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Growth Performance of the Green Tiger Prawn *Penaeus semisulcatus* De Haan in Cages in the Gulf of Mannar off Mandapam, Southeast Coast of India

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Abstract

Two experiments were conducted in rectangular box type cages. In experiment 1, growth of juveniles was compared at two densities (13 ind.m^{-2} and 21 ind.m^{-2}) with the clam meat. In experiment 2, growth of juveniles was studied at a single density (13 ind.m^{-2}) but with two different feeds (squid and compound pellet diet). In experiment 1, growth of both male and female significantly differed between the two densities, being higher at the lower density. In experiment 2, average growth performance of both male and female was higher with the compound diet. All males in the four treatments attained maturity at the age of 5 months. All females at the lower density reached maturity at the age of 6 months; this finding illustrates the suitability of low density culture for the development of broodstock in cages in the sea. Growth parameters (L_∞ and k) were estimated for each sex in each treatment. As growth significantly differed between treatments for both sexes in the two experiments, L_∞ and k differed accordingly, revealing the possibility of an influence of density and diet on the growth parameters. In all four treatments for both sexes, lifespan for *Penaeus semisulcatus* is estimated to 3+ years. The results of this study revealed that growth parameters such as $L\infty$ and k are subject to variation depending on density and diet of the species in question.

Introduction

The green tiger prawn *Penaeus semisulcatus* (Penaeidae) is more resistant to white spot syndrome virus (WSSV) than other cultivable penaeid prawns (Chen et al. 2004; Maheswarudu and Josileen, 2008), which makes it a potential candidate for prawn culture. A resistant species is particularly needed today, because disease is strongly and negatively impacting the prawn culture industry. Attempts to culture *P. semisulcatus* have been made in Kuwait (Ameeri and Cruz, 2006), Taiwan (Liao and Chao, 1987), Israel (Seidman and Issar, 1988), Hong Kong (Tseng and Cheng, 1981), and Turkey (Turkmen, 2007). In India, attempts to culture this species resulted in poor growth in grow-out pond (Nandakumar, 1982; Maheswarudu et al. 1995, 1996b). To study the growth of this species in the marine environment and to evaluate the effect of density and diet on growth, we designed an experimental study that was conducted using cages situated in the sea. Herein, we describe the growth performance of *P. semisulcatus* cultured at two densities or fed with two different feeds. We used the von Bertalanffy growth model to examine the variation of growth parameters in relation to the differential growth recorded in the cages in the sea.

Materials and Methods

The present study was conducted in the Gulf of Mannar, off Mandapam Regional Centre of Central Marine Fisheries Research Institute (09° 16' 16.7"N; 079° 07' 56.0" E).

Cages

Experiments were conducted in rectangular box type (1.0 × 0.75 × 0.5 m) cages. The cage frame was fabricated using 20 mm G I iron rods with eight horizontal (2 x 4) and four vertical pieces. Two 1.0 × 0.75 m rectangular frames were built and fixed firmly to four vertical rods at four corners with a gap (height) of 0.5 m between the two frames. All four vertical rods extended for 0.30 m from the bottom of the frame to form four legs. A square-shaped lid (0.3 × 0.3 m) was placed in one corner of the top frame to allow feeding. The entire cage frame (box) including the lid was wrapped with two layers of nylon webbing (inner layer: 12 mm mesh size; outer layer: 25 mm mesh size). The external layer was to prevent predators from entering the box and the inner layer was to retain the prawn.

All 12 cages were fixed at 1.56 ± 0.26 m depth in a line parallel to the shore. Each cage was fixed by inserting the four legs into the sea bed until the bottom of the frame touched the sea bed. One 10 cm diameter casuarinas pole also was fixed near the cage, and the cage was tied to the pole to strengthen the support against waves. Sand from the shore was placed in the cage on the bottom of the frame up to a height of 10 cm to create a burrowing habitat for the prawns. Feed was given once per day in the evening (17.00 hrs), as described below for each treatment in each experiment.

Once each month during low tide, each cage was lifted and animals were collected and brought to the nearby prawn hatchery. Length (up to 1.0 mm) and weight (up to 1.0 g.) were measured individually. Sexual maturity of each individual was recorded by observing the union of the petasma and the presence of a spermatophore at the base of the fifth pleopods in males and the size and colour pattern of the ovary in females (Rao 1968). The animals were maintained in plastic troughs filled with aerated sea water until the cage was cleaned with a soft nylon brush. All of the fouling organisms that had settled on the external layer were removed, the cage was refixed in the same location, and the animals were replaced into the cage to continue the experiment.

In the Gulf of Mannar, where rearing experiments were conducted in the cages, the bottom water temperature, salinity, and pH were at 29.32 ± 1.09 ºC, 31.42 ± 1.55 ppt, and 8.38 ± 0.03, respectively.

Seeding the cages

For the present study, juvenile *P. semisulcatus* were reared in a marine earthen pond by stocking it with hatchery-produced post larvae (PL_{35}). In the hatchery, nauplii were obtained from gravid females that had developed in the rematuration system without resorting to eyestalk ablation (Maheswarudu et al. 1996a; Radhakrishanan et al. 2000). Nauplius $_1$ (N_1) to post-larva$_1$

(PL_1) were reared in a 1 t capacity larval rearing tank at a density of 50,000 $N_1 \cdot t^{-1}$ under diffused aeration and a natural photoperiod; they were fed with *Chaetoceros calcitrans* at a concentration of 100–250 cells$\cdot$ ml^{-1}. The temperature and salinity were 29.0 ± 1.4 °C and 30.6 ± 1.5 ppt, respectively. In the outdoor nursery linear cement tank (7 t capacity) equipped with a flow-through water system (200% water replacement$\cdot$ day^{-1}), PL_1 to PL_{35} were reared at a density of 3,000 postlarvae $\cdot$ t^{-1} by feeding them egg custard mixed with prawn meat at a rate of 1–10 mg$\cdot$ $larva^{-1} \cdot day^{-1}$. The temperature and salinity were 30.5 ± 1.7 °C and 30.7 ± 1.5 ppt, respectively. In an earthen marine pond (0.08 ha), PL_{35} to juveniles were reared at a density of 6 postlarvae$\cdot m^{-2}$. They were fed a compound diet consisting of 420 g $\cdot kg^{-1}$ protein, 50 g$\cdot$ kg^{-1} fat, and 40 g . kg^{-1} fibre (Starter feed, Encee Feeds Pvt Ltd, Bangalore) at a rate of 15% of the biomass/day for a period of 40 days. The water depth, temperature and salinity during pond rearing were 0.9 ± 0.1 m, 30.6 ± 1.6 °C and 31.0 ± 1.4 ppt, respectively. After 40 days, these juveniles were used to stock the cages, as described in each experiment.

Experiment 1

This experiment was conducted between September 1992 and March 1993 and was designed to compare the growth performance of juvenile *P. semisulcatus* (progeny 1) at two different densities. A brooder (153 mm total length (TL) 31.0 g^{-1}) spawned 108,000 eggs, from which 90,000 nauplii hatched (83.33% hatch rate). All of these nauplii were reared up to PL_1 and we obtained 22,500 PL_1 (25.0% survival). These PL_1 were reared up to PL_{35}, and we obtained 10,800 PL_{35} (mean total length; 23.6 ± 3.1 mm; 48.0% survival). These PL_{35} then were reared in an earthen pond to a stockable size (Table 1) for the cages.

Juveniles were stocked in cages at two densities: 21 ind . m^{-2} and 13 ind . m^{-2}; the experiment was run for 120 days in triplicate for each density. Prawns were fed with clam meat daily at 30.0% of the biomass.

Experiment 2

This experiment was conducted between October 1992 and April 1993 and was designed to compare the growth performance of juvenile *P. semisulcatus* (progeny 2) fed two different feeds: squid and a compound diet (consisting of 400 g. kg^{-1} protein, 50 g . kg^{-1} fat, and 40 g . kg^{-1} fibre (Grower feed, Encee Feeds Pvt Ltd, Bangalore). A brooder (168 mm TL 45.0 g^{-1}) spawned 150,000 eggs, from which 140,000 nauplii hatched (93.33% hatch rate). All of these nauplii were reared up to PL_1 with 23.5% survival. In the nursery the survival from PL_1 to PL_{35} was 51.5%. These PL_{35} (mean total length: 23.4 ± 3.4 mm) were reared in an earthen pond up to stockable size (Table 2) for the cages.

Juveniles were stocked at a density 21 ind. m^{-2} in six cages, three for squid feed treatment (treatment 1) and three for compound diet treatment (treatment 2). In treatment 1, squid was given daily at 30.0% of biomass. In treatment 2, compound diet was given daily at 15.0% of the biomass. This experiment was conducted for 120 days, but data were available for only 90 days because the nylon webbing of all six cages was damaged after 110 days due to rough weather, and all of the surviving animals escaped.

Data analysis

Total length (mm) and weight (g) of each individual in each cage for each treatment were measured at monthly intervals. Data from the triplicate cages for each treatment were pooled by sex, and mean length and standard deviation were computed for the corresponding time period. A t-test was used to compare the growth between sexes at different periods between the two density treatments in experiment 1 and between the two feed treatments in experiment 2. The growth in terms of total length and weight that was traced from hatching (N_1) to 205 days in experiment 1 for different sexes and densities was entered in FISAT-II (Growth increments file and Length at age file), and growth parameters for the von Bertalanffy model (L_∞ and k) were computed. Similarly, in experiment 2, the growth, which was traced from hatching (N_1) to 175 days for different sexes and feeds, was entered in FISAT II (Gayanilo Jr. et al. 2005), and growth parameters were estimated. Using L_∞ and k values, total length at ages 0.5, 1, 2, and 3 years for each sex and for each treatment, for two different methods [i.e. Growth increments (Gulland & Holt Plot) and Length- at- age] were computed. Mean total length (0.30 mm) of N_1 and mean total length (4.82 mm) of post $larva_1$ (PL_1) were used based on previously published data (Devarajan et al. 1978), and t_0 was assumed to be 0. All individual total lengths and weights that were collected at monthly intervals were pooled by gender for each treatment, and length-weight relationship parameters, such as a & b, were computed accordingly using the least squares regression on log transformation of the equation: $W= aL^b$. W_∞ for corresponding L_∞ that was calculated by two different methods [i.e. Growth increments (Gulland & Holt Plot) and Length- at- age] for each sex in each treatment, was computed by using concerned a and b values. Slopes (b values) for the length-weight relationship between sexes in each treatment were compared using ANCOVA (Snedecor and Cochran, 1980). Similarly, slopes (b values) for each sex were compared between the density treatments in experiment 1 and between the feed treatments in experiment 2.

Table 1. Sex wise comparison of total length (Mean± SD), weight (Mean± SD) and survival (%) of green tiger prawn *Penaeus semisulcatus* reared at two density trials for a period of 120 days.

	Density -1						**Density -2**					
Duration of culture (days)	Total length (mm)		Weight (g)		Survival (%)		Total length (mm)		Weight (g)		Survival (%)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Stocking	77.6 ± 8.3	77.1 ± 5.3 ^{NS}	5.7 ± 0.5	5.5 ± 0.5^{NS}	100	100	77.6 ± 8.3 ^{ns}	77.1 ± 5.3 $^{NS, ns}$	5.7 ± 0.5 ^{ns}	5.5 ± 0.5 $^{NS, ns}$	100	100
30	103.9 ± 4.1	104.6 ± 3.5^{NS}	11.0 ± 1.7	11.6 ± 0.8^{NS}	89	100	106.0 ± 3.1 ^{ns}	104.2 ± 13.6 $^{NS, ns}$	10.2 ± 0.7^{ns}	10.6 ± 2.4 $^{NS, ns}$	80	80
60	115.8 ± 2.3	117.5 ± 2.7°	13.4 ± 0.9	15.0 ± 1.8°°	89	86	116.3 ± 5.8 ^{ns}	122.5 ± 7.2°, **	14.0 ± 1.4^{ns}	17.5 ± 4.1 °°, *	80	80
90	122.3 ± 0.6	126.5 ± 0.5°°	18.3 ± 2.1	20.5 ± 0.54°	33	29	127.3 ± 5.2 ^{ns}	133.0 ± 5.6 °°, **	18.0 ± 2.5^{ns}	23.25 ± 2.2°°, *	60	60
120	126.0 ± 2.8	133.0 ± 4.2°°	19.0 ± 1.4	25.5 ± 3.5°°	33	29	131.0 ± 5.7 *	144.0 ± 9.5°°, **	21.0 ± 1.4*	29.33 ± 3.6 °°, *	40	40
Mean performance	0.4▲	0.46▲	0.11▼	0.17 ▼	31^		0.44▲	0.56▲	0.13 ▼	0.19 ▼	40^	

▲= Total length/day; ▼= Weight/day
^ = Pooled survival for both sexes at the end
NS= Not significant at P >0.05 level between sexes
° = Significant at P < 0.05 level between sexes
°° = Significant at P < 0.01 level between sexes
ns = Not significant at P> 0.05 level between treatments
* = Significant at P < 0.05 level between treatments
** = Significant at P < 0.01 level between treatments

Results

Experiment 1

Table 1 shows the sex-wise comparison of total length, weight, and survival of *P. semisulcatus* juveniles reared at two densities for 120 days. Growth in total length and weight did not differ between sexes for the first 30 days of the experiment but significantly varied from day 60 onward at both densities. Female registered faster growth than male. Growth in terms of total length and weight for males did not differ significantly between the two densities (P >0.05) for the initial period of 90 days, whereas it differed by day 120 (P < 0.05). For females, growth in terms of total length and weight did not differ significantly between the two densities for the first 30 days, but it differed significantly from day 60 onwards and the difference was more significant for total length (P < 0.01) than for weight (P < 0.05). These juveniles exhibited faster growth at the low density compared to the high density.

A gradual decline in survival over time for both sexes at both the densities was recorded. At the lower density, the survival was higher for males than for females, whereas survival was the same for both sexes at the higher density. Average survival at the termination of the experiment was higher at low density than that at high density. On day 60 all males at both densities attained maturity, which was also supported by observing spermatophore deposition in females (18%) that were in the post moult stage. In the low density group, by day 90 the gonads of all females were in the late maturing stage and by day 120 all females were in the spent recovery stage. In contrast, gonads of females in the high density group did not advance beyond the early maturing stage.

Experiment 2

Table 2 shows the sex-wise comparison of total length, weight, and survival of *P. semisulcatus* reared with two different feed treatments. Growth significantly differed between sexes in both treatments, with females registering faster growth. Growth in terms of total length for males and females did not vary between the two treatments for the first 30 days, but it varied significantly from day 60 onwards. Weight significantly varied between the two treatments on day 90 for males and from day 60 onwards for females. Average performance in terms of total length and weight was higher comparatively when *P. semisulcatus* was fed the compound diet. Survival at termination of the experiment did not differ significantly between the two treatments.

All males in both treatments attained sexual maturity by day 60. Females in both treatments had only reached the early maturing stage by day 90. In both treatments, females had lower survival than males.

Table 2. Sex wise comparison of total length (Mean ± SD), weight (Mean ± SD) and survival (%) of green tiger prawn Penaeus semisulcatus fed with two different feeds squid and compound diet for a period of 90 days

	Squid (Treatment-1)						Compound diet (Treatment-2)					
Duration of culture (days)	Total length (mm)		Weight (g)		Survival (%)		Total length (mm)		Weight (g)		Survival (%)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Stocking	59.9 ± 1.7	59.9 ± 1.7^{NS}	2.3 ± 0.4	2.3 ± 0.4^{NS}	100	100	60.2 ± 2.1^{ns}	$60.2 \pm 2.1^{NS, ns}$	2.3 ± 0.4^{ns}	$2.3 \pm 0.4^{NS, ns}$	100	100
30	102.3 ± 3.7	101.7 ± 2.5^{NS}	9.9 ± 0.6	10.0 ± 0.8^{NS}	91.6	75	105.3 ± 0.5**	$106.2 \pm 4.4^{NS,}$ **	10.2 ± 0.4^{ns}	$10.3 \pm 0.6^{NS, ns}$	100	91.6
60	111.3 ± 2.9	$116.7 \pm 5.8^{\circ\circ}$	13.1 ± 1.0	$14.7 \pm 2.3^{\circ\circ}$	91.6	75	115.3 ± 0.5**	$122.8 \pm 2.5^{\circ\circ,}$ **	13.0 ± 1.1^{ns}	$17.7 \pm 1.9^{\circ\circ,}$ **	100	66.6
90	116.5 ± 2.1	$124.0 \pm 1.4^{\circ\circ}$	15.5 ± 0.7	$20.0 \pm 0.0^{\circ\circ}$	75	50.6	122.3 ± 0.5**	$132.5 \pm 2.4^{\circ\circ,}$ **	17.0 ± 1.41*	$23.5 \pm 2.2^{\circ\circ,}$ **	100	66.6
Mean performance	0.63▲	0.71▲	0.15▼	0.2▼	75.0^		0.69▲	0.8▲	0.16▼	0.23▼	75.0^	

▲= Total length/day; ▼= Weight/day
^ = Pooled survival for both sexes at the end
NS= Not significant at $P > 0.05$ level between sexes
° = Significant at $P < 0.05$ level between sexes
°° = Significant at $P < 0.01$ level between sexes
ns = Not significant at $P > 0.05$ level between treatments
* = Significant at $P < 0.05$ level between treatments
** = Significant at $P < 0.01$ level between treatments

Growth parameters

Table 3 shows the estimated growth parameters (L_∞ & k) determined by the two methods for each treatment and sex. As growth differed between sexes in all treatments, L_∞ & k varied accordingly. Females had higher L_∞ values and lower k values than those of males. The values of L_∞ & k for each sex also varied between treatments in both experiments.

Table 3. Estimated growth parameters (L_∞ & k) for male and female of green tiger prawn *Penaeus semisulcatus* in four treatments by following two different methods [Growth increments (Gulland & Holt Plot) and Length-at-age] of FISAT- II

	Growth increment				Length- at -age			
Treatment	L_∞ (mm)		k^{-year}		L_∞ (mm)		k^{-year}	
	Male	Female	Male	Female	Male	Female	Male	Female
Densit-1	239	290	1.27	1.04	232	272	1.68	1.32
Densit-2	275	340	1.07	0.91	270	320	1.32	1.08
Squid	200	260	1.55	1.17	196	230	1.68	1.20
Compound diet	256	284	1.18	1.13	246	274	1.32	1.20

Length-weight relationship parameters

Table 4 shows the sex-wise and treatment-wise estimated length-weight relationship parameters and computed W_∞ values. Slopes (b values) did not vary for both sexes between the two treatments in either experiment. However, slopes significantly varied between sexes in experiment 1 and not in experiment 2. Values of W_∞ for females were higher than those for males.

Life span

The estimated sizes attained at age 0.5, 1, 2, and 3 years for each sex in all four treatments computed for the two different methods are given in Table 5. Similarly, the estimated weights at these ages are given in Table 6. Data from all four treatments show the existence of differential growth between sexes, with male exhibiting lesser growth comparatively. In addition, the longevity for both sexes of *P. semisulcatus* is 3+ years.

Discussion

This study demonstrated the influence of density and diet on the growth performance of juvenile green tiger prawns in cages deployed in the sea. In experiment 1, juveniles reared at two densities showed differential growth and survival, with higher growth and survival at the lower density. This finding shows that density influences growth and survival of this prawn.

Table 4. Estimated length- weight relationship parameters (a, b & r^2 values)) and W_∞ (Two methods- Gulland &Holt plot and Length -at- age) for male and female of *P. semisulcatus* in four treatments.

	Male					Female				
				W_∞(g)					W_∞(g)	
Treatment	a	b	r^2	Gulland & Holt Plot	Length-at-age	a	b	r^2	Gulland & Holt Plot	Length-at-age
Density-1	0.00039	2.21	0.93	70	65	0.0000967	2.52**	0.95	154	132
Density-2	0.000337	2.24▼	0.93	97	93	0.0000782	2.56**,▼	0.95	241	207
Squid	0.0000293	2.76	0.97	65	61	0.0000228	2.82ns	0.97	146	104
Compound diet	0.0000337	2.72▼	0.98	119	107	0.0000224	2.82ns,▼	0.98	181	168

ns= Not significant between sexes at *P*> 0.05 level
**=Significant between sexes at *P* < 0.01 level
▼=Not significant between two treatments at *P* > 0.05 level

Table 5. Estimated sizes (Total length in mm) at the age 0.5,1, 2 and 3 year, by following Von Bertalanffy growth function, for male and female of *Penaeus semisulcatus* in four treatments.

	Estimated size (Total length in mm)															
	Growth increments (Gulland & Holt Plot)								Length- at -age							
Treatment	Male				Female				Male				Female			
	0.5 year	1 year	2 year	3 year	0.5 year	1 year	2 year	3 year	0.5 year	1 year	2 year	3 year	0.5 year	1 year	2 year	3 year
Densit-1	112	172	220	234	118	187	254	277	132	189	224	230	131	199	253	267
Densit-2	114	181	243	264	124	203	285	318	130	198	251	265	134	211	283	307
Squid	108	158	191	198	115	179	235	252	111	159	189	195	104	161	209	224
Compound diet	114	177	232	249	123	192	254	274	119	180	228	241	124	191	249	267
Mean total length	112	172	221	236	120	191	257	280	123	182	223	233	123	191	248	266

Table 6. Estimated sizes (Weight in g.) at the age 0.5, 1, 2 and 3 year, by following Von Bertalanffy growth function and length-weight relationship, for male and female of *Penaeus semisulcatus* in four treatments.

	Estimated size (Weight in g.)															
	Growth increments (Gulland & Holt Plot)								Length- at -age							
Treatment	Male				Female				Male				Female			
	0.5 year	1 year	2 year	3 year	0.5 year	1 year	2 year	3 year	0.5 year	1 year	2 year	3 year	0.5 year	1 year	2 year	3 year
Densit-1	13	34	59	67	16	52	111	138	19	42	61	65	21	60	110	126
Densit-2	13	38	73	89	18	63	150	199	18	46	79	89	22	70	148	183
Squid	12	34	58	64	15	52	111	135	13	35	56	61	11	38	80	97
Compound diet	13	44	91	110	17	62	136	169	15	46	88	102	18	61	128	155
Mean wt.	13	37	70	83	17	57	127	160	16	42	71	79	18	57	116	140

Ameeri and Cruz (2006), who conducted culture trials with *P. semisulcatus* at different densities in an indoor running seawater system, reported a significant decrease in growth with increasing densities. They also reported low survival at higher densities, which they attributed to crowded conditions causing physiological stress on the animals in two ways: limited space and water quality. In our study, we eliminated the issue of poor water quality (prawns were reared in cages with extensive water exchange). Thus, we attribute the lower growth and survival at the higher density to the limited space available for each prawn.

In our study, males attained sexual maturity at the age of 5 months and females at the age of 6 months. Mating took place at the age of 5 months, and ovary development and spawning in females occurred 2 months after mating. This result illustrates that although males attain sexual maturity 1 month before females attaining sexual maturity, females are ready for mating and to receive spermatophores at the age of 5 months, and ovary development and spawning take place for a period of 2 months from mating. Males attaining sexual maturity prior to females were also reported in the blue swimming crab *Portunus pelagicus* (Josileen and Menon, 2005). It shows that ovary development in female crustaceans may be triggered after securing spermatophores. Thomas (1975) reported size at maturity for male and female *P. semisulcatus* to be 115 mm TL and 125 mm TL, respectively. Maheswarudu et al. (1994) studied age and growth of this species by its length frequency distribution; they reported that age at maturity of males and females (corresponding to 115 mm TL for male and 125 mm TL for Female) is 6 months.

Although males attained sexual maturity in all four treatments, females attained sexual maturity only at the lower density in experiment 1. This finding shows the suitability of stocking these prawns at a lower density (13 ind. m^{-2}) if the goal is for the females to attain sexual maturity. It also shows that attaining maturity in female penaeid prawns is more complicated than it is in males. In commercial hatcheries, endocrine manipulation by eyestalk ablation is used to induce maturation in females only (Browdy, 1998). The results of the present study suggest that a lower stocking density is suitable for future broodstock development of penaeid prawns in cages/pens in open sea waters.

In experiment 2, juveniles fed with two different diets showed differential growth, with faster growth in prawns fed the compound diet. One explanation is that the compound diet provided more adequate nourishment than squid alone. The high feeding value of squid meal or squid by-products to obtain good growth in penaeid prawns has been reported by several authors (Kitbayashi et al. 1971; Deshimaru and Shigeno, 1972; Lim et al. 1979; Fenucci et al. 1980; Guillaume et al. 1989; Achuthankutty et al. 1993). On a wet weight basis, squid meal consists of only 312 g. kg^{-1} protein (Hulan et al. 1979). In contrast, the compound diet consisted of a higher protein content (400 g. kg^{-1}), and this may explain the better growth in prawns in this treatment compared to the squid alone treatment. Growth trials of juvenile *Penaeus merguiensis* conducted to assess their dietary protein requirement showed that optimum protein levels in the range of 340 to 420 g. kg^{-1} are required to support maximum growth (Sedgwick, 1979). Babu (1999) conducted an experimental study on growth of juvenile *P. semisulcatus* with semi-purified diets of different ratios of protein with varying amounts of digestible energy and reported that protein requirement range is 350 to 400 g. kg^{-1} to obtain maximum growth.

In all four treatments of both experiments, growth differed between sexes, with females exhibiting faster growth than males, irrespective of density, feed, and progeny tested. This result illustrates the genetic inheritance of fast growth in females. Similar results were reported for *P. semisulcatus* (Thomas 1975; Mohamed et al. 1981; Liao and Chao, 1987; Maheswarudu et al. 1994; Karen et al. 2006) and for other penaeid prawns (Rao et al. 1993; Yamada et al. 2007; Gopal et al. 2010; Hossain and Ohtomi, 2010).

The results of our study show that growth of *P. semisulcatus* juveniles is influenced by both density and diet. The influence of these factors also was detected in the growth parameters L_∞ and k, thus illustrating that growth parameters are density and diet dependent. Variation in growth parameters for *P. semisulcatus* from two fishing grounds (Gulf of Mannar and Palk Bay) was reported (Maheswarudu et al. 1994). Spatial variation in growth parameters in wild populations of *P. semisulcatus* from coastal waters of Kuwait, eastern Saudi Arabia, Bahrain, and Qatar also have been reported, suggesting the possibility of influence of environment, food availability, and population density on growth parameters (Ye et al. 2003).

In each experiment in the present study, growth in terms of total length and weight differed between the two treatments for each sex. However, the length-weight relationship parameters (b slopes) did not differ between the two treatments for each sex, confirming the proportionate progression in both total length and weight in all four treatments. In experiment 1, the length-weight relationship parameter b (slope) significantly differed between sexes in each treatment. In contrast, in experiment 2, the b value did not differ between sexes, perhaps due to variation in the age of prawn, data were available for 6 months in experiment 2, comparatively to that of experiment 1 (7 months). This implies that the variation in the length-weight relationship between sexes up to the pre-adult stage was not significant but that it was more pronounced after the prawn attained sexual maturity, with females gaining more weight than males for a given total length. Similarly, age- (life stage-) related differential growth between sexes was reported in *Penaeus monodon* (Primavera et al. 1998). However, males gaining more weight than females for a given length after the onset of maturity was reported in *Farfantepenaeus duorarum* (Diaz et al. 2001).

The present study shows that longevity of *P. semisulcatus* is 3+ years, irrespective of the influence posed by density and diet. The present study is confirming the life span, reported to this species earlier, in wild population (Maheswarudu et al. 1994).

In summary, the present study demonstrates that both density and diet influence growth of the green tiger prawn *P. semisulcatus* at the juvenile level. Because growth is affected by density and diet, the von Bertalanffy growth model parameters L_∞ and k vary accordingly. Dimorphic growth is well pronounced in this species, with females growing faster than males irrespective of progeny, density and diet. Although growth in terms of total length and weight is affected by density and diet, the length-weight relationship parameter b does not vary, revealing the fact that progression in total length and weight is proportionate. The total length-weight relationship (b) does not significantly differ between sexes up to pre-adult stage (up to 175 days age), but significant variation occurs at the onset of maturity (205 days). The life span of *P. semisulcatus* is 3+ years and it is not affected by density and diet. Males attain sexual maturity at the age of 5 months and females attain sexual maturity at the age of 7 months, but females participate in mating and receive spermatophores at the age of 5 months. In this study, females attained sexual maturity only at the lower density (13 ind . m^{-2}), which suggests that this low density should be used for broodstock development in cages/pens in the sea. The present study also suggests that *P. semisulcatus* has a long life span with a slow growth rate; males and females reach 13–16 g and 17–18 g, respectively, at the age of 6 months. This implies that it is possible to obtain prawns of 15–17 g mean weight (59–67 head on count . kg^{-1}) in the grow-out pond after 5 months of culture (1 month hatchery phase + 5 months grow-out phase), assuming a male to female ratio of 1:1.

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