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Studies on Molting, Molting Frequency and Growth of Shrimp (*Penaeus monodon*) Fed on Natural and Compounded Diets

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Abstract

Postlarval and subadult *Penaeus monodon* were reared in plastic bowls and tanks and fed on different natural diets - mussels, chopped shrimp and beef liver - and compounded dry and moist diets in order to investigate the relationship of molting to growth. Molting frequency was found to vary according to diet. Smaller shrimp had greater frequency of molting than larger ones.

Introduction

Molting is one of the most important physiological processes for crustacean growth since increase in body size occurs in a series of steps associated with the castings of the old exoskeleton (Passano 1960). In shrimp, as in other crustaceans, the rate of growth is a function of both the frequency with which they molt and the size increment per molt (Kurata 1962; Schafer 1968; Wickins 1982). As there is a paucity of information in the literature regarding these important biological aspects in the largest penaeid shrimp (*Penaeus monodon*), the present study was undertaken with the objectives of investigating the molting frequency of postlarval and subadult *P. monodon*, with emphasis on the influences of diets (natural and compounded) on the molting and gain per-molt increment. The work is based on the author's M.Sc. thesis (Kibria 1985).

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Materials and Methods

The experiment was undertaken at the Unilever Findon Research Station, Scotland, UK. Two size groups of *P. monodon*, postlarval (0.015-2.500 g) and subadult (14.00-26.00 g), were used to study molting and growth. The shrimp were reared in local seawater at 29±1°C.

Postlarvae were reared in small circular plastic bowls (34 cm diameter) and subadults in rectangular tanks (1 m^2). The bowls were covered with plastic lids, and tanks with plastic sheets to prevent loss of shrimp and to reduce evaporation, i.e, to maintain salinity at 20 ppt.

Every morning, each bowl and tank were checked to collect any molts and to record numbers of dead shrimp before siphoning off any uneaten food.

Experiments with Postlarvae

The postlarvae were offered a variety of diets (Table 1) in two experimental situations. Water flow was 1 $l \cdot min^{-1}$ and the pH of the water was 7.3-7.35.

Table 1. Diet components of postlarvae and subadult *P. monodon*.

Feed	Proteins	Carbohydrates	Oil	Ash	Moisture
FC1	32.5	11.0	3.5	10.5	36.5
FC16	45.0	17.6	4.0	17.2	10.0
Mussel	57.2	20.4	4.6	8.6	9.2
President	43.4	22.2	4.5	12.5	8.4

Following a first (failed) experiment in which molts could not be found, the procedure outlined below was used.

Postlarvae between 0.516 and 0.87 g were used. The duration of the experiment was 28 days. Fifteen bowls were stocked at the rate of 10 postlarvae per bowl (i.e., 112.5$\cdot m^{-2}$). Small pieces of plastic tags were used to mark each postlarva; each mark was dipped into superglue (Beecham, UHU, UK) and carefully inserted onto the carapace. Molted prawns left their exoskeleton along with the plastic piece on the carapace, so whether molts were eaten or lost, it was possible to count the number of postlarvae molted, simply by observing the numbers with tags and numbers without tags. Molted shrimp were retagged every day.

Experiments with Subadults

Subadult shrimp were reared in six 1-m^2 tanks and fed with three different compounded diets. Temperature was as above, but water flow was 6 $l \cdot min^{-1}$.

The length of trial was 42 days and shrimp were between 19.54 and 25.88 g. Stocking density was 10 per tank (i.e., $10 \cdot m^{-2}$). Individuals were marked with plastic tags (as for the postlarvae) and, in addition, bird rings were placed on the eye stalk. This technique facilitated identification of individual shrimp and also allowed the study of molting frequency and growth of individual shrimp irrespective of size, sex and diet. Molted shrimp lost their tags along with their carapace; however, the bird ring remained on their eye stalk.

Six shrimp were randomly selected (two per diet) to study weight change in relation to premolt, postmolt and intermolt stages. These shrimp were weighed at two-day intervals.

Handling of Experimental Data

The following definitions were utilized to analyze data relevant to molting, molting frequency and growth rate:

- Molting rate M_r = M/N where M = number of molts and N = number of living shrimp;
- Molts per day M_d = M/d where d = length of trial in days;
- Molt cycle M_c = N/M_d where N = average number of living shrimp;
- Mean daily weight gain (A_{dg}) = b-a/d where a = mean initial weight; b = mean final weight;
- Per cent gain per day = 100(lnb - lna)/d.

Results and Discussion

The average molt cycle of the postlarvae was found to range from 4.3 to 5.7 days and the intermolt period slightly increased with size (Fig. 1).

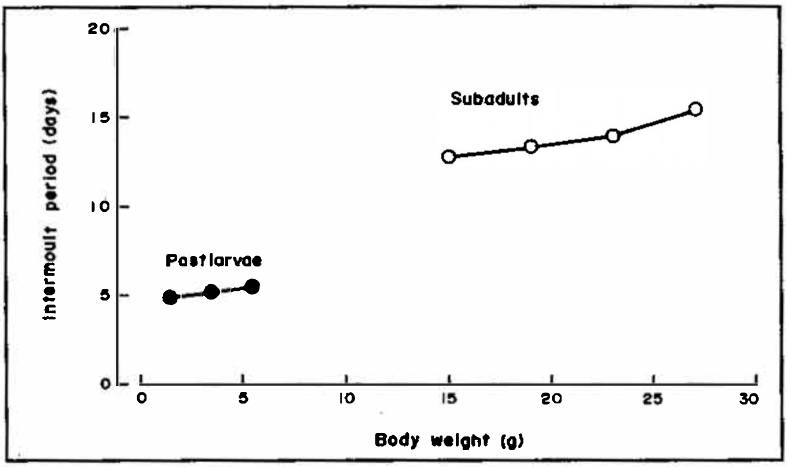

Fig. 1. Relationship between intermoult period and size of subadult and postlarvae shrimp.

Postlarvae fed on compounded diets (FC1 and FC16) had better growth rates than those fed on fresh diets (mussels and liver). Low survival of postlarvae was found with the chopped shrimp diet and postlarvae were found dead following ecdysis.

An approximately linear relationship was found between the size of shrimp and the intermolt period (Fig. 1). It was also observed that the molting frequency declined as the shrimp increased in size. The intermolt period varied between sexes (Table 2). Male *P. monodon* had a slightly longer intermolt period than females, which may be related to the slightly higher growth rate obtained

Table 2. Mean intermolt period of male and female *P. monodon*.

Sex	Size range (g)	Intermolt period (days)
Male	13-16.9	13.33±1.7
Female	13.16.9	13.00±1.0
Male	17-20.9	13.47±1.9
Female	17-20.9	13.25±1.36
Male	21-24.9	14.62±1.05
Female	21-24.9	13.68±1.42
Male	25-28.9	16.33±1.25
Female	25-28.9	15.46±2.02

with female shrimp. The molt cycle period varied with the type of diet fed and averaged between 10.0 and 14.5 days for the subadult shrimp.

Growth rate correlated with the per cent gain per molt; the highest growth rate, with FC1, resulting in highest percentage gain per molt (Table 3).

Table 3. Key statistics on postlarvae reared over a period of 4 weeks and of subadult *P. monodon* reared for 6 weeks.

	Postlarvae[a]			Subadults[b]		
Diet	Molt cycle (days)	% Gain (day^{-1})	% Gain per molt	Molt cycle (days)	% Gain (day^{-1})	% Gain per molt
FC1	4.25	5.11	25.78	13.8	0.31	7.10
FC16	4.99	4.85	20.6	14.5	0.22	6.00
Liver	5.15	4.26	22.0	-	-	-
Mussel	5.66	4.05	22.9	-	-	-
President	-	-	-	10.1	0.15	3.61

[a]For 30 postlarvae per treatment
[b]For 20 subadults per treatment

A cycle of weight gain and loss in *P. monodon* was observed during the premolt and the postmolt period and the loss of weight immediately following ecdysis averaged 4.9%, which can be linked with the loss of the old exoskeleton.

Determination of molting frequency on the basis of actual molts collected was not possible since many exuviae were eaten by the shrimp themselves. Shrimp with higher growth rate appeared to have less preference for their exuviae. Consumption of exuviae by other shrimp species has been reported by Forster (1976), Segal and Roe (1975) and Thomas et al. (1984). Although postlarvae fed liver (initial average weight 0.52 g) were smaller in size than those fed FC16 and FC1, they molted less frequently which may indicate that their diet and its composition influenced molting frequency. Wickins (1984) reported that the postlarvae of *P. monodon* (0.36-2.28 g) molted at an interval of 6-9 days, greater than observed here. In the larger shrimp, it was found that the intermolt period may be correlated with size, sex and diet.

In these experiments, the temperature was kept constant at 29±1°C. Several authors have reported that this and other factors affect molt frequency, e.g., temperature (Travis 1954; Catedral et al. 1977), hypercapnic seawater (Wickins 1984), light, food, temperature and water quality (Dall 1965), size and sex (Wickins and Beard 1974), water chemistry (Cripps 1976), density, food type and abundance, shelter and water temperature (Peebles 1977).

I found that there was a slight variation in the molt cycle of male and female *P. monodon* with respect to size. Such a correlation was not noticed in *P. indicus* by Emmerson (1980). However, my observation is similar to Kamiguchi's (1971), who found that smaller animals molt more frequently than larger animals, and that body size and sexual state also affect the length of the intermolt cycle.

Growth in *P. monodon* was also observed to vary depending on size, sex and diet. The growth rate was higher in smaller than in larger shrimp, related to the higher molting frequency observed in postlarvae. Natural diets gave the best growth and survival rate in the young postlarvae (initial experiment), but as the shrimp grew, the compounded diets FC1 and FC16 became better than natural diets. Weight gain per day was observed to increase with postlarvae size, but with the larger shrimp it decreased with increasing size.

Wickins (1978) and Lim et al. (1978) recorded good growth of *P. monodon* postlarvae when fed with natural diets (fresh mussel, frozen shrimp, squid meal, shrimp meal and fresh brown mussel) which is also confirmed in my initial experiment.

Female *P. monodon* gained slightly more weight than males although statistical analysis did not show any significant difference between sexes ($P>0.05$). Liao (1977) indicated that there is a significant difference in growth between male and female *P. monodon* over 13.03 g in extensive culture, and over 28.51 g in intensive culture. Since the shrimp were below 28.51 g, this may have been the reason for nonsignificant differences between sexes in the present study. Motoh (1981) states that growth disparity between sexes begins at approximately 2.5 months.

The protein levels of diets FC1 and FC16 (which gave the best growth to postlarvae and large shrimp) were 32.5 and 45%, respectively. Alva and Lim (1983) obtained best growth of *P. monodon* with 40% protein diet. Bages and Sloane (1981) stated that the growth of *P. monodon* was proportional to the amount of protein in the diet. The overall best growth was produced by the moist diet FC1. New (1976) suggested that moist diets are more efficient than dry ones for rearing shrimp due to the leaching of soluble attractant materials from moist diets and also partly to the destruction of labile components in the dry compounded diets.

In the present experiments, there was found to be a correlation between molting and mortality of *P. monodon*. A higher mortality was obtained with the postlarvae and subadult shrimp fed with chopped shrimp and President diet, respectively. Highest mortality was recorded with postlarval shrimp on the day of molting: 57% subadult shrimp died on the day of molting, 29% one day after molting and 14% two days before the expected molting day. Alva and Lim (1983) reported that mortalities of *P. monodon* juveniles were highest at molt state B (52.9%) followed by state A (31.6%) and state C (15.5%). According to the study made by Peebles (1978) on *Macrobrachium rosenbergii*, postmolt animals in states A and B suffered their mortalities within 24 hours and premolt shrimp in state D became more susceptible to death with time.

There was an observed weight change during the premolt and postmolt state in *P. monodon*. A sharp increase in weight began about two to three days before molting and about two to four days following molting. Just after ecdysis a sudden drop in weight was recorded which appeared to be related to the loss of the old exoskeleton. Carlisle (1960) and Lockwood (1968) observed a similar weight gain in other crustaceans and suggested that this was due to water absorption, firstly for the removal of the old exoskeleton, and also to expand the soft new cuticle.

From the above study, it can be concluded that more research is needed on molting, in particular with very young postlarval *P. monodon* in order to obtain higher growth and to lower the mortality rate that is associated with molting. There is a need to know further about how to increase the frequency of molting to achieve better growth. Factors such as growth, reproduction, natural mortality, migration and recruitment are known to have close links with the molt cycle of crustaceans (Caddy 1987).

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