GROWTH OF THE BLUE SWIMMER CRAB, *PORTUNUS PELAGICUS* (LINNAEUS, 1758) (DECAPODA, BRACHYURA) IN CAPTIVITY

BY

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ABSTRACT

The growth of hatchery produced *Portunus pelagicus* crabs was monitored under laboratory conditions by recording growth at each moult from the 1st crab instar onwards. Male and female crabs attained sexual maturity by their 12th and 14th moult, respectively. The experiment lasted for 455 days when the last crab died. This paper describes the growth of male and female crabs in each moulting stage, with details of their carapace width and length, chelar length and height, abdominal width and length, and total weight. Moulting frequency, secondary sexual characteristics, and moult increments were also monitored. VBGF (Von Bertalanffy Growth Formula) fit was obtained using the methods of Gulland & Holt (1959), Fabens (1965), and Munro (1982). The L_∞ values calculated by the different methods ranged between 204.1 and 219.8 mm in males, and between 188.6 and 211.8 mm in females.

RÉSUMÉ

La croissance des crabes *Portunus pelagicus* nés en écloserie a été suivie en conditions de laboratoire en notant la croissance à chaque mue à partir du 1er stade crabe. Les crabes mâles et femelles atteignaient la maturité sexuelle à leur 12ème et 14ème mue, respectivement. L'expérience s'est terminée après 455 jours à la mort du dernier crabe. Ce travail décrit la croissance des crabes mâles et femelles à chaque stade de mue, avec les détails de largeur et longueur de la carapace, longueur et hauteur des pinces, largeur et longueur de l'abdomen et poids total. La fréquence des mues, les caractères sexuels secondaires, et les augmentations de mue étaient également suivis. La VBGF (formule de croissance de Von Bertalanffy) a été calculée en utilisant les méthodes de Gulland & Holt (1959), Fabens (1965) et Munro (1982). Les valeurs de L_∞ calculées par les différentes méthodes étaient de 204,1 à 219,8 mm chez les mâles et 188,6 à 211,8 mm chez les femelles.

INTRODUCTION

The blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758), is the major marine crab landed from bottom trawl nets and set gill nets in India. Because of

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its importance in terms of availability, abundance, and local or export demand, a detailed investigation was conducted on its growth pattern. Moreover, in recent years shrimp culture has encountered heavy losses due to disease outbreaks in Asia, which warrants the need to diversify culture operations in order to utilize the farm and to include other biologically suitable and economically viable crustaceans in the production process. The authors have studied the complete larval development of the species in an elaborative way (Josileen & Menon, 2004) and mass seed production technology has also been developed (Josileen, 2001). The present study provides information on the suitability of the blue swimmer crab for mariculture.

Crustaceans are equipped with a hard exoskeleton that must be shed in order to grow, i.e., through moulting or ecdysis. Quantifying patterns of crustacean growth is difficult. Although there have been many studies, there is no generally accepted or convincing model describing crustacean growth, which is comparable to the models widely applied to fish growth. Among the reasons for this are the complications of incremental, discontinuous growth by moulting and the variety of life history strategies expressed by crustaceans. The best way of describing the growth of many crustacean species is by observing their moulting pattern. Crustacean growth is dependent upon the duration of the intermoult (moult interval) and size increase at each moult (moult increment) (Hartnoll, 1982). The processes of the moulting cycle have been adequately described by Skinner (1985).

This paper presents the growth of *P. pelagicus* from the first crab stage to sexual maturity, and further to the 16th crab stage. Moulting frequencies in males and females, growth increment (length, width, weight), secondary sexual characteristics, the maturation moult, and behaviour during moulting are all described.

MATERIALS AND METHODS

The growth of *Portunus pelagicus* from the first instar to stage 16 was studied by rearing the crabs in the laboratory. For this purpose, the juvenile blue swimmer crabs were produced in the hatchery. Forty-five healthy crabs (instar I) within a size range of 2.0-2.5 mm carapace width (CW) were used for the experiments (a total of 3 trials, with 15 crabs each).

First instar crabs were stocked in two-litre capacity plastic tubs (one crab in each tub), reared until they attained 10 mm CW, and then transferred to 30-litre capacity plastic tubs (one crab in each tub) until they reached a minimum size of 35 mm CW. Plastic tubs were provided with a sand bottom and small shelters. These experiments were conducted at a salinity of 35 ± 1‰ in filtered seawater. Ninety percent water exchange was done once each morning between 08.30 and

09.30 hours. Animals were fed with egg-prawn custard until the size of 10 mm CW and later with fresh clam meat and small shrimps. Every day before feeding, excess feed and faecal matter were siphoned out and the water was replaced. Continuous aeration was provided in each tub. The tubs were arranged in such a way that all of them received a uniform exposure to light. Animals were observed daily for moulting. After each moult and subsequent sufficient hardening, morphometric and weight measurements were taken. The exuviae were collected and preserved.

Crabs above the size of 35 mm CW were transferred to a 1000-1 capacity fibreglass tank (at a maximum of 5 specimens /tank) provided with a sand bottom and coral stones, and with bamboo baskets as shelters. Each animal was given a number, using a "Letro" label maker. The label was attached to the carapace and readily visible through the water column, making it easy to identify and locate the moulted crab (fig. 1). Following each moult and after sufficient hardening of the exoskeleton, a new label was attached to the crab's carapace and measurements

Fig. 1. A group of experimental specimens of *Portunus pelagicus* (Linnaeus, 1758) with 'identity stickers' on the carapace.

were taken. Fifty percent of the water was exchanged daily. The feeding schedule as well as the observations continued as described above.

The maturation system for the crabs was developed in the hatchery following the methods suggested by Maheswarudu et al. (1996). The crabs above 60 mm CW were transferred into a collapsible polyvinyl pool of 8' diameter (approx. 2.50 m) with an 8000-litre capacity. An in situ sand bed filter of 5-10 cm height was set on a perforated, false bottom that was installed at about 15 cm height over the entire surface area of the maturation pool. Four PVC tubes of 1 m height and 50 mm diameter were fixed vertically in the peripheral region of the sand bed at equal distances. The water column in the pool above the sand bed was maintained at 75 cm depth. An air-water lifting system was arranged in the tank through the air dispersing stones. Water recirculation was maintained at the rate of 300% per day by lifting the filtered seawater from below the sand bed through the PVC pipes. Daily, a 25-30% water exchange was given and once in a week exchange was 100%. The pool was covered with a lid to reduce light intensity (<100 lux). Water pH was maintained at 8.0-8.2 by the addition of sodium carbonate whenever necessary. Individual numbers were given to the crabs in the same way as mentioned above. The animals were fed daily ad libitum with clam meat, shrimp meat, and squid meat in the morning and evening hours. Faecal matter and untaken food were siphoned out in the morning before water exchange. Animals were observed regularly, especially the female crabs, i.e., for spawning frequency in each moult cycle.

Water quality plays an important role in growth and maturation in captivity and the following water quality parameters were maintained throughout the experiment: salinity, $35 \pm 1‰$; temperature, 26-30°C; PH, 8.2 ± 0.1; dissolved O_2, 5-7 mg/l; ammonia, <0.1 ppm; nitrite, <0.05 ppm.

Temperature was monitored using a thermometer graduated 0-50°C. A digital meter was used for the determination of pH. Salinity was determined with a refractometer (ACUTE, Japan). Nitrite and ammonia were estimated using a nutrient kit (Merck, Germany).

Data analysis. — The data of the laboratory rearing experiments on the growth of male and female crabs were entered as a growth increment data file in the computer program FiSAT. Further analysis of growth increment for fitting a growth curve was carried out using Gulland & Holt (1959), Fabens (1965) and Munro's (1982) methods. The estimates of L_∞ and K thus obtained were analysed using the inverse Von Bertalanffy growth equation, to arrive at corresponding length at age. The optimum parameters (L_∞ and K) were fixed, based on the data obtained during the laboratory growth studies.

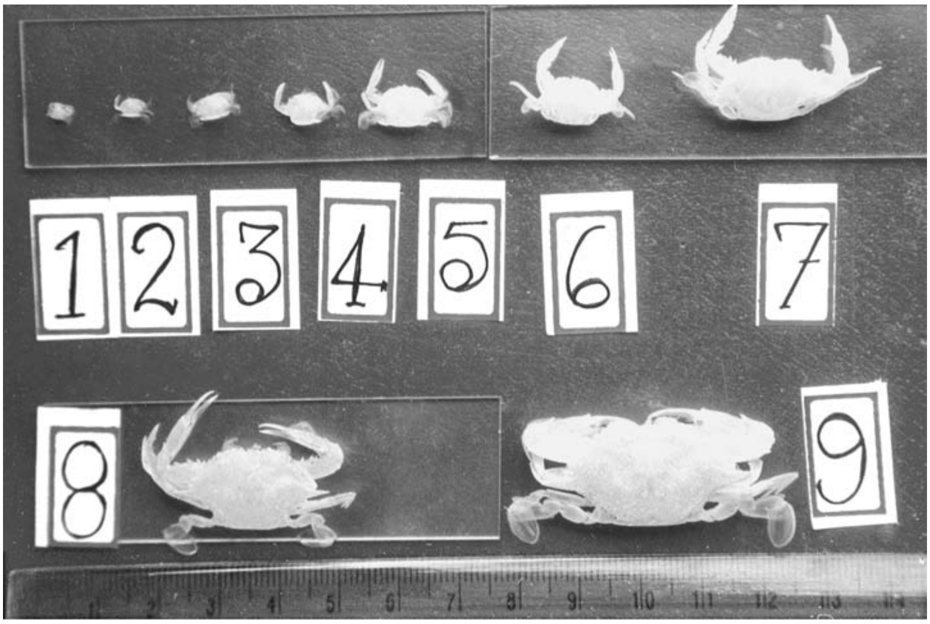

Fig. 2. Moulted shells of crab instars 1-9 of *Portunus pelagicus* (Linnaeus, 1758) grown in the laboratory.

RESULTS

Male crabs grew from an initial average carapace width of 2.38 ± 0.18 mm to 159.86 ± 3.52 mm CW, i.e., from first instar to 16th instar in a mean period of 272 days. Males were reared to a maximum of 455 days. The average total weight gained was 275.00 ± 25.41 g from an initial weight of 0.008 g (table I).

Female crabs grew from an initial average CW of 2.43 ± 0.34 mm CW to 154.31 ± 2.73 mm, and reached the 16th instar in a mean of 332 days. The average weight gain during that period was from 0.006 g to 210.33 ± 18.39 g (table II, and figs. 2, 3).

In male crabs, the average growth increment in carapace width increased steadily through the juvenile phase up to the 14th moult and then decreased. The same pattern of growth was observed in carapace length until the 14th moult. There after, it began to fluctuate. The highest percent growth per moult (CW) occurred from the 1st to 2nd instar (77.73%) and the lowest percentage was during the moult from 15th to 16th instar (13.06%). The carapace length increment showed the highest percentage growth per moult from the 11th to 12th instar (37.99%) while the lowest was from the 14th to 15th instar, (11.12%) (table III).

In females, the growth increment in carapace width increased through the 12th instar and then declined. The maximum percentual increase in carapace width was in the 1st to 2nd instar (68.72%) and the lowest was from the 15th to 16th instar

TABLE I

Growth (with standard deviation) of male *Portunus pelagicus* (Linnaeus, 1758) in the laboratory

Crab stage	Min. days from prev. instar	Total days	Max. days from prev. instar	Total days	Average days from prev. instar	CW (mm)	CL (mm)	CPL (mm)	CPD (mm)	TW (g)
1	0	0	0	0	0	2.38 ± 0.18	–	–	–	0.008
2	2	2	4	4	2.83 ± 0.76	4.23 ± 0.24	–	–	–	0.014
3	3	5	4	8	3.40 ± 0.55	5.13 ± 0.18	–	–	–	0.042
4	3	8	5	13	4.33 ± 1.03	6.55 ± 0.33	–	–	–	0.082
5	4	12	7	20	5.60 ± 1.14	9.10 ± 0.39	–	–	–	0.1
6	4	16	7	27	5.63 ± 1.19	12.13 ± 0.85	6.94 ± 0.31	–	–	0.189
7	4	20	7	34	6.00 ± 1.15	16.63 ± 0.25	9.00 ± 0.50	–	–	0.299
8	5	25	10	44	7.88 ± 1.73	23.17 ± 1.04	12.17 ± 0.29	–	–	1.088 ± 0.91
9	6	31	10	54	8.38 ± 1.41	33.86 ± 1.77	16.20 ± 0.41	–	–	2.41 ± 0.70
10	10	41	19	73	14.83 ± 3.31	46.38 ± 3.45	19.50 ± 0.50	20.38 ± 0.48	4.94 ± 0.43	5.13 ± 0.68
11	15	56	19	92	16.33 ± 1.51	60.80 ± 1.82	26.14 ± 1.35	24.85 ± 1.24	8.05 ± 0.93	14.90 ± 1.10
12	12	68	18	110	15.80 ± 3.11	82.25 ± 1.17	36.07 ± 1.73	49.08 ± 2.33	11.73 ± 0.25	36.22 ± 3.31
13	18	86	33	143	25.83 ± 5.42	99.01 ± 3.45	44.00 ± 1.87	60.67 ± 2.52	13.20 ± 0.57	68.33 ± 10.18
14	23	109	40	183	30.33 ± 6.53	122.13 ± 3.50	56.50 ± 1.91	84.50 ± 1.38	17.18 ± 0.96	123.14 ± 4.74
15	33	142	74	257	50.67 ± 14.77	141.39 ± 2.66	62.78 ± 2.77	102.71 ± 4.31	18.00 ± 1.31	188.92 ± 15.83
16	60	202	87	344	73.71 ± 8.96	159.86 ± 3.52	72.22 ± 2.99	121.56 ± 2.96	20.91 ± 4.12	275.00 ± 25.41

CW, Carapace width; CL, carapace length; CPL, chelar propodus length; CPD, chelar propodus depth/height; TW, total weight.

TABLE II

Growth (with standard deviation) of female *Portunus pelagicus* (Linnaeus, 1758) in the laboratory

Crab stage	Min. days from prev. instar	Total days	Max. days from prev. instar	Total days	Average days from prev. instar	CW (mm)	CL (mm)	AW (mm)	AL (mm)	TW (g)
1	0	0	0	0	0	2.43 ± 0.34	–	–	–	0.006
2	2	2	4	4	2.83 ± 0.75	4.10 ± 0.14	–	–	–	0.01
3	3	5	5	9	3.80 ± 0.84	5.20 ± 0.25	–	–	–	0.024
4	3	8	5	14	3.83 ± 0.75	6.58 ± 0.57	–	–	–	0.075
5	4	12	7	21	5.80 ± 1.09	9.62 ± 1.10	5.40 ± 0.29	–	–	0.099
6	4	16	7	28	5.60 ± 1.79	13.40 ± 0.60	7.25 ± 0.25	–	–	0.177
7	4	20	8	36	6.20 ± 1.79	17.20 ± 1.20	9.38 ± 0.14	–	–	0.32
8	6	26	9	45	7.00 ± 1.22	24.27 ± 2.06	12.25 ± 0.32	–	–	1.44 ± 0.32
9	7	33	10	55	8.80 ± 1.30	33.33 ± 3.78	16.97 ± 1.44	–	–	2.43 ± 0.50
10	10	43	18	73	14.0 ± 3.54	48.00 ± 4.76	22.30 ± 1.26	9.63 ± 0.95	14.13 ± 1.31	5.98 ± 0.72
11	14	57	19	92	16.6 ± 2.07	62.88 ± 3.57	27.63 ± 2.29	15.13 ± 1.93	17.88 ± 2.25	15.63 ± 1.70
12	12	69	22	114	16.0 ± 2.92	85.50 ± 6.75	36.20 ± 3.46	20.50 ± 0.71	24.13 ± 2.59	32.22 ± 2.85
13	17	86	34	148	25.2 ± 6.66	101.78 ± 2.78	44.11 ± 2.15	25.07 ± 3.12	30.56 ± 3.01	64.33 ± 7.50
14	28	114	47	195	36.4 ± 7.37	120.43 ± 2.23	51.83 ± 1.17	34.88 ± 3.71	37.00 ± 1.15	106.50 ± 9.94
15	45	159	101	296	68.2 ± 21.04	139.29 ± 1.81	62.50 ± 1.16	42.75 ± 1.76	47.28 ± 2.17	150.50 ± 2.90
16	98	257	129	425	112.0 ± 11.89	154.31 ± 2.73	68.23 ± 2.01	50.73 ± 1.38	55.86 ± 2.22	210.33 ± 18.39

CW, Carapace width; CL, carapace length; AW, abdominal width; AL, abdominal length; TW, total weight.

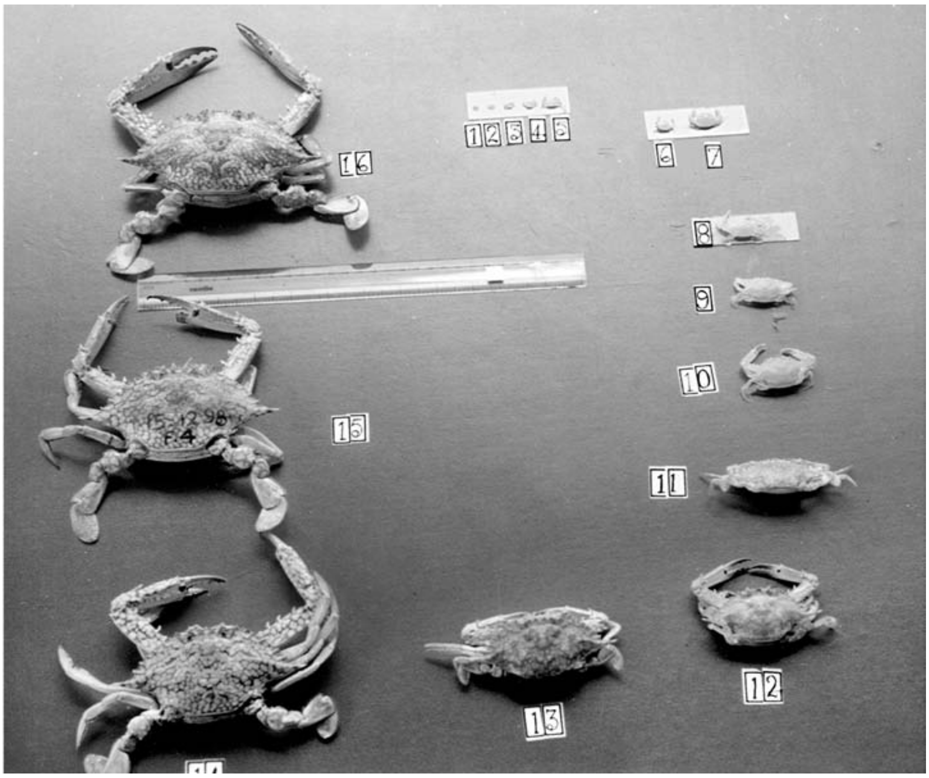

Fig. 3. Moulted shells of crab instars 1-16 of female *Portunus pelagicus* (Linnaeus, 1758) grown in the laboratory.

(10.78%), as is the case in males. The moult increment pattern for carapace length was similar to that of carapace width. The maximum percent increase in carapace length was observed from the 8th to 9th instar (38.53%) and the lowest percentage was from the 15th to 16th stage, (9.17%) (table IV).

In crabs, there are certain morphological features that come to full expression at sexual maturity. These secondary sexual characters are prominent in both sexes. In males, pubertal changes include the colour of the chelae and other pereiopods, length and height of the pereiopods, and length of the first pleopods relative to the sternites in the sternal depression. In the present study, there was a drastic change in the length of the chelae in males by their 12th moult. The total growth increment was 24.23 mm from the previous moult, accompanied by a 97.51% increase in chelar propodus length. Chelar propodus height also increased, i.e., by 3.68 mm (45.71%), but this was more prominent in subsequent, mature moult.

The onset of sexual maturity was explicit in female crabs, too. In contrast to males, the passage of a female through the pubertal moult was indicated by gross changes in the abdomen and accessory reproductive structures. The most evident

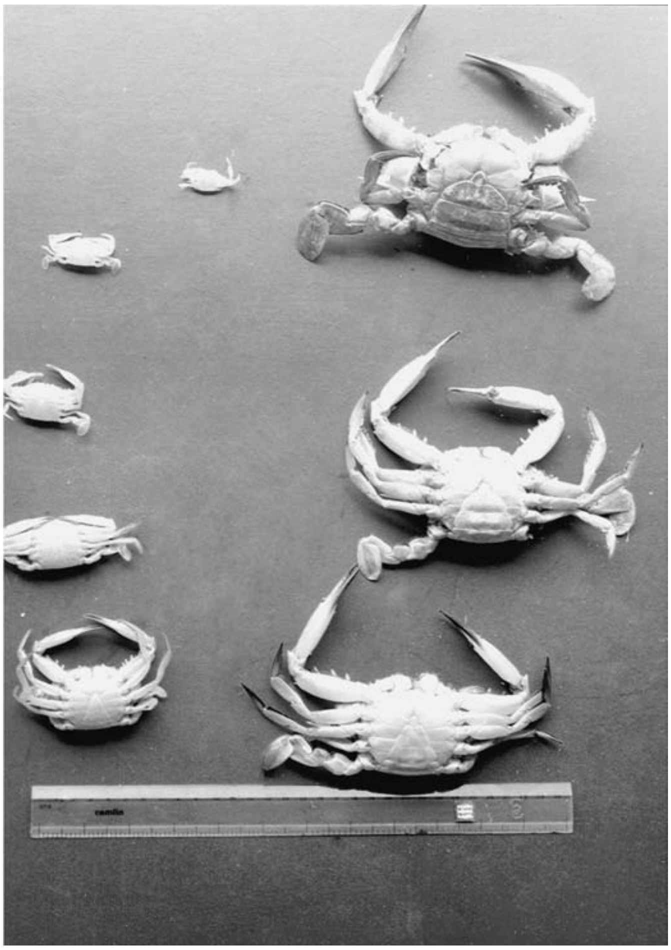

Fig. 4. Moulted shells of laboratory reared female *Portunus pelagicus* (Linnaeus, 1758), showing the increase in abdominal width during subsequent moultings.

in the female was the change of the triangular abdomen to an oval shape, which in the course of later moults almost became semicircular (fig. 4). In juveniles, the abdomen was held tightly against the sternum. By the pubertal moult, the abdominal flap became free and all abdominal somites articulated freely and were bordered by small setae. If the abdomen of the female was lifted, the round oviduct openings were seen. These openings were slit-like in juvenile crabs. There are four pairs of biramous pleopods on the second to fifth abdominal somites and the pleopodal endopodites bear clusters of long, silky setae to which the eggs are attached during spawning.

Another interesting observation in the female pubertal moult was the peculiar colouration on the dorsal surface of the abdomen. When a female approaches its

TABLE III

Growth increments (average) in laboratory reared male *Portunus pelagicus* (Linnaeus, 1758)

Crab stage	CW (mm)	%	CL (mm)	%	CPL (mm)	%	CPD (mm)	%	TW (g)	%
1	–	–	–	–	–	–	–	–	–	–
2	1.85	77.73	–	–	–	–	–	–	0.006	75.00
3	0.90	21.28	–	–	–	–	–	–	0.028	200.00
4	1.42	27.68	–	–	–	–	–	–	0.040	95.24
5	2.55	38.93	–	–	–	–	–	–	0.018	21.95
6	3.03	33.30	–	–	–	–	–	–	0.089	89.00
7	4.50	37.10	2.06	29.68	–	–	–	–	0.110	58.20
8	6.54	39.33	3.17	35.22	–	–	–	–	0.789	263.88
9	10.69	46.14	4.03	33.11	–	–	–	–	1.322	121.51
10	12.52	36.98	3.30	20.37	–	–	–	–	2.720	112.86
11	14.42	31.09	6.64	34.05	4.47	21.93	3.11	62.96	9.770	190.45
12	21.45	35.28	9.93	37.99	24.23	97.51	3.68	45.71	21.320	143.09
13	16.76	20.38	7.93	21.99	11.59	23.61	1.47	12.53	32.110	88.65
14	23.12	23.35	12.5	28.41	23.83	39.28	3.98	30.15	54.810	80.21
15	19.26	15.77	6.28	11.12	18.21	21.55	0.82	4.77	65.780	53.42
16	18.47	13.06	9.44	15.04	18.85	18.35	2.91	16.17	86.080	45.56

CW, Carapace width; CL, carapace length; CPL, chelar propodus length; CPD, chelar propodus depth/height; TW, total weight.

TABLE IV

Growth increments (average) in laboratory reared female *Portunus pelagicus* (Linnaeus, 1758)

Crab stage	CW (mm)	%	CL (mm)	%	AW (mm)	%	AL (mm)	%	TW (g)	%
1	–	–	–	–	–	–	–	–	–	–
2	1.67	68.72	–	–	–	–	–	–	0.004	66.67
3	1.10	26.83	–	–	–	–	–	–	0.014	140.00
4	1.38	26.54	–	–	–	–	–	–	0.051	212.50
5	3.04	46.20	–	–	–	–	–	–	0.024	32.00
6	3.78	39.29	1.85	34.26	–	–	–	–	0.078	78.79
7	3.80	28.36	2.13	29.38	–	–	–	–	0.143	80.79
8	7.07	41.10	2.87	30.60	–	–	–	–	1.120	350.00
9	9.06	37.33	4.72	38.53	–	–	–	–	0.990	68.75
10	14.67	44.01	5.33	31.41	–	–	–	–	3.550	146.09
11	14.88	31.00	5.33	23.90	5.50	57.11	3.75	26.54	9.650	161.37
12	22.62	35.97	8.57	31.02	5.37	35.49	6.25	34.96	16.590	106.14
13	16.28	19.04	7.91	21.85	4.57	22.29	6.43	26.65	32.110	99.66
14	18.65	18.32	7.72	17.50	9.81	39.13	6.44	21.07	42.170	65.55
15	18.86	15.66	10.67	20.59	7.87	22.56	10.28	27.78	44.000	41.31
16	15.02	10.78	5.73	9.17	7.98	18.67	8.58	18.15	59.830	39.75

CW, Carapace width; CL, carapace length; AW, abdominal width; AL, abdominal length; TW, total weight.

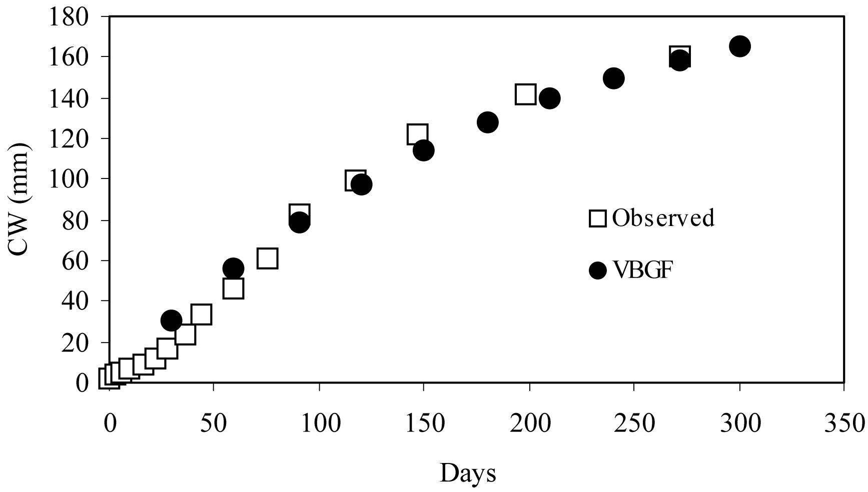

Fig. 5. Observed and fitted growth (Von Bertalanffy Growth Formula) in male *Portunus pelagicus* (Linnaeus, 1758) grown in the laboratory.

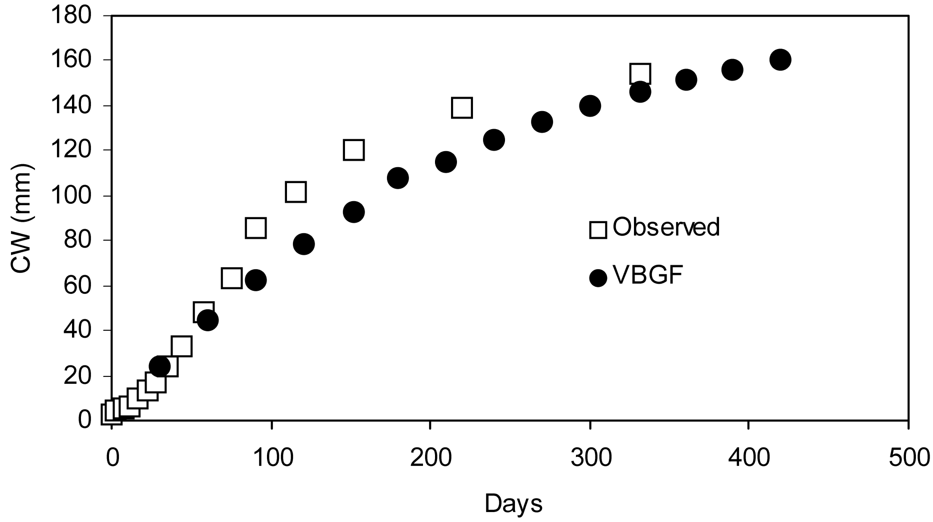

Fig. 6. Observed and fitted growth (Von Bertalanffy Growth Formula) in female *Portunus pelagicus* (Linnaeus, 1758) grown in the laboratory.

pubertal moult, or moults from one mature instar to the next, the dorsal surface of the abdomen attains a bluish-brown colour that persists for 3 to 4 days. This colour gradually disappears as the principal layer of the exoskeleton becomes fully calcified and the abdomen then changes to white, a colour similar to the other white under-surfaces. This bluish-brown colour was also associated with the pre-pubertal moult, but was not prominent as in the pubertal moult. It provided an

TABLE V
Details of Von Bertalanffy Growth Formula and Growth Coefficient in male and female *Portunus pelagicus* (Linnaeus, 1758)

Method	L_∞ (mm)	K	Growth equation
Male			
Gulland & Holt (1959)	219.8	1.82	$L_{(t)} = 219.8\{1 - \exp^{-1.82(t-t_0)}\}$
Munro (1982)	208.0	1.90	$L_{(t)} = 208.0\{1 - \exp^{-1.90(t-t_0)}\}$
Fabens (1965)	204.1	1.80	$L_{(t)} = 204.1\{1 - \exp^{-1.80(t-t_0)}\}$
Female			
Gulland & Holt (1959)	211.8	1.70	$L_{(t)} = 211.8\{1 - \exp^{-1.70(t-t_0)}\}$
Munro (1982)	211.0	1.64	$L_{(t)} = 211.0\{1 - \exp^{-1.64(t-t_0)}\}$
Fabens (1965)	188.6	1.62	$L_{(t)} = 188.0\{1 - \exp^{-1.62(t-t_0)}\}$

indication that the next moult of the animal would be the maturation moult. In the present study, the abdominal width increment was 9.81 mm (39.13%) during the maturation moult. The maximum abdominal length increase was during the 15th moult, i.e., 10.28 mm (27.78%).

In male crabs, the weight increment steadily increased after each moult. The maximum percentage of weight gain was from the 7th to 8th moult (263.88%) and the minimum was from the 4th to 5th moult (21.95%). In females, like in males, the maximum and minimum percentual incremental changes in weight were recorded during the 7th to 8th moult (257.50%), and 4th to 5th moult (32.00%), respectively. In general, the percentage of growth decreased after maturity, particularly in female crabs.

The growth in length of laboratory grown male and female *Portunus pelagicus* was analysed. Linear growth had a high correlation value, but the fitted growth curve was linear only during the juvenile phase. Growth followed the asymptotic curve as given in the Von Bertalanffy Growth Formula (VBGF) (figs. 5, 6), thus the data were analysed for VBGF using three different methods: Gulland & Holt (1959), Fabens (1965) and Munro (1982). The L_∞ values ranged between 204.1 and 219.8 mm in males and 188.6 and 211.8 mm in females. The growth coefficient (K) varied from 1.8 to 1.9 and 1.62 to 1.7 in males and females, respectively. The details are given in the table V.

Based on the L_∞ and K values, monthly growth values of *P. pelagicus* male and female crabs were computed using the inverse VBGF, and are presented in the tables VI and VII. The monthly growth estimates of male *P. pelagicus* following Munro's method (1982), when compared to actually observed data, gave very close values, while in females the observed mean growth was close to that observed in the Fabens (1965) method. Accordingly, at the end of 1st, 2nd, and 3rd year, males attained a length of 176.9, 203.3 and 207.3 mm and females of 151.3, 181.2 and 187.2 mm, respectively.

DISCUSSION

The results of the laboratory studies show that growth is fast, and a carapace width of 100 mm was reached in an average period of four months. This is a commercially accepted size, though at present there is no minimum size regulation for crab fishery in the country. Males attained maturity earlier than females: three months as opposed to five months for females. Only two reports are available on the laboratory growth of *Portunus pelagicus* from Indian waters: Prasad & Tampi (1953) reported that megalopae of *P. pelagicus* collected from Palk Bay, Mandapam, took one month to attain a size of 8.5 mm CW. In the present study, the maximum number of days taken by megalopae to reach a crab size of approximately 9 mm CW was 24 days and the minimum was 16 days. In the present study, the intermoult duration is shorter, however, a comparison with Prasad & Tampi's (1953) data is difficult, as their conclusions were based on a single experiment. From the same geographical area, Ameer Hamsa (1982) reported that 11-25 mm CW *P. pelagicus* reared in tanks attained a size of 140-150 mm in 12 moults after a period of 14 months. In the present study, the 11-25 mm size group includes three instar groups (6^{th}, 7^{th}, and 8^{th}) and, it took only 6-7 months to grow to 140 mm (15^{th} instar) (tables I, II). In the present study, growth was more rapid and crabs reached the same size in almost half the time. Hence, the range given by Ameer Hamsa (1982) might have included different instar groups.

Similarly, Menon (1952) gave the moulting and growth of the closely related portunid crab, *Portunus sanguinolentus* (Herbst, 1783) (as *Neptunus sanguinolentus*). He inferred that there were 11 moults in the course of growth from 13 to 60 mm, based on one year of fishery data. These moult numbers are much higher than in *P. pelagicus*, which moulted only 5 times in this size range. Only by rearing the crabs in captivity, the number of moults can be confirmed.

The average moult increments in males and females up to a carapace width of 100 mm or, in other words, till the attainment of sexual maturity, were equal, and at larger sizes the moult increment of females was considerably less. Mackay & Weymouth (1935), Butler (1961) and Bennett (1974) have come to similar conclusions. In females, the annual growth is less than that of males, due to their lesser moult increments and lower moulting frequency. Lesser moult increments may be due to the utilization of nutrients for egg production and body growth. Portunid crabs are capable of multiple spawnings from a single insemination at

TABLE VI

Monthly growth of laboratory grown male *Portunus pelagicus* (Linnaeus, 1758) (based on the Von Bertalanffy Growth Formula)

	L_∞	219.8	204.1	208.0
Age	K	1.82	1.80	1.9
Month	Year			
1	0	30.90	28.40	30.50
2	0	57.50	52.90	56.50
3	0	80.40	74.00	78.60
4	0	100.00	92.10	97.60
5	0	116.90	107.70	113.80
6	0	131.30	121.10	127.60
7	0	143.80	132.70	139.30
8	0	154.50	142.60	149.40
9	0	163.70	151.20	158.00
10	0	171.60	158.60	165.30
11	0	178.40	164.90	171.60
12	1	184.20	170.40	176.90
13	1	189.20	175.10	181.40
14	1	193.50	179.10	185.30
15	1	197.20	182.60	188.70
16	1	200.40	185.60	191.50
17	1	203.10	188.20	193.90
18	1	205.50	190.40	196.00
19	1	207.50	192.30	197.70
20	1	209.20	194.00	199.20
21	1	210.70	195.40	200.50
22	1	212.00	196.60	201.60
23	1	213.10	197.60	202.50
24	2	214.10	198.50	203.30
25	2	214.90	199.30	204.00
26	2	215.60	200.00	204.60
27	2	216.20	200.60	205.10
28	2	216.70	201.10	205.50
29	2	217.10	201.50	205.90
30	2	217.50	201.90	206.20
31	2	217.80	202.20	206.50
32	2	218.10	202.40	206.70
33	2	218.40	202.70	206.90
34	2	218.60	202.90	207.00
35	2	218.70	203.00	207.20
36	3	218.90	203.20	207.30

the previous moult. This could be a reason for the longer moulting cycle in female crabs. Williamson (1900) suggested that the presence of sperm in the spermathecae of a female crab inhibits moulting, and that a batch of sperm will fertilize two or more annual spawnings. The weight of male crabs is also considerably greater

TABLE VII

Monthly growth of laboratory grown female *Portunus pelagicus* (Linnaeus, 1758) (based on the Von Bertalanffy Growth Formula)

Age Month	L_∞ K Year	196.9 1.05	190.4 1.37	190.0 1.42
1	0	16.5	20.5	21.2
2	0	31.6	38.9	40.0
3	0	45.5	55.2	56.8
4	0	58.1	69.8	71.7
5	0	69.8	82.8	84.9
6	0	80.4	94.4	96.6
7	0	90.2	104.8	107.0
8	0	99.1	114.0	116.3
9	0	107.3	122.2	124.5
10	0	114.8	129.6	131.8
11	0	121.7	136.1	138.3
12	1	128.0	142.0	144.1
13	1	133.8	147.2	149.2
14	1	139.0	151.9	153.8
15	1	143.9	156.0	157.8
16	1	148.3	159.7	161.4
17	1	152.4	163.0	164.6
18	1	156.1	166.0	167.4
19	1	159.5	168.6	170.0
20	1	162.7	170.9	172.2
21	1	165.5	173.0	174.2
22	1	168.2	174.9	176.0
23	1	170.6	176.6	177.5
24	2	172.8	178.1	178.9
25	2	174.8	179.4	180.2
26	2	176.6	180.6	181.3
27	2	178.3	181.6	182.2
28	2	179.9	182.6	183.1
29	2	181.3	183.4	183.9
30	2	182.6	184.2	184.6
31	2	183.8	184.8	185.2
32	2	184.9	185.4	185.7
33	2	185.9	186.0	186.2
34	2	186.8	186.4	186.6
35	2	187.7	186.9	187.0
36	3	188.4	187.2	187.3

than that of female crabs, and this is evident after maturity has been reached. In the present study, the 14th, 15th, and 16th instars of the male attained a total average weight of 123.14 g, 188.92 g and 275.00 g, respectively, whereas females recorded 106.50 g, 150.50 g and 210.33 g respectively. Accentuation of the larger increments in weight at moulting of male crabs may be due to the allometric growth of their chelae. Moult frequency in male crabs seems to be more closely related to total live weight than to carapace width. Female moult frequency was also related to carapace width and total live weight. Other workers also reported that the difference between the sexes is probably due to the greater size of the male chelae, which results in male crabs being heavier than females of the same carapace width (Hancock & Edwards, 1967; Bennett, 1974). In the present study female crabs took more days to reach the 16th instar than males, even though the growth in females is slightly faster till they attain 100 mm carapace width. To reach the 16th instar stage from the first, males took an average of 272 days only but females attained the same stage after 332 days, even though their total carapace width and total weight were less. Bennet (1974), Mc Caughran & Powell (1977), and Melville-Smith (1989) also reported similar findings in other species of crabs.

Mauchline (1976) concluded that the length of the intermoult period increased directly as the cube of the body length, or logarithmically as the body length, or in relation to the successive moultings. Present findings are also in conformity with Carroll (1982), who reported that unsexed juveniles have a constant ratio between chela height and carapace width up to approximately 65 mm CW. Beyond this size, discontinuous relative growth occurs as chela height to carapace width ratios of sexually mature males and females diverge from the juvenile proportions.

In crustaceans, lost appendages are replaced only by moulting. Smith (1990) has conducted studies to examine long-term effects of autotomy on the growth of the portunid crab, *Callinectes sapidus* Rathbun, 1896. He found that after loss of a single cheliped, the animal could regenerate almost 90% of its normal limb length in the first moult following autotomy, and nearly 100% by the second moult. In the present observations, too, *Portunus pelagicus* was able to regenerate a lost single chela or other limbs, to 90% of their normal size in the next moult, and this did not affect the moult increment or moult interval. However, in multiple limb loss both moult interval and moult increment were adversely affected. The effects of limb loss appear to be additive, such that the moult increment decreases proportionally as increasing numbers of limbs are lost (Bennett, 1973; Kuris & Mager, 1975). Studies on the same species by Ary et al. (1987), showed that limb removal in early stages of anecdysis did not significantly affect the duration of the intermoult period compared to the intact controls.

The two most important environmental factors that affect moulting and growth in crustaceans, are temperature and the quality and quantity of food. Compared to these parameters, light and salinity have little effect on both moulting and intermoult period. In India, largely a tropical country, the growth of *P. pelagicus* is not influenced by the almost uniform ambient temperature, and the more so at Mandapam, where the temperature is always on the higher side and fluctuations are minimal throughout the year, such in contrast to temperate regions. Leffler (1972) reports that in *Callinectus sapidus* average growth rate increased with increase in temperature from 13°C to 34°C. He also mentions that *C. sapidus* farms, where heated effluent water in the winter and cooler offshore water during summer are used, could grow blue crabs from first instar to market size in 7 to 8 months rather than the normal 10-11 months. Salinity variations were only marginal: hence, it is assumed that salinity is not a major factor determining or controlling growth. In his comprehensive review, Hartnoll (1982) likewise concluded that many growth studies in several species of crustaceans found no significant changes in the intermoult period with reference to salinity.

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