JOURNAL OF THE
WORLD AQUACULTURE SOCIETY

Vol. 45, No. 5
October, 2014
doi: 10.1111/jwas.12148

Production Comparison of Three Genetic Strains of Freshwater Prawn, *Macrobrachium rosenbergii*, Raised Under Two Pond Management Technologies

James H. Tidwell, Oluwapelumi O. Odeyemi, Shawn D. Coyle, Kyle J. Schneider, and Leigh A. Bright[1]

Aquaculture Research Center, Kentucky State University, 103 Athletic Road, Frankfort, KY 40601, USA

Abstract

Three genetic strains (Texas [cultured], Hawaii [cultured], and Myanmar [wild]) of freshwater prawn, *Macrobrachium rosenbergii*, were characterized and compared under two pond grow-out management technologies using a 3 × 2 factorial design. Juvenile prawns (45 d nursed juveniles) from each strain were stocked at individual average weights of 0.4 ± 0.3 g (Texas), 0.3 ± 0.2 g (Hawaii), and 0.3 ± 0.2 g (Myanmar). The low input management technology prawns were stocked at 24,700 /ha with no added substrate. The high input management technology prawns were stocked at 74,100 /ha with the addition of artificial substrate. Each of the six treatment combinations were replicated in three, 0.04 ha earthen ponds (total of 18 ponds). Prawns were fed a sinking pellet (32% protein) once daily at a standardized rate. After 112 d, prawns were harvested, bulk weighed, and counted. Survival of Texas strain (95%) was significantly higher ($P \leq 0.05$) than Myanmar strain (77–80%) under both management technologies with survival of Hawaii strain (86–91%) intermediate and not significantly different ($P > 0.05$) from other strains. Under both management technologies, average weight, total production, and marketable percentage (>20 g) was significantly better ($P \leq 0.05$) in Texas and Hawaii strains in comparison to the Myanmar strain. These data appear to indicate that the cultured strains evaluated in this study demonstrate positive impacts of domestication and do not indicate inbreeding depression.

Global production volume of freshwater prawn, *Macrobrachium rosenbergii*, increased approximately 168% between 1998 and 2012 while global production value increased by over 250% during the same period (FAO 2014). In 2012 total production of *M. rosenbergii* was 220,254 megatonnes (FAO 2014). Despite overall growth of the prawn industry, some countries have reported declines in production. In Taiwan and Thailand, declines have often been attributed to inbreeding depression of hatchery stocks (New and Valenti 2000; Chareontawee et al. 2007).

Between 1965 and 1966, approximately 36 individual prawns were translocated from Penang, Malaysia to the Anuenue Fisheries Research Center in Hawaii (Fujimura and Okamoto 1972) to establish a commercial prawn industry. Following their introduction a team of researchers led by Takuji Fujimura developed mass rearing techniques for hatchery production. The production advancements made in Hawaii during the early 1970s initiated a rapid expansion of the prawn industry throughout the world (New 2010). However, many cultured stocks used today in the USA are still derived directly or indirectly from the 36 individuals imported to Hawaii in the 1960s. Additionally, hatcheries are typically initiated with small numbers of individual brood animals and broodstock are often sourced directly from production ponds stocked with their own juveniles. Thus, chance breeding of closely related individuals is greatly increased, increasing the possibility of inbreeding depression (Mather and de Bruyn 2003).

Although freshwater prawn farming represents an almost US $2 billion industry, relatively little attention has been paid to their genetic attributes. Hedgecock et al. (1979) were the first

[1] Corresponding author.

to evaluate genetic diversity in this species based on protein polymorphism. Although Hedgecock et al. (1979) noted little measured variation among the populations evaluated, broad range differences were found, suggesting the use of an "eastern" and "western" form. More recently, attempts to decipher levels of genetic diversity in prawns have focused on more sensitive systems such as molecular markers. Chareontawee et al. (2007) evaluated microsatellite diversity in five hatchery and two wild prawn populations in Thailand and found no significant differences in the levels of genetic diversity between the hatchery and wild populations. The authors suggested that reported declines in prawn production in Thailand were unlikely caused by inbreeding. Schneider et al. (2013) evaluated microsatellite diversity among seven cultured and two wild prawn populations, with a focus on North American cultured strains, and found significant reduction in genetic diversity and evidence of nonrandom mating in many populations when compared with a wild population from Myanmar.

On the basis of the findings by Schneider et al. (2013) that many of the cultured US strains demonstrated low levels of genetic diversity, there is a need to evaluate whether genetic deterioration has occurred in cultivated prawn strains. Therefore, the objective of this research was to evaluate production traits of two commercial strains (Texas and Hawaii) and one wild strain (Myanmar) of freshwater prawn to determine if cultured prawns demonstrate inbreeding depression or beneficial domestication. Further, strain performance may be influenced by gene environment interactions, therefore management technology should be considered. For this reason, grow-out comparisons were evaluated in two trials under two management technologies typically utilized in temperate prawn culture (Tidwell and D'Abramo 2010). To compare growth of the three genetic strains, and evaluate interactions between strain and performance under different management systems, a 3×2 factorial design was utilized with main effects being genetic strain (Myanmar, Hawaii, and Texas) and management technology (low input and high input).

Materials and Methods

On the basis of genetic diversity analysis presented by Schneider et al. (2013) three strains were chosen for grow-out evaluation and included Texas (cultured), Hawaii (cultured), and Myanmar (wild). The Texas strain was considered the reference strain based on its wide use within the continental USA. The Hawaii strain was selected based on its genetic distance from the Texas strain, moderate level of genetic diversity, and long history of commercial production. The Myanmar strain was chosen based on the high level of genetic diversity observed in this population.

Broodstock from all three strains were maintained in indoor tanks at the Kentucky State University Aquaculture Research Center (KSU ARC). In January 2009, male and female prawns of the same strain were paired. In March, advanced berried females were moved to separate hatching tanks. Larvae were stocked into separate 1500 L tanks at 50 /L. Larviculture procedures were similar to those described in Yasharian et al. (2005). After metamorphosis, postlarvae were moved to separate 3420 L nursery tanks inside a greenhouse and stocked at 430 pl/m^2 of substrate 5.9 pl/L. Water temperatures were maintained at 27–28 C for 45 d prior to pond stocking. On the day of stocking, 300 individuals from each strain were blotted dry then individually weighed to determine mean stocking weight. The individual mean stocking weights ($X \pm$ SD) were 0.4 ± 0.3, 0.3 ± 0.2, and 0.3 ± 0.2 g for the Texas, Hawaii, and Myanmar juveniles, respectively.

In low input management technology ponds, ungraded juveniles from the three strains of *M. rosenbergii* were stocked in rotations of 100 animals until the target density of 24,700 /ha was attained. No artificial substrate was used in the nine low input ponds. Juvenile prawns were fed a commercial sinking prawn diet containing 32% crude protein and 7% crude fat (Burris Aquaculture Feeds, Franklinton, LA, USA). Prawns were fed once a day by spreading the feed uniformly over the ponds. Prawns in low input ponds were fed at 25 kg/ha/d, until prawns reached an average weight of 5 g. Prawns were then fed a percentage of body weight according to feeding schedule established by D'Abramo et al. (1995). Feeding rates in ponds were increased to 37.5 kg/ha/d, 29 d after stocking, and to 45 kg/ha/d, 87 d after stocking.

For high input technology ponds, ungraded juveniles of the three strains were stocked in rotations of 100 into randomly assigned ponds, with three replicate ponds per genetic strain. The final stocking density was 74,100 /ha. Ungraded juveniles were used to avoid biasing genetic comparisons. Ponds in the high input management technology trial were provided with artificial substrate in the form of polyethylene "construction/safety fence" having 120 cm wide panels and a mesh size of 7.0×3.5 cm (length × width). The substrate was placed in a vertical orientation and at a rate to increase the surface area of each pond by 50%, as described by Tidwell et al. (2000). Juveniles in high input ponds were fed the same diet as in low input ponds. Feeding rates in high input ponds were also based on a standardized feeding chart (D'Abramo et al. 1995). Rates were initially 25 kg/ha/d and increased to 37.5 kg/ha/d, 29 d after stocking, 75 kg/ha/d, 55 d after stocking, and 110 kg/ha/d, 87 d after stocking.

In both trials, water quality parameters including dissolved oxygen (DO), temperature (C), and pH were monitored twice daily (0800 and 1600 h), with a model 85 oxygen meter (YSI Inc., Yellow Springs, OH, USA) and an Acorn pH meter (Oakton Instruments, Vernon Hills, IL, USA). Total ammonia-nitrogen (TAN) and nitrite-nitrogen ($N\text{-}NO_2$) were monitored once a week using HACH Odyssey DR/2500 digital spectrophotometer (HACH Company, Loveland, CO, USA). Unionized ammonia concentrations were calculated from afternoon temperature, afternoon pH, and TAN values as described by Boyd (1979). Alkalinity and hardness were monitored once weekly using a HACH digital titrator.

After a 112 d grow-out period, ponds were drained and harvested. A random sample of ≥300 prawns from each pond were individually weighed and classified into one of the following sexual morphotypes: berried females (BE), open females (OP), virgin females (VF), blue claw males (BC), orange claw males (OC), and small males (SM) (Cohen et al. 1981; D'Abramo et al. 1989). The BE and OP morphotypes were later consolidated into a group termed reproductive female (RF) representing sexually mature females (Tidwell et al. 2000). Prawns ≤2.0 g were placed in a group termed indeterminate (ND) as they could not be reliably classified as male or females.

Measurements of growth performance within each trial were computated as follows: feed conversion ratio (FCR) = total weight of feed fed (kg)/total live weight gain (kg), production/size index (PSI) = production (kg/ha) × average weight (g)/1000, specific growth rate (SGR) = percentage weight gained (%)/number of days to gain the weight. Production data were first analyzed as a 3×2 factorial and evaluated for significant statistical interactions between the main effects of genetic strain (3 strains) and production technologies (2 levels). If significant interactions were indicated ($P \leq 0.05$), then data on water quality, prawn growth performance, production and population structure were analyzed as six treatment combinations and compared by analysis of variance (ANOVA) using Statistix version 9.0 (Analytical Software, Tallahassee, FL, USA). Differences were considered significant at $P \leq 0.05$. If significant differences between treatment combinations were found, Fisher's LSD test was used to separate means. Prior to analysis, data representing ratios and percentages were transformed to arc sin values. The untransformed data are presented here to facilitate comparisons.

Results

Statistical analysis indicated significant interactions ($P \leq 0.05$) between main effects (genetic strains and management technology) for certain production statistics. For total production (kg/ha), differences among the three genetic strains, when raised under the high input technology, were all statistically different ($P \leq 0.05$). However, when raised under the low input technology, the total production achieved by the Texas and Hawaii strains was not significantly different ($P > 0.05$), though both were significantly greater ($P \leq 0.05$) than the Myanmar strain.

There was also a significant interaction between main effects when analyzed in terms of marketable production (kg/ha of animals ≥20 g). The interaction was based on the lack of significant difference (overlap) of two genetic strains raised under the two different production technologies. Production of marketable prawns (≥20 g) of Texas strain raised in the low-density management system was not significantly different ($P > 0.05$) from Myanmar prawns raised under high input production.

When significant interactions ($P \leq 0.05$) are indicated, comparisons of each main effect can only be made in the context of the level of the other main effect. Subsequent analyses were based on the six treatment combinations.

There were no significant differences ($P > 0.05$) among the six treatment combinations in terms of overall means of measured water quality variables and were considered suitable conditions for prawn culture. Overall means for DO, temperature, pH, alkalinity, total hardness, unionized ammonia, and N-NO_2 for the study period were 8.1 ± 3.1 mg/L, 24.9 ± 4.8 C, 8.8 ± 3.3, 94.7 ± 8.4 mg/L, 136 ± 10 mg/L, 0.02 ± 0.11 mg/L, and 0.04 ± 0.02 mg/L, respectively.

Survival of the Texas strain was significantly higher ($P \leq 0.05$) than the Myanmar strain under both management systems (Table 1). Survival of the Hawaii strain was intermediate and not significantly different ($P > 0.05$) from the Texas strain in high input ponds and not significantly different ($P > 0.05$) from Myanmar ponds in low input ponds.

Production rates (kg/ha) were significantly higher ($P \leq 0.05$) in Texas strain prawns raised in the high input technology (2614 kg/ha) than in any other treatment combination (Table 1). They were followed by Hawaii-high input (2303 kg/ha) which was significantly greater ($P \leq 0.05$) than Myanmar-high input (1430 kg/ha). Total production of all genetic strains in high input ponds was significantly greater than production of any of the genetic strains in low input management ponds. Within low input ponds, production of Texas strain prawns (996 kg/ha) was significantly greater ($P \leq 0.05$) than Myanmar strain prawns 476 kg/ha) but not significantly different from the Hawaii strain (8580 kg/ha).

Prawn size is considered to be extremely density dependent. However, in this study the average size of each strain was not significantly different ($P > 0.05$) when raised in the different management systems (Table 1). The average harvest weight of Texas and Hawaii strain prawns was not significantly different ($P > 0.05$) within either management system and Myanmar prawn raised under either management system was significantly smaller ($P \leq 0.05$) than Hawaii and Texas prawns raised in either low input or high input systems.

PSI combines total production (kg/ha) with average harvest weight and gives a relative measure of a systems ability to increase production while maintaining average weight. PSI was significantly higher ($P \leq 0.05$) in Texas and Hawaii prawns (96 and 78, respectively) than in high input Myanmar prawns (35) or low input-Texas (42) or Hawaii (35), which were not significantly different ($P > 0.05$). The PSI of Myanmar-low input ponds (12) was significantly lower ($P \leq 0.05$) than any other treatment combination.

FCR was significantly lower ($P \leq 0.05$) (more efficient) in the Texas and Hawaii strains in high input ponds (2.6 and 3.0, respectively) than in Myanmar-high input (4.9) or Myanmar-low input (9.0) or Hawaii-low input (5.1) ponds.

The percentage of the population achieving marketable size (≥20 g) or premium sizes (≥30 g) was affected by strain but not production technology. There was no significant difference ($P \leq 0.05$) in the percentage reaching marketable sizes (≥20 g) among Texas or Hawaii strains whether in low input or high input systems. The Myanmar strain in either low input or high input ponds had significantly lower percentages ($P \leq 0.05$) achieving sizes of ≥20 g in both low input and high input systems than any of the Texas or Hawaii treatment combinations. Treatment relationships were similar in terms of prawns achieving sizes ≥30 g.

TABLE 1. *Mean (±SEM) of total production, average harvest weight, survival, feed conversion ratio (FCR), production size index (PSI), and specific growth rates (SGR) of genetic strain prawns cultured in low input management technology ponds. Means with a different letter within a row are significantly different (P ≤ 0.05) by ANOVA.*

	Low input			High input		
Variable	Myanmar	Hawaii	Texas	Myanmar	Hawaii	Texas
Production (kg/ha)	475.7 ± 85.5^{e}	857.9 ± 170.6^{d}	996.3 ± 70.3^{d}	1430.2 ± 235.9^{c}	2303.2 ± 246.7^{b}	2614.2 ± 157.1^{a}
Average harvest weight (g)	25.3 ± 4.0^{c}	39.8 ± 3.2^{ab}	41.8 ± 1.2^{a}	23.8 ± 2.0^{c}	33.7 ± 2.4^{b}	36.8 ± 1.2^{ab}
Survival (%)	77.0 ± 9.2^{c}	85.8 ± 6.4^{bc}	95.3 ± 1.9^{a}	79.9 ± 8.8^{c}	91.2 ± 1.9^{ab}	94.7 ± 1.2^{a}
FCR	9.0 ± 1.8^{a}	5.1 ± 1.0^{b}	4.2 ± 0.3^{bc}	4.9 ± 0.9^{b}	3.0 ± 0.3^{c}	2.6 ± 0.2^{c}
PSI	12.4 ± 2.9^{c}	4.8 ± 6.4^{b}	41.7 ± 3.0^{b}	34.6 ± 5.8^{b}	78.3 ± 10.8^{a}	96.4 ± 6.4^{a}
Relative SGR (%/day)	4.01 ± 0.15^{b}	4.37 ± 0.08^{a}	4.18 ± 0.03^{ab}	3.98 ± 0.08^{b}	4.23 ± 0.06^{ab}	4.07 ± 0.03^{b}
% Marketable (>20 g)	51.4 ± 8.3^{b}	77.2 ± 1.6^{a}	71.7 ± 3.1^{a}	46.5 ± 3.2^{b}	78.9 ± 5.3^{a}	75.0 ± 3.5^{a}
% Premium (>30 g)	35.6 ± 9.2^{bc}	58.7 ± 5.0^{a}	59.1 ± 2.6^{a}	31.2 ± 4.8^{c}	53.5 ± 10.6^{ab}	64.0 ± 2.8^{a}
Marketable production >20 g (kg/ha)	253 ± 61^{c}	665 ± 88^{b}	715 ± 51^{b}	672 ± 102^{b}	1833 ± 242^{a}	1963 ± 137^{a}
Marketable production >30 g (kg/ha)	178 ± 57^{b}	513 ± 96^{b}	589 ± 41^{b}	454 ± 98^{b}	1262 ± 329^{a}	1668 ± 18^{a}

ANOVA = analysis of variance; SEM = standard error of the mean.

While total production is important, if average sizes are negatively impacted, a large portion of the crop may not achieve marketable sizes. Marketable production (kg/ha) of prawns achieving minimum (≥20 g) or premium (≥30 g) sizes is an important production variable. On the basis of minimum marketable size of 20 g, the greatest production was in high input ponds stocked with Texas (1963 kg/ha) or Hawaii strain ponds (1833 kg/ha) which were not significantly different ($P > 0.05$). Among high input ponds, the Myanmar strain prawns had significantly lower ($P \leq 0.05$) production (672 kg/ha) which was not significantly different from the production of Texas and Hawaii strain prawns under low input management (715 and 665 kg/ha, respectively). Myanmar prawns in low input ponds had production rates (253 kg/ha) significantly lower ($P \leq 0.05$) than any treatment combination. Relationships based on production (kg/ha) of premium sizes (≥30 g) were similar among the different treatment combinations except that production in Myanmar-low input ponds was significantly different ($P \leq 0.05$) from Hawaii or Texas-low input of Myanmar-high input ponds.

In terms of population structures, the number of males classified as BC as a percentage of total males was significantly higher ($P \leq 0.05$) in Texas strain prawns in high input management (75%) than in any other treatment combination (Tables 2 and 3). The percentage of BC males Hawaii-HI (4.4%) was not significantly different ($P > 0.05$) from the Hawaii or Texas strains in low input management (2.0 and 3.0%, respectively). No BC males were identified in Myanmar strain prawns under either management system. In terms of OC males as a percentage of total males there were no significant differences ($P > 0.05$) in Texas or Hawaii strain in either low or high input management ponds of 62–74% of males identified as OC. Myanmar prawns had lower percentages of OC and there was no significant difference based on low input or high input management (39 and 35%, respectively). The percentage of total males classified as SM was significantly lower ($P \leq 0.05$) in Texas and Hawaii strain prawns than in Myanmar prawns, over both management practices. There was no significant difference ($P > 0.05$) in SM percentages of Texas or Hawaii strains in either low

TABLE 2. *Mean (±SEM) for the percentage of prawns classified into six morphotypes relative to the either total males or total females of prawns sampled at harvest from prawns cultured in low input management technology ponds. Means with a different letter within a row are significantly different (P ≤ 0.05) by ANOVA.*

	Low input			High input		
Variable	Myanmar	Hawaii	Texas	Myanmar	Hawaii	Texas
Blue claw, BC (% of males)	0.0 ± 0.0^{c}	2.0 ± 0.2^{bc}	3.0 ± 0.5^{bc}	0.0 ± 0.0^{c}	4.4 ± 2.4^{ab}	7.5 ± 1.0^{a}
Orange claw, OC (% of males)	38.5 ± 7.1^{b}	73.7 ± 0.2^{a}	61.6 ± 3.7^{a}	35.0 ± 3.4^{b}	70.4 ± 4.9^{a}	65.8 ± 4.8^{a}
Small male, SM (% of males)	61.5 ± 7.1^{a}	24.2 ± 2.3^{b}	35.4 ± 3.9^{b}	65.0 ± 3.4^{a}	25.2 ± 6.6^{b}	26.8 ± 4.1^{b}
Reproductive female, RF (% of females)	6.6 ± 3.7^{b}	3.9 ± 0.5^{b}	10.6 ± 2.5^{b}	11.2 ± 2.9^{b}	15.3 ± 7.4^{b}	31.9 ± 5.1^{a}
Virgin female, VF (% of females)	93.4 ± 3.7^{a}	96.1 ± 0.5^{a}	89.4 ± 2.5^{a}	88.8 ± 2.9^{a}	84.8 ± 7.4^{a}	68.1 ± 5.1^{b}
Male (%)	31.7 ± 0.9^{b}	52.8 ± 1.6^{a}	55.9 ± 2.7^{a}	37.8 ± 3.2^{b}	55.2 ± 3.1^{a}	50.0 ± 1.9^{a}
Female (%)	68.3 ± 0.9^{a}	47.2 ± 1.6^{b}	44.1 ± 2.7^{b}	62.2 ± 3.2^{a}	44.8 ± 3.1^{b}	50.0 ± 1.9^{b}
Sex ratio (male/female)	0.5 ± 0.0^{b}	1.1 ± 0.1^{a}	1.3 ± 0.1^{a}	0.6 ± 0.1^{b}	1.3 ± 0.2^{a}	1.0 ± 0.1^{a}
Indeterminate, ND (%)	2.2 ± 1.1^{b}	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}	9.2 ± 4.8^{a}	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}

ANOVA = analysis of variance; SEM = standard error of the mean.

TABLE 3. *Mean (±SEM) of average harvest weight of sexual morphotypes of three genetic strains of prawns cultured in low input management technology ponds. Means with a different letter within a row are significantly different (P ≤ 0.05) by ANOVA.*

	Low input			High input		
Variable (Average weight)	Myanmar	Hawaii	Texas	Myanmar	Hawaii	Texas
Blue claw, BC (g)	N/A	69.4 ± 3.9^{a}	66.9 ± 6.5^{a}	N/A	60.3 ± 1.7^{a}	67.5 ± 1.2^{a}
Orange claw, OC (g)	43.8 ± 3.7^{a}	44.2 ± 3.8^{a}	52.3 ± 1.0^{a}	45.9 ± 1.8^{a}	39.6 ± 3.0^{a}	45.4 ± 1.3^{a}
Small male, SM (g)	9.4 ± 0.0^{a}	11.1 ± 1.2^{a}	9.0 ± 0.3^{a}	8.7 ± 0.7^{a}	8.8 ± 0.1^{a}	9.1 ± 0.4^{a}
Reproductive female, RF (g)	40.1 ± 4.0^{bc}	50.9 ± 6.7^{a}	49.5 ± 0.6^{ab}	36.2 ± 1.0^{c}	35.1 ± 1.9^{c}	39.8 ± 1.2^{bc}
Virgin female, VF (g)	22.9 ± 3.2^{bc}	31.0 ± 1.0^{a}	32.0 ± 1.8^{a}	21.6 ± 0.5^{c}	27.1 ± 1.2^{ab}	28.6 ± 0.9^{a}
Indeterminate, ND (g)	1.6 ± 0.1^{a}	N/A	N/A	1.4 ± 0.1^{a}	N/A	N/A

ANOVA = analysis of variance; SEM = standard error of the mean; N/A = not applicable.

input or high input ponds, ranging from 24 to 35%. The percentage of male prawns classified as SM was 62% in Myanmar-low input and 65% in Myanmar-high input and these values were not significantly different ($P > 0.05$).

Sex ratios (male/female) were significantly affected by genetic strain but not by management system. The sex ratio of Texas and Hawaii strain ponds ranged from 1.0 to 1.3 over the four treatment combinations and differences were not statistically significant. Myanmar prawns had a significant shift toward females with a sex ratio of 0.6 in high input ponds and 0.5 in low input ponds and the difference was not significant ($P > 0.05$).

In terms of average weights of the morphotypes there were no significant differences ($P > 0.05$) between Hawaii or Texas strains for BC (no BC were found in Myanmar prawns) or for OC or SM prawns over all six treatment combinations (Table 3). The average weight of RF was significantly higher ($P \leq 0.05$) in Hawaii-LI than in Myanmar-LI and Hawaii-HI and Texas-LI than in Myanmar-LI and Hawaii-HI and Texas HI. The average weight of VF was significantly lower ($P \leq 0.05$) in both Myanmar treatment combinations than in any of the Hawaii and Texas treatment combinations, which were not significantly different ($P > 0.05$).

Discussion

The results demonstrate that the commercial Hawaii and Texas strains performed better than the wild Myanmar strain in terms of total production, average harvest weight, survival, FCR, PSI, and SGR for both the low input and high input management technologies. These results suggest that the cultured strains evaluated in this study do not exhibit inbreeding depression as suspected but rather appear to demonstrate the positive impacts of domestication. Similarly, Malecha (1980) reported superior performance of the cultured Anuenue strain over wild stocks and suggested this was due to incipient domestication.

The Hawaii and Texas strains have likely adapted to certain aspects of the culture environment such as crowding, diet or food, competition, and water quality (Doyle 1980). Similar changes have been documented with the domestication of the channel catfish, *Ictalurus punctatus* (Burnside et al. 1975); the Amphipod, *Gammarus lawrencianus* (Doyle and Hunte 1981); and the African siluriform catfish, *Heterobranchus longifilis* (Agnese et al. 1995).

Prawns are known to prefer natural foods like aquatic insects, chironomids, microalgae, oligochaetes, rock slime organic matter, etc. (Schroeder 1983; Tidwell et al. 1995). Nhan (2009) suggested that unlike cultured prawns, wild prawns do not readily accept formulated diets. The Myanmar strain may have been reluctant to accept an artificial diet, which may account for the higher FCR. The production results from this study observed for the Myanmar strain corroborate the suggestion by Nhan (2009) that over time domesticated strains outperform wild strains due to the fact that domesticated strains are better adapted to the artificial environment.

The Hawaii and Texas strains could also have been artificially selected for temperate climate culture conditions and therefore better suited for the culture temperatures observed in this study. The temperature range for optimal growth of freshwater prawns is 29–31 C (New 1990; Tidwell and D'Abramo 2010) and the satisfactory metabolic temperature range is 26–32 C (Sandifer and Smith 1985; Boyd and Zimmermann 2000). Tidwell et al. (1994) reported high production rates for prawns reared at an average temperature of 25 C, which was the average pond temperature recorded in this study. However, the wild Myanmar strain may perform more optimally at higher temperatures more similar to their natural tropical climate, which has a reported average temperature of 32 C for the coastal delta region. Sarver et al. (1979) showed that the cultured Anuenue strain performed better than wild strains of *M. rosenbergii* when compared at a lower temperature (19 C). However, Malecha (1980) compared temperature tolerance of the Hawaii (Anuenue) strain prawns with the less domesticated founder stock from Malaysia and found that the Hawaii strain actually had decreased tolerance to low temperatures.

In the high and low input managed ponds, the average coefficients of variations for individual body weights of the Myanmar prawns (84 and 72%, respectively) were higher than those of the Texas (49 and 59%) and Hawaii (46 and 49%) prawns. Apparently, domestication of Texas and Hawaii strains resulted in a significant decrease in variability of body weights.

Results of this research do not support reduced fitness or inbreeding depression in the two commercial strains evaluated (Texas and Hawaii). In fact, these data tend to support the positive impacts of domestication. Domestication is a genetic selection process which works through geographic and reproductive isolation, inbreeding, and small population size to produce changes in the species involved. Animals poorly adapted to the culture environment are eliminated and each subsequent generation could be better adapted. The next phase of this line of research should be to evaluate intraspecific hybrids of the strains for the potential positive impacts of heterosis.

Acknowledgments

We would like to thank Robert Janes and Danny Yancey for the management of the culture ponds during the weekends. This research was funded by a USDA CSREES 1890 Institution Capacity Building Grant to Kentucky State

University under agreement USDA/CSREES Project # 2006-02916.

Literature Cited

Agnese, J. F., Z. J. Otem, and S. Gilles. 1995. Effect of domestication on genetic variability, fertility, survival and growth rate in a tropical siluriform: *Heterobranchus longifilis* Valenciennes 1840. Aquaculture 131:197–204.

Boyd, C. E. 1979. Water quality in warmwater fish ponds. Auburn University, Agriculture Experiment Station, Auburn, Alabama, USA.

Boyd, C. and S. Zimmermann. 2000. Grow-out systems – water quality and soil management. Pages 221–238 *in* M. B. New and W. C. Valenti, editors. Freshwater prawn culture – the farming of *Macrobrachium rosenbergii*. Blackwell Science, Oxford, UK.

Burnside, M. C., J. W. Avault Jr., **and W. G. Perry.** 1975. Comparison of a wild and domestic strain of channel catfish grown in brackish water. Progressive Fish Culturist 37:52–54.

Chareontawee, K., S. Poompuang, U. Na-Nakom, and W. Kamonrat. 2007. Genetic diversity of hatchery stocks of giant freshwater prawn *Macrobrachium rosenbergii* in Thailand. Aquaculture 271:121–129.

Cohen, D., Z. Raanan, and T. Brody. 1981. Population profile development and morphotypic differentiation in the giant freswater prawn *Macrobrachium rosenbergii*. Journal of the World Mariculture Society 12:213–234.

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 temperate zone ponds. Journal of the World Aquaculture Society 20:81–89.

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

Doyle, R. W. 1980. Selection and inbreeding of cultivated *Macrobrachium rosenbergii* in Thailand. Report on Programme for the Expansion of Freshwater Prawn Farming (FAO/UNDP/THA/75/008) Bangpagong, Chacheongsao, Thailand.

Doyle, R. W. and W. Hunte. 1981. Genetic change in "fitness" and yield of a crustacean population in a controlled environment. Journal of Experimental Marine Biology and Ecology 52:147–156.

FAO. 2014. FIGIS-Fisheries Statics – Species Query. Accessed March 19, 2014, at http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en.

Fujimura, T. and H. Okamoto. 1972. Notes on progress made in developing a mass culturing technique for *Macrobrachium rosenbergii* in Hawaii. Pages 313–327 *in* T. V. R. Pillay, editor. Coastal aquaculture in the Indo-Pacific region. Fishing News Books, Blackwell Science, Oxford, UK.

Hedgecock, D., D. J. Stelmach, K. Nelson, M. E. Lindenfelser, and S. R. Malecha. 1979. Genetic divergence and biogeography of natural populations of *Macrobrachium rosenbergii*. Proceedings of the World Mariculture Society 10:873–879.

Malecha, S. R. 1980. Development and general characterization of genetic stocks of *Macrobrachium rosenbergii* and their hybrids for domestication. Sea Grant Quarterly 2(4):1–6.

Mather, P. B. and M. de Bruyn. 2003. Genetic diversity in wild stocks of the giant freshwater prawn (*Macrobrachium rosenbergii*): implications for aquaculture and conservation. NAGA WorldFish Center Quarterly 26(4):4–7.

New, M. B. 1990. Freshwater prawn culture: a review. Aquaculture 88:99–143.

New, M. B. 2010. History and global status of freshwater prawn farming. Pages 1–11 *in* M. B. New, W. C. Valenti, J. H. Tidwell, L. R. D'Abramo, **and** M. N. Kutty, editors. Freshwater prawns: biology and farming. Wiley-Blackwell, Oxford, UK.

New, M. B. and C. W. Valenti. 2000. Freshwater prawn culture – the farming of *Macrobrachium rosenbergii*. Blackwell Science, Oxford, UK.

Nhan, D. T. 2009. Optimization of hatchery protocols for *Macrobrachium rosenbergii* culture in Vietnam. PhD thesis. Ghent University, Belgium.

Sandifer, P. A. and T. I. J. Smith. 1985. Freshwater prawns. Pages 63–125 *in* J. V. Huner **and** E. E. Brown, editors. Crustacean and mollusc aquaculture in the United States. AVI Publishing, Westport, Connecticut, USA.

Sarver, D., D. Onizuka, and S. Malecha. 1979. Development and characterization of genetic stocks and their hybrids in *Macrobrachium rosenbergii*. Physiological responses and larval development rates. Proceedings of the World Mariculture Society 10:880–892.

Schneider, K. J., J. H. Tidwell, B. Gomelsky, K. W. Pomper, G. C. Waldbieser, E. Saillant, and P. D. Mather. 2013. Genetic diversity of cultured and wild population of the giant freshwater prawn *Macrobrachium rosenbergii* based on microsatellite analysis. Aquaculture Research 44(9):1425–1437.

Schroeder, G. L. 1983. Sources of fish and prawn growth in polyculture ponds as indicated by ä analysis. Aquaculture 35:29–42.

Tidwell, J. H. and L. R. D'Abramo. 2010. Grow-out systems – culture in temperate zone. Pages 180–194 *in* M. B. New, W. C. Valenti, J. H. Tidwell, L. R. D'Abramo, and M. N. Kutty, editors. Freshwater prawns: biology and farming. Wiley-Blackwell, Oxford, UK.

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.

Tidwell, J. H., C. D. Webster, **J. D. Sedlacek**, **P. A. Weston**, **W. L. Knight**, **S. J. Hill**, **L. R. D'Abramo**, **W. H. Daniels**, **M. J. Fuller, and J. L. Montanez.** 1995. Effects of complete and supplemental diets and organic fertilization on production of *Macrobrachium rosenbergii* and associated benthic macroinvertebrate populations. Aquaculture 138:169–180.

Tidwell, J. H., S. D. Coyle, **A. Van Arnum, and C. Weibel.** 2000. Production response of freshwater prawns *Macrobrachium rosenbergii* to increasing amounts of artificial substrate in ponds. Journal of the World Aquaculture Society 31:452–458.

Yasharian, D., S. D. Coyle, **J. H. Tidwell, and W. E. Stilwell.** 2005. The effect of tank colouration on survival, metamorphosis rate, growth and time to metamorphosis in freshwater prawn (*Macrobrachium rosenbergii*) rearing. Aquaculture Research 36:278–283.