based pricing has not yet developed in the US, a price relationship from Thailand (New, 2000a,b) was modeled using the equation: Expected price (\$/kg) = $4.603 \times e^{(-0.027 \times \text{Size})}$; adjusted $R^2 = 69.75\%$. Based on the differences in average prices received for 35 g animals in the US and Thailand during 1999–2000, the entire curve was price shifted up by \$9.02 kg^{-1}. Differential pricing was then applied to three size-based groups (>30, 20–30, < 20 g). Variable costs, fixed costs, and fixed output prices were based on Dasgupta and Tidwell (2003).

3. Results

Stocking of different graded portions had no significant impact ($P > 0.05$) on measured water quality variables. Overall means ($\pm$ S.E.) were: temperature (combined AM and PM), 27.9 ± 0.2 °C; dissolved oxygen (combined AM and PM), 8.3 ± 0.2 mg^{-1}; pH, 8.9 ± 0.1; total ammonia–nitrogen, 0.34 ± 0.02 mg^{-1}; un-ionized ammonia–nitrogen, 0.13 ± 0.0 mg^{-1}; and nitrite–nitrogen, 0.02 ± 0.01 mg^{-1}. These values represent suitable conditions for prawn culture.

3.1. Production

Overall survival was 88%. Average individual weights of prawns in the three treatments at sample dates and harvest are shown in Fig. 1. At harvest, there was no significant difference ($P > 0.05$) in survival of prawns from the ungraded, lower grade, or upper grade fractions. Total production and average individual weight were significantly greater ($P \leq 0.05$) in prawns from the upper grade fraction (3292 kg ha^{-1}; 43 g) than in the

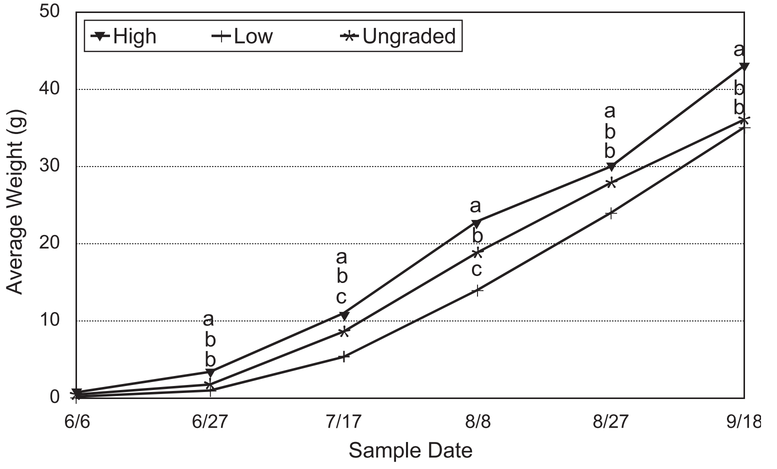

Fig. 1. Average individual body weights of prawns at different sample dates and final harvest for prawns stocked into ponds as ungraded, upper graded, or lower graded juveniles. Sample means with different letters indicate significant differences ($P < 0.05$).

lower (2556 kg ha^{-1}; 35 g) or ungraded treatments (2871 kg ha^{-1}; 36 g) (Table 1). The difference in total production and average weights of prawns stocked from the ungraded and lower graded fractions was not statistically significant (P>0.05). Feed conversion was significantly more efficient ($P \leq 0.05$) in the upper graded fraction (2.0) than in the lower graded (2.5) fraction. The feed conversion ratio in ungraded prawns (2.3) was intermediate and was not significantly different (P>0.05) from other treatments. Partially due to differences in initial stocking weights of the three groups, Absolute Specific Growth Rate (g/day) was significantly higher ($P<0.05$) in prawns from the upper grade fraction compared to the ungraded and lower grade fractions, which were not significantly different (P>0.05). Relative Specific Growth Rate ($\%^{-1}$day) was significantly different ($P \leq 0.05$) among all three treatments with lower>ungraded>upper graded. The Production Size Index (PSI) (which combines both total production and average individual weight) was also significantly different ($P \leq 0.05$) among all treatments with upper (142)>ungraded (104)>lower grade (89).

The total overall impact of grading procedures on system wide production was also evaluated by contrasting the combined lower grade and upper grade averages with ungraded controls for these production variables. These contrasts indicate that overall combined production of lower grade and upper grade ponds was equal to or greater than ungraded ponds in all measured production variables except survival. However, contrasts indicate these differences were not statistically significant (P>0.05).

The impact of stocking different graded portions on the range of variation in individual sizes at harvest was evaluated by comparing the coefficients of variation of individual weights within treatments. Comparisons indicate stocking of the upper grade fraction of the population significantly reduced ($P \leq 0.05$) the size variability (i.e. the range of individual body weights) at harvest when compared to ungraded controls. Stocking of the

Table 1
Mean (± S.E.) harvest weight, production, survival, feed conversion ratio (FCR), production size index (PSI)[a], daily yield (SGR) and marketable percentages of prawns cultured in ponds for 104 days after being stocked with Ungraded juveniles (Control ungraded), Upper Graded juveniles, or Lower Graded juveniles

Variable	Treatment			Reference
	Control Ungraded	Upper Graded	Lower Graded	$\bar{x}$ of Upper and Lower
Harvest weight (g)	36.1 ± 0.5b	43.1 ± 0.0a	35.1 ± 1.8b	39.1
Production (kg ha^{-1})	2871 ± 81b	3292 ± 72a	2556 ± 256b	2924
Survival (%)	91.3 ± 1.3a	87.8 ± 2.0a	83.8 ± 12.4a	85.8
FCR	2.1 ± 0.1ab	1.9 ± 0.0b	2.5 ± 0.3a	2.2
SGR (g/day)	0.34 ± 0.00b	0.40 ± 0.00a	0.33 ± 0.02b	0.37
SGR (%/day)	4.18 ± 0.12b	3.86 ± 0.00c	4.96 ± 0.05a	4.41
PSI	103.6 ± 4.4b	141.9 ± 3.0a	89.4 ± 4.7c	111.6
% Marketable (>20 g)	82.9 ± 7.9a	95.0 ± 1.31a	79.7 ± 8.6a	87.4
% Premium (>30 g)	57.0 ± 10.4b	78.3 ± 1.0a	57.8 ± 11.4b	68.1

Values are means ± S.E. of three replicate ponds. Treatment means within a row followed by a different letter are significantly different ($P \leq 0.05$) by ANOVA. The recombined mean (reference) of upper and lower treatment means is for comparison only and was not included in the statistical analyses.

[a] PSI=[Production (kg ha^{-1}) × average weight (g)] ÷ 1000.

lower grade portion did not significantly impact (P>0.05) size variation at harvest compared to ungraded controls.

Marketability of the product is a very powerful consideration when evaluating management and production techniques. Some management procedures can increase total production but actually decrease marketable production due to decreases in average weights or increased size variability. Based on individual animal weights, if 20 g is considered a minimum harvestable size, there was no significant difference (P>0.05) in the treatments in the percentage of animals achieving marketable weights (Table 1). However, the percentage of animals reaching premium sizes (>30 g) was significantly greater ($P \leq 0.05$) in upper grade animals than in lower grade or ungraded groups, which were not significantly different (P>0.05). Marketable production (kg ha^{-1}), which considers both total production and average weights achieved, was significantly higher ($P \leq 0.05$) for the upper grade treatment than in lower graded or ungraded treatments based on both minimum marketable weights of 20 and 30 g (Fig. 2). In fact, production of prawns >20 g in upper grade prawns was increased 30% above ungraded animals. In upper grade animals, production of premium size animals (>30 g) was increased 53% above ungraded animals. The combined average production of premium size animals in upper and lower graded treatments was 23% greater than that produced by stocking ungraded animals.

3.2. Population structure

The percentage of males achieving sexually mature blue claw status was significantly higher ($P \leq 0.05$) in upper grade animals than in lower grade (Fig. 3). The number of

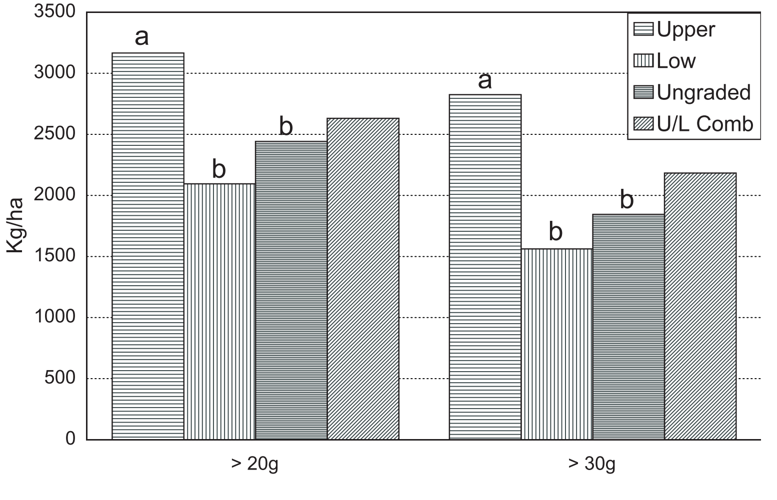

Fig. 2. Marketable production (kg ha^{-1}) of prawns based on minimum sizes of 20 or 30 g after 104 days for prawns stocked into ponds as ungraded, upper graded, or lower graded juveniles. Different letters indicate significant treatment differences (P<0.05) within each size category. An average of the upper graded and lower graded treatment (U/L Comb) is included for comparison but was not included in statistical comparisons.

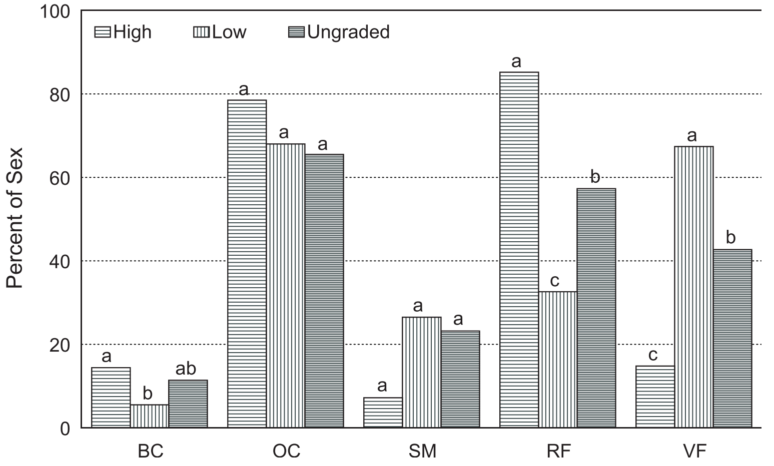

Fig. 3. Percent distribution (% of sex) according to number of each male (BC, OC, SM) and, female (RF, VF) morphotype at harvest for prawns stocked into ponds as ungraded, upper graded, or lower graded juveniles. Sample means with different letters indicate significant treatment differences ($P<0.05$) within morphotypes.

males developing into blue claws in ungraded prawns was intermediate between lower grade and upper fractions and was not significantly different ($P>0.05$) from those groups. Impacts of grading procedures on population structures were much more pronounced in females than in males (Fig. 3). The percentage of females achieving sexual maturity was significantly different ($P \leq 0.05$) between all three treatments with upper grade>ungraded>lower grade. Within males, the only difference in morphotype sizes was in orange claw males which were significantly larger ($P \leq 0.05$) in upper graded ponds than in the ponds stocked with lower grade prawns or ungraded ponds which were not significantly different ($P>0.05$) (Table 2). Average sizes of female morphotypes were not significantly different among treatments ($P>0.05$).

Table 2
Average individual weights (g) of prawns classified into five morphotypes at harvest for prawns in ponds for 104 days after being stocked with ungraded juveniles (Control ungraded), Upper Graded juveniles, or Lower Graded juveniles

Variable	Treatment			Reference
	Control Ungraded	Upper Graded	Lower Graded	$\bar{x}$ of Upper and Lower
Blue claw (BC)	61.0 ± 2.5a	67.4 ± 4.1a	62.8 ± 7.1a	60.2
Orange claw (OC)	45.8 ± 2a	53.8 ± 1.0a	43.1 ± 2.9b	48.1
Small male (SM)	8.7 ± 0.0a	10.3 ± 0.5a	9.5 ± 0.8ab	9.9
Reproductive female (RF)	35.5 ± 1.5a	36.5 ± 0.5a	37.9 ± 2.1a	37.2
Virgin female (VF)	25.7 ± 1.8a	31.8 ± 1.1a	28.8 ± 3.5a	30.3

Values are means ± S.E. of three replicate ponds. Treatment means within a row followed by a different letter are significantly different ($P \leq 0.05$) by ANOVA. The recombined mean (reference) of upper and lower treatment means is for comparison only and was not included in the statistical analyses.

Table 3
Net annual returns for a 0.4-ha pond unit utilizing ungraded, upper graded, lower graded, or even numbers of upper and lower graded prawns under two pricing scenarios (all fixed at \$0.10 each or \$0.08 for lower graded, \$0.10 for ungraded, and \$0.12 for upper graded) and two pricing scenarios at harvest (all sold at \$12.10/kg or using size-based differential pricing[a])

Pricing scenario	Control ungraded	Upper graded	Lower graded	Upper and Lower
Stocker price fixed Market price fixed	\$4954	\$6975	\$3563	\$5269
Stocker price varied Market price fixed	\$4954	\$6479	\$4059	\$5269
Stocker price fixed Market price varied	\$5005	\$7176	\$3607	\$5392
Stocker price varied Market price varied	\$5005	\$6680	\$4103	\$5392

Net return calculation includes variable costs (stocking, feeding, energy, labor, harvest, and maintenance) and fixed costs (depreciation and interest). All monetary figures are in year 2000 US\$.

[a] Differential prawn pricing equation: Expected price (\$/kg) = $4.603 \times e^{(-0.027 \times \text{Size})}$, where Size = whole prawn/lb.

3.3. Economics

In every modeled production and pricing scenario, upper-graded juvenile stocking and lower graded juvenile stocking strategies generated higher and lower incomes, respectively, than the income from stocking ungraded juveniles (Table 3). However, stocking both upper and lower graded juvenile into separate ponds in the same model farm resulted in average net returns that were consistently greater than net returns from stocking only ungraded juveniles on the same farm. This clearly puts size grading of juveniles in an economic perspective: while stocking lower graded juveniles might result in inferior income possibilities, distributing an equal water area into upper and lower graded juvenile stocking will result in expected returns that are superior to stocking ungraded juveniles. Table 3 also shows that differential pricing of juveniles at stocking increased net returns from ponds using lower graded animals and differential pricing based on prawn size at harvest result in higher net returns for ponds using upper graded juveniles.

4. Discussion

Stocking of the upper graded group increased total production, average weights, PSI, marketable percentage of premium animals (>30 g), and marketable production based on both 20 and 30 g compared to ponds stocked with lower graded or ungraded juveniles. Only in PSI and relative growth rate were production variables decreased in the lower grade fraction compared to ungraded controls. The positive impact of stocking the upper portion is in agreement with the previous studies (Karplus et al., 1986, 1987; D'Abramo et al., 1991; Daniels and D'Abramo, 1994; Tidwell et al., 2002). However, the impact of stocking the lower fraction differs somewhat from the previous studies. Karplus et al. (1986) working in a low density polyculture system reported that use of lower graded juveniles decreased production approximately 10% and this difference was statistically significant ($P \leq 0.05$). In the current study, we found a decrease of similar magnitude (11%), however, this difference was not statistically significant ($P > 0.05$). If the mean production of the upper and lower graded fractions in Karplus et al. (1986) are averaged (520 kg ha^{-1}), the overall mean is lower than the results from the ungraded treatment (685 kg ha^{-1}). However, in the present study, the combined average total production of upper and lower treatments (2924 kg ha^{-1}) is higher than ungraded (2871 kg ha^{-1}), representing an overall positive impact.

Impacts on population structure also differ from those summarized by Karplus et al. (1986) who indicated that major impacts of grading were primarily manifested among male morphotypes. In this study, larger impacts were found in female morphotypes with the use of lower grade animals decreasing the number of sexually mature females at harvest (−43%) and use of upper grade animals increasing the numbers of sexually mature females (+41%) when compared to the ungraded treatment.

Examination of Fig. 1 seems to support the contention of Karplus et al. (2000) that the use of lower grade animals may be detrimental unless a sufficient growout period is available to allow them to compensate for their lower stocking size. It would appear however that the period may be shorter than proposed. Due to the large production benefits generated by the upper grade fractions, if the lower grade fraction performs similar to the ungraded portion, the cumulative impact will be positive, and should be sufficient to justify the grading of juveniles prior to pond stocking. Economic analyses also indicate that while returns from lower graded juveniles are lower than returns from ungraded prawns, use of both lower and upper is superior to the use of ungraded prawns. While Karplus et al. (2000) indicated a need for 140–150 growing days, under the conditions evaluated here, this period appears to be closer to 120 days.

Acknowledgements

We thank Daniel Yancey and Johnathan McKinney for their daily management of culture ponds and Karla Hochstrasser for typing the manuscript. This research was supported by USDA/CREES grant to Kentucky State University under agreement KYX-80-91-04A. Funding was also provided by Kentucky's Regional University Trust Fund to the Aquaculture Program as KSU's Program of Distinction.

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