Some aspects of biology and exploitation of the green tiger prawn, *Penaeus* (*Penaeus*) *semisulcatus* de Haan from Mandapam (Palk Bay) and Pamban (Gulf of Mannar), southeast coast of India

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ABSTRACT

The results of the exploitation of *Penaeus* (*Penaeus*) *semisulcatus* by the Mandapam-based small mechanized vessels and shrimp trawl nets operating at 7–13 m depth in the Palk Bay, and Pamban-based shrimp trawl nets operating in the Gulf of Mannar at 7–45 m depth, are presented. The catch per unit of effort in both the regions declined from 1986–87 to 1988–89. The spawning took place throughout the year with two peaks, one during July–September and the other during February–March. The overall growth rate, estimated from the modal progression in the monthly length frequency distribution, was 13.75 mm per month for females (60-285 mm) and 12.3 mm per month for male (71–225 mm) in the Palk Bay. In the Gulf of Mannar it was 13.0 mm per month for female (86–225 mm) and 10.0 mm per month for males (91–180 mm). The differential growth between the sexes occurred as the prawns grew to 40–50 mm size. Males/females attained a size of 115/125 mm at the end of 6 months, 170/195 mm at 12 months, 215/250 mm at 24 months and 230/270 mm at the end of 36 months in the Palk Bay. The corresponding male/female sizes in the Gulf of Mannar were 120/135 mm, 170/200 mm, 200/250 mm and 205/265 mm. The commercial fishery in both the regions was contributed by the 0-year group prawns. The total mortality rates in the population exploited in these regions were relatively high, particularly for the male population. The stock in the fishing grounds considered at present is being subjected to over-exploitation.

Penaeus (*Penaeus*) *semisulcatus* is the principal species exploited in the Palk Bay and Gulf of Mannar off the Mandapam region. Earlier studies on its biology and fishery from the Mandapam region have been made by Thomas (1974, 1975) and Nanda Kumar (1980, 1983). The present paper gives the results of study on some aspects of biology and population dynamics of *P. semisulcatus*

from Palk Bay and Gulf of Mannar in the Mandapam region.

MATERIALS AND METHODS

Data on catch and effort of small shrimp trawlers landed at Mandapam and Pamban centres were collected regularly once a week from July 1986 to June 1989, except for 5 months from October 1987 to February 1988 at the former centre and for 4 months from July 1987 to October 1987 at the latter. The monthly catch was estimated following the conventional method of raising the average

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weight of the catch realized on observation days to the total number of units operating and then to the total number of actual fishing days in that month. The total fishing effort in terms of actual fishing hours was also estimated in a similar manner.

Prawn samples were analysed in the laboratory for total length (measured from tip of rostrum to tip of telson), sex and maturity stages of female which were classified into 5 stages as per Rao (1968). The length measurements were grouped into 5 mm class intervals and the number of prawns in each length group was estimated on the basis of sample weight and the estimated total catch for the day which was then raised to monthly catch.

The methods employed for age and growth studies, mortality and exploitation rates are given in the concerned section.

RESULTS

The Fishery

The mechanized fishing vessels, mostly of 9.14–9.75 m long fitted with 36–48 hp engines, based at the fish landing centre at Mandapam on the Palk Bay side, operate in the Palk Bay. The fishing ground covered by these vessels extends as far as off- Thondi on the northwest of Mandapam up to the EEZ border between India and Sri Lanka on the northeastern side. Besides being shallow, the near shore waters of this region is characterized by the luxuriant growth of sea grasses up to about 4 m depth. The bottom of the ground is generally muddy and the prawn fishing is carried out at 7–13 m depth. Following the local regulations, the vessels go for fishing to the northwestern and northeastern regions on alternate days during night.

The vessels based at the southern shore of Pamban generally go for fishing in the Gulf of Mannar. The prawn fishing grounds covered by these vessels are located to south off Mandapam at about 7–45 m depth beyond the islands. The bottom of the ground here is

mostly sandy or composed of coral sand debris.

In both the centres bottom shrimp trawl nets having cod-end mesh size of 26 mm are employed for fishing. Single-day trips from 1500 hr to 0900 hr are generally resorted to in both the centres. In certain seasons, the stay-over-a-day fishing is also carried out at Pamban.

The prawn fishing at this region is carried out throughout the year. However, the fishing activities are lean during northeast monsoon months (November–December) in the Palk Bay and during southwest monsoon months (June–August) in the Gulf of Mannar.

The total and monthly catches of *P. semisulcatus* landed by the mechanized vessels at Mandapam during 1986–87 and 1988–89 are given in Table 1. The data for 1987–88 were not considered being incomplete. Although the magnitude of the fishery was almost the same during these two years and the total fishing effort increased by 4.5% in 1988–1989 over that of 1986–87, the catch per unit of effort showed a slight decrease from 1986–87 to 1988–89.

The estimated annual and monthly catches of *P. semisulcatus* landed at Pamban are given in Table 2.

Spawning Season

Distribution of different maturity stages of females *P. semisulcatus* in various months during 1986–87 and 1988–89 at Mandapam and Pamban followed a similar pattern, and hence the data of these centres for the two years were pooled. The occurrence of late-maturing and mature prawns in all the months, although in varying intensity, showed continuous spawning throughout the year in the population of *P. semisulcatus* in this area. However, two peak spawning seasons, one during July–September and the other during February–March, could be distinguished from

Table 1.   Monthly estimated catch (tonnes) effort (hr) and catch rate (kg/hr) of *Penaeus semisulcatus* by shrimp trawlers at Mandapam during 1986–89

Month	1986–87			1987–88			1988–89		
	Effort	Catch	Catch rate	Effort	Catch	Catch rate	Effort	Catch	Catch rate
July	52 886	61.645	1.166	35 650	28.427	0.797	39 913	38.564	0.966
Aug	50 763	60.652	1.195	35 650	18.538	0.520	41 200	40.850	0.992
Sep	42 975	46.518	1.082	38 250	31.710	0.829	30 375	24.300	0.800
Oct	36 038	37.014	1.027	—	—	—	24 720	18.612	0.752
Nov	37 500	43.313	1.155	—	—	—	30 000	33.900	1.130
Dec	33 945	39.155	1.153	—	—	—	31 930	31.137	0.975
Jan	29 993	25.388	0.847	—	—	—	6 200	4.461	0.719
Feb	28 350	21.321	0.752	—	—	—	21 855	14.425	0.660
Mar	31 000	30.504	0.984	37 200	32.364	0.870	33 475	25.287	0.755
Apr	31 000	24.480	0.790	26 000	31.898	1.226	44 250	34.755	0.785
May	31 000	25.420	0.820	37 975	59.071	1.555	67 813	86.831	1.280
June	31 775	33.341	1.049	37 500	50.500	1.346	85 500	94.230	1.102
Total	437 225	448.751	1.026	248 225[*]	252.508[*]	1.017[*]	457 231	447.352	0.978

[*]Value for the period of 7 months only

Table 2.   Monthly estimated catch (tonnes) effort (hr) and catch rate (kg/hr) of *Penaeus semisulcatus* by shrimp trawlers at Pamban during 1986–89

Month	1986–87			1987–88			1988–89		
	Effort	Catch	Catch rate	Effort	Catch	Catch rate	Effort	Catch	Catch rate
July	10 638	9.391	0.882	—	—	—	11 250	9.891	0.879
Aug	14 625	17.835	1.220	—	—	—	14 850	8.721	0.587
Sep	17 400	14.255	0.819	—	—	—	15 600	6.240	0.400
Oct	21 600	18.297	0.847	—	—	—	16 200	27.864	1.720
Nov	24 960	49.556	1.985	15 600	18.720	1.200	14 040	15.730	1.120
Dec	24 440	56.796	2.324	7 290	8.168	1.120	24 300	48.924	2.013
Jan	25 389	54.609	2.151	15 912	23.375	1.469	18 225	13.973	0.766
Feb	16 770	23.186	1.383	9 180	7.032	0.766	16 200	18.900	1.166
Mar	19 013	33.443	1.759	10 485	8.568	0.817	14 175	7.439	0.524
Apr	20 827	35.063	1.683	19 858	15.343	0.772	9880	8.658	0.876
May	13 439	16.356	1.217	15 525	19.440	1.252	12 150	11.934	0.982
June	16 473	30.341	1.842	11 136	15.225	1.367	13 000	16.250	1.250
Total	225 574	359.128	1.592	104 986[*]	115.871[*]	1.103[*]	179 870	194.524	1.081

[*]Value for the period of 8 months only

the relatively higher percentage occurrence of prawns of late maturing and mature stages. Greater number of immature prawns were generally encountered in November–December and again in April–May.

Age and Growth

The growth of *P. semisulcatus* from Gulf of Mannar and Palk Bay was studied for sizes separately by observing distribution and tracing the progression of modes in different months (Table 3).

The size of *P. semisulcatus* from Gulf of Mannar and Palk bay ranged from 71 m to 225 mm in male and from 60 to 285 mm in female. The monthly average rate of growth traced from the 8 modal progression series varied from 11.6 to 16.3 mm for female and 10.0 to 13.3 mm for male. The overall rate of growth per month was 13.75 mm in females and 12.3 mm in males.

In the Gulf of Mannar the size of *P. semisulcatus* ranged from 86 to 225 mm in female and from 91 to 180 mm in male. The monthly average rate of growth recorded for female population in this ground was 10.0–17.5 mm with an overall average rate of 13.0 mm. For male it was 8.8–11.6 mm with an overall rate of 10.0 mm. The smallest modal size group observed in the fishery of Palk Bay was at 78 mm for female and 83 mm for male; in the fishery of the Gulf of Mannar it was 103 mm for both the sexes. This indicated that prawns belonging to relatively larger size group was recruited into the fishery of the Gulf of Mannar than that of the Palk Bay. The results showed that 3-month-old prawns were entering into the fishery in the Palk Bay and 5-month-old into the Gulf of Mannar. The size attained at intervals of 3 months were taken and L_α and K values were estimated following Ford-Walford Plot. K values were raised for an year. The values obtained for L_α were 231.4 and 279.1 mm for male and female, respectively, at Mandapam whereas these were 204.7 and 267.4 mm at Pamban. The K values at Mandapam were 1.34 (male) and 1.16 (female) and at Pamban these were 1.7 (male) and 1.37 (female).

The size of the species at different ages was estimated by substituting the L_α and K values in the well-known von-Bertalanffy equation; t_0 was assumed as zero. The sexwise and centrewise length at different age obtained from von Bertalanffy equation, and from actual observation of progression of modal sizes in the monthly length frequency distribution (selected curves of Table 3) are given in Table 4. The agreement between the observed and estimated size at Pamban seems to be fairly satisfactory. However, appreciable difference existed in the observed and estimated values of younger prawns at Mandapam. This might be due to the rapid growth of smaller size groups. Besides, pooling of samples obtained from the shallow north-western region and the deeper northeastern area of the fishing ground could have also brought forth this difference. Although differential growth between the sexes was observed both in the population of Gulf of Mannar and Palk Bay, the growth rate of female in the former area was faster as compared to the latter region. However, from 11 months onwards male grew faster in the Palk Bay than in the Gulf of Mannar. Based on the observations on the age and growth and the maximum size recorded in the fishery of this region, it might be inferred that the life span of the species is about 3[+] years.

Age Composition

The age composition of the populations in the Gulf of Mannar and Palk Bay in four age groups, viz. 1–6, 7–12, 13–18 and 18 months and above, was estimated from the

Table 3.   Sexwise modal progression and monthly average growth in *Penaeus semisulcatus* at Mandapam and Pamban

Initial mode (mm)	Month of occurrence	Final mode (mm)	Month of occurrence	Growth increments (mm)	Duration (months)	Monthly average growth (mm)
MANDAPAM
Female						
93	Sep 1986	198	June 1987	105	9	11.6
83	Oct 1986	178	May 1987	95	7	13.6
88	Apr 1987	163	Sep 1987	75	5	15.0
88	May 1987	153	Sep 1987	65	4	16.3
83	Apr 1988	188	Dec 1988	105	8	13.1
78	May 1988	198	Feb 1989	120	9	13.3
93	Nov 1988	173	Apr 1989	80	5	16.0
98	Dec 1988	168	May 1989	70	5	14.0
Average				715	52	13.75
Male						
103	Aug 1986	143	Nov 1986	40	3	13.3
108	Jan 1987	138	Apr 1987	30	3	10.0
88	Apr 1987	128	July 1987	40	3	13.3
88	May 1987	138	Sep 1987	50	4	12.5
83	Apr 1988	148	Sep 1988	65	5	13.0
93	July 1988	153	Dec 1988	60	5	12.0
103	Dec 1988	148	Apr 1989	45	4	11.3
93	Jan 1989	133	Apr 1989	40	3	13.3
Average				370	30	12.3
PAMBAN
Female						
123	July 1986	193	Jan 1987	70	6	11.6
118	Oct 1986	178	Apr 1987	60	6	10.0
113	Dec 1986	193	June 1987	80	6	13.3
113	Nov 1987	188	May 1988	75	6	12.5
108	Jan 1988	178	July 1988	70	6	11.6
103	Nov 1988	188	Apr 1989	85	5	17.0
108	Dec 1988	178	Apr 1989	70	4	17.5
Average				510	39	13.0
Male						
123	Oct 1986	158	Feb 1987	35	4	8.8
108	Dec 1986	143	Mar 1987	35	3	11.6
108	Nov 1988	148	Mar 1989	40	4	10.0
103	Jan 1988	133	Apr 1988	30	3	10.0
Average				140	14	10.0

Table 4. Observed and estimated size (mm) of *Penaeus semisulcatus* at various ages

Age (months)	Mandapam				Pamban			
	Male		Female		Male		Female	
	Observed average size	Estimated size	Observed average size	Estimated size	Observed average size	Estimated size	Observed average size	Estimated size
1		24.4		25.7		27.1		28.8
2		46.3		49.1		50.6		54.6
3	86.3	65.8	88.0	70.3		71.0		77.5
4	105.0	83.4	113.6	89.5		88.8		98.0
5	119.4	99.0	130.1	106.9	104.3	104.1	109.0	116.3
6	129.6	113.0	141.3	122.8	120.0	117.4	132.0	132.6
7	139.0	125.5	152.9	137.2	131.3	128.9	147.0	147.1
8	147.0	136.7	164.4	150.3	140.0	139.0	160.2	160.1
9	155.0	146.7	172.0	162.2	149.0	147.7	170.0	171.7
10		155.6	180.8	172.9	158.0	155.3	179.3	181.9
11		163.7	188.0	182.7		161.8	185.5	191.2
12		170.8	196.0	191.6		167.5		199.4
13		177.2		199.7		172.4		206.7
14		182.9		207.0		176.7		213.3
15		188.1		213.6		180.4		219.1
16		192.6		219.7		183.6		224.3
17		196.7		225.2		186.4		228.9
18		200.4		230.1		188.8		233.1
24		215.5		251.7		197.9		250.1
30		223.3		263.8		201.8		258.6
36		227.2		270.5		203.5		262.9

size-age data. The contribution of male and female population in each of these age groups by number and percentage in the fishery is given in Table 5. The bulk of the catch in both the regions was formed of the prawns belonging to 6–12 months of age in all the 3 years of observations. While the contribution of older age group prawns (18 months and above) decreased in the fishery of Palk Bay, they were significantly absent in the fishery of Gulf of Mannar. On the other hand, the smaller prawns of the age group 1–6 months contributed to the fishery of this region.

Total Mortality

The instantaneous rate of total mortality Z was estimated by the length-converted catch

Table 5   Abundance of different age groups of *Penaeus semisulcatus* in trawl catches at Mandapam and Pamban during 1986–89 (estimated numbers)

Year	Mandapam							
	6 months (up to 115 mm)	%	12 months (116–170 mm)	%	18 months (171–200 mm)	%	Above 18 months (201 and above)	%
Male								
1986–87	3 313 474	40.4	4 836 146	58.8	49 378	0.6	15 080	0.2
1987–88	4 261 643	66.6	2 075 558	32.5	56 140	0.9		
1988–89	4 328 739	41.0	6 303 254	59.0	...	...		...
Total	11 903 856	47.2	13 214 958	52.3	105 518	0.4	15 080	0.2
	6 months (up to 125 mm)	%	12 months (126–195 mm)	%	18 months (196–230 mm)	%	Above 18 months (231 and above)	%
Female								
1986–87	3 363 184	26.5	8 904 989	70.2	328 825	2.6	85 915	0.7
1987–88	3 261 068	41.0	4 664 519	58.6	30 430	0.4		
1988–89	4 101 382	35.8	7 214 492	63.2	98 762	0.9	6 756	0.1
Total	10 725 634	33.5	20 784 000	64.8	458 017	1.4	92 671	0.3
	Pamban							
	6 months (up to 120 mm)	%	12 months (121–170 mm)	%	18 months (171–190 mm)	%	Above 18 months (191 % above)	%
Male								
1986–87	1 078 843	24.0	3 425 849	75.9	5837	0.1	...	...
1987–88	788 385	33.0	1 601 162	67.0	---	---	...	...
1988–89	2 557 782	48.2	2 747 015	51.8	---	---	---	---
Total	4 425 010	36.3	7 774 026	63.6	5837	0.1	---	---
Female	up to 135 mm		136–200 mm		201–235 mm		236 and above	
1986–87	994 853	12.5	6 865 610	86.3	91409	1.2	---	---
1987–88	570 358	23.1	1 884 407	76.4	12280	0.5	---	---
1988–89	2 407 531	50.8	2 288 118	48.2	47077	1.0	---	---
Total	3 972 742	26.2	11 038 135	72.8	150766	1.0	---	---

curve method of Pauly (1980) for each year separately. The total estimated number per year was considered. In general, the annual total mortality rate in female was relatively lower than male in both the centres (Table 6). In both male and female there was an increas-ing trend of Z values at both the centres from 1986–87 to 1988–89.

Natural and fishing mortality

Initially an attempt was made to estimate the natural mortality (M) by plotting Z value

Table 6 Total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) of *Penaeus semisulcatus* at Mandapam and Pamban during 1986–89

Year and sex	Mandapam				Pamban			
	Z	M	F	E	Z	M	F (Z—M)	E
1986-87								
Male	7.12	2.06	5.06	0.71	11.41	2.61	8.8	0.77
Female	6.9	1.78	5.12	0.74	9.29	2.10	7.19	0.77
1987-88								
Male	17.27	2.06	15.21	0.88	9.2	2.61	6.59	0.71
Female	7.49	1.78	5.71	0.76	10.42	2.10	8.32	0.79
1988-89								
Male	17.4	2.06	15.34	0.88	15.56	2.61	12.95	0.83
Female	10.03	1.78	8.25	0.82	8.15	2.10	6.05	0.74
Average								
Male	13.93	2.06	11.87	0.85	12.05	2.61	9.44	0.78
Female	8.14	1.78	6.36	0.78	9.28	2.10	7.18	0.77

against the effort (fishing hours). However, some of the plots showed no correlation. Some of the values obtained were negative and unrealistic. Therefore, the natural mortality was calculated by using equation of Alagaraja (1984):

$$M = -\ln(0.01)/T_{max}$$

where $T_{max} = 3/K$.

The natural mortality M in the Palk Bay was 2.06 and 1.78 for the male and female populations respectively. In the Gulf of Mannar it was slightly higher being 2.61 for male and 2.10 for female (Table 6).

The fishing mortality F obtained by deducting the natural mortality (M) from the total mortality (Z) showed higher rate for female (6.05–8.32) in the Gulf of Mannar than that in the Palk Bay (5.12–8.25) and for male higher rate in the Palk Bay (5.06–15.34) than that in the Gulf of Mannar (6.59–12.95).

Exploitation Rate

The exploitation rate (E) was calculated by the formula:

$$E = \frac{F}{F + M}$$

where, E exploitation rate; F fishing mortality; and M natural mortality.

The average exploitation rate of *P. semisulcatus* was higher in the Palk Bay than in the Gulf of Mannar. As the E values were above 0.5 in all the years, the stock of *P. semisulcatus* was being over-exploited in both the regions (Gulland 1971).

DISCUSSION

With the increasing demand for prawns, the exploitation of the juveniles as well as adult populations is increasing over the years. The total annual catch of *P. semisulcatus* realized from the Palk Bay was higher than that from the Gulf of Mannar. This was mainly due to the greater number of vessels, consequently increased fishing effort, operating from the former centre. However, the catch rates realized were better in the fishery of Gulf of Mannar indicating the more productive nature of the fishing grounds. Besides, fishing in the Gulf of Mannar is carried

out in relatively deeper waters than in the Palk Bay.

P. semisulcatus exhibits differential growth rate between the sexes, females growing faster than the males. Mohamed *et al.* (1981) observed significant differences in growth between the sexes, as *P. semisulcatus* attains a carapace length of 18 mm (5.85 g) in Kuwait waters. Liao and Chao (1987) reported the differential growth in prawns at 20.73 g as seen from pond-cultured material. In the present study, the differential growth rates were at a size of 40–50 mm.

The monthly average growth rate of male and female *P. semisulcatus* as observed from the modal progression in the monthly length frequency distribution shows relatively higher rate for both the sexes in the Palk Bay than in the Gulf of Mannar (Table 3). However, it may be noted that the prawns belonging to smaller modal size groups are better represented in the Palk Bay fishery, whereas in the Gulf of Mannar, the prawns measuring over 100 mm modal size groups occur, reflecting consequently better overall growth rates in the former region. That *P. semisulcatus* grows at varying rates between these two ecosystems, and perhaps, at different rates in the same ecosystem at different life stages, is indicated by the data presented in Table 4. A comparison of the observed growth of males in the Palk Bay and Gulf of Mannar shows that the species grows at a faster rate in the former area, but the estimated growth reveals that the males grow better in the Gulf of Mannar up to a size of 155 mm and thereafter, at a relatively faster rate in the Palk Bay. In females, observed growth rate is better in the Palk Bay, whereas the estimated growth rate is found always higher in the Gulf of Mannar. Differential growth rate of *P. semisulcatus* dependent on seasons has been reported by Tseng and Chang (1981) and Liao and Chao (1987). How far the growth rate of *P. semisul-*

catus in this region is influenced by the seasonal changes, ecological characteristics or depth of the fishing grounds could be understood only by further intensive studies.

The growth parameters, L_α and K values and the life span estimated as 3^+ years for *P. semisulcatus* in the present study agree with those obtained by Jones and Van Zalinge (1981) for the species in Kuwait waters. However, the estimated K and L_α (carapace length) values reported by Van Zalinge *et al.* (1979) and Mathews (1981) in the same area were slightly higher. In this study also L_α and K the two fishing grounds differed (Table 4). Based on the progression of modal sizes in the monthly length frequency distribution and from age-size determined from the von Bertalanffy equation it is observed that males and females of *P. semisulcatus* in the fishery of Palk Bay attain a size of 115/125 mm at of 6 months, 170/195 mm at 12 months, 215/250 mm at the end of 24 months and 230/270 mm at 36 months. The corresponding male and female sizes in the fishery of Gulf of Mannar are 120/135, 170/200, 200/250 and 205/265 mm. The commercial fishery in both the regions is contributed by the 0-year group prawns.

The total mortality rates in the population of *P. semisulcatus* exploited in this region are relatively high particularly for the male population. Such high mortality rates were also estimated by Mohamed *et al.* (1979) for *P. semisulcatus* fishery in the Kuwait waters. The natural mortality is found to be within the range of 2 and 3, agreeing with the observation of Garcia (1981).

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