

# Experimental Studies on the Cannibalistic Habit of *Macrobrachium rosenbergii* (de Man)

K.K.C.NAIR, MICKOVIC BRANISLAV, H.ROSENTHAL, K.V.JAYALAKSHMI and JUTTA NOST

National Institute of Oceanography, Regional Centre, Providence Road, Kochi-682018.

## Abstract

Cannibalistic habit of *Macrobrachium rosenbergii* in intensive cultures was studied in a semi-recycled fresh water system under varying environmental conditions. Observations were made on the moulting rate, mortality rate, tube occupancy and substrate preference under different light intensities and their inter and intra relations studied through linear correlations and their variations by MANOVA. Growth pattern was determined using Schnutes versatile growth model. The morphometry of the animals were studied to understand the damage or loss of appendages due to cannibalism and its trend of variation in relation to number of tubes. In intensive cultures, cannibalism appeared to be independent of the physical surroundings and the animals were found more susceptible to cannibalism soon after the moult. This can be guarded by providing suitable hideouts. Dried commercial feed, alternated with fresh animal tissues was found to be the best feed. Chitinous food or any amino-polysaccharide as supplementary feed was found to reduce cannibalism upto 70%

## Introduction

*Macrobrachium rosenbergii* (de Man), the giant palaemonid fresh and brackish water prawn of tropical Asian countries and Far East has become an esteemed food world over and it proved to be a potential species in aquaculture. Much work has been done on its general biology, survival rate, adaptability to environmental conditions, feeding habits, breeding behaviour and growth under culture conditions. In *Macrobrachium rosenbergii*, territoriality, intra-specific-agnostic behaviour and cannibalism are major behavioural events that can cause problems in intensive culture systems. Hence, the degree of success to culture this species may ultimately depend on techniques to mitigate or completely eliminate the losses caused by this behaviour. To achieve this, basic behavioural studies and factors controlling cannibalism are essential. Several important works on methodology of this potential problem have already been published in earlier years. (Ling, 1967; Fujimura, 1974; Segal and Roe, 1975; Smith and Sandifer, 1975; Mercy and Sankaran, 1992; Thampy and Mohanakumaran Nair, 1992; Sebastian *et al.*, 1992). Yet cannibalism and territorial behaviour of *M. rosenbergii* remain as an important obstacle in intensive culture of this species. The design of the present 64 days experimental study was to improve our knowledge on culture system under controlled conditions.

## Materials and Methods

The experiments were conducted in six circular perspex tanks of 116.2 l capacity, each with an inflow of 48 l/h from a semi-recycled fresh water system. Water quality was monitored once a day. Temperature, pH, Ammonia, Nitrite and Nitrate varied between 27.15-27.9°C, 7.01-8.12, 0.03-0.33mg/l, 0.02-0.67mg/l and 0.03-0.79mg/l. respectively. In each tank, 40

juvenile prawns of varying sizes from same brood stocks were introduced. Identical conditions in replicates were provided in all the aquaria including the controls which were devoid of any artificial substrate. The four pairs of test aquaria were equipped with PVC tubes (50 mm diameter and 18 cm long) arranged in bundles (13x2 in each tank in one set and 20x2 in each tank in the second set). This was done in order to assess the effect of habitat structure (ie., hiding places) on growth and survival. Feeding was restricted to three rations/day after removing the left over from the previous feeding. Wet and dry food were given on alternate days. The commercial dry food used contained 32% protein and 12% fat and fresh food used was *Mytilus* flesh. The food ration per day was limited to 15% of the body weight. Animals were exposed to 12 hrs bright light (light intensity, 0.10mEm<sup>-2</sup> Sec<sup>-1</sup>) and 12 hrs darkness. Twilight (light intensity, 0.015mEm<sup>-2</sup> Sec<sup>-1</sup>) conditions were also simulated during morning and evening hours. Continuous aeration was applied to all the tanks through aquaria air stones and oxygen was always kept at saturation level.

Observations were made on moulting rate, mortality rate, tube occupancy and substrate preference during darkness, twilight and bright light in the morning hours and vice versa during the evening. Observations were also made at noon under full day light. The morphometry of the animals noted in every twenty days interval to assess damage or loss of appendages as often noticed due to cannibalism. To maintain the same stocking density in all the tanks, throughout the experiment, lost animals due to cannibalism were replaced every 7th day from the original stock population which was maintained in a separate tank.

To study the effect of cannibalism, various biological phenomena were observed such as daily mortality, moulting, tube occupancy and number of animals found attached to the

substrates but not inside the crevices. All these observations were made at different times of the day. Growth was determined by weight increase. Direct cannibalistic effects were measured by loss/damage of appendages. These two measures were observed at different time intervals during the experiments. Measures were determined and MANOVA tests (Sokal and Rohlf, 1981) were applied to study the significance of the observed difference in mortality rates, moulting rates, tube occupancy and number of animals over the substrates at different times of the day and corresponding light intensities. Duncans lsd test (Federer, 1967) was applied to compare the rates pair wise if MANOVA resulted in significant differences. The versatile growth model by Schnute (1981) was fitted to study the growth pattern at different ages and the best model based on the values of a and b in the relation

$$U = -(a+bZ)$$

is determined. Also the best model among a collection of the 11 models (Snedecor and Cochran, 1967) based on least sum of squares of errors is determined using the programme, (Jayalakshmy, in press).

## Results and Discussion

### Cannibalism and moulting

*Macrobrachium rosenbergii* (de Man) is aggressive and cannibalistic when reared at high densities (Smith and Sandifer, 1975, Thampy and Mohanakumaran Nair, 1992). Low stocking rate could be suggested as a possible means to reduce cannibalism. Cannibalism invariably follows attack made on animals undergoing moulting. In particular, in tanks provided with low number of hideouts, moulting during morning hours resulted in mortality caused by cannibalistic activity during evening hours ( $r=0.365^a$ , a=the calculated r is significant at 5% level of significance). But in control tanks and in tanks with high number of hiding tubes this relation was not pronounced. Even a larger animal when it moults in the presence of smaller intermoult stages, its chances of getting killed by the smaller animals were found much greater (Smith and Sandifer 1975). To trace moulting in isolation is easy, but in intensive culture it is rather tedious. However, moulting data provided here are reliable except for some moults possibly missed close to midnight hours. High moulting rate was observed both during noon and evening hours especially in tanks with more number of hideouts ( $r=0.645^a$ ). Moulting invariably takes place at night and often the absence of exuvia leads us to assume an absence of moulting. When given an opportunity, *Macrobrachium rosenbergii* eats its exuvia. All isolated individuals completely consumed its discarded exoskeleton within 24 hours. The number of animals remaining outside the tubes were significantly positively related between the consecutive times of the day such as morning and noon ( $r=0.552^a$ ) irrespective of the number of tubes provided, but between noon and evening ( $r=0.518^a$ ) only in the tanks with 40 tubes as hide outs. The

average moulting rate showed variation with respect to time of the day ( $F=71.0033$ ,  $P<0.05$ ), age of the animals ( $F=2.5232$ ,  $P<0.01$ ) and the number of hideouts ( $F=1.718$ ,  $P<0.25$ ). During the first 30 minutes following a moult, an animal is most vulnerable to cannibalism. Ling (1967) has observed that small young animals moult more frequently than large ones. Moulting frequency may well be a function of size rather than age (Segal and Roe, 1975). But in our study we have not correlated moulting rate with the size of the animal, but with age. The moulting rate was highly dependent on age (up to 32 days) from the commencement of the experiment. Further, the variation was found to depend on combined variations in the number of tubes and time of the day ( $F=2.578$ ,  $P<0.05$ ), time and age ( $F=1.654$ ,  $P<0.01$ ) and number of tubes and age ( $F=1.245$ ,  $P<0.05$ ). The dependence on age was more during evening hours and it further increased with increase in the number of hideouts.

Generally moulting rate was found to increase with consequent increase in the number of tubes, more so during the morning and noon hours. However, moulting rate was maximum during the evening hours in all cases in tanks with 26 tubes and, least during morning hours [Table 1.a(i)]. Moulting and mortality were found to be inversely related, during morning and noon and positively related during evening hours but both not highly significant. [Figs. 1.1(a)-1.1(i) and Figs 1.2(a)-1.2(i)]. Then the question, if small animals moult more frequently than large animals of the same age, why few of them remain small. Possibly, moulting frequency is not growth determined as suggested by Segal and Roe (1975).

In *Macrobrachium rosenbergii* moulting and cannibalism are believed to be interdependent. But this was not so evident in most of our experiments. Only in tanks with moderate number of hideouts (26 tubes) 10% moulting related mortality was evident. In the remaining two sets of experiments many animals

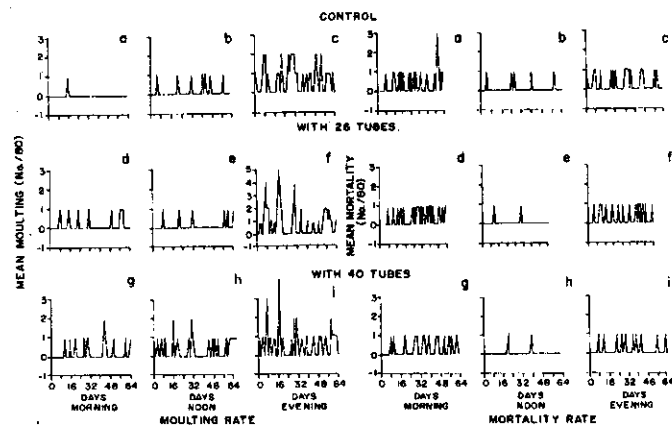


Fig. 1.1 Showing the mean moulting rate (number/80) in the three sets of experimental tanks - control (a, b, c), with 26 tubes (d, e, f) and with 40 tubes (g, h, i) during morning, noon and evening respectively.

Fig. 1.2 Showing the mean mortality rate (number/80) in the three sets of experimental tanks-control (a, b, c), with 26 tubes (d, e, f) and with 40 tubes (g, h, i) during morning, noon and evening respectively.

Table 4. showing the (a) rearing trials with *Macrobrachium rosenbergii* juveniles in containers equipped with and without hideout tubes and their effect on moulting rate (%), mortality rate (%), Tube occupancy (%) and average number of animals over substrates and (b) the relative growth rate (Z) and the relative growth rate of the relative growth rate (U), observed weight (O) and fitted weight (F). X = average, C.V(%) = coefficient of variations. Data combined for two replicates in each series. (I) Moulting rate

	X			C.V (%)										
	Morning	Noon	Evening	Morning	Noon	Evening								
Control	01.65	10.93	60.90	7.93	2.85	1.18								
26 tubes	12.52	09.45	79.74	2.64	3.10	1.44								
40 tubes	17.25	39.10	67.20	2.42	1.40	1.26								
<b>(ii) Mortality Rate</b>														
Control	34.44	07.83	28.10	1.64	3.43	1.59								
26 tubes	32.82	03.25	26.54	1.43	5.56	1.68								
40 tubes	28.11	03.11	15.63	1.59	5.56	2.32								
<b>(iii) Tube occupancy rate during (*) Dark, (**) Twilight and (***) full light</b>														
	*	**	***	***	*	**	***							
	X	C.V%	X	C.V%	X	C.V%	X	C.V%	X	C.V%	X	C.V%	X	C.V%
26 tubes	13.1	39.9	13.0	41.2	15.9	39.7	15.3	45.1	12.4	49.8	10.7	41.5	10.9	38.7
40 tubes	14.8	54.7	14.7	35.4	17.5	37.1	16.6	44.6	12.0	44.1	16.5	41.8	13.1	38.2
<b>(iv) Number of animals over substrates</b>														
	X	C.V(%)	X	C.V(%)	X	C.V(%)								
26 tubes	11.68	45.57	14.30	42.77	10.04	46.06								
40 tubes	11.99	43.47	16.68	41.98	13.05	46.13								
<b>(b) Growth model</b>														
	Control a = 0.1574, b = -0.0052			With 26 tubes a = -0.0484, b = 0.0035			With 40 tubes a = 0.0852, b = -0.0025							
Days	O	Z	U	F	O	Z	U	F	O	Z	U	F		
1	6.18	--	--	6.176	6.02	--	--	6.016	6.03	--	--	6.031		
12	6.91	0.011	--	6.911	6.91	0.011	--	6.071	7.80	0.027	--	6.743		
21	7.65	0.012	-0.111	7.577	7.31	0.011	-0.019	7.259	8.61	0.012	-0.062	7.389		
43	8.82	0.007	-0.046	8.491	10.09	0.017	-0.007	8.925	10.34	0.009	-0.018	9.239		
64	10.57	0.009	-0.048	11.769	12.47	0.011	-0.048	10.873	12.36	0.010	-0.048	11.436		

died owing to various causes and were subsequently cannibalized. Only about 5% was confirmed as moult related cannibalism. Ling and Merican (1961) felt that cannibalism and hunger were directly related, but mostly among males. However, well fed animals in our study did attack and cannibalize others as it was noted by Segal and Roe (1975).

In a test study conducted, chitinous food or any aminopolysaccharide as supplementary feed was found to reduce cannibalism upto 70%. Segal and Roe (1975) reported a cannibalistic rate of 59% (19 out of 32) and Minamizawa and Morizane (1970) 56% (14 out of 25) within 60 days. In most cases cannibalistic behaviour was exercised by cutting off appendages in full or partly or cutting out some flesh from some other portions of the body. Both sexes were found to be cannibalistic, but more so in males. Number of moulting was lowest (68) in control where the maximum damage or loss of appendages were noticed (418). In tanks with moderate a number of hiding tubes the highest number of moultings (93) were noted. Here the damage or losses of appendages were next to the highest observed (335). Fairly high moulting (85) with least damage of appendages (326) were noted in tanks, with maximum number of hideouts. In general, the loss or damage of appendages increased as the animal advanced in age. (Figs 2.1).

### Mortality

During the present study, total mortality, mostly due to cannibalism or due to undetermined causes, was highest in control tanks where no hideouts were provided and it was least in tanks with maximum number of hideouts. This suggests that less number of hideouts or its absence will enhance the mortality considerably in intensive cultures [Table 1.a(ii)]. Smith and Sandifer (1975) have observed a 4 times higher mortality rate in tanks (95 litres) without, substrate compared to those with substrate (11%) for the first 4 weeks in the case of early post larvae (~26 mg.). They have observed that mortality rate was not affected by the substrate configurations until after the eighth week when mortality in tanks with vertical substrates increased. At the end of the study period (60 days) they have found a mean mortality in the tanks with horizontal substrates, vertical substrates and without any substrates as 34.7, 45.5 and 67.6% respectively. At the conclusion of 18th day experiment using artificial floors in experimental tanks, Foster (1970) reported a mortality rate of 3.65%/day in substrate tanks as compared to 5.93%/day in controls without substrate. Analysis of Variance revealed mortality rates between different times of the day (morning, noon and evening considerably differ to in all the tanks ( $F=25.679$ ,  $P<0.005$ ), [Figs. 1.2(a)-1.2(i)], irrespective of the number of tubes ( $F=1.15$ ,  $P>0.05$ ) and age of the animals

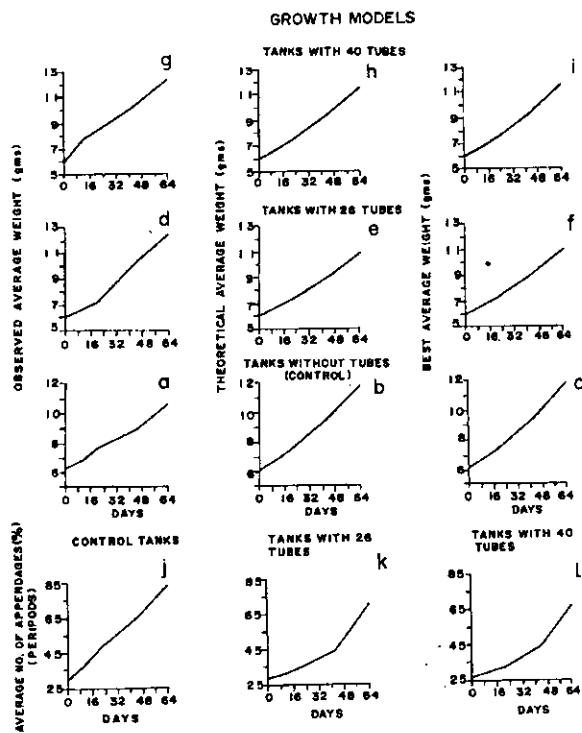


Fig. 2. Showing the pattern of growth during morning (a, d, g), noon (b, e, h) and evening (c, f, i) and average number of appendages (Pereopods) lost (%) (j, k, l) in the three sets of experimental tanks-control, with 26 tubes and with 40 respectively.

( $F=1.24$ ,  $P>0.01$ ). In general, average mortality rate decreased with increasing number of hideouts during morning, noon and evening observations with least value (3.1%) during noon and highest (34.4%) during morning hours and with highest variation during noon hours [Table 1.a(ii)].

#### Tube occupancy and substrate preference

It has been suggested by various authors that in *Macrobrachium* culture, the nature of the substratum offered for hiding has a profound effect on success of aggression and on subsequent cannibalism (Ling, 1969, Fujimura and Okamoto, 1970; Mercy and Sankaran, 1992). Use of natural substrates, including sticks, branches, gravel, shells or water plants in rearing tanks has been suggested as a means of shelter for prawn. Such materials do not appear practical for intensive rearing systems. The most promising approach appears to be the mass rearing of prawns in tanks of large surface area or shelters. In the present experiments, except in control tanks, PVC tubes of suitable diameter were selected and used according to the relative size of the animals. Tubes of lesser diameter when used, animals were found to avoid them and in tubes with greater diameter more than one animal were found to occupy in one tube leading to more cannibalism. Mortality and availability of adequate hideouts were found directly related in intensive cultures, where more and varied hideouts relative to the age of the animals resulted in less cannibalism. It has been found that under full light intensity animals did not show any significant

difference in the tube occupancy, on comparing the different times of the day, or age of the animals ( $F<1.00$ ,  $P>0.01$ ) other than a slight decreasing trend with increase in age, more so during morning and noon. In the case of animals in tanks with 40 tubes as hideouts tube occupancy did not vary much during twilight other than showing an increasing gradient with age during evening hours. Whereas in tanks with 26 tubes, it varied between morning and evening ( $F=2.875$ ,  $P<0.10$ ), with intensity of light ( $F=3.748$ ,  $P<0.05$ ) and with age ( $F=3.268$ ,  $P<0.005$ ) where significant increase was noted during morning. In morning hours, number of animals in tubes varied between 4 and 8 whereas the variation was mostly between 2 and 5 during evening under twilight. With full light, the number was found to vary between 6 and 10 during morning and noon hours whereas between 3 and 5 in the evening hours. This was indicated by the high value of F statistic for time and intensity of light interaction ( $F=13.492$ ,  $P<0.005$ ), intensity and age ( $F=1.543$ ,  $P<0.05$ ) and time and age ( $F=1.717$ ,  $P<0.05$ ). In general with increase in light intensity the tube occupancy was found to increase reaching a maximum during morning full light [Table 1.a(iii)]. In the evening a definite pattern could not be ascertained owing to an increase in the tube occupancy during the twilight hours.

Even though hideouts were provided animals were found to remain over the tubes occasionally. This was found to depend highly on the number of tubes ( $F=8.241$ ,  $P<0.005$ ), time of the day ( $F=111.342$ ,  $P<0.005$ ) and age of the animal ( $F=13.621$ ,  $P<0.005$ ), [Table 1.a(iv)]. The number of prawns occupying the tubes and that remaining over the tubes were found highly dependent on the different light intensities ( $0.307^a < r < 0.560^a$  for morning,  $.205 < r < 0.329^a$  for evening and  $0.318^a < r < 0.430^a$  for noon).

Other than tubes as hideouts, artificial substrates such as pebbles, submerged habitats such as broken tiles, vertically kept plastic nets, and tiered horizontally arranged rocks were tried by various authors (Smith and Sandifer, 1975; Sebastian *et al.*, 1992; Mercy and Sankaran, 1992) with varying success to reduce mortality. As it was observed in the present study, their studies also showed that prawns reared in tanks containing either horizontal or vertical substrates grow faster and had a higher survival rate than those reared in tanks not containing any hideout places.

#### Growth rate

Growth rate of juveniles and adults of *Macrobrachium rosenbergii* obtained by different workers are extremely difficult to compare because of variations and conditions specified and unspecified. The growth of prawns among tanks with substrate was similar and more rapid than in tanks without substrate. In groups, more aggressive males and females grow faster than less aggressive forms. In isolation, males, on an average grow faster for a longer period and thus get bigger. Moulting

frequency does not appear to be directly related to growth rate, but rather growth rate is related to food consumption, regardless of the moulting frequency (Segal and Roe, 1975). In the present study, on an average, food conversion efficiency was found to be 32.03% for control, 44.09% for tanks with 26 tubes and 45.52% for tanks with 40 tubes. The utilization of food was more efficient among prawns in tanks containing artificial substrates compared to control as observed by Segal and Roe, (1975). The growth rate observed over the period of the experiment in various sets were, in control, 11.28 mg/day, with 26 tubes, 16.74 mg/day and with 40 tubes, 16.40 mg/day. Regardless of the control tanks, animals in tanks with 26 tubes showed the maximum growth where the fighting tendency was more for hideouts. In this case the observation by Segal and Roe, (1975) comes handy where they have reported that aggressive animals show more growth than less aggressive ones. Comparable increase in daily average growth was reported by Minamizawa and Morizane (1970) on post larvae reared over 60 days at 30 C. The highest growth rate on *Macrobrachium rosenbergii* was reported by Ling (1969) i.e. 34% weight gain/day but he has no temperature data or other particulars. He himself has reported a weight gain by only 8.7% for the same species in an earlier work. Venugopalan and Thampy (1992) have reported a growth rate of 5.3 mg/day for animals reared in low saline (2ppt) waters and the growth was found to reduce (2.49 mg/day) as the salinity increased (8ppt). The maximum growth of an organism occurs at its osmotic point since the energy expended in osmoregulation should be the lowest at an animals iso-osmotic point (Kinne, 1971). The iso-osmotic point of *Macrobrachium rosenbergii* was reported to be at 17-18 ppt (Smith and Sandifer, 1975). None of the workers could observe maximum growth for this organism at this salinity level (Goodwin and Hansen, 1975; Perdue and Nakamura, 1976) indicating that iso-osmotic growth concept is not acceptable in the case of *Macrobrachium rosenbergii*. In general all workers agree that *Macrobrachium rosenbergii* grow more rapidly atleast at some stage during their life span (Fujimura and Okamoto, 1970; Ling, 1969;). Ling (1969) has also observed that until about 60mg in weight, both males and females of *Macrobrachium rosenbergii* grow at the same rate and then onwards the growth rate of females declines.

#### Growth Model

From the Schnutes (1981) model it was observed that, for control tanks Z was positive and U was negative (Table 1.b) satisfying the linearity assumption with a decreasing trend for U over Z (F=619.646, P<0.005). Also, b=-1 (t=2775.4, P<0.005) and b=0 (t=14.3718, P<0.005) were not the best fit violating the pattern either according to Logistic model or Gompertz model as suggested by Sreekumaran Nair *et al.*, (1983). Since a=0 (t=1.2076, P>0.005) is found to be better and b not equal to 0, the general model, model 3 of Schnute has been taken as the best statistical model (F=15.855, P<0.05) among a collection

of 11 models given by him explaining about 78.85% of the variation in the weight distribution with respect to age. The fitted equation of the model is  $Y(t)=[0.99057-0.57495(t-1)/11000]^{-192.3076}$ . [Fig. 2(a)-2(c)].

In the case with 26 tubes the growth pattern is not according to Schnutes assumption (F=1.26, P>0.05), (Table 1(b)). Also b=1 (t=187.1208, P<0.05) is not significant. But b=0 (t=0.6523, P>0.05) is found to a reliable value for the rate of change of U. However a=0 (t=4.5522, P<0.05) is far from reality leading to violation of assumption of any particular pattern for growth as given by Schnute. Hence Schnutes general model, Model 2 is fitted as the best one upto the first 21 days of the experiment and thereafter the function becomes undefined. The fitted equation of the model 2 is

$$Y(t)=6.02x \exp[0.457378(1-\exp(0.0484(t-1)))] \text{ [Figs.2(d)-2(f)]}$$

and from 21 days onwards the fitted model is model 3, given by the equation,

$$Y(t)=[(1.006302584+0.36119(t-1)/11000)285.7143]. \text{ [Figs.2(d)-2(f)]}$$

However considering the experimental period as a whole, the statistically best model is model 3 as given above (F=19.46, P>0.05) explaining about 82.19% of the variations in the growth pattern. In the case of tanks with 40 tubes the observed growth rate did not satisfy the Schnutes (Table 1(b)) assumption of linearity (F=1.704, P>0.05). In this case also b=-1 is not acceptable (t=305.497, P<0.005). But b=0 (t=0.7548, P>0.05) and a=0 (t=0.0204, P>0.05) are found to be appropriate. Therefore tth power curve has been suggested as the best growth pattern (F=12.9067, P<0.05) explaining about 74.85% of the variations in the weight distribution and hence the fitted Model is  $Y(t)=5.939423x(1.0153343)^t$  [Fig.2(g)-2(i)].

Since in none of the three cases, either the Logistic model or the Gompertz model could not describe the growth pattern, it is suggested that the growth pattern is not symmetrically sigmoid and also more than one physiological stanza is not evident in the life span of *Macrobrachium rosenbergii*.

Total elimination of cannibalistic tendency of *Macrobrachium rosenbergii* (de Man) in intensive cultures may be a far fetched idea but it can well be minimized by studying its circadian behaviour at different life stages or by selective breeding for docility. Other than providing adequate hideouts of varying number, hideouts of different dimensions depending on life stages may also reduce the cannibalistic tendency to a considerable extent.

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