

Heterogeneous Individual Growth of *Macrobrachium rosenbergii* Male Morphotypes

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Abstract

In a single cohort of small freshwater prawn, *Macrobrachium rosenbergii*, the size range of females in the population is rather small. However, among the males, three major morphotypes are found and each has a distinct size category. The differential growth pattern in males, termed "heterogeneous individual growth" (HIG), is a major bottleneck confronting the profitability of farming this species. An attempt is made to understand the cause and impact of HIG on the culture system and methods by which HIG could be minimized in growout in order to maximize the market yield structure of the harvested population.

Introduction

Macrobrachium rosenbergii, the giant freshwater prawn, has been one of the most desirable candidate species for freshwater aquaculture in different parts of the Indo-Pacific region. Knowledge of the biology of this species, the rapid growth and bigger size it could attain, good disease resistance and good demand in both domestic and export markets have made it one of the most important species for freshwater culture in India. The breakthrough in its seed production and larval rearing technology has led to a new wave of enthusiasm among the prawn farmers for its monoculture and polyculture along with fish species like catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*). Fallow polders, paddy fields, homestead ponds and coconut garden channels are used for the culture of *M. rosenbergii*. Studies have been carried out on nursery rearing, different stocking densities, duration of culture, stocking of batch graded and size graded population, role of shelters and added substrates, etc. (Smith et al. 1981,

Karplus et al. 1986, 1987, D'Abramo et al. 1989, Kurup et al. 1996, Tidwell et al. 1999).

However, the wide disparity in growth and resulting differential size structure among a cohort of males is a major bottleneck in its successful aquaculture. This size disparity enabled the investigators to group the males under three basic morphotypes (Cohen et al. 1981, Kuris et al. 1987) namely small male (SM), orange clawed male (OC) and blue clawed male (BC). The harvested prawns from the culture operations have diverse weights and the individual weights range from 5 to 250 g at harvest. The presence of large quantities of undersized small male prawns makes the culture highly uneconomical and, therefore, it is not the total production that affects the economic viability but the marketable yield size structure.

Concept of Size Heterogeneity

M. rosenbergii is known to exhibit a complex social organizational hierarchy (Ra'anan and Cohen 1984), comprising

morphologically distinct dominant, subdominant and subordinate animals. The predominance of a definite social hierarchy among the male morphotypes increases the differential growth pattern within these prawns. Hence, in sexually mature single as well as multi-aged populations of *M. rosenbergii*, the size distribution of the female population is rather homogeneous. By contrast, the males show heterogeneous individual growth and therefore can be differentiated into three distinct morphotypes. The wide disparity in size structure of the cultured stock and the skewness in their weight distribution, which is profoundly influenced by the male morphotypes, apparently appears to be a commercial disadvantage of this species. The three male morphotypes represent three developmental stages of the male maturation process and are known to undergo transformation from SM → OC → BC (Ra'anan and Cohen 1984, Karplus et al. 1992). SM occupies the initial stage of the developmental pathway (Cohen et al. 1981). SMs are subordinate, not territorial and their bodies and second chelips are translucent. OC

stage is subdominant and represents a stage of high somatic growth (Ra'anana 1982). Depending on the spination and claw color, an OC has three different transitional stages which represent three distinct stages in the transformation pathway. The transitional stages of OC are weak orange clawed (WOC), strong orange clawed (SOC) and transforming orange clawed (t-SOC). BC represents the terminal stage in the morphotypic transformation pathway and is characterized by thick and dark-blue claws. The growth at this stage is least and only the length of the second cheliped increases. The long chelae and the distinct blue color help it to create a territory of its own. Weak blue clawed (WBC) forms are one of the transitional stages of BC (Harikrishnan and Kurup 1997). The terminal morphotypic stage of BC with relatively small body size in terms of carapace length and body weight disproportionate with claw length is termed old blue clawed (OBC). This complex social structure that is basically confined to males of *M. rosenbergii* is termed "heterogeneous individual growth" (HIG). HIG is one of the limiting factors for uniform growth and development of *M. rosenbergii*, in the growout system.

In farms, generally, 50% of the male population comprises the SM having a weight range of 5-20 g, while OC forms about 40% which is characterized by a wide weight range of 30-180 g, whereas BC forms only 10% representing the highest weight class and reaching up to 250 g. Hence, the economic viability of farming this species is profoundly influenced by the relative proportion of OC and BC morphotypes and their allied intermediary stages in the harvested population (Kurup et al. 1996).



Fig 1. From top: small male (SM), blue clawed male (BC) and old blue clawed (OBC)

Factors Underlying HIG

In general, the heterogeneous growth shown by the males of *M. rosenbergii* has been associated with: (a) intrinsic factors such as genetic differences, hatching order or age of metamorphosis (Smith et al. 1978, Sandifer and Smith 1979); (b) environmental factors giving rise to competition in cases of limited resources such as space and food (Magnuson 1962); and (c) social factors such as position within the size hierarchy, social status and territoriality (Symons 1972). Inevitably, most of the studies pertaining to the size heterogeneity concentrated on social interactions of various morphotypes in natural growout systems (Cohen et al. 1981, Ra'anana and Cohen 1984, Karplus et al. 1991, 1992, Karplus and Hulata 1995). Broadly, the factors underlying HIG can be differentiated into: (a) extrinsic factors and (b) intrinsic factors. Since the extrinsic factors chiefly elaborate the social implications of the prawns and their environment,

this is assumed to be the major factor affecting the differential growth. Although the effects of various physico-chemical parameters on the growth and survival of *M. rosenbergii* have been worked out, their implications on size heterogeneity have been dealt with only secondarily to the social hierarchy. In a usual phase, SM transforms to OC and then to BC, but once a set of prawns reach the terminal morphotype it inhibits the transformation of other small males to successive stages (Ra'anana and Sagi 1985). The dominant BC capable of drawing a territory of its own is termed "bull" and the undersized suppressed SM is termed "runt" (Karplus et al. 1992).

In *M. rosenbergii*, a social stimulus, i.e., the presence or absence of a "bull" results in stunning or accelerating growth of a "runt". Growth suppression in "runt" is based on reduced size increment, while the molting rate remains the same. The social interactions among the different male morphotypes regulate their

growth and morphotype stage (Karplus and Hulata 1992). In order to attain the dominant position in the population, the “runts”, when given a chance, immediately transform to successive stages and become dominant males. As a result, the subordinate males, instead of following a definite path of SM → OC → BC through its intermediary stages, skip some of the transitional stages to attain a subterminal position in the transformation pathway (Karplus et al. 1991, 1992). OC transforms into BC only after becoming larger than the largest BC in its vicinity (Karplus et al. 1992). This phenomenon is the “leap frog” growth pattern and it results in a series of differently sized BC whose size is positively correlated with the time of its transformation (Karplus et al. 1991). Recently, it was noted that the size and color of the claw alone decide the supremacy of a particular prawn to its counterparts in an area irrespective of the body size (Kurup et al. 1999). Under high density culture systems where the population is more complex, the transformation of undersized prawns results in the variation in the claw color only without much increment to their body size. Hence, the body size of these prawns is comparable to that of OC while their claw size and color resembles that of BC.

Intrinsic factors governing size heterogeneity include the inborn traits associated with ontogenesis along with biological and genetic differentiation. Since all these factors become evident from the larval stage itself, HIG could be traced from the embryonic development phase occurring in the egg mass of *M. rosenbergii* (Malecha et al. 1981). Studies linking the embryonic development to the size heterogeneity in different

species of *Macrobrachium* show that the size of egg, utilization of yolk, hatching order, hatching intensity etc. are correlated with the phenomenon of differential growth (Kulesh and Guiguinak 1993, Ranjeet and Kurup 1999, 2000). During the further development of postlarvae, two separate categories of juveniles emerge, one which is faster growing and with greater feeding aptitude named ‘jumper’ and the other a much weaker and slow growing ‘laggard’. The differential growth from the hatchery phase itself implies that there exist two separate populations of juveniles with difference in the somatic growth. It would thus appear that size heterogeneity may be a cumulative effect of both intrinsic and extrinsic factors, and its intensity has a direct relationship with the stocking density. But to date little attention has been given to characterize the intrinsic factors associated with size heterogeneity. One of the most important tools to unravel the mystery of differential growth is genetic studies. Available literature on genetics is scarce and only investigations related with the proximate composition of various morphotypes have been carried out (Sureshkumar and Kurup 1998). Very recently, studies on the difference in the electrophoretic patterns of protein banding, composition of different protein subunits, amino acid profile, RNA/DNA ratio of individual morphotypes have indicated that the differential growth could also have a genetic basis (Ranjeet and Kurup 2001). The knowledge gained through these studies would be of immense potential in unraveling the intrinsic factors associated with HIG so that strategies and solutions can be worked out to minimize HIG of cultured populations.

Implications of HIG on Culture Economics: A Case Study

In order to unravel the intricate problems associated with size heterogeneity, a study was conducted starting November 1999 in the growout systems of Kuttanad (South India) to understand the role of stocking density on the population characteristics, weight distribution, morphotypic composition, net yield and income from four polders under different stocking densities. The polders are traditional paddy fields reclaimed from Vembanad Lake lying 1m below sea level and separated from the lake with strong peripheral embankments. Polders with a water spread area of 2 to 6 ha were used. Postlarvae of *M. rosenbergii* were stocked at 14,000, 25,000, 40,000 and 60,000/ha in polders I, II, III and IV, respectively. The prawns were fed with a diet comprising groundnut oil cake, rice bran and boiled meat of edible clam in equal proportions at 10% of the prawn biomass. Water in the pond was exchanged periodically. At the end of the culture period of 8 months, the ponds were harvested. Random samples of 500-1000 prawns from each growout were examined on the day of harvest. All the prawns were sorted according to their sex. The males were then classified into SM, SOC and SBC and transitional stages namely WOC, t-SOC, WBC and OBC (Harikrishnan and Kurup 1997). All the prawns were measured to the nearest millimeter and weighed to the nearest gram.

Table 1 shows that density dependent variation amplified effects on population structure, morphotypic composition, sex ratio, retrieval rate and mean weight attained by individual prawns. The gross production from the four

polders amounted to 320, 480, 630 and 510 kg/ha for polders I, II, III and IV, respectively. Maximum survival (42%) was registered in polder I which had the least density while it was least (23%) in polder IV with a high density of 60,000/ha. The mean weight attained by individual prawns also showed a declining trend with increase in density. Maximum mean weight was recorded in polder I (56.8 g) followed by polder II (51.3 g). Polders III and IV had comparatively lesser weight prawns (41.2 g and 36.7 g, respectively). The proportion of males and females was dissimilar at all the four densities and the sex ratio worked out to be 1:1.26, 1:1.28, 1:1.39 and 1:1.70 in polders I to IV. At a higher density, the competition for food and space might have resulted in vulnerability of prawns to predation.

Table 2 presents the proportion of different morphotypes of male *M. rosenbergii* at different stocking densities. A remarkable shift in the proportions of SM and OBC, the terminal morphotypic stages of *M. rosenbergii*, could be noticed between low and high densities. The proportion of SM and WOC grew with increasing density while the frequency of t-SOC and OBC showed a declining trend. The proportion of SM was appreciably higher in stocking density of 60,000/ha (20%) while it was least at a density of 14,000/ha (14%). Similarly high proportions of t-SOC and OBC were noticeable at lower density of 14,000/ha (24% and 17%) while their percentage reduced considerably at stocking density of 60,000/ha in polder IV (12% and 11%, respectively). Similarly, spent females were proportionately higher in polders I and II (25.5% and 23.2%, respectively) while the undersized berried females dominated in polder IV (30.1%).

This may be because under lower densities the females had a faster morphotypic progression and maturity which resulted in the appearance of larger spent females in the final harvest.

Similarly, the reduction in the growth and mean weight of prawns with increasing density may be attributed to a variety of reasons such as competition for food, early sexual maturity, hyperactivity of subordinate individuals, loss of exuvia, aggressiveness and social hierarchy (Karplus et al. 1986a, 1986b). Since the prawns are graded according to their weight classes into six grades, the price which the farmer gets for the harvest depends on the quantity of higher weight group prawns which fetch a better price. At present, the weight group followed is <50, 50-60, 60-80, 80-120, 120-230 and >230 g. The price for <50 g prawns is Rs.

80/kg (US\$1 = Rs. 48.80 as of 2002) which is comparatively less compared to >250 g which fetches Rs. 330/kg. Based on the above mean tariff, the total revenue generated from the five treatments can be worked out as Rs. 60,166/- in Polder 1, Rs. 87,216/- in Polder 2, Rs. 114,408/- in Polder 3 and Rs. 86,241/- in Polder 4 respectively (Table 1). The results from this study suggest the importance of relative proportions of OC and BC in the population to improve the net yield and the negative impact of undersized SM and WOC in reducing the market size structure at the final harvest which ultimately influences the economic viability of prawn farming.

Ways to Minimize HIG

The potential for successful culture of *M. rosenbergii* lies in

Table 1. Stocking density and the final population structure of *M. rosenbergii* in the four polders used for the culture.

	Polder I	Polder II	Polder III	Polder IV
Water spread area	2 ha	4.5 ha	2.5 ha	6 ha
Duration of culture	8 months	8 months	8 months	8 months
Stocking density (/ha)	14,000	25,000	40,000	60,000
% retrieval	42%	38%	34%	23%
% marketable prawns	58%	48%	43%	24%
Population structure (dominated by)	t-SOC, OBC and WBC	t-SOC, WBF and OBC	WBF, SM and OBC	SM, BF, WOC and OBC
Average weight (g)	56.8	51.3	41.2	36.7
Gross production (kg/ha)	320	480	630	510
Marketed yield (kg/ha)	278	314	460	412
Marketed revenue (Rs/ha)	60,166	87,216	114,408	86,241
Sex ratio	1: 1.26	1:1.28	1:1.39	1: 1.70

Note: 1USD = 48.89 Indian Rupees

Table 2. Proportion of different morphotypes of male *M. rosenbergii* in different stocking densities.

Morphotype	Percentage contribution of male morphotypes in the harvested population of <i>M. rosenbergii</i>			
	Stocking density			
	14,000/ha	25,000/ha	45,000/ha	60,000/ha
SM	14	17	16	20
WOC	9	15	15	16
SOC	13	11	10	12
t-SOC	24	14	12	12
WBC	9	14	20	18
SBC	13	12	15	11
OBC	18	17	12	11

Note: SM = small male; WOC = weak orange clawed; SOC = strong orange clawed; t-SOC = transforming orange clawed; WBC = weak blue clawed; SBC = strong blue clawed; OBC = old blue clawed.

standardizing the stock size, use of quality seed and management procedures both prior and after stocking. To date, not much emphasis has been given to understanding the role of different management strategies to achieve an increase in the production and mean weight of the prawns. Various management approaches designed to minimize HIG have concentrated on selective harvesting or size grading of pond populations of prawns. Malecha et al. (1981) proposed a management practice that included pre-harvest size grading and restocking of non-market-size prawns after complete harvesting. Other studies have evaluated the potential for increasing yield by size grading nursery populations prior to stocking. (D'Abramo et al. 1989) and also by resorting to stocking of size graded post larvae (Karplus et al. 1986, 1987). Stock manipulation has been routinely practiced for the husbandry in order to optimize production. Apart from this initial screening, attempts have also been made to standardize the stocking density at different stages of culture. The duration, pattern and stock size during the nursery phase have also been subjected to change in order to increase the retrieval rate. With the advent of cull harvest techniques, farmers can now market the prawns depending on the weight class and correspondingly improve revenue.

Conclusion

Among the various intrinsic and extrinsic factors associated with the culture of the *M. rosenbergii*, differential growth happens to be a serious threat to the farmers resulting in heavy economic loss. Although the exact cause for the size heterogeneity among male

morphotypes has not been understood, it can be said that HIG is a cumulative effect of both intrinsic as well as extrinsic factors. The magnitude of this differential growth greatly depends on the management that the farmer adopts. Once the factors responsible for differential growth are identified and resolved, *M. rosenbergii* has a high potential to be a major species in aquaculture both for domestic and export markets. For this to happen, further research is needed.

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