Observations on the production of the giant freshwater prawn, *Macrobrachium rosenbergii*, in the Transvaal, South Africa

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Abstract

The feasibility of establishing a production unit in South Africa for the giant freshwater prawn, *Macrobrachium rosenbergii,* largely as a result of the demand for prawns, was investigated.

A suitable site was identified at the Lisbon Estates in the eastern Transvaal Lowveld and the first inland prawn production unit, comprising 1,43 ha of pond space, was established there in 1981. Promising yields of 1,2 t·ha^{-1} were obtained after a grow-out interval of 172 d.

The prawns reached a mean mass of 28,6 g at a feed conversion ratio of 2,49:1. Survival was 76%. Production constraints were predation by the African clawed frog, *Xenopus* sp., and occasional low levels of oxygen in the water. The only disease detected was "black spot" (secondary infection) on the gill lamellae of a small proportion of the prawns.

Freshwater prawn production in South Africa will be viable in warm temperate to subtropical sites, provided that the soils and water source are suitable, that a nursery phase is included and that selective harvesting is employed.

Introduction

The desire to culture *M. rosenbergii* has persisted since the first successful attempts at controlled production of juveniles of this prawn (Ling and Merican, 1961). Both monoculture (Sandifer and Smith, 1978; 1979; Brody et al., 1980; Tribawono, 1980; Arieli et al., 1981; Ra'anan et al., 1984) and polyculture with a variety of fish species (Ling, 1969; Bardach et al., 1972; Goodwin and Hanson, 1975, Chao, 1979; Ling and Costello, 1979; Ra'anan and Cohen, 1983) have been successfully undertaken.

While little attention was paid to culture in South Africa, visits to culture units in Taiwan laid the foundation for the pilot project on *M. rosenbergii* here. The farm Lisbon Estates in the eastern Transvaal was chosen as the site. It is situated in a warm temperate to subtropical climate, potentially suitable for culture and possesses a developed infrastructure. An ample supply of piped water from the nearby Sabie River is available at the site. A source of semi-skilled labour is available in the proximity of the farm. The farm lies in a developed tourist area with potential market outlets, including the Kruger National Park, towns (e.g. Nelspruit) and nearby hotels.

Materials and methods

Grow-out ponds

Ease of harvesting and control are important determinants for pond size selection (Goodwin and Hanson, 1975). Six earthen ponds varying in size between 0,1550 and 0,2935 ha, totalling 1,43 ha, were used for prawn grow-out. These are smaller than ponds used in Hawaii (0,4 ha; Shang and Mark, 1982), Mexico (0,5 ha; Menez, 1982) and Mauritius (0,4 to 1,0 ha; Thompson, 1985)

Nursery

Nurseries have been used extensively for the care and growth of juvenile prawns (Sandifer and Smith, 1978; Liao and Chao, 1982; Cohen and Ra'anan, 1983; Thompson, 1985) and have been demonstrated to result in greater survival and yield (Ra'anan et al., 1984; Thompson, 1985). The nursery installed at the site consisted of a tunnel frame, with a floor area of 210 m^2, covered by clear plastic sheeting. Four circular black plastic tanks with a diameter of 6 m and height of 1,2 m were used to house the post-larvae (PL). Tank water was cycled through an adjacent biological filter, with oxygen supplied from an airblower. Clusters, each consisting of 5 short 40 mm PVC pipes, were placed in the tanks to provide additional surface area and refuges.

A total of 149 000 PL obtained from the Camaron Hatchery Co., Mauritius, in October 1982, were acclimatised prior to introduction to the tanks. The PL were released into the tanks when the temperature difference between tank and import water was less than 1,0°C and pH difference less than 0,4. The period of acclimatisation varied between 30 and 60 min. Three tanks received 38 000 PL each (1,3 PL·ℓ^{-1}) and one 35 000 PL (1,2 PL·ℓ^{-1}). These densities fall within the range of 0,5 to 3 PL·ℓ^{-1} used by Sandifer and Smith (1978) in trials on *M. rosenbergii.* Water quality parameters including temperature (°C), Secchi disc visibility (cm), pH and un-ionised ammonia (mg·ℓ^{-1}) (Standard Methods, 1971) were monitored daily.

The PL were fed on strained egg custard (steam-boiled egg and skim milk powder) for the first week. Egg custard and crushed formulated feed pellets (38% protein) were used alternately in the second week and crushed pellets thereafter. Cooked chicken was provided occasionally. The daily food ration was determined by feeding the PL 10% of wet body mass, calculated after weekly growth analyses. Twenty per cent of the ration was fed at 08:00 and 80% at 16:00 and the tanks were cleared of excess food and debris twice daily.

Growth was analysed by determining orbito-telson length (mm) and wet mass (g) weekly.

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TABLE 1
NURSERY TANK ORIGIN, POND STOCKING AND DENSITY OF JUVENILES

Tank origin of juveniles	Mean weight (g)	Quantity stocked in pond (n)					
		1	2	3	4	5	6
Total		10 489	15 113	14 963	9 252	7 000	13 250
Stocking density ($juv \cdot m^{-2}$)		3,6	5,6	5,2	4,9	3,5	7,0

Pond management

River water, stored in earthen reservoirs, was pumped or gravity fed through gauze and gravel filters, respectively, into the ponds over a period of 21 to 34 d before stocking with juveniles. Pipe clusters were placed on the bottom of each pond and traps were installed to capture frogs.

De-fluorinated phosphoric acid (21,8% P) and limestone ammonium nitrate (28% N), in the ratio 13 : 38 : 0 (N : P : K), at a concentration of 45 $kg \cdot ha^{-1}$, were used to fertilise the ponds. The number of applications during the season depended on water nutrient levels.

Ambient air and water temperatures were recorded daily on a hydro-thermograph in two ponds. Analyses for physico-chemical water quality parameters including Secchi disc visibility (cm), turbidity (FTU), pH, dissolved oxygen ($mg \cdot \ell^{-1}$), specific conductance ($\mu S \cdot cm^{-1}$), alkalinity ($mg \cdot \ell^{-1}$ as $CaCO_3$), calcium ($mg \cdot \ell^{-1}$ as $CaCO_3$), total hardness ($mg \cdot \ell^{-1}$ as $CaCO_3$), un-ionised ammonia ($mg \cdot \ell^{-1}$), nitrite ($mg \cdot \ell^{-1}$), nitrate ($mg \cdot \ell^{-1}$) and orthophosphate ($mg \cdot \ell^{-1}$) were conducted.

Stocking of juveniles in ponds

The juveniles were stocked at densities of between 3,5 and 7,0 m^{-2} (Table 1) in the ponds in November 1982.

Feeding programme

Crushed pellets were fed to the juveniles during the first 2 months and whole pellets (25% protein) for the rest of the grow-out. The diet was occasionally augmented with barley and chopped fresh fish. The daily ration (dry mass) was determined as a percentage of the prawn mean wet mass. The percentage was lowered gradually during the grow-out from 10 for smaller, to 2 for larger prawns. The daily ration was spread over the pond surface at 08:00 (20%) and 16:00 (80%).

Growth, harvest and market preparation

Growth analyses were conducted between pond stocking and final harvest in May 1983. The mean orbito-telson length (mm) and mean mass (g) was determined. Samples were collected by seine netting. During final harvest the ponds were emptied of water and netted. The prawns were washed, sorted into size classes and frozen in a mini batch cryogenic freezing chamber supplied with liquid nitrogen. Prawns were stored in a freezer unit (-14°C) for marketing.

Results

Nursery

During the acclimatisation period the difference in pH between tank and import water varied between 0,3 and 0,4 and the temperature difference was 5,4°C. The concentrations of un-ionised ammonia in the tanks were negligible. The concentration in one of the last import bags opened was, however, high (2 $mg \cdot \ell^{-1}$). The acclimatisation period varied in length between 30 and 60 min and the transfer of the PL to the tanks took a total of 7,5 h. Mean water temperatures varied from 27,0 to 31,9°C. The pH varied from 7,6 to 8,5, with the range between 7,0 and 9,4. Mean un-ionised ammonia concentrations varied between 0 and 0,23 $mg \cdot \ell^{-1}$ (range 0 to 0,85 $mg \cdot \ell^{-1}$). Secchi disc visibility varied between 50 and 100 cm.

The total quantity of egg custard, pellets and chicken feed fed per tank was 0,785 kg, 13 kg and 1,0 kg respectively.

The mean wet mass of the PL ranged from 0,45 to 1,22 g after 47 to 54 d. The mean growth rate varied from 9,2 to 22,3 $mg \cdot d^{-1}$. Survival varied between 39,4 and 52,0% with a total mean survival of 47,0%. The feed conversion ratio ranged from 0,81:1 to 1,89:1.

Grow-out

Water chemistry, feeding and management

Physico-chemical water quality parameters were analysed on 14 occasions during the grow-out. The mean minimum water temperature increased to above 20°C between 11 and 17 October 1982, and declined to below 20°C between 9 and 15 May 1983. The mean minimum temperature was thus greater than the 20°C or more (needed for effective growth of *M. rosenbergii*) for a period of 204 d (6,8 months). The highest mean minimum and maximum values attained were 28,6°C and 32,3°C.

Mean monthly Secchi disc visibility (SDV) varied from 18 to 53 cm (range 12 to 80 cm). SDV decreased gradually during the grow-out. As high turbidity, caused by the suspension of clay colloids in the pond water, was undesirable, aluminium sulphate was occasionally administered to the ponds at a concentration of 20 $mg \cdot \ell^{-1}$ to reduce the levels. The mean pH in the ponds varied between 6,9 and 9,2 (range 6,25 to 9,4). There were occasions when pH was below 6,5 and above 9,0. The pH of the inflow water was determined once, at the beginning of grow-out, and was found to be 6,2. Mean specific conductance varied between 145 and 255 $\mu S \cdot cm^{-1}$ (range 130 to 280 $\mu S \cdot cm^{-1}$). Mean alkalinity values varied between 27,7 and 90,0 mg·ℓ^{-1} as $CaCO_3$ (range 2 to 95 mg·ℓ^{-1}) and tended to fluctuate in respective ponds during the season. Mean calcium and total hardness varied from 28,7 to 45,0 mg·ℓ^{-1} (range 21 to 50 mg·ℓ^{-1}) and 45,0 to 76,7 mg·ℓ^{-1} (range 34 to 84 mg·ℓ^{-1}) as $CaCO_3$ respectively. Oxygen determination caused difficulties and was measured once only. The values varied between 3 and 6 mg·ℓ^{-1}. Mean un-ionised ammonia values varied from 0,3 to 1,3 mg·ℓ^{-1} (range 0,05 to 2,4 mg.ℓ^{-1}) and were generally high throughout the grow-out. The concentration of un-ionised ammonia in the inflow water was determined once, at the beginning of grow-out, and was 0,02 mg·ℓ^{-1}. Mean nitrite values varied between 0,008 and 0,013 mg·ℓ^{-1} (range 0 to 0,067 mg·ℓ^{-1}). Mean nitrate and orthophosphate concentrations in the ponds varied from 2,0 to 5,72 mg·ℓ^{-1} (range 0,9 to 8,4 mg·ℓ^{-1}) and 0,16 to 1,12 mg·ℓ^{-1} (range 0 to 1,65 mg·ℓ^{-1}) respectively during the grow-out. The fertiliser applications made to the ponds were designed to ensure adequate nutrient levels. De-fluorinated phosphoric acid was applied on 3 to 5, and limestone ammonium nitrate on 2 to 4 occasions.

The quantity of food administered to the ponds during the grow-out varied between 576 and 814 kg.

Growth, survival and feed conversion ratio

The analyses for growth are shown in Table 2. The grow-out for ponds 5 and 6 was terminated in January 1983 (Table 2) as a rapid downpour of rain resulted in the deposit of large amounts of soil in the ponds from runoff, and adversely affected water quality. The grow-out period varied between 148 and 178 d. (Table 2). Total grow-out, with the nursery phase included, varied between 202 and 228 d. The mean mass at harvest varied between 25,8 and 29,3 g. Survival varied between 7,4 and 76%. A total of 784,6 kg (752,0 kg·ha^{-1}) was harvested from ponds 1 to 4 at the end of the grow-out. The greatest yield achieved was 326,8 kg (1 217,1 kg·ha^{-1}) (Pond 2) representing an increment in mass of 6,85 kg·ha^{-1}·d^{-1}. The mean mass in Pond 2 was 28,6 g and the survival was 76%. The final harvest in Pond 4 was only 33,62 kg as excessive mortalities (as a result of severe anoxia) occurred during the night of 27 March 1983. The feed conversion ratio varied between 2,87:1 and 19,7:1 with the mean for all the ponds 3,58:1.

Market preparation and strategy

The division of the prawns at harvest into market size classes is shown in Table 3. The percentages of marketable prawns with a mass of more than 23 g were 60%, 49%, 43% and 71% of the harvested prawns in Ponds 1 to 4 respectively. Twenty-one per cent of the prawns in the total harvest had a mass of more than 30 g. A total of only 21,7% of the entire harvest from the ponds was less than 15 g in size. The females were found within a narrow range of mean sizes from 15 to 40 g in Ponds 1 to 3. Most females at harvest were in breeding condition with eggs developing in the ovaries, or berried. In contrast, the males were more widely spread in size from 5 to 75 g in Ponds 1 to 3. Blue claw and orange claw males were found in the larger size classes and a distinct group of smaller males in the lower size classes.

The method of rapidly freezing the harvested prawns with liquid nitrogen in a cryogenic freezing chamber and storing them on ice in a freezer (-14°C) proved satisfactory. The prawns were transported to the market on ice and were in good condition on arrival at the market outlets, even after travelling a distance of over 500 km. Market outlets included a supermarket chain store, hotels in the eastern Transvaal, the Kruger National Park, restaurants in Johannesburg and Pretoria and the population in the vicinity of the site.

Discussion

The high un-ionised ammonia concentration in one of the last import bags opened suggests that Mauritius is the limit with respect to distance and foreign import of PL. The long acclimatisation period is necessary to reduce the observed water quality differences between local and import water.

Water quality in the nursery was acceptable and it appears that the stocking density did not overburden the biological filters. Stocking densities may be increased as Cohen and Ra'anan (1983) successfully nursed PL at a density of 4·ℓ^{-1}. The mean individual mass attained by the nursed juveniles is better than that described by Cohen et al. (1983). The mean daily individual mass increment is greater than that achieved by Sandifer and Smith (1978). The latter authors, however, reported a survival of 94,7% which is far greater than the value achieved in this study. Mortalities were possibly partly due to cannibalism and may be substantiated by the fact that the feed conversion ratio of 0,81:1 to 1,89:1 is relatively low. The ratio achieved for PL nursed by Fujimura and Okamoto (1970) for 62 d was 3,21:1.

The nursery system was successful in terms of both its design and operation and is recommended as a necessary component of the infrastructure of a prawn culture unit in South Africa.

Water temperature is important and, from the results obtained for the ponds, it is clear that *M. rosenbergii* can be cultured to marketable size over a period of 6 to 7 months between November and May in warm temperate to sub-tropical parts of South Africa.

The greatest problem encountered with water quality was high levels of turbidity. This emphasises the fact that it is of prime importance to conduct a thorough analysis of the soil of a potential site (Goodwin and Hanson, 1975), and to determine its characteristics and possible effect on water quality before the site is chosen.

The alkalinity of the water is greater than the minimum of 40 mg·ℓ^{-1} considered by Boyd (1982) to indicate conditions suitable for aquaculture. The pH values are within the range of 6,5 to 9,0 (Swingle, 1961 in Boyd, 1982), regarded to be beneficial for growth. The high un-ionised ammonia levels resulted from the presence of up to 60 hippopotami (*Hippopotamus amphibius*) in a storage reservoir and probably affected prawn growth adversely, particularly in view of the results obtained by Wickins (1976). There were occasions when the level was greater than the 48 h LC_{50} value of un-ionised ammonia derived by Wickins (1976) for *M. rosenbergii*. As the site was the only area available and was too far from the Sabie River to establish an independent water source, the existing irrigation system had to be utilised. The nitrate levels were well below the 4 week LC_{50} value of 15,4 mg·ℓ^{-1} derived by Wickins (1976).

It is difficult to decide on a particular fertilisation programme as different ponds, even in close proximity to one another, react differently to the increased nutrient levels after fertilisation (Swingle, 1947 in Boyd, 1982) and many different types of fertilisers and programmes are used (Boyd, 1982). SDV was in the region of the range of values (15 to 25 cm) suggested by Willis and Berrigan (1977) to be indicative of satisfactory phytoplankton development in prawn ponds. The programme used proved satisfactory and may be recommended as a basis for culture elsewhere in South Africa. The advantage of using liquid

TABLE 2
ANALYSES FOR GROWTH OF PRAWNS IN THE PONDS DURING THE GROW-OUT

Pond	Stocking density ($PL \cdot m^{-2}$)	Juveniles stocked n	Growth period (d)	Mean mass (g) Stocked	Harvested	Survival %	Biomas ($kg \cdot ha^{-1}$) Stocked	Harvested	Biomass increment ($mg \cdot juv^{-1} \cdot d^{-1}$)	($kg \cdot ha^{-1}$)
1	3,6	10 498	160	1,22	29,3	65	43,6	681,2	175,5	3,99
2	5,6	15 113	172	0,7	28,6	76	39,2	1 217,1	162,2	6,85
3	5,2	14 963	148	1,22	25,8	58	63,0	773,2	166,1	4,8
4	4,9/8,4*	9 252/15 860	178	0,45	29,2	7,4	21,9	180,1	161,5	0,9
5	3,5	7 000	44	0,45	4,3	92,0	15,9	139,9	87,5	2,81
6	7,0	13 250	43	0,45	4,12	1,3	31,5	3,8	85,3	

*The surviving population of 6 440 juveniles from Pond 5 and 172 juveniles from Pond 6 were translocated to Pond 4 on 5/1/83 and 4/1/83 respectively. The biomass stocked was calculated from the original stocking density.

TABLE 3
DIVISION OF FINAL PRAWN HARVESTS IN PONDS 1 TO 4 INTO MARKET SIZE CLASSES

Pond	Size class (%)* SH	SS	S	SQ	LQ	K
1	1	6	12	21	40	21
2	5	8	10	28	26	23
3	2	10	13	34	26	17
4	0,3	8	8	12	24	47
Mean	2,7	7,7	11,3	27,1	29,1	21,5

* Shrimps (SH)	$0 < x \leq 5$
Extra small (SS)	$5 < x \leq 10$
Small (S)	$10 < x \leq 15$
Queens - small (SQ)	$15 < x \leq 23$
Queens - large (LQ)	$23 < x \leq 30$
King (K)	$x > 30$

x is the weight of an individual prawn.

fertilisers to ensure that the nutrients dissolve into the water immediately and completely, is counterbalanced by the higher cost. Although organic fertilisers, e.g. chicken manure, are cheaper, they do, however, have the disadvantage of dropping to the pond floor and decaying. As *M. rosenbergii* is extremely sensitive to low dissolved oxygen levels and inhabits the pond floor, care must be taken to prevent accumulation and decay of organic matter. The most serious limitation to the results is the lack of information on dissolved oxygen. The severe and unexpected development of anoxia in Pond 4 on one occasion illustrates its disastrous effect and the need for continuous management, for, despite daily analysis for water quality parameters as well as visual inspection, anoxia developed.

The food programme was successful, as borne out by the best food conversion ratio of 2,49:1. It must be noted, however, that the prawns do not only utilise supplemental food, but ingest natural food from the ponds as well (Weidenbach, 1982). The cases where ratios were high probably reflect overfeeding. This derives from the fact that it was difficult to assess the mortality of prawns. The Epol pellets were formulated specifically to improve the ration and retain their stability in water for 55 min, which ensured that the prawns ingested the rations (Forster, 1972). The pellet ration was suitable as a nutritional source and may be used as the primary source of food for a culture unit.

The best production result obtained, using extensive stocking densities, is better than the production Chao (1979) reported for Taiwan, although the grow-out period of 172 d was longer. The mean mass achieved was greater than that given by Chao (1979) and survival was lower. This illustrates that, despite constraints, the production is comparable to that achieved in countries with established freshwater prawn industries. Although the mean production is relatively low, production for individual ponds is good. Production as a whole will improve as management is refined and greater experience with the aquaculture of *M. rosenbergii* is gained. The prawn populations at final harvest exhibited morphotypic variation as described by Ra'anan and Cohen (1983). If the market size range proposed by Chao (1979) is considered, 78,3% of the total harvest will be market-size prawns after the grow-out period. If minimum market size is taken as 23 g (Ra'anan and Cohen, 1983 proposed 25 g) then 51,2% of the total harvest will be market-size prawns. If a large enough nursery is available, the harvested prawns can be housed there in clear water for at least 24 h to flush the alimentary canal. Hence the most attractive product can be supplied to the market, i.e. live with no evidence of the so-called "black vein", or rather, alimentary canal.

Survival varied considerably and adverse water quality conditions, particularly the development of anoxia, and predation by *Xenopus* sp., were the main contributory factors to mortality. These are management related problems and may be prevented as experience in freshwater prawn culture is gained. Although disease conditions did occur, the prawns were mostly disease free.

Conclusion

There is potential for freshwater prawn culture in South Africa, provided certain conditions are met. Sites with a warm temperate to subtropical climate will provide conditions for the minimum required grow-out of 7 months. Sites with good agricultural soils are preferable and an adequate, nutrient-free supply of water is essential. A fertilisation programme must be applied to stimulate pond productivity and specially formulated pellets administered as supplemental feed. A nursery phase of 6 to 8 weeks prior to grow-out is an absolute necessity. Prawns must be harvested selectively and the alimentary canal flushed, if possible, before they are supplied to the market fresh or deep frozen.

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