CHAPTER – 5

REPRODUCTIVE BIOLOGY

5.1. INTRODUCTION:

Penaeus. monodon is the largest species among the penaeid prawns, commercially known as Jumbo Tiger Prawn or Black Tiger Prawn. It is widely distributed and is a very commercially important species in India and with respect to the national market. Rao (2000) studied the reproduction and the spawning of *P. monodon* and reported that sexes are separate, similar to other penaeids. Maturity is attained in females at TL of 196 – 200 mm and in males at TL of 166 – 170 mm. The five maturity stages distinguished in the ovary could be termed as immature, early maturing, late maturing, mature or ripe and spent. Depending on the size of females, fecundity ranges from 200000 to 1000000 eggs. Spawning is reported at 40 – 80 m depth in the sea. Knowledge of spawning seasons and distribution of spawning areas are important for the management of fisheries. For penaeid shrimps, spawning seasons is determined either from the percentage of mature females present in the catch or from the changes in gonadal indices (Crocos and Kerr, 1983; Garcia, 1985; Bauer and Vega, 1992; Crocos and Coman, 1997; Minagawa et al., 2000; Crocos et al., 2001; Costa and Fransozo, 2004; Aragon-Noriega and Garcia Juarez, 2007). In the Philippines, spawning is throughout the year with two peaks viz., February – March or July and October – November, although it varies from year to year (Motoh, 1981). Rajyalakshmi et al., (1985) reported the peak season as October – April corresponding to the post – monsoon season coinciding with an increase in the salinity along the Odisha Coast, while it varies from place to place (Su and Liao, 1986). Su et al., (1990) observed September – December as the peak spawning season. Though information on reproductive biology is available for *P. monodon* from various parts of the world, the same is lacking from the Digha coast of northern Bay of Bengal. Assuming that the resource landed in Digha is from one unit stock, which is reproductively isolated from

similar other stocks, it becomes an absolute necessity to study the reproductive biology of *P. monodon* from Digha coast. The present study from Digha coast, the first of its kind, aims to elucidate the reproductive biology which includes information on the breeding season, size at sexual maturity, sex ratio and fecundity of *P. monodon*.

5.2. REVIEW OF LITERATURE

In nature, males and females are almost equally represented with sex ratio close to 1:1 (Fisher, 1958). Costa et al. (2010) suggested that sex ratio of females are related to the greater vulnerability of females to fishing due to their size. Fisher (1958) stated that for shrimps of same age, females grow faster than males, making them more susceptible to fishing. Teikwa and Mgaya (2003), from the studies along the coastal waters of Bagamoyo in Tanzania observed the sex ratio in *P indicus* and *P. monodon*.

Rao (2000) studied the reproduction and the spawning of *P. monodon* off Kakinada. Teikwa and Mgaya (2003) observed the size at first maturity to be different within sexes for *P. indicus* and for *P. monodon*. Jayawardane et al. (2002) from the western coastal water of Sri Lanka studied the reproductive biology of *P. monodon*. Khan et al. (2003) observed the spawning season of *P. monodon* to be twice in a year viz., winter season (February) and summer season (September). Motoh (1981) studied the maturation and spawning of *P. monodon* from the Philippines. The five maturity stages distinguished in the ovary were termed as immature, late maturing, early maturing, mature or ripe and spent. *P. monodon* is found to spawn throughout the year off Kakinada with different peak periods in different years. Similar trend in spawning was observed by Rao (2000) from Visakhapatnam. It has been observed along the east coast that recruitment of post larvae to the estuaries and backwaters and of juveniles to the inshore waters is in tandem with random peaks observed in their abundance (Rao, 1975; Subramanyam, 1965; Subramanyam and Rao, 1968).

Fecundity increases with length and weight. According to Teikwa and Mgaya (2003), for *P. indicus*, fecundity varied from 40,000 to 222,000 eggs and for *P. monodon*, fecundity varied from 72,000 to 314,000 eggs. They concluded that in larger prawns, much of the available energy is devoted to egg production rather than growth and as a result fecundity increases with body size. Correlation between fecundity and carapace length and fecundity and body weight is extremely useful for predicting the number of eggs produced by one individual of certain length and weight. Motoh (1981) reported on a positive correlation between carapace length of females in *P. monodon* and fecundity and Villegas et al. (1986) demonstrated a positive correlation between fecundity and weight of *P. monodon*. Primavera (1989) stated that number of eggs (fecundity) in a complete spawning for ablated females of *P. monodon* averages 300,000 (range: 100,000 – 800,000) and for wild spawners averages 500,000 (range: 200,000 – 1,000,000). Depending on the size of the females, fecundity in general ranges from 2 to 10 lakh. In the sea, spawning takes place at depths varying from 40 to 80 m (Rao, 2000).

5.3. MATERIALS METHOD:

Samples were collected randomly from the trawl landings at Digha Mohana landing centre from Bay of Bengal of West Bengal coast during January 2011 to December 2013. It is assumed that the catch landed at Digha and randomly sampled for biology is from one unit stock available along the coast of West Bengal and Odisha in the northern Bay of Bengal. From enquiry, it was ascertained that the fishing ground of trawlers capturing shrimps ranged from Digha to Paradeep. Total length of the individual was measured to the nearest millimeter (mm) and total weight to 0.1 g. Based on the external characters such as the presence of sex organs, petasma for males and thelycum for females, the sexes (males and females) were distinguished. The different maturation stage of females has been categorized into five stages, the classification of which is based on ovum size, gonad expansion, and

coloration (Villaluz et al., 1969; Primavera, 1980; Motoh, 1981)**.**In the present study, maturity was classified into immature, early maturing, late maturing, mature and spent-recovering stages based on the size, colour and yolk formation (Primavera, 1989). Individuals were termed immature if they possessed immature, spent-recovering and early maturing ovaries and were termed mature if they possessed late maturing and mature ovaries. From the dorsal side, gonads were carefully dissected out and preserved in 5% buffered formalin for studies on fecundity and ova diameter after weighing them to the nearest 0.001 g.For managing the fisheries optimally, prior information on sex ratios is essential. Knowledge on sex ratio is important for ensuring a proportional fishing of two sexes by devising appropriate fishing advisories to optimally sustain the resource. Sex population estimation is defined the abundance of any sex at a particular time or the population in natural condition. Sex ratio should be 1:1 in a healthy population. Sex composition is influenced by fishery independent factors viz., temperature, water velocity, and vulnerability of females to their predators, migratory phase and other ecological hazards and by fishery dependent factors viz., gear selectivity. Based on the monthly estimated numbers of females and males in the sample, sex ratio for the population was estimated. Chi-square test using Microsoft Excel was employed to test the monthly homogeneity of male and female distribution (Snedecor and Cochran, 1968). The average size at which 50% of the individuals were mature is termed as size at first maturity. Size at first maturity (Lm_{50}) was estimated, minimizing the trawl selectivity, using the procedure of King (1995), wherein the fraction of matured fish (late maturing, mature and running ovaries) were logistically fitted against each length class.

For indicating the maturity and spawning periodicity and for forecasting the breeding season, gonado - somatic index (GSI) is widely used in fisheries science. GSI increases with an advancement in the maturation of the fish. GSI was estimated in relation to the body

weight based on the following formulae:

$$\text{Gonado-somatic Index} = \frac{\text{Weight of the gonad (g)}}{\text{Weight of the fish (g)}} \times 100$$

Just prior to spawning, the ovaries of gravid females swiftly increase in size and therefore GSI is an appropriate tool for identifying days and seasons of spawning. The development and growth of gonad simultaneously takes place in the fish and as the fish grows the GSI increases. GSI is also related to the amount of food available in water and also the temperature of the water (Khan et al., 2003).

To determine the spawning season, proportion of gravid and ripe females (IV and V) in each month were observed and the highest percentage were taken to determine the spawning period.The number of ova laid by a fish during its spawning season is termed as fecundity. It depends on several factors such as age, size of fish, rainfall, and salinity of water and may differ in different races of the same species. This reproduction is an essential aspect of fish biology which must be understood to explain the variation of the level of population as well as to make efforts to increase the amount of fish harvest. The information on the fecundity is an important part of the fish biology, which is useful in several applied aspects of fishery science, including fishery management of any water bodies. From the anterior, middle and the posterior regions of mature and running ovaries, samples of ovaries were collected and fecundity was estimated by multiplying the number of ova to the total ovary weight in all subsamples.

$$\text{Fecundity} = \frac{\text{Weight of the ovary (g)}}{\text{Average weight of the sample (g)}} \times \text{Number of ova in the sample}$$

The number of ova per unit weight (g) of fish was expressed as relative fecundity. The regression relation between total length and weight and fecundity was fitted using the least square method (Snedecor and Cochran, 1968). The significant differences in slopes between the regression lines were tested by Analysis of Covariance (ANACOVA) (Snedecor and Cochran, 1968).

5.4. RESULS

5.4.1. Sex ratio:

During January 2011 to December 2013, 242 males and 391 females of *P. monodon* were examined amounting to a sample size of 633. The ratio of males and females (sex ratio) is presented in Tables 5.1 and 5.2. The overall yearly sex ratio was observed to be 1:1.6 (males: females). Chi-square test showed that the annual distribution of males and females is not significantly different from 1:1 ratio at 0.05% level ($p>0.05$), although the sex ratio varied from month to month during the study period.

5.4.2. Spawning season:

Average Gonado Somatic Index (GSI) of females of *P. monodon* is presented in Table 5.3 and Figure 5.2. In the present study, GSI was observed to be higher between January and July .The maximum value (GSI=10.36±1.27) was observed in June and minimum value (GSI=7.77±0.78) was in October. The GSI of females' *P. monodon* observed two peaks, in the months of January and June. The highest GSI of 10.36±1.27 in June, indicate that most females were mature in this month.

The percentage of mature females is presented in Figure 5.1. The highest mature percentage was observed in the month of February (88.89%) and June (85.4%). The lowest percentage was observed in the month of September (65.2%). Mature females in all months were observed to be >50% indicating that *P. monodon* spawns more or less throughout the year.

5.4.3. LM_{50}:

The length at first maturity is presented in Figure 5.3. In the present study, 163.5 mm was observed as the length at first maturity.

5.4.4. Fecundity:

In the present study, length and weight of mature females of *P*. *monodon* ranged from 125-260±2.32 mm and 47-261±3.73 g. The estimated number of ova in the mature ovary ranged from 120155 to 961240 in ovary weight ranging 5 g to 40 g. The relationship between fecundity with length, fecundity with weight and fecundity with carapace length of *P. monodon* was LogF= 2.504619+2.22789 LogL (r=0.669), LogF= 3.431298+0.94095 LogW (r= 0.684) and LogF= 4.072154 +1.618803 Log CL (r= 0.66). There was significant variation ($p<0.05$) in the slope of regression relations of body length and weight with fecundity. The scatter diagrams for the weight with fecundity, total length with fecundity and carapace length with fecundity relationships for females are illustrated in Figures 5.4, 5.5 and 5.6 respectively.

5.5. DISCUSSION

5.5.1. Sex Ratio:

In the present study, the sex ratio observed was 1:1.6 (males: females) from the Digha coast of West Bengal, India. This could be attributed to changes in the fishing ground and fishing pattern of trawl nets and the pattern of migration during breeding seasons of both sexes. Females, of same age, grow faster than males. Trawl selectivity, influencing the size of shrimp caught, in all probability have led to the observed biased sex ratio. In general sex ratio is known to be close to 1:1 (males: females) in nature (Fisher, 1958). Costa et al. (2010) suggested that sex ratio of females are related to the greater vulnerability of females to fishing due to their size. Sarda (2010) observed from Kozihikode, Kerala, India on the annual sex ratio between male and female to be 1.07:1.

5.5.2. Spawning seasons:

Two peak spawning seasons were observed with highest mature percentage of females in February and June. The results of GSI indicated the spawning season to be during January-February and June. Similar results were reported by Khan et al. (2003). Khan et al. (2003) observed the spawning season of *P. monodon* twice in a year viz, during winter (February) and summer (September). Along the Kakinada coast, *P. monodon* spawned throughout the year with peaks varying in various years. Similar spawning phenomenon was observed off Visakhapatnam by Rao (2000). Amanat and Quareshi (2011) from the coastal water of Pakistan observed the peak spawning activity during August to October with a secondary peak during February to March. Shrimps have generally more than one spawning period in a year. The process of ovarian maturation goes through different reproductive stages viz, undeveloped, developing, nearly ripe, ripe and spent. After completion of first spawning, shrimps rest in a developing stage before going through the maturation cycle again (Jayawardane et al., 2003).

5.5.3. Fecundity:

The estimated number of ova in the mature ovary ranged from 120155 to 961240 of *P. monodon* in my present study. Fecundity depends on the size of females. Babu (2014) observed fecundity at 723251 for 270 g from Bhairavapalem (A.P) India, which slightly varies from the results of the present study. This may due to differences of environment and on the availability of food. With an increase in prawn size, there was an increase in fecundity, indicating that in larger prawns energy was used for egg production rather than for growth. Motoh (1981) reported on a positive correlation between carapace length of females in *P. monodon* and fecundity and Villegas et al. (1986) demonstrated a positive correlation between fecundity and weight of *P. monodon*. Primavera (1989) mentioned that fecundity of *P. monodon* in a complete spawning averages 300000 (ranges from 100000 to 800000) for

ablated females and averages 500000 (ranges from 200000 to 1000000) for wild spawners. The relationship between fecundity and weight is a better predictor of fecundity than fecundity and length with high correlation values.

5.5.4. Length at First Maturity (LM_{50}):

Length at first maturity was observed to be 163.5 mm in the present investigation. The results differed from Rao (2000), who studied the reproduction and the spawning of *P. monodon* from Kakinada, possibly due to differences in food, temperature and water quality impacting maturity stages. According to Rao (2000), the females attain maturity at 196-200 mm and males at 166-170 mm total length. Amanat and Qureshi (2011) estimated size at onset of sexual maturity at 13.33 cm from the lagoon water of Pakistan.

Plate 5.1. Male *P. monodon.*

Plate 5.2. Female *P. monodon.*

Plate 5.3. Fully mature gonad of *P. monodon.*

Table 5.1.Annual sex ratio of *P. monodon* collected from Digha coast during January 2011to December 2013.

2011						2012					2013				
Month	Male	Female	d2/e	Sig	F/M	Male	Female	d2/e	Sig	F/M	Male	Female	d2/e	Sig	F/M
Jan	10	9	0.026	S	0.9	8	13	0.595	S	1.6					
Feb	14	9	0.543	S	0.6	9	11	0.1	S	1.2	11	16	0.463	S	1.5
Mar	6	7	0.038	S	1.2	6	15	1.929	S	2.5					
Jun	3	14	3.559	S	4.7	5	21	4.923	NS	4.2	13	13	0	S	1
Jul	4	11	1.633	S	2.8	5	10	0.833	S	2	19	9	1.786	S	0.5
Aug	3	19	5.818	NS	6.3	8	18	1.923	S	2.3	4	17	4.024	NS	4.3
Sep	5	20	4.5	NS	4	11	13	0.083	S	1.2	6	13	1.289	S	2.2
Oct	4	23	6.685	NS	5.8	13	8	0.595	S	0.6	11	9	0.1	S	0.8
Nov	4	12	2	S	3	7	21	3.5	S	3	19	5	4.083	NS	0.3
Dec	4	21	5.78	NS	5.3	14	15	0.017	S	1.1	11	14	0.18	S	1.3

S=Significant.

NS=Not significant

Table 5.2.Average monthly sex ratio of *P. monodon* collected from Digha coast during January 2011to December 2013.

Month	Male	Female	Total	Chi square value	Significant	F/M
Jan	18	22	40	0.2	S	1.222222
Feb	34	36	70	0.028571	S	1.058824
Mar	12	22	34	1.470588	S	1.833333
Apr	5	5	10	0	S	1
Jun	21	48	69	5.282609	NS	2.285714
Jul	28	30	58	0.034483	S	1.071429
Aug	15	54	69	11.02174	NS	3.6
Sep	22	46	68	4.235294	NS	2.090909
Oct	28	40	68	1.058824	S	1.428571
Nov	30	38	68	0.470588	S	1.266667
Dec	29	50	79	2.791139	S	1.724138
Total	242	391	633	17.53633	NS	1.615702

S=Significant, NS=Not significant

Note: Data for three years are pooled and presented.

Table 5.3.Annual gonadosomatic index (Mean±SE) of *P monodon* collected from Digha coast during January 2011to December 2013.

Month	2011	2012	2013	Mean
January	9.70± 1.8	10.56±4.3		10.13±0.45
February	5.42±0.6	10.73± 0.9	9.23± 0.8	8.50±1.63
March	9.59±6.0	8.32± 0.6		9.17± 0.60
April		9.45±2.0		9.45±2.0
June	11.42±0.9	11.82±0.3	7.84± 1.2	10.36±1.27
July	9.41±0.9	8.70±1.8		9.03±0.35
August	8.62±1.3		8.91±0.8	8.82± 0.15
September	7.65±0.8	10.24±0	6.34± 0.7	8.09±1.16
October	7.01±0.4	9.39±0.4	6.90±0.05	7.77±0.78
November	6.90±0.6	11.94±1.0	6.40±0.02	8.41±1.76
December	10.06±1.2		7.50±0.9	8.81±1.28

Note: Data for three years are pooled and presented.

Figure 5.1.Average maturity percentage of female *P. monodon* collected from Digha coast during January 2011to December 2013.

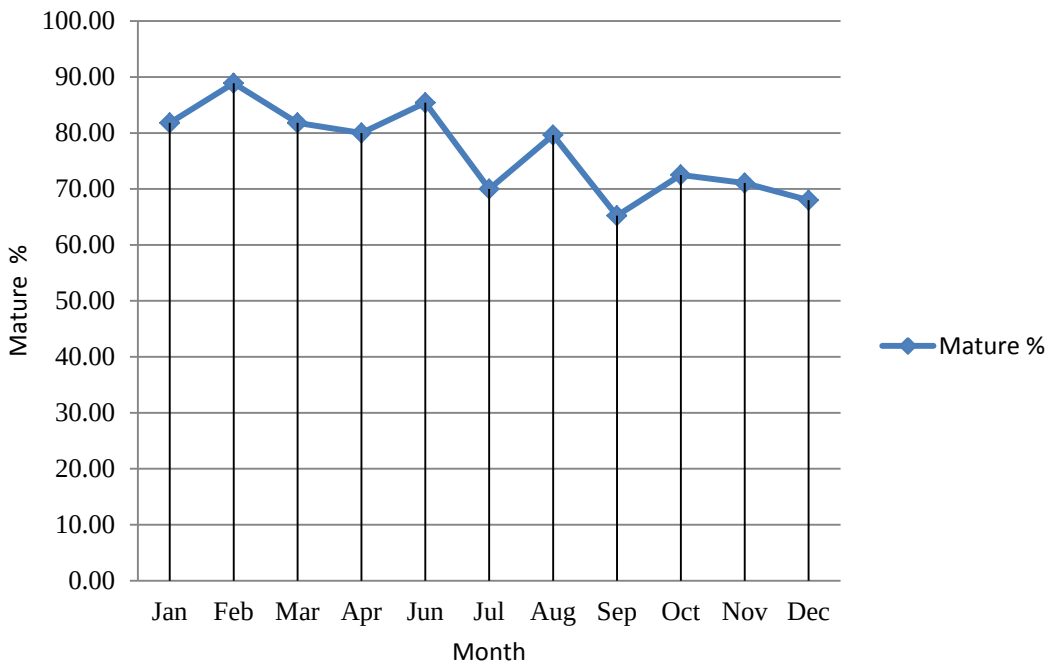

Figure 5.2.Average gonadosomatic index (GSI) of female *P. monodon* collected from Digha coast during January 2011to December 2013.

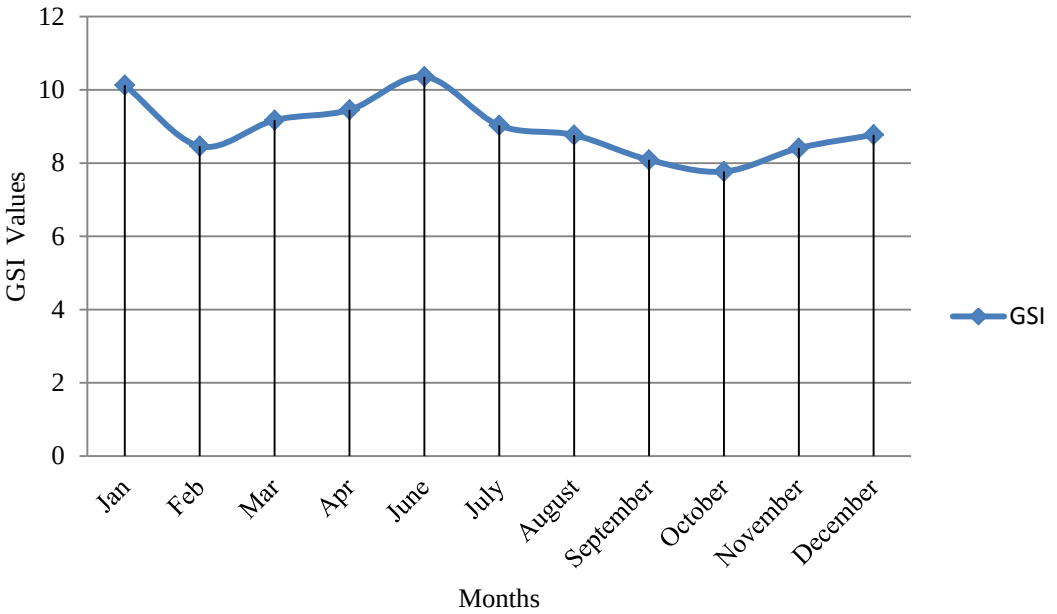

Figure 5.3.Length at first maturity (LM_{50}) of female *P. monodon* collected from Digha coast during January 2011to December 2013.

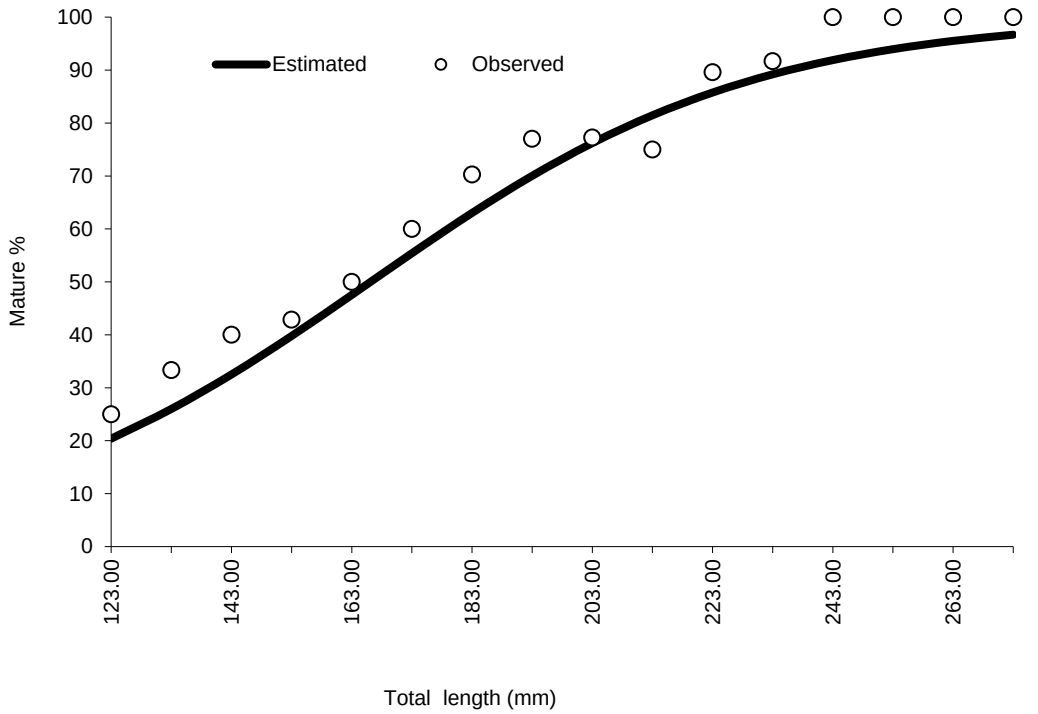

Figure 5.4.Weight - fecundity relationship of females of *P. monodon* collected from Digha coast during January 2011to December 2013.

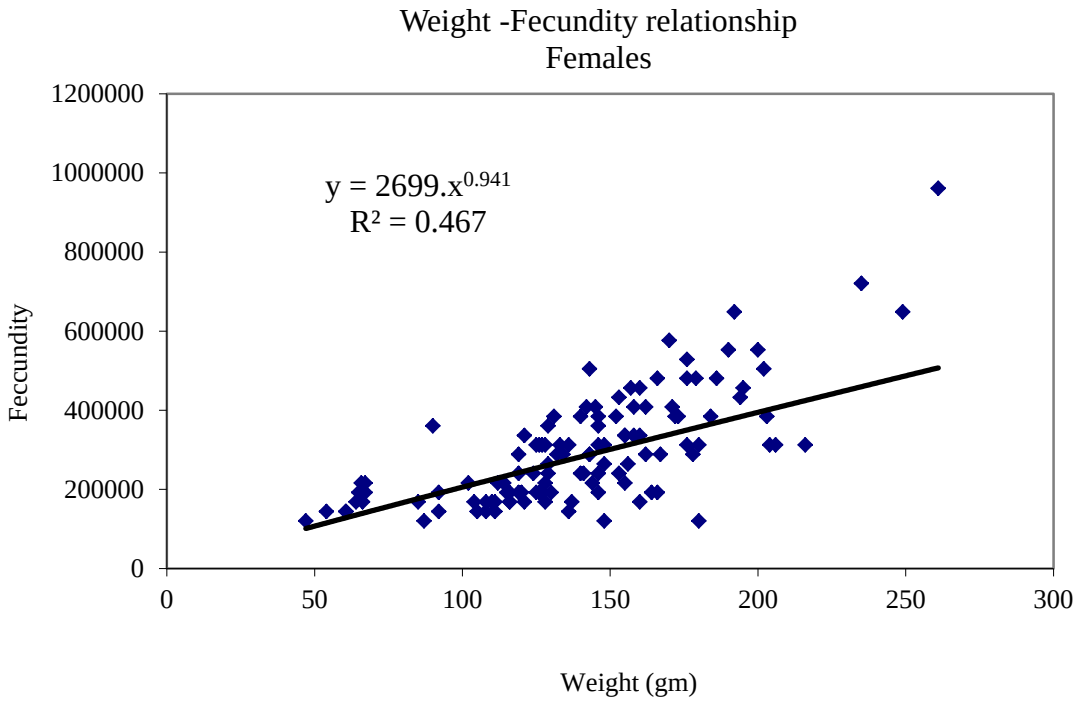

Figure 5.5.Total length - fecundity relationship of females of *P monodon* collected from Digha coast during January 2011to December 2013.

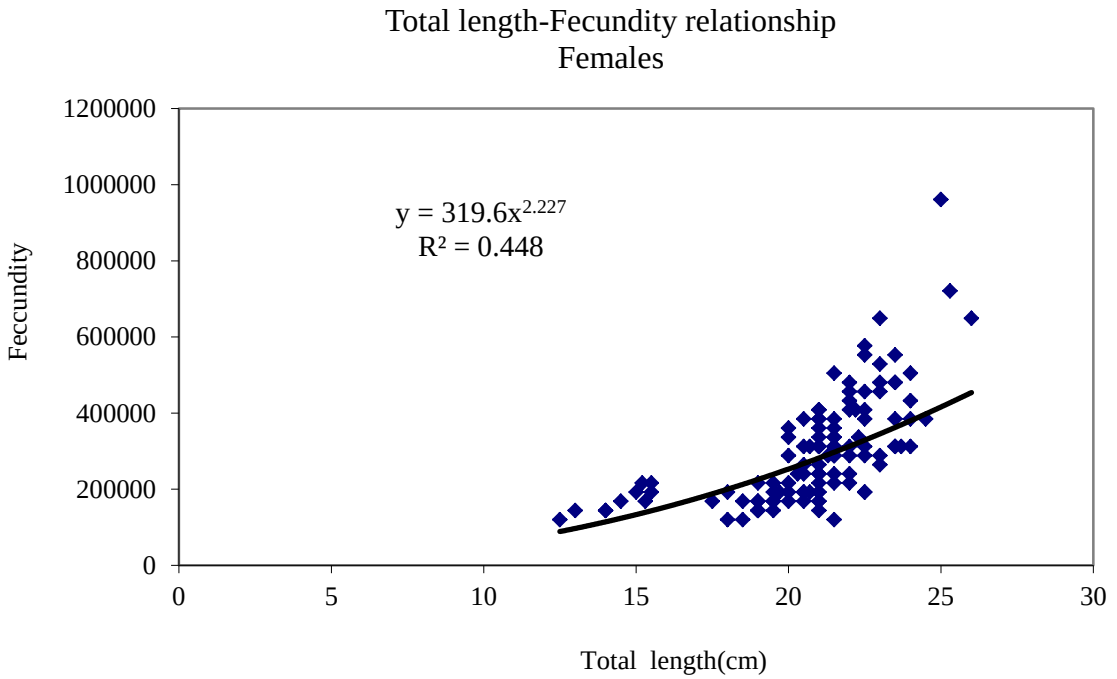

Figure 5.6.Carapace length - fecundity relationship of females of *P monodon* collected from Digha coast during January 2011 to December 2013.