

Effects of eyestalk ablation on moulting and growth of penaeid prawn *Metapenaeus dobsoni* (de Man)

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Penaeid prawns *M. dobsoni* of two different size ranges were ablated both unilaterally (UEA) and bilaterally (BEA) and subjected to individual study. The UEA prawns consumed almost the same amount of food as the control prawns in the size group, 35-40mm. but consumed about 57.8% more food than the control prawns in the larger size group, 48-53mm. Growth was estimated as length and weight changes and significant variation was observed. The moult rate and dry moult weight showed marked differences. Average intermoult period increases with second ablation. Dry weight of moult in every succeeding moult was found to decrease irrespective of the level of ablation. Unilateral eyestalk ablation resulted in increase in dry weight whereas bilateral eyestalk ablation reduced the dry weight of moult and this decrease in the rate increased after each subsequent moult. In the larger size group, values of protein efficiency ratio (PER) were almost same as that of the lower size group. The UEA prawns exhibited highest conversion efficiency. The production rate of UEA prawns was 84% more than that of the control whereas BEA prawns indicated negative production. The same trend followed for net growth efficiency also. The results suggest that unilateral eyestalk ablation can be resorted to accelerate growth and conversion efficiency. Eyestalk ablation has been frequently resorted in matured forms for inducing maturation of gonads. For the first time attempts have been made to compare between the effects of removing one eyestalk versus two and changes taking place in juvenile forms especially in their physiology related to growth.

Keywords: Penaeid prawns. Eyestalk ablation, Growth. Moulting. *Metapenaeus dobsoni*

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Of various relations attributed to the crustacean eyestalks, the relation between the eyestalks and moulting is of great significance. Moulting in crustaceans was thought to be regulated by two hormones-the moult inhibiting hormone and moulting hormone. It is believed that the moult inhibiting hormone is produced in the eyestalk and stored in the sinus gland and the moulting hormone is produced in Y organ. When the eyestalks are ablated, the moult inhibiting hormone is excluded thus allowing the moulting hormone to act. Thus the removal of eyestalks shortens the intermoult period. Several investigators worked on the endocrine control of moulting and growth in decapod crustaceans²⁻⁴. In the present paper, an attempt has been made to study the moulting changes in the animal *Metapenaeus dobsoni* due to different levels of eyestalk ablation.

Prawn fishery is an important marine resource in India and accounts for about 1% of total marine fish

landing and about 50% of the total marine fishery export. Prawn farming in brackish water can enhance production to augment the export potential. Two important requirements in culturing prawns are the availability of prawn seeds and methodology to accelerate growth.

Eyestalk ablation is a frequently adopted procedure for induced maturation of gonads and spawning. This method has also been tried on a few occasions to enhance growth in some crabs and lobsters. The crustaceans eyestalk is known to have a neurohaemat function due to the presence of the X-organ-sinus gland system. Excision of eyestalk is a classical endocrinological experiment to determine the functions of the eyestalk neurosecretory system. Besides, the established effect of the reproductive function, manipulation of the hormonal supply by eyestalk extirpation can bring about alterations in the physiology of prawns. However, very little work has been done in this regard, especially in penaeid prawns.

Due to their high commercial value, to achieve maximum yield and optimum harvest many experi-

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ments have been designed to study metabolism, reproduction and behaviour of penaeid prawns. Eyestalk ablation is usually resorted to obtain enhanced growth. This method is also most frequently performed for inducing maturation of gonads and spawning of prawns. Extirpation of an eyestalk removes the endocrine system of prawns located in the eyestalk which influences growth, reproduction and other metabolic activities. Besides, eyestalk ablation is reported to influence lipid metabolism, protein metabolism, carbohydrate metabolism, hydromineral regulation, gonad inhibition and limb growth.

Moulting in Crustacea is part of the mechanism of growth. Change in form and increase in size can only occur when the hard calcareous exoskeleton is shed and before the new cuticle is hardened. The moult cycle can be divided into four stages which facilitates analysis of its control. They are proecdysis: preparatory to moulting, ecdysis, shedding of old cuticle, metecdysis: stage immediately after ecdysis denoted by mineral deposition and protein synthesis and anecdysis or intermoult when normal growth takes place⁶. Removal of eyestalk leads to increased weight and decreased osmolality of haemolymph^{7,8}. Unilateral eyestalk ablation has been employed to induce both ovarian maturation and spawning with varying success in many species⁹⁻¹¹. Unilateral eyestalk ablation can also be used to shorten the moult interval and to stimulate gonad development in shrimps¹².

Enhanced growth rate in unilaterally eyestalk ablated fresh water prawns, *Macrobrachium lankesteri*⁵ and *M. malcolmsonii*¹³ respectively has been reported. Feeding experiments and food conversion efficiency have been carried out in many species of penaeid prawns. In the oriental prawn *Penaeus aztecus*, the growth rate and food conversion efficiency under different conditions had been studied¹⁴. Also the growth and conversion efficiency of *Metapenaeus monoceros* fed on detritus had been studied¹⁵. Similarly, Royan *et al*¹⁶, have worked out the conversion efficiency of *M. monoceros* fed on different types of food. Feeding experiments and conversion efficiency of the same species fed with compounded diets was attempted¹⁷. Effect of the unilateral ablation of the eyestalk excision on the energy budget of juveniles of the Malayan prawn *Macrobrachium rosenbergii* was attempted¹.

* The present study has been undertaken with a view to observe the effects of both unilateral and bilateral eyestalk ablation on moulting and growth of penaeid prawn *Metapenaeus dobsoni* (de Man). For the first

time attempts have been made to understand changes taking place in juvenile forms especially in their physiology related to growth.

Materials and Methods

Collection of prawns—*Metapenaeus dobsoni* was collected from Cochin Backwaters and from prawn culture fields. The prawns were collected in large plastic buckets, sorted and transferred to rearing tanks of the main recycling system¹⁹.

Sea water collection—Sea water was collected from the near shore area of Fort Cochin. The water was filtered and transported in large carboys of 25 and 50 litre capacity. Salinity was adjusted to the desired standard by adding aerated fresh water. Salinity and dissolved oxygen were measured by standard methods²⁰. eH and pH were measured by electrodes (Century, India). Salinity of sea water in the recycling system was periodically monitored and changes in salinity compensated by adding fresh water. Water was kept fully saturated with oxygen by providing continuous aeration. pH of the water was maintained close to the value 8 by adding anhydrous calcium carbonate. The temperature of the system was recorded both in the morning and evening and the mean value was taken.

Size and weight measurements—The length of the prawn was measured by vernier calipers. Measurement was taken from the base of the rostrum to the base of the telson. Weight of the prawn was taken using electronic balance after blotting the animal on a filter paper.

Feeding—Prawns were fed with fresh clam meat twice per day. For feeding, food, approximately equivalent to 20% of the body weight of the animal was used. The unused food was removed after 6 to 8 hrs. The individual compartments and PVC tanks were cleaned daily. The moult, excreta and unused food were blotted and weighed separately. They were dried for sufficient length of time at 55°C until a constant weight was achieved and stored in the desiccators for further analysis.

Eyestalk ablation—Extirpation of eyestalk removes the X-organ-sinus gland complex. Different procedures are suggested viz., constriction of eyestalk with catgut, cauterization, enucleation and surgical removal of eyestalk. All these procedures are successful in unilateral eyestalk ablation (UEA), but in bilateral eyestalk ablation (BEA) occasional mortality was observed. In the present study eyestalk⁸ were removed using sterile surgical blades by which mortality was

reduced to the minimum. Prawns in the inter-moult stage were chosen for eyestalk ablation. During ablation, the eyestalk was ablated with the prawn held in pre-cooled sea water to reduce the heart beat rate and loss of haemolymph. For bilateral eyestalk ablation, the second eyestalk was removed after a considerable lapse of time. By adopting this procedure zero mortality was achieved. The ablated prawns were maintained in separate troughs.

Growth studies—Two sets of experiments using different size groups were conducted lasting for 15 days. The set consisted of (1) *Metapenaeus dobsoni* : 35-40mm. size group and (2) *Metapenaeus dobsoni* : 48-53 mm. size group. For both the experiments on growth, salinity was maintained at 16 ± 1 PSU. The prawns were acclimatized at this salinity for about a week and eyestalks were ablated. The animals were starved for 24 hr and weighed before the commencement of the experiment. In each set of experiment, 24 prawns were maintained, 8 BEA, 8 UEA and 8 intact ones as control animals. The prawns were maintained individually in separate containers. The initial and final length and weight measurements of individual prawns were recorded. The calorific values of different samples were determined by the acid digestion method. In each analysis 0.1 g of the dried sample was used. Four samples of each material were digested and mean value taken. The calorific values were expressed as cal/g dry weight.

Moult and growth—The growth of crustaceans can be described in terms of the growth factors at each moult and the duration of the successive inter moult periods. The growth factor is the percentage increase in body size at the moult. The growth process basically represents a balance between wear and deterioration on one hand and repair and regeneration on the other, a process that under certain conditions also leads to increase in body size²².

The crustacean body is ensheated by a thick covering of cuticle called exoskeleton secreted by the epidermis. The presence of this rigid exoskeleton hinders growth and the growth process in crustaceans is achieved only by periodic shedding of the cuticular exoskeleton. This shedding of skeleton or moulting forms the most important metabolic event which dominates the life cycle of crustaceans²³.

It has been known that a typical arthropod under good conditions doubles its weight and increases its linear size at each ecdysis (Prizbran and Megusar, 1912 as cited by Needhan²⁴). This ratio was disputed

by Kadur , who reviewed various aspects of relationship of moulting and growth, to age or size of the crustaceans. During moulting the crustaceans show many cyclic changes in the structure, physiology and biochemistry, leading to growth²⁶. Effect of eyestalk ablation on moulting and growth has been done mainly on lobsters and in most of these cases, growth was estimated in terms of increase in length or wet body weight²⁷⁻²⁹. Eyestalk ablation especially bilateral eyestalk ablation leads to accumulation of water³⁰. Hence increase in wet weight of body cannot be taken as the appropriate criteria to evaluate the growth. Hence growth is measured in terms of dry weight increase, production in calories besides the increase in length and wet body weight. Along with this, conversion and growth efficiencies of the prawns were also evaluated. Further, whole body protein, lipid and carbohydrate composition were also estimated for assessing growth.

Production—Production P is defined as $P = P_2 - P_1 + M$ where P_2 is the energy content of the animal after experimental period, P_1 is the initial energy content and M is the calories expended in terms of moult formed. This value gives the actual amount of energy invested which can be considered as the real growth.

Net growth efficiency—The net growth efficiency of ablated and control prawns was estimated by the formula, Net growth efficiency = $\{Px100\}/A$ where P is the production in calories and A is the assimilation in calories.

Food conversion ratio (FCR)—Food conversion ratio was determined by the formula of Sedgwick³¹. $FCR = \text{total dry weight of food fed (g) / total wet weight gain (g) over the experimental period.}$

Protein efficiency ratio (PER)—Protein efficiency ratio = $\text{Wet weight gain / dry weight of protein calculated using Sedgwick's formula}^{31}$.

Results

Food consumption—Eyestalk ablation significantly altered the food consumption rate (Fig.1). In the 35-40 mm size group the average weight of food consumed by the BEA prawns (0.101g) was 21.5% less than the consumption of control prawns (0.129g). However, the UEA prawns showed not much change in the consumption rate (0.128g) compared to control prawns. In the 48-53 mm size group consumption rate of BEA prawns (0.146g) was 43.4% less than that of the control prawns (0.257g) and that of UEA prawns (0.360g), 57.8% more than that of the control. More variation in the food consumption rate among the

prawns was observed in the smaller size group. The difference in the food consumption in both size groups were found to be highly significant ($t_{(14)} > 11.9632, P < 0.05$) except between UEA and control of the lower size group ($P > 0.05$) (Table 1).

Moulting—Ablation was found to have a significant effect on moulting (Table 2). In the lower size group, the differences in the moulting frequencies among ablated and control prawns were found to be significant ($F_{(2,14)} = 10.34, P < 0.05$). This comparative study was carried out after transforming the data as $Y = X^{2.5}$ for additive purpose of the original data for the application of F test³². The average moulting frequencies of BEA, UEA and control prawns were 3.0, 2.5, and 2.0 respectively. In the higher size group, the moulting frequencies were additive and hence no transformation was required. Analysis of variance carried out showed that the differences were highly significant ($F_{(2,14)} = 19.05, P < 0.05$). The average rate of moulting of BEA, UEA and the control prawns were 3.0, 2.3 and 1.3 respectively indicating more than double the rate for BEA and exactly double the moulting rate for UEA when compared to that of the control. In the lower size group, the average moulting days for the first to second moult was 6.75, 8.5 and 11.25 days while for the moulting from second to the

third, the average intermoult days were 5.57, 6.67 and no third moult for the BEA, UEA and control prawns respectively. In the case of larger size group the average intermoult period for the moulting from first to second was 6.125, 8.5 and 10 whereas for moulting from second to third, the values were respectively 4.83, 5.67 and no third moult for BEA, UEA and intact prawns. It has been inferred that bilateral ablation was a very strong inducer of moulting during any season of the year³³.

Moult weight—In order to investigate whether accelerated moulting by eyestalk ablation has affected the quality of moult, the dry weight of moult was recorded. In the size group, 35-40mm, the average moult dry weight for BEA was 18.48% more than the control while 6.78% more than the UEA. In single eyestalk ablation an increase of 10.91% was observed with respect to intact prawns. Hence an increase in dry weight of first moult resulted at each stage of eyestalk ablation. But after the second moult (intact prawns had not moulted in few cases) there was no significant difference between the dry weight of moults of BEA and UEA and that of BEA and control ($t_{(14)} < 0.71664, P > 0.05$). In the third stage of moult, dry weight had decreased by 4.40% for BEA ($X = 0.0087g$) compared to UEA ($X = 0.0091g$)

Table I—Significance of the difference between the food consumption in *M. dobsoni* tested using Student's *t* statistics

Level of ablation	35-40mm size group			48-53 mm size group		
	BEA	UEA	Control	BEA	UEA	Control
BEA prawns		12.8909*	11.9632*		96.5088*	54.6499*
UEA prawns		—	0.2763		—	54.4746*
Control prawns			—			—
Average	0.101	0.128	0.129	0.146	0.360	0.257
Standard deviation	0.025	0.017	0.022	0.024	0.021	0.017
Coeff. of variaion(%)	24.713	13.415	17.140	16.595	5.920	6.665

*- Calculated *t* is significant at 1% level of significance ($P < 0.01$)

Table 2—Moulting frequency and intermoult periods of ablated and control prawns, *M. Dobsoni*

No	35-40 mm size group									48-53mm size group								
	Moulting frequency			Inter moult period 1			Inter moult period 2			Moulting frequency			Inter moult period 1			Inter moult period 2		
	BEA	UEA	Control	BEA	UEA	Control	BEA	UEA	Control	BEA	UEA	Control	BEA	UEA	Control	BEA	UEA	Control
1	2	3	1	7	8	*	6	*	*	3	2		6	10	*	5	*	*
2	3	2	2	6	10	12	6	*	*	3	3		6	8	*	6	6	*
3	2	3	1	8	8	*	*	6	*	2	3		7	8	11	*	5	*
4	3	3	2	6	7	11	5	7	*	3	2		5	9	*	4	*	*
5	3	2	1	6	10	13	5	*	*	3	2		7	11	*	4	*	*
6	3	2	1	7	9	*	6	*	*	2	2		6	6	9	*	*	*
7	3	3	1	7	7	*	6	7	*	3	2	2	7	8	*	5	*	*
8	3	2	2	7	9	9	5	*	*	3	3	1	6	8	*	5	6	*

whereas intact prawns had no third moult. Hence in general subsequent moult decreases the dry weight irrespective of the level of ablation. In higher size group, a decrease of 18.02% in dry weight of moult for BEA compared to control and a decrease of 22.22% compared to UEA was observed. UEA prawns recorded an increase of 5.402% in dry weight due to single eyestalk ablation compared to the control (Table 3).

In second moult same trend was observed, for BEA ($X^- = 0.013g$), a decrease of 39.81% with respect to control ($X^- = 0.0216g$) while for UEA ($X^- = 0.0224g$), an increase of 3.71% was observed compared to control (Table 3). Second eyestalk had drastically reduced the dry weight by an amount of 41.90%. In third moult the average has still reduced ($X^- = 0.0091g$) for BEA and for UEA ($X^- = 0.0229g$) and no third moult for control. But on comparing between eyestalks a drastic decrease in dry weight (60.41%) resulted due to the second eyestalk. In this case it is observed that unilateral eyestalk ablation resulted in gain in dry weight compared to no ablation. Also this gain in dry weight decreased after each successive moulting. A second ablation reduced the dry weight of moult and this decrease in the rate, in-

creased after each subsequent moult. Considering the three moults, it could be stated that BEA prawns showed a decrease in moult dry weight of 28.42% over that of the control while UEA recorded an increase of 4.55% over that of the intact prawns while successive ablation reduced the dry weight by 32.06% during moulting. The changes in the dry weight of moult were highly significant ($t_{(14)} > 2.076$, $P < 0.05$). It has been observed that the experimental vitellogenesis obtained by eyestalk ablation most frequently also hinders all limb bud growth, but occasionally permitted the development of the intermoult stage. It has also been observed³⁴ that intermoult periods of *Penaeus monodon* Fabricius increased with the increase in the size of the experimental shrimps, decreasing water salinity in the range 10-30ppt has no significant effects on Moulting cycle of *Penaeus monodon*.

Length—The length measurements of the species in the two size ranges studied showed that, in 35-40 mm size group, the average length increase recorded in the BEA ($X^- = 4.6875mm$) prawns were 17.19% and in the UEA ($X^- = 5.00mm$) prawns an increase of 25% compared to the control prawns, thus registering a decrease of 6.25% in the length increase due to second eyestalk ablation. In the higher size group, also a

Table—3 Significance of the difference between the dry weights of moults of *M. dobsoni* tested using Student's *t* statistics

Level of ablation	Moult 1			Moult 2			Moult 3		
	BEA	UEA	Control	BEA	UEA	Control	BEA	UEA	Control
<i>35-40 mm size group</i>									
BEA prawns	—	2.0761*	6.0385"	—	0.7166	—	—	—	—
UEA prawns	—	—	4.3521"	—	—	—	—	—	No moult
Control prawns	—	—	—	—	—	—	—	—	No moult
Average	0.01181	0.011063	0.009975	0.008888	0.008962	—	—	—	No moult
Stand. deviation	0.00212	0.001676	0.000829	0.000727	0.000291	—	—	—	No moult
Coeff. variation(%)	17.9554	15.15258	8.3085	8.1805	3.2500	—	—	—	No moult
<i>48-53 mm size group</i>									
Level of ablation	Moult 1			Moult 2			Moult 3		
	BEA	UEA	Control	BEA	UEA	Control	BEA	UEA	Control
BEA prawns	—	15.16067**	6.50611**	—	30.6142**	No moult	—	No moult	No moult
UEA prawns	—	—	1.7995	—	—	No moult	—	—	No moult
Control prawns	—	—	—	—	—	—	—	—	—
Average	0.019912	0.025600	0.02429	0.01307	0.02243	No moult	—	—	—
Stand. deviation	0.001306	0.002485	0.00486	0.001744	0.00149	No moult	—	—	—
Coeff. variation(%)	6.5567	9.7069	20.0088	13.3786	6.6662	No moult	—	—	—

** - *t* statistic significant at 1% level of significance ($p < 0.01$)

*- *t* statistic significant at 5% level of significance ($p < 0.05$)

similar trend was observed registering an increase of 176.55% for BEA ($X^- = 4.05\text{mm}$) and an increase of 38.13% for UEA ($X^- = 4.80\text{mm}$) compared to intact ($X^- = 3.475\text{mm}$). All the differences were statistically highly significant ($t_{(14)} > 10.3709$, $P < 0.05$) and length increase was highly homogeneous among the different prawns (C.V.% = 9.94).

Wet weight—In the lower size group, wet weight increase obtained was found to be significantly different ($F_{(2,14)} = 28.79$, $P < 0.01$). BEA ($X^- = 0.1406\text{g}$) and UEA ($X^- = 0.2341\text{g}$) prawns recorded 2.087% and 69.96% as increase in wet weight over the control ($X^- = 0.1378\text{g}$) thereby resulting in a decrease of 189.87% in the increase of wet weight in BEA compared to UEA. The difference in the increase between BEA and control was not significant ($t_{(14)} = 1.346$, $P > 0.05$). The distribution in wet weight was more uniform in the control prawns (C.V.% ≤ 5.90). In the case of the higher size group, the difference in wet weight increase among the ablated and control prawns was significant ($F_{(2,14)} = 173.98$, $P < 0.001$). BEA ($X^- = 0.2064\text{g}$) and UEA ($X^- = 0.31025\text{g}$) recorded an increase of 17.76% and 77.03% over that of the control ($X^- = 0.1753\text{g}$) whereas it registered a decrease of 33.48% due to second eyestalk ablation. The pairwise differences were all high ($t_{(14)} > 12.3459$, $P < 0.05$). In this case more uniformity was observed in the wet weight increase (C.V. % ≤ 7.649).

Dry weight—The values of dry weight of this species in the lower size group showed significant differences between the various levels of ablation ($F_{(2,14)} = 63.156$, $P < 0.01$) with average dry weight decrease of 0.02313g for BEA registering 194.38% decrease, and for UEA ($X^- = 0.05138\text{g}$), recording an increase of 109.69% compared to control ($X^- = 0.0245\text{g}$) thereby showing a decrease of 145.10% in the dry weight due to second eyestalk ablation. The dry weight increase was more homogeneous for UEA (C.V.% < 9.82) whereas for BEA, (C.V.% = 22.10) and control (C.V.% = 11.54), it varied with the prawns. All these differences in the dry weight at the three levels of ablation were highly significant ($t_{(14)} > 34.755$, $P < 0.01$).

Food conversion ratio (FCR)—Food conversion ratio was determined by the formula of Sedgwick³¹.

$FCR = (\text{total dry weight of food fed} / \text{total wet weight gain over the experimental period})$. FCR is determined to interpret utilization of food and conversion efficiency of prawns. FCR values were presented in

Fig.1a for lower size group and in fig.1b for larger size group. The FCR values when subjected to statistical two way ANOVA showed a significant difference among the ablated and control prawns ($F_{(2,14)} = 7.8938$, $P < 0.05$). The UEA prawns had the lowest average FCR in both the size groups indicating maximum food conversion efficiency. In 35-40 mm size group, BEA ($X^- = 3.0875$) showed a decrease of 18.35% while UEA ($X^- = 2.3038$), a decrease of 39.07% compared to the control ($X^- = 3.7813$) thereby recording an increase of 34.02% in FCR values due to second eyestalk ablation. Ablated prawns showed more variation (C.V.% = 11.12) than control prawns (C.V.% = 5.72) in FCR values with high significance between ablated and unablated prawns ($t_{(14)} > 12.7971$, $P < 0.05$).

In the higher size group, a similar pattern was observed indicating a decrease of 8.21% for BEA ($X^- = 3.0188$) over the control ($X^- = 3.2888$), while UEA ($X^- = 2.8788$) showed a decrease of 12.47% over that of the control. These differences were highly significant ($t_{(14)} > 14.4684$, $P < 0.05$) with high uniformity in FCR values (C.V.% = 6.42) in all cases of ablation.

Protein efficiency ratio (PER)—On analyzing quantitatively it was obtained that UEA prawns showed higher PER values in the two sets of experiments. Among the 35-40 mm size group of this species, the average values of PER for BEA ($X^- = 0.6365$) showed an increase of 24.77% while UEA ($X^- = 0.8515$) an increase of 66.92% over the control ($X^- = 0.5101$) with more uniformity in the distribution (C.V.% < 10.88). These differences were highly significant ($t_{(14)} > 13.9632$, $P < 0.05$) (Fig.1a). Among the larger size group, slightly lower values were observed generally with an increase of 19.38% for BEA ($X^- = 0.6429$) over the control ($X^- = 0.505$) while a decrease of 18.57% over UEA ($X^- = 0.7404$) thereby showing a net increase of 46.61% for UEA over the control prawns (Fig.1b). The observed values of PER were highly varying for BEA (C.V.% = 14.3) with significant difference between the ablated and intact prawns ($t_{(14)} > 8.056$, $P < 0.05$) in all pairs of comparisons.

Production—This value gives the actual amount of energy invested which can be considered as the real growth. The values of production for the UEA prawns were maximum in terms of calories and the values were 169.88 and 271.75 for the lower (Fig.1a) and bigger size group (Fig.1b) respectively. At the same

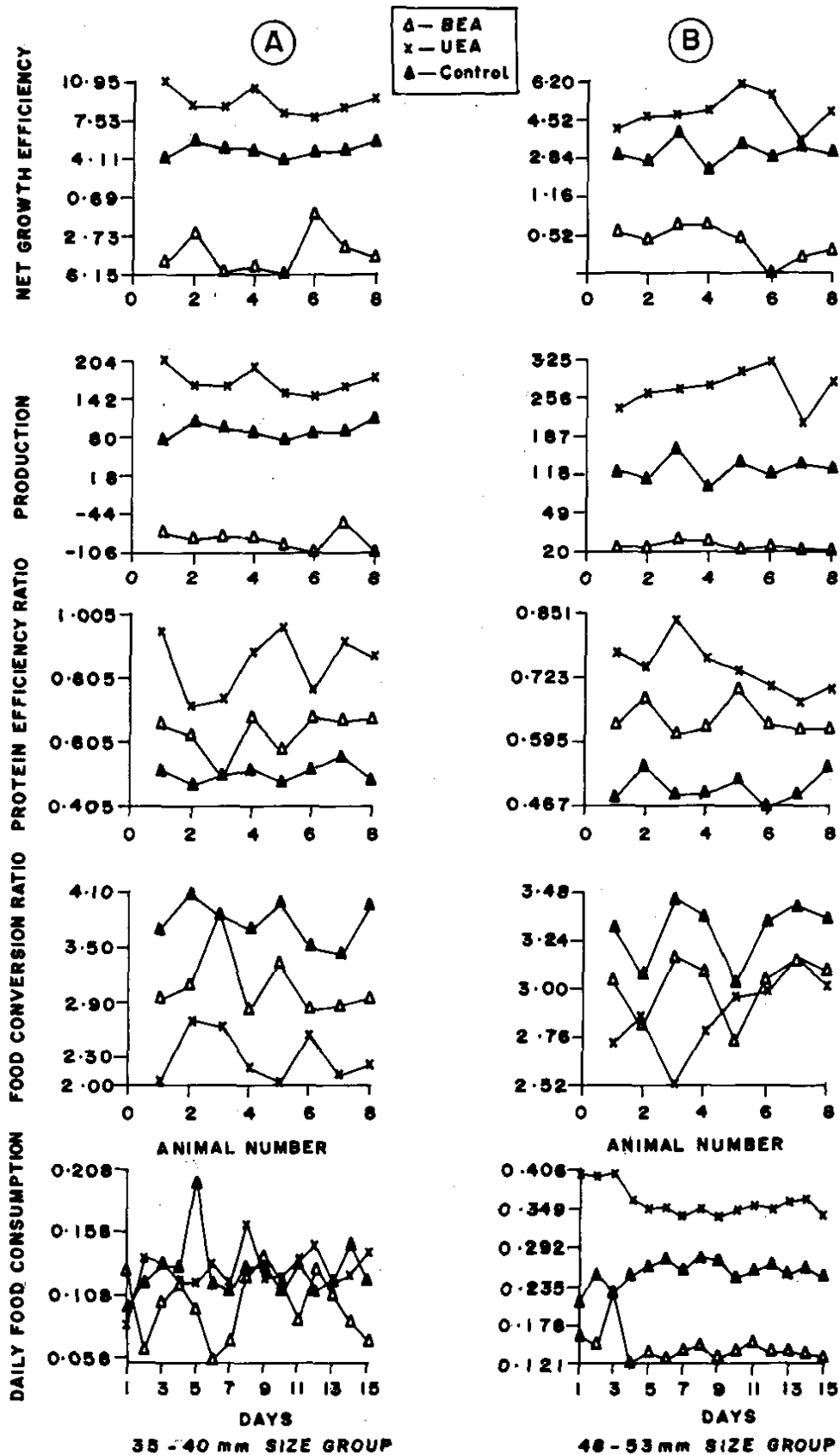


Fig. 1—Effects of eyestalk ablation on daily food consumption, food conversion ratio, protein efficiency ratio, production and net growth efficiency in A: 35-40 mm size group; B: 48-53mm size group of *Metapenaeus dobsoni*.

time for BEA prawns the corresponding values were negative (-84.75 for 35-40mm and -10.95 for 48-53mm size group) indicating that no growth has taken place. Among the intact prawns the values were respectively 92.375 and 128.875. The rate of decrease in production for BEA were 191.75% and 108.49% whereas for UEA the rate of increase were 83.89% and 110.86% compared to control indicating high degree of difference in the production values ($t_{(14)} > 26.3523$ for both size groups, $P < 0.05$) between ablated and un-ablated prawns with moderate variation in the production values ($11.32 < C.V.\% < 58.26$) at all levels of ablation.

Net growth efficiency—Values obtained for net growth efficiency showed that in 3 way ANOVA there is significant difference between the three levels of ablation ($F_{(2,14)} = 313.74\%$, $P < 0.001$) after transforming the data as $Y = (X+7)^{1.43}$ due to nonadditivity of data for the lower size group and the transformation is $Y = (X+2)^{0.86}$ for the bigger size group due to the same reason. BEA prawns recorded a net growth efficiency of -5.005 indicating a decrease of 200% compared to control ($X^- = 5.00$) and a decrease of 155.02% compared to UEA (9.0975). UEA prawns presented an increase of 81.9% with respect to control thereby showing high significance ($t_{(14)} > 26.2172$, $P < 0.05$) for the differences in net growth efficiency.

In the 48-53 mm size group, BEA ($X^- = -0.8363$) showed a decrease of 126.60%, UEA ($X^- = 4.8688$) an increase of 54.87% compared to control ($X^- = 3.1438$) which resulted in a decrease of 117.18% due to second eyestalk removal. All these differences were highly significant ($t_{(14)} > 14.5752$, $P < 0.01$) with high variation with respect to different animals ($C.V.\% > 82.75$).

Discussion

UEA prawns consumed more food than the control prawns as observed³⁵ in crayfish, adult *Procambarus clarkii*, where unilateral eyestalk ablation resulted in a significant increase in the food consumption rate for ablated compared to non-ablated thereby stating that physiological components has a positive effect on integrating the energetic balance. Dry weight of moult in every successive moult was found to decrease irrespective of the level of ablation in this study while Stella *et al.*³³ had drawn the inference that bilateral ablation is a very strong inducer of moulting. Average intermoult period increased with second eyestalk ablation irrespective of size group whereas Jeraporn³⁴

observed that intermoult periods of *Penaeus monodon* Fabricius increased with the increase in the size of the experimental shrimp.

It has been suggested that the size alone may not be taken in account in determining the age and that older individuals of smaller size might be present in the sample. Chakravarthy³⁶ noticed that there was loss of pigmentation in the eyestalk ablated animals especially after moulting. He noticed that the animals were dark blue with blue bands dorsally on the exoskeleton. After eyestalk ablation the animals developed crimson red pigmentation particularly at the terminal parts of the body and also on the peopods gradually becoming grayish white in colour. He further noticed that in his study on males of *Macrobrachium rosenbergii* (de Man) shortening of the intermoult period and increase of growth was more in bilaterally eyestalk ablated prawns than in unilaterally ablated ones or the controls. High mortality following eyestalk ablation has been reported in many crustaceans. It had also been noticed³⁵ that mortality was high in eyestalk-less animals. It was more in bilaterally ablated prawns than the unilaterally ablated ones. High mortality in bilaterally eyestalk ablated animals and high survival in unilaterally ablated animals was observed in *Macrobrachium lankesterii*. It was found that several operated animals died at the time of moulting particularly in bilaterally eyestalk ablated prawns. It is due to the fact that there is a rapid increase in the body size of the eyestalk-less animals followed by impairing preparations for moult and this leads to failure at moult ultimately leading to death. High survival rate and generally higher growth rate of unilaterally ablated lobsters compared with unablated lobsters resulted in the highest gross yield, indicating that unilateral ablation may be a viable option to consider in accelerating the growth of small juvenile of *Pamclirus ornatus* to a marketable size of 200-300g³⁷.

In an attempt to increase the frequency of moulting through eyestalk ablation, it was revealed³⁸ that the smaller size group responded quickly than the bigger size group. The weight increment in all the size groups of his study showed a steady rate of growth. Sanjeevraj *et al.*³⁸ also observed that both moulting and growth in eyestalk ablated prawns recorded higher values than that of their unablated counterparts with a striking difference in the food conversion efficiency between the ablated and unablated groups as observed in the present study. In the study on social control of growth in *Macrobrachium rosenbergii* V.

following unilateral eyestalk ablation on jumpus and lazzards, it was observed³⁹ that, eyestalk ablation had no effect on growth of male jumpus and ablation had a highly significant effect on growth of male and female lazzards, manifested in both, increase in size increment per moult and shortening of moult interval. In the present study, average intermoult period increased with second ablation. During winter, in *Cherax quadricarinatus*, both females, that had spawned previously and first time spawners that were eyestalk ablated, moulted significantly and more frequently than intact females⁴⁰. In the present study, dry weight of moult in every succeeding moult was found to decrease irrespective of the level of ablation. Unilateral eyestalk ablation resulted in increase in dry weight whereas bilateral eyestalk ablation reduced the dry weight of moult and this decrease in the rate, increased after each subsequent moult. In the larger size group, values of protein efficiency ratio (PER) were almost same as that of the lower size group. The UEA prawns exhibited highest conversion efficiency. The production rate of UEA prawns was 84% more than that of the control whereas BEA prawns indicated negative production. The same trend followed for net growth efficiency also. The results suggest that unilateral eyestalk ablation can be resorted to accelerate growth and conversion efficiency.

References

- Bliss D E, Endocrine control of metabolism in the land crab, *Gecarcinus lateralis* (Frem.). 1. Differences in the respiratory metabolism of sinus glandless and eyestalk-less crabs, *Biol Bull* (Woods Hole, Mass.), 104 (1966) 275.
- Abramowitz R K & Abramowitz A A, Moulting, growth and survival after eyestalk removal in *Uca pugilator*, *Bio Bull*, 78 (1940) 179.
- Scudamore H H, The influence of the sinus gland upon moulting and associated changes in crayfish, *Physiol Zool*, 20 (1947) 187.
- Ponnuchamy R, Reddy S R & Shakunthala K, Effect of eyestalk ablation on growth and food conversion efficiency of fresh water prawn, *Macrobrachium lankesteri* (de Man). *Hydrobiologia*, 77(1981) 77.
- Cooke M I & Sullivan E R, Hormones and neurosecretion in *The biology of Crustacea*, Vol.3, edited by D E Bliss and H L Mantel (Academic Press, London), 1985, 205.
- Carlisle D B & Dohrn P F R, Sulla presunza di un ormone d' accrescimento in un Crustacea decapoda, *La Lysmata seticaudata*. *Risso Ric Sci Torino*. 23(1953) 95.
- Heit M & Fingerman M, The role of an eyestalk hormone in the regulation of sodium concentration of the blood of the fiddler crab *Uca pugilator*, *Comp Biochem Physiol*, 50A (1975) 223.
- Naghabhushanam R & Jyothi M, Hormonal control of osmoregulation in the fresh water prawn, *Caridina weberi*, *J Anim Morphol Physiol*, 24 (1977) 20.
- Santiago A C, Successful spawning of cultured *Penaeus monodorn* (Fab.) after eyestalk ablation, *Aquaculture*, 11(1977) 185.
- Primavera J H, Induced maturation and spawning in 5 month old *Penaeus monodorn* (Fab.) by eyestalk ablation, *Aquaculture*, 13(1978) 355.
- Zaib Un Nisa Ahmed M, Natural and induced spawning of Pakistan penaeid shrimps in the laboratory. *J Zool*, 33:2, (2001) 125.
- Lin J Zhang D & Crewell R L R, Lake Buena Vista, FL(USA), 21-25 Jan, *Aquaculture*, (2001) 378.
- Murugadas S & Mathavan, Influence of eyestalk ablation on somatic growth and egg production in the commercially important riverine prawn, *Macrobrachium malcolmsonii*. *Asian Fish Sci*, 1 (1987) 124 (Abstract only).
- Venkitaramiah A, Lakshmi G J & Gunter G, Effect of protein level and vegetable matter on growth and food conversion efficiency of brown shrimp. *Aquaculture*, 6(1973) 115.
- Qasim S Z & Easternson D C V, Energy conversion in the shrimp *Metapenaeus monoceros* (Fab.) Fed on detritus, *Indian J Mar Sci*, 3(1974) 131.
- Royan J P, Sumithra Vijayaraghavan & Wafar M V M, Food conversion efficiency in the shrimp *Metapenaeus monoceros* (Fab.) fed on different foods, *Indian J Mar Sci*, 6 (1977) 100.
- Sumithra Vijayaraghavan, Wafar M V M & Royan J P. Feeding experiments in the *Metapenaeus monoceros* (Fabr.) *Indian J Mar Sci*, 7(1978) 185.
- Perez Cruz M E & Luna Figueroa J, Effect of the unilateral ablation of the eyestalk extirpation on the energy budget of juveniles of the Malayan prawn *Macrobrachium rosenbergii*, *J Univ Cienc Technol*, 4:1 (1995) 10.
- Nair K K C, Gopalakrishnan T C, Sankaranarayanan V N *et al.*, Closed sea water/brackish water flow through siphon system for the cultivation, maintenance and management of marine/estuarine organisms under controlled/simulated conditions. CSIR patent filed in 1992 (no.829) and granted in 2001(no.186483/15-9-2001).
- Strickland J D H & Parsons T R, *A practical handbook of sea water analysis* (Fish. Res. Bd. Canada) 167(1963) 311.
- Karzinkin G S & Tarkovskaya O I, *Techniques for the investigation of fish physiology*, edited by E N Pavlovski, (Academic Press, New York) 1964, 122.
- Aiken D E, Moulting and growth, in *The biology and management of lobsters*, edited by JS Cobb and BF Phillips (Academic Press, New York), Vol. 1, 1980 91.
- Highnam K C & Hill L, *The comparative endocrinology of the invertebrates*. (English Language Book Society) first edition, 1979, 298.
- Needhan A E, Temporal pattern of growth, in *The growth process in animals*, (Pitman, London), 1964 16.
- Kadur H A, Ionic influence on oxygen consumption in *Metapenaeus monoceros* (Fab.), *J Anim Morphol Physiol*, 9 (1962) 32.
- Passano L M, Moulting and its control, in *Physiology of Crustacea*, edited by TH Waterman (Academic Press, Inc., New York). 1(1960) 73.
- Sochasky J B, Failure to accelerate moulting following eyestalk ablation in decapod crustaceans, *Fish Res Board Canada*, 431(1973) 1.
- Rao K R, Fingerman S W & Fingerman M, Effects of exogenous ecdysones on the moult cycles of fourth and fifth stage in American Lobsters, *Homarus americanus*. *Comp Biochem Physiol*, 44A (1913) 1105.

- 29 Radhakrishnan E V & Vijayakumaran M, Effect of eyestalk ablation in spiny lobster *Panulirus homarus* (L.) Moulting and growth, *Indian J Fish*, 31(1984) 130.
- 30 Kamemoto F I & Tullis R E, Hydro-mineral regulation in decapod Crustacea, *Gen Comp Endocrinol*, 3(1972) 299.
- 31 Sedgwick R W, Influence of dietary protein and energy on growth, food consumption and food conversion efficiency in *Penaeus merguensis* (de Man), *Aquaculture*, 16(1979) 7.
- 32 Federer W G, *Experimental designs* (Wiley International Publishing company, NewYork) 1967, 467.
- 33 Stella V S, Lopez Greco L S & Rodriguez E M, Effects of eyestalk ablation at different times of the year on moulting and reproduction of the estuarine grapsid crab, *Chasmagnathus granulata*, *J Crust Biol*, 20:2 (2000) 239.
- 34 Jirapom Trisak, Moulting periods of *Penaeus monodon* Fabricius and the experiments on moulting stimulation by water changing, salinity control, eyestalk ablation and application of tea seed cake. Abstracts of master of science theses, *Fish Sci*, (2000) 32.
- 35 Sierra Uribe E, Diaz Herrera F & Bueckle Ramirez L F, Effect of unilateral eyestalk ablation on the physiological energetics of *Procambarus clarkii*, *Aquaculture*, 40 (1999) 13.
- 36 Chakravarthy M S, Effect of eyestalk ablation on moulting and growth in prawn *Macrobrachium rosenbergii*, *Indian J Mar Sci*, 21(1992) 287.
- 37 Juinio Menez M A & Ruinata J, Survival growth and food conversion efficiency of *Pamilirus ornatus* following eyestalk ablation, *J Aquaculture*, 146:3-4 (1996) 225.
- 38 Sanjeevraj G, Ravikumar B & Gopalakrishnan P, Effect of eyestalk ablation on moulting and growth of different size groups of *Macrobrachium rosenbergii*. *Proceedings of the National Seminar on water quality issues in aquaculture systems*, Dec. 18-19, 1996,(1997) 147.
- 39 Ilan Karplus & Gidian Hulata, Social control of growth in *Macrobrachium rosenbergii* V. the effect of unilateral eyestalk ablation on jumpus and lazzards. *Aquaculture*, 138:1-4 (1995) 181.
- 40 Amir Sagi, Rami Shoukrun, Tal Levy *et al.* Reproduction and moult in previously spawned and first time spawning red claw cray fish *Cherax quadricarinatus* females following eyestalk ablation during winter reproductive arrest period. *J Aquaculture*, 156:1-2(1997)101.