A Preliminary Assessment of Growth, Survival, Yield, and Economic Return of Australian Red Claw Crayfish, *Cherax quadricarinatus*, Stocked at Three Densities in Earthen Ponds in a Cool, Temperate Climate

Carl D. Webster
Kenneth R. Thompson
Laura A. Muzinic
Daniel H. Yancey
Siddhartha Dasgupta
Youling L. Xiong
David B. Rouse
Lukas Manomaitis

ABSTRACT. Juvenile (mean weight 8.1 g) Australian red claw crayfish, *Cherax quadricarinatus*, were stocked in July at three rates of 12,000/ha, 18,000/ha, and 24,000/ha into two, 0.02-ha earthen ponds in

Carl D. Webster, Kenneth R. Thompson, Laura A. Muzinic, Daniel H. Yancey, and Siddhartha Dasgupta, Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601.

Youling L. Xiong, Department of Animal Sciences, University of Kentucky, Lexington, KY 40546.

David B. Rouse and Lukas Manomaitis, Department of Fisheries and Allied Aquacultures, Auburn University, Auburn, AL 36849.

a cool temperature region of the United States (Kentucky) and grown for 70 days. Red claw were fed a pelleted marine shrimp diet twice daily. Ponds had continual aeration provided. Dissolved oxygen and temperature were measured twice daily (0900 and 1530 hours); total ammonia nitrogen (TAN), nitrite, and alkalinity were measured twice weekly; and pH was measured daily. At harvest, there were no significant ($P > 0.05$) differences in final individual weight, percentage weight gain, specific growth rate, feed conversion ratio, percentage survival, yield, and economic return among all treatments and averaged 58.4 g, 805%, 3.04%/day, 7.47, 42.7%, 461 kg/ha, and $-$$2659/ha, respectively. There were no significant ($P > 0.05$) differences in the percentage of males and females harvested from the ponds among any stocking rate with males comprising 48.2% and females comprising 51.8%. Final individual weight of males and females was not significantly ($P > 0.05$) different among all treatments. These data indicate that there is no advantage to stocking red claw at rates below 24,000/ha in terms of growth, survival, yield, and economic return and that red claw can grow to marketable size in a cooler temperate region of the United States with a short (<110 days) growing season by stocking a larger-size (8 g) red claw. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com> © 2004 by The Haworth Press, Inc. All rights reserved.]*

INTRODUCTION

Australian red claw crayfish, *Cherax quadricarinatus*, is a tropical species found in the river systems of northern Queensland and the Northern Territory, Australia, and Papua New Guinea. Red claw have a fast growth rate, are tolerant of a wide range of water temperatures, can achieve high (600 g) maximum weights, are tolerant of crowded conditions, do not have a free-swimming larval stage which eliminates the need for expensive hatcheries, and newly-released individuals can consume prepared diets reducing or eliminating the need to feed live foods (Webster et al. 1994; Masser and Rouse 1997). There are some difficulties in farming red claw in the United States, especially production of crayfish in earthen outdoor ponds. Water temperatures must be maintained between 23-32°C to achieve maximum growth potential; water temperatures

below 20°C reduce growth rates, while water temperatures below 10°C are lethal, causing a limitation for farmers in less temperate regions. As a result, producers growing red claw outdoors in the United States will be constrained to a shorter grow-out season compared to tropical regions.

Production of young red claw in Australia is usually practiced in earthen ponds at low densities. However, the level of production of red claw in the U.S. may be intensive in nature so as to maximize yield. There is a report on pond-production of newly-hatched red claw (Jones 1995); however, there are only a few reports on pond-production of larger (>2 g) juvenile red claw (Brummett and Alon 1994; Karplus et al. 1995; Karplus et al. 1998; Rouse and Kahn 1998; Jones and Ruscoe 2000; Salame and Rouse 2000) and of these, only a few have been conducted in a cool, temperate climate.

In the temperate climate of the mid-southern region of the U.S., a growing season of only 3 to 5 months is possible for culture of a tropical aquaculture species. One strategy to increase production of a tropical species (such as red claw) grown in a cool temperate region (such as Kentucky) is to stock as early in the season as possible with juveniles that are as large as possible and/or to reduce stocking density so as to achieve a larger harvest-size individual at the end of the growing season. Stocking size and stocking density (rate) have been shown to have a profound impact on yield for a variety of cultured crustaceans (Geddes and Smallridge 1993; Daniels et al. 1995; Tidwell et al. 1999). However, there is only limited information on the effect of stocking density on growth, feed conversion, survival, and economic return of red claw grown in ponds in temperate climates.

Pinto and Rouse (1996) reported an inverse relationship between stocking density and final individual weight of red claw when stocked in ponds and that animals stocked at $3/m^2$ had higher harvest weights than individuals stocked at a higher ($5/m^2$) density; however, that study was conducted in the warmer climate of the southeastern U.S. It has been shown that the freshwater prawn, *Macrobrachium rosenbergii*, can grow in cooler regions of the U.S. in ponds during a short (<110 days) growing season (Tidwell et al. 1993, 1994, 1996). There is no data on stocking red claw at less than $3/m^2$ (very low density) in cooler climates. It may be that reducing stocking density may improve growth and allow producers to grow and market a highly-desired seafood product. The purpose of the present study was to determine growth, produc-

tion, survival, and economic return of red claw stocked at very low densities in earthen ponds in a cool temperate region of the U.S.

MATERIALS AND METHODS

Description and Stocking of Ponds

Ponds were located at the Aquaculture Research Center, Kentucky State University, Frankfort, KY. The surface area of all experimental ponds was 0.02 ha and the average water depth was approximately 1.1 m. In May, ponds were drained and treated with two applications of liquid fertilizer (10-34-0) at an initial rate of 9.0 kg/ha of phosphorus to achieve an algae bloom and refilled immediately.

Juvenile red claw were obtained from a commercial supplier (Inacua S.A., Guayaquil, Ecuador[1]) and stocked into ponds on July 13, 2001. On the stocking date, mean stocking weight was determined from a sample of 30 juvenile red claw that were individually weighed (mean weight of 8.1±3.5 g). Two replicate ponds were randomly assigned to each of the three stocking rates (densities) of either 12000/ha ($1.2/m^2$), 18000/ha ($1.8/m^2$), or 24000/ha ($2.4/m^2$).

Upon arrival to the Aquaculture Research Center, the styrofoam shipping containers were opened and red claw inspected. Red claw had been shipped without water and had moist fabric packed with them. Holes had been punched through all sides of the shipping containers. Red claw were shipped at a rate of 1,250/container. Visual inspection indicated that approximately 50% of the red claw had died in route. A decision was made to place the containers directly into the ponds and live red claw were hand-counted into the appropriate pond. Dead red claw were removed from the containers and discarded.

Diet and Feeding Rates

A commercial marine shrimp diet (35% protein; Rangen Inc., Buhl, Idaho) was fed to all red claw. Two separate feedings, each consisting of one-half of the total daily ration, were distributed over the entire surface of each pond between 0800-0830 and between 1530-1600 hours for 10 weeks. Red claw were fed a percentage of body weight based

---

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

upon a feeding chart devised by C. D. Webster (unpublished data). Survival was assumed to be 100%. Feeding rates were adjusted every two weeks based on an assumed feed conversion ratio of 3:1 throughout the study. Red claw were fed 4% of estimated body weight with an assumed harvest weight of 250 g. While this feeding rate would most-likely be in excess of what could be consumed, it was decided that diet should not be a limiting factor in the study and that growth of red claw should be optimized considering the short growing period (mid-July until mid-September) of this study.

Water Quality Management

Dissolved oxygen (DO) and water temperature in all ponds were monitored twice daily (0900 h and 1530 hours) with a YSI Model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio). A 1/2-HP electric aerator was placed in each pond and run continuously throughout the duration of the study. pH was measured daily (1530 hours) by means of an electronic pH probe (pH pen; Fisher Scientific, Cincinnati, Ohio). Water samples were collected twice weekly (1300 hours) and levels of total ammonia nitrogen (TAN), nitrite, and alkalinity were measured. TAN and nitrite were determined according to the procedures for a Hach DREL/5 spectrophotometer (Hach Co., Loveland, Colorado). Alkalinity was measured according to the titration method (Hach Co., Loveland, Colorado).

Harvest

Ponds were harvested between September 19-24, 2001. Three days prior to harvest, water levels in ponds were lowered to approximately 0.5 m at the drain end. On the day of harvest, the standpipe in each pond was lowered so that all water was completely drained from the pond. All red claw were manually harvested from the pond. The entire pond bottom was then searched for any red claw hiding in depressions or under algae. Total weight and number of red claw from each pond were recorded at the harvest. Specific growth rate (SGR) and feed conversion ratio (FCR) were calculated as follows:

SGR (%/day) = $[(\text{Ln } W_f - \text{Ln } W_i)/T] \times 100$; where W_f is the average final individual weight, W_i is the average initial weight at stocking, and T is the culture period in days.

FCR = total diet fed (kg)/total wet weight gain (kg).

An index of economic return (ER) per hectare of production was also calculated to provide a suitable measure for determining the optimal stocking size and profitability. Only those factors of economic significance related to this experiment, as shown below, were considered. The ER index was modified from that used in Maguire and Leedow (1983) and Jones and Ruscoe (2000) in that a cost for electricity was based on farm records for cost of operating a 5-HP electric paddlewheel aerator pro-rated on an hourly basis ($0.33/hr.), and a 15-year amortization on the cost of a 5-HP paddlewheel aerator (required to aerate a 1 ha pond since economic data are based upon a per hectare basis) are included in the equation:

$ER = (Y_c) - [Y_J + Y_D + Y_E + Y_A]$; where Y_c is the value of the crop, Y_J is the cost of juveniles, Y_D is the cost of the diet, Y_E is the cost of electricity, and Y_A is the amortized cost of the aerator. Cost of the juveniles was $0.26 each; cost of diet (including freight delivery costs) was $0.66/kg; cost of electric for a 5-HP paddlewheel was $7.92/day; and cost of an aerator over a 15-year period was $227/yr. Value of the red claw produced was calculated based upon $10/kg (David B. Rouse, Auburn University, pers. comm.)

Statistical Analyses

Data on final individual weight (g), percentage weight gain, percentage survival, total yield (kg/ha), SGR, FCR, and ER were analyzed by ANOVA using the SAS ANOVA procedure (SAS, 1994). Duncan's multiple range test was used to compare treatment means. Since one pond stocked at 12,000/ha had low (11%) survival, FCR values could not be calculated for this treatment. Thus, FCR data were analyzed by t-test for the treatments stocked at 18,000/ha and 24,000/ha. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984). All statistical computations were performed at the $P = 0.05$ probability level.

RESULTS

The stocking densities used during this study did not affect the water quality parameters measured. Water quality remained consistently high in all ponds (Table 1) and was suitable for red claw culture (Masser and Rouse 1997). All ponds were aerated continuously so the dissolved oxygen levels averaged 6.08 mg/L for the morning and 9.91 mg/L for the after-

noon. Water temperature in the morning averaged 25.8°C during the study period while the afternoon water temperature averaged 27.8°C. Total ammonia nitrogen, nitrite, alkalinity, and pH were not significantly different ($P > 0.05$) among treatments and averaged 0.57 mg/L, 0.1 mg/L, 87.9 mg/L, and 8.97, respectively, during the study (Table 1).

There were no significant differences ($P > 0.05$) in final individual weight, percentage weight gain, specific growth rate (SGR), feed conversion ratio (FCR), percentage survival, yield (kg/ha), and economic return (ER) of red claw stocked at either 12,000/ha, 18,000/ha, or 24,000/ha and these averaged 58.4 g, 805%, 3.04%/day, 7.47, 42.7%, 461 kg/ha, and –$2659/ha, respectively (Table 2).

There were no significant differences ($P > 0.05$) in the percentages of males and females harvested from ponds among any treatment (Table 3). The percentage of males harvested among the three stocking rates averaged 48.2% while the percentage of females averaged 51.8%. Final individual weight of males and females was not significantly ($P > 0.05$) different among all treatments with males averaging 65.0 g and females averaging 52.1 g.

DISCUSSION

Data from the present study indicate that there appears to be no advantage of stocking red claw at rates below 24,000/ha ($2.4/m^2$) as final individual weight, percentage weight gain, yield, SGR, FCR, and per-

TABLE 1. Means (±SE) of water quality parameters measured in ponds stocked with red claw crayfish stocked at three different densities. There were no significant ($P > 0.05$) differences among treatments for any water quality parameter.

	Stocking rate (no./ha)		
	12,000	18,000	24,000
Dissolved oxygen (mg/L; a.m.)	5.97±0.59	6.44±0.07	5.84±0.45
Dissolved oxygen (mg/L; p.m.)	10.09±0.26	9.54±0.17	10.11±0.67
pH	9.0±0.3	9.0±0.4	8.9±0.4
Temperature (°C; a.m.)	25.99±0.20	25.49±0.22	25.93±0.58
Temperature (°C; p.m.)	28.06±0.22	27.40±0.35	28.06±0.55
TAN (mg/L)	0.5±0.5	0.5±0.4	0.7±0.6
Nitrite (mg/L)	0.1±0.1	0.1±0.1	0.1±0.1
Alkalinity (mg/L)	92.0±7.8	82.0±10.6	89.7±10.0

TABLE 2. Mean (±SE) final weight, percentage weight gain, specific growth rate (SGR), feed conversion ration (FCR), percentage survival, yield, and economic return (ER) of red claw crayfish stocked at three densities and grown in earthen ponds. There were no significant differences (*P* > 0.05) among treatments for any parameter.

	Stocking rate (no./ha)		
	12,000	18,000	24,000
Final weight (g)	64.65±13.35	56.96±1.08	53.47±0.63
Weight gain (%)	692±164	597±13	1125±578
SGR (%/day)	2.93±0.30	2.78±0.03	3.40±0.73
FCR	5.95[1]	7.11±1.97	9.34±2.00
Survival (%)	32.7±21.7	47.8±1.8	47.5±6.6
Yield (kg/ha)	289±221	488±29	607±88
ER ($/ha)	−2470±2436	−2141±597	−3365±880

[1] Due to the low survival of one replicate pond stocked at this density, FCR could not be calculated. Thus, only one value for FCR could be given and no statistical analysis on FCR could be conducted for the treatment stocked at 12,000 red claw/ha.

TABLE 3. Mean percentages and average final individual weights of male and female red claw harvested from ponds stocked at different rates and grown for 70 days. Values in the same column with the same letters are not significantly different (*P* > 0.05).

	Male		Female	
Stocking rate	Harvest	Final weight	Harvest	Final weight
(no./ha)	(%)	(g)	(%)	(g)
12,000	51.4±3.2a	73.9±16.9a	48.6±3.2a	55.3±10.9a
18,000	47.3±2.0a	63.3±0.5a	52.7±2.0a	51.3±1.1a
24,000	45.8±1.1a	57.7±1.4a	54.2±1.1a	49.8±0.2a

centage survival were not increased at the lower stocking densities. Growth of red claw in the present study was similar to, or higher than, previous reports. Absolute growth of red claw in the present study ranged from 0.6 to 1.0 g/day which is higher than other reported values ranging from 0.3-0.5 g/day (Jones 1988; Medley 1991; Brummett and Alon 1994; Rouse and Kahn 1998). Final individual weight and SGR of red claw in the present study were similar to, or higher than, other reports. Brummett and Alon (1994) stocked red claw (initial weight of 3.9 g) into

earthen ponds at a rate of 25,000 red claw/ha and reported an average final individual weight of between 54 and 56 g. Medley (1991) reported an average weight of 40 g after 90 days when red claw were stocked at $1/m^2$, while Pinto and Rouse (1996) reported final individual weight of 67 g of red claw stocked at $1/m^2$ and 48 g for red claw stocked at $3/m^2$ after 90 days of culture. Salame and Rouse (2000) stated that after 90 days of culture, red claw (1-2 g) stocked into ponds at a density of $4/m^2$ had final individual weights of 30 g when fed a pelleted diet and 34 g when fed a pelleted diet with additional forage provided. Sagi et al. (1997) stocked red claw (1-2 g initial weight) in earthen ponds (400 m^2) at a density of 2,200 red claw per pond and had an average harvest weight of 43 g after 160 days.

Percentage weight gain and SGR of red claw in the present study was also high averaging 805% and 3.04%/day among all treatments. Jones and Ruscoe (2001) stocked red claw (average weight of 13 g) into pens with different substrates at a density of 12.5 red claw/m^2 and reported that after 162 days of culture, red claw had final individual weight of 33 g, with an SGR of 0.59%/day. Jones and Ruscoe (2000) reported an SGR value of 1.6%/day for small (4 g) red claw stocked at $3/m^2$.

While the present study indicates that there are no differences in growth for red claw stocked at either 12,000/ha ($1.2/m^2$) or 24,000/ha ($2.4/m^2$), growth data from the present study is in contrast to other studies (Pinto and Rouse 1996; Jones and Ruscoe 2000). Pinto and Rouse (1996) stocked red claw (5 g) at densities of 1, 3, and $5/m^2$ and reported an average that growth rate was inversely correlated with density. Red claw stocked at 1, 3, or $5/m^2$ had final weights of 67, 48, and 38 g, respectively. The values reported for red claw stocked at $1/m^2$ and $3/m^2$ were similar to those reported in the present study. However, the duration of the present study was 70 days compared to 158 days used in Pinto and Rouse (1996), although they stocked a smaller (3 g) red claw compared to the size stocked in our study.

Jones and Ruscoe (2000) stated that after 140 days, small (4.7 g) red claw stocked at 3, 9, or $15/m^2$ had final weights of 45.2, 31.4, and 28.2 g, respectively, while large (17 g) red claw stocked at 3, 9, $15/m^2$ had final average weights of 60.6, 46.3, and 43.9 g, respectively. Red claw stocked at $3/m^2$ had significantly higher average final weight compared to red claw stocked at $9/m^2$ and $15/m^2$ for both stocking sizes (small and large).

FCR values reported in the present study are similar to or higher (ranging from 6.0 to 9.3) than what has been reported previously for red claw. Jones and Ruscoe (2000) stated FCR values between 1.4 and 7.4

for different sizes of red claw stocked into pens and fed a prepared diet. FCR values reported in the present study are similar to the value stated in Rouse and Kahn (1998) of 8.0 when red claw were fed a 32% protein pelleted diet supplemented with 250 kg/ha of dried alfalfa hay added to ponds every two weeks. The higher than desired FCR values in the present study are probably due to two main factors. One was that actual survival was much lower than the forecast survival used to determine feeding rates. A 100% survival rate was assumed when determining the amount of each diet to be fed. Since the red claw had an average percentage survival of 42%, probably due to delayed mortality caused from shipping stress, this should have increased FCRs. A lower survival rate (60-80%) should be used in future calculations of the amount of diet to be fed.

Secondly, since the stocking size of red claw used in the present study was large (8 g), an average individual harvest weight of 250 g was used in calculating how much diet was to be fed. Actual harvest weight averaged 58 g for all treatments. Thus, the calculation of the amount of diet to be fed would be much higher than necessary. Use of lower forecasted harvest weights in calculating the amount of diet to be fed would improve the FCR. Good management and economic practices should be used in the future so as to minimize diet waste so that water quality can be maintained, excessive nitrogen loading will be prevented, high sediment quality will be preserved, and financial wastefulness will be minimized so that profitability can be maximized.

In comparison with other studies of red claw and other *Cherax* species, survivals achieved in the present study were similar to or higher than survival rates reported by (Brummett and Alon 1994; Rouse and Kahn 1998; Salame and Rouse 2000; Jones and Ruscoe 2001), but lower than other reports (Pinto and Rouse 1996; Sagi et al. 1997; Jones and Ruscoe 2000). Jones and Ruscoe (2000) reported survival percentages ranging between 76.6-87.5%; however, Jones and Ruscoe (2001) reported survival values ranging from 15.1% for red claw stocked into pens placed in ponds with no substrate to a high of 75.1% for red claw stocked into pens with mesh bundles provided as substrate. Survival values of red claw stocked into pens with other substrate types ranged from 17.5% (flat sheets) to 51.4% (tires). The survival percentages from the present study, while not as high as some treatments, may indicate that when red claw are stocked at less than $3/m^2$, substrate (shelters) may not need to be provided. This would reduce expense, since some of the substrate used by Jones and Ruscoe (2001) are expensive (such as

PVC pipe), or may be environmentally detrimental to water quality (such as the use of old tires).

The lower survival reported in the present study was probably due to shipping stress. Red claw arrived at our facility from Ecuador in poor physical shape. Approximately 50% of the red claw had died in transit. These were removed as the live animals were hand-counted into the ponds. Since survival was consistent in most ponds (one pond had only 11% survival), it may be that the survival values were a result of delayed mortalities following shipping rather than an event that occurred during culture. The pond with only 11% survival was the last pond stocked and red claw may have been severely stressed by the time of stocking.

Yield of red claw in the present study (461 kg/ha) was similar to other studies in which red claw were grown in ponds. Brummett and Alon (1994) reported that red claw had an average yield of 501 kg/ha, while Salame and Rouse (2000) stated that red claw stocked at $4/m^2$ had yields of 594 kg/ha and 889 kg/ha when fed a pelleted diet or fed a pelleted diet with additional forage provided, respectively. Rouse and Kahn (1998) reported a yield of 352 kg/ha when red claw were monocultured at an initial stocking rate of 20,000/ha. Yields in the present study were reduced by the lower-than-expected survival percentages. Jones and Ruscoe (2000) stated that when red claw were stocked in pens which had been placed into ponds, yields of between 1.04 and 5.52 tons/ha were achieved. However, these yields were based upon production within the 16-m^2 pens and may not be reflective of values obtained when red claw are stocked into ponds. However, Pinto and Rouse (1996) did report pond yields of 1,029 kg/ha when red claw were stocked at $3/m^2$.

At harvest in the present study, red claw populations were 48.2% male and 51.8% female (Table 3). There were very few (<1%) intersex animals and these were counted as males. Intersex red claw are those animals that exhibit both male and female secondary sexual characteristics (Medley and Rouse 1993). These results were not affected by stocking density. Pinto and Rouse (1996) reported a 1:1 sex ratio of male to female while Medley et al. (1993) observed a ratio of 23% male, 60% female, and 17% intersex. Karplus et al. (1995) stated that 47% of the red claw harvested from a study were male, 52% were female, and only 1.3% were intersex. Rouse and Kahn (1998) reported that 55% of the harvested red claw were male, 35% were female, and 11% were intersex.

Mean average weights of male and female red claw harvested in the present study were not different and averaged 65 g for males and 52 g for females. This is similar to other reports. Karplus et al. (1995) reported that red claw with an initial weight of 3 g and grown for 92 days

of culture in earthen ponds, male red claws had an average final weight of 34.5 g while females had an average final weight of 31.9 g. Rouse and Kahn (1998) stated that while not statistically different ($P > 0.05$), male red claw had higher individual harvest weights (84 g) compared to females (62 g) after 135 days of culture. However, Sagi et al. (1997) reported that male red claw grown for a second growing season had significantly higher harvest weights than females and recommended that monosex (male) culture of red claw be adopted so as to optimize growth and production.

Data on economic return (ER) from the present study indicate that percentage survival is the most critical factor for profitability. The low survival values and high costs of production costs (overfeeding, use of an expensive marine shrimp diet, and constant aeration) resulted in an overall financial loss. It appears imperative that to optimize ER, red claw juveniles used for stocking should be carefully shipped so as to reduce stress and mortality, thereby increasing yield and financial return.

The objective of the present study was to evaluate if there were any advantages to stocking red claw at very low densities in order to maximize growth. Based upon the data, a producer in a temperate region can stock red claw at 24,000/ha ($2.4/m^2$) and still obtain good growth, no difference in survival, and no adverse effects on water quality. By careful feeding, stocking healthy juveniles, and stocking early in the growing season so as to increase final individual harvest weight and yield, it may be that red claw have a favorable economic return for interested producers, especially if large (>80 g) individuals can be grown and sold to live markets who might pay a premium (> \$10.00/kg) price.

ACKNOWLEDGMENTS

REFERENCES

Brummett, R.E., N.C. Alon. 1994. Polyculture of Nile tilapia (*Oreochromis niloticus*) and Australian red claw crayfish (*Cherax quadricarinatus*) in earthen ponds. Aquaculture 122: 47-54.

Daniels, W.H., L.R. D'Abramo, M.W. Fondren, and M.D. Durant. 1995. Effects of stocking density and feed on pond production characteristics and revenue of harvested freshwater prawns *Macrobrachium rosenbergii* stocked as size-graded juveniles. Journal of the World Aquaculture Society 26:38-47.

Geddes, M.C., and M. Smallridge. 1993. Survival, growth, and yield of the Australian freshwater crayfish *Cherax destructor* in extensive aquaculture ponds. Aquaculture 114:51-70.

Jones, C.M. 1988. Aquaculture potential of *Cherax quadricarinatus*: research objectives and planning results. Pages 73-78 in: L.H. Evans and D. O'Sullivan, eds. Proceedings of the First Australian Shellfish Aquaculture Conference, Corbin University of Technology, Western Australia, Australia.

Jones, C.M. 1995. Production of juvenile redclaw crayfish, *Cherax quadricarinatus*, (von Martens) (Decapoda, Parastacidae) III. Managed pond production trials. Aquaculture 138:247-255.

Jones, C.M., and I.M. Ruscoe. 2000. Assessment at stocking size and density on the production of redclaw crayfish, *Cherax quadricarinatus* (von Martens) (Decapoda: Parastacidae), cultured under earthen pond conditions. Aquaculture 189:63-71.

Jones, C.M., and I.M. Ruscoe. 2001. Assessment of five shelter types in the production of redclaw crayfish *Cherax quadricarinatus* (Decapoda: Parastacidae) under earthen pond conditions. Journal of the World Aquaculture Society 32:41-52.

Karplus, I., A. Barki, S. Cohen, and G. Hulata. 1995. Culture of the Australian red-claw crayfish (*Cherax quadricarinatus*) in Israel. I. Polyculture with fish in earthen ponds. Israeli Journal of Aquaculture-Bamidgeh 47:6-16.

Karplus, I., M. Zoran, A. Milstein, S. Harpaz, Y. Eran, D. Joseph, and A. Sagi. 1998. Culture of the Australian red-claw crayfish (*Cherax quadricarinatus*) in Israel. III. Survival in earthen ponds under ambient water temperatures. Aquaculture 166: 259-267.

Maguire, G.B., and M.I. Leedow. 1983. A study of optimum stocking density and feed rate for school prawns *Metapenaeus macleavi* (Haswell) in some Australian brackish water farming ponds. Aquaculture 30:285-297.

Masser, M.P., and D.B. Rouse. 1997. Production of Australian red claw crayfish. Circular ANR-769, Alabama Cooperative Extension Service, Auburn University, Auburn, Alabama.

Medley, P.B. 1991. Suitability of the Australian Red Claw, *Cherax quadricarinatus* (von Martens) for Aquaculture in the Southeastern United States. Master's Thesis, Auburn University, Auburn, Alabama.

Medley, P.B., and D.B. Rouse. 1993. Intersex Australian red claw crayfish *(Cherax quadricarinatus)*. Journal of Shellfish Research 12:93-94.

Medley, P.B., D.B. Rouse, and Y.J. Brady. 1993. Interaction and disease relationships between Australian red claw crayfish (*Cherax quadricarinatus*) and red swamp crayfish (*Procambarus clarkii*) in communal ponds. Freshwater Crayfish 9:50-56.

Pinto, G.F., and D.B. Rouse. 1996. Growth and survival of the Australian red claw crayfish *Cherax quadricarinatus* at three densities in earthen ponds. Journal of the World Aquaculture Society 27:187-193.

Rouse, D.B., C.M. Austin, and P.B. Medley. 1991. Progress towards profit? Information on the Australian crayfish. Aquaculture Magazine 17(3):46-56.

Rouse, D.B., and B.M. Kahn. 1998. Production of Australian red claw *Cherax quadri-carinatus* in polyculture with Nile tilapia *Oreochromis niloticus*. Journal of the World Aquaculture Society 29:340-344.

Sagi, A., A. Milstein, Y. Eran, D. Joseph, I. Khalaila, U. Abdu, S. Harpaz, and I. Karplus. 1997. Culture of the Australian red-claw crayfish (*Cherax quadricar-inatus*) in Israel. II. Second growout season of overwintered populations. Israeli Journal of Aquaculture-Bamidgeh 49(4):222-229.

Salame, M.J., and D.B. Rouse. 2000. Forage-based feeding in commercial red claw ponds in Ecuador. Journal of Applied Aquaculture 10(3):83-90.

SAS. 1994. SAS/STAT User's Guide, Version 6, Fourth Edition. SAS Institute, Inc., Cary, North Carolina.

Tidwell, J.H., C.D. Webster, D.H. Yancey, and L.R. D'Abramo. 1993. Partial and total replacement of fish meal with soybean meal and distillers' by-products in diets for pond culture of the freshwater prawn (*Macrobrachium rosenbergii*). Aquaculture 118:119-130.

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., L.R. D'Abramo, C.D. Webster, S.D. Coyle, and W.H. Daniels. 1996. A standardized comparison of semi-intensive pond culture of freshwater prawns *Macrobrachium rosenbergii* at different latitudes: production increases associated with lower water temperatures. Aquaculture 141:145-158.

Tidwell, J.H., S. 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.

Webster, C.D., L.S. Goodgame-Tiu, J.H. Tidwell, and D.B. Rouse. 1994. Evaluation of practical feed formulations with different protein levels for juvenile red claw cray-fish (*Cherax quadricarinatus*). Transactions of the Kentucky Academy of Science 55(3/4):108-112.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jer-sey.