



Gonadal Development and Fecundity of Swimming Crab *Portunus segnis* (Forsk., 1775) in Coastal Waters of Balochistan, Pakistan

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ABSTRACT

This paper deals with a study of sexual maturity by gonadal development, fecundity and gonado-somatic index (GSI) of *Portunus segnis* from Balochistan, Pakistan. The size at sexual maturity attained by the study of gonads, showed that the smallest mature male had 76 mm short carapace width (SCW) in size and the largest male immature crab had 90 mm SCW. In case of female smallest mature crab had 70 mm SCW, while the largest immature crab had 92 mm SCW. The minimum number of eggs estimated in the female *P. segnis* was 86,392 while maximum number of eggs was found to be 1,555,820 in a crab of 138 mm SCW. The average fecundity was $523,773 \pm 279,204$. The GSI values of male crab ranged from 0.70 to 6.20 having a mean of 3.80 ± 1.08 (Mean \pm SD). In case of female, GSI values of samples ranged from 0.71 to 13.33% having a mean of 5.46 ± 3.25 (Mean \pm SD).

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Authors' Contribution

SR conceived and designed the study. EM and RM conducted field and lab work. AB and EM analyzed the data. SR and EM drafted this manuscript.

Key words

Gonadal development, Fecundity, Berried crab, *Portunus segnis*

INTRODUCTION

Portunus segnis (Forsk., 1775) is one of most commercially important and edible crab that belongs to the family Portunidae, found in Pakistan waters. *P. segnis* is native to the Indian Ocean, from Pakistan westwards to Arabian Gulf, the east coast of Africa, Madagascar and Mauritius and Red Sea (Lai *et al.*, 2010).

Reproductive biology of *P. segnis* is dependent on temperature of the sea water, for example, the feeding habits and movement of these species are limited when the definite temperature increases or decreases, and this phenomenon is different between sexes. Studying the reproductive biology, particularly fecundity and season of spawning is meaningful for full comprehension of populace elements of every crustacean species. Fundamental data about inhabitants, reproductive activity and biology is indispensable for strategists to setup guideline for the reduction of population. In this manner, an investigation of reproductive biology of *P. segnis* can be profitable

for administration of blue crab population in this region as well as in other areas. For assessing stock reproductive potential, the estimation of fecundity might offer biological reference points (BRPs) for management of sustainable fisheries (Campbell and Robinson, 1983; Goni *et al.*, 2003; Tallack, 2007; Cooper *et al.*, 2013). The reproductive potential could be resulted to the biggest egg commitment by a specific number of females that spawn in the population (Kanciruk and Herrkind, 1976; Chang *et al.*, 2007). However, there is insignificant number of investigations about the reproductive biology of this species in this belt of the Balochistan coastline. For fishery management of this shellfish, there is likewise a complete lack of knowledge. This study was therefore undertaken for effective utilization of *P. segnis* asset around close shore environments of Balochistan, Pakistan. In this paper, gonad development, size of sexual maturity, fecundity and GSI of *P. segnis* are presented.

MATERIALS AND METHODS

Portunus segnis were collected from commercial landing site of Dam Sonmiani at (25°09' N, 66°29' E) Lasbela, Pakistan coast. Samples were collected monthly wise from August 2017 to May 2018. Samples of *P. segnis* were immediately transported to the laboratory, where crabs were sexed, weighed and measured. Crabs with intact appendages were weighted to the nearest gram on a top loading electronic balance after blotting with a paper towel. Short carapace width (SCW) was taken by

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the digital vernier calliper (Digimatic Caliper CD-6 'CSX) from the base of the ninth antero-lateral teeth (Fig. 1). To investigate the gonadal growth macroscopically, the carapace of the crabs was opened. For the study of gonadal development to establish the maturity phases, male and female crabs (Fig. 2) were dissected and macroscopically analyzed each month (Based on the reproductive staging criterion defined by Kumar *et al.* (2003). For the study of GSI analysis, each crab's carapace was removed and the whole gonad was safely separated and weighted to the nearest 0.01 g (GW). Before the dissection, weight was also noted for each dissected crab. GSI was determined using the Sukumaran and Neelakantan (1997) formula.

$$\text{GSI} = (\text{Gonad weight} / \text{Body weight}) \times 100$$

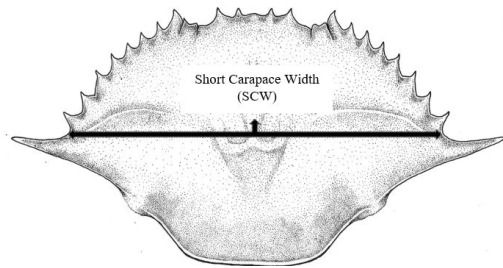


Fig. 1. Measurement of Short Carapace Width (SCW) for study of reproductive biology of *Portunus segnis*.

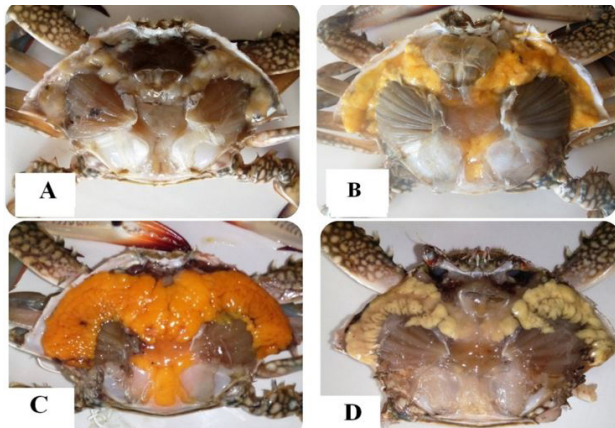


Fig. 2. Macroscopic appearance of female ovary to show different maturity stages of female *P. segnis*, (A) immature, (B) maturing, (C) fully mature, (D) spent.

For the study of fecundity only those berried crabs, which had light yellow, grey and black coloured eggs, were used for the study of fecundity. Three separate egg phases were observed depending on colour: Stage I: The egg mass was light yellow to deep yellow, with no eye spots evident in the eggs. Stage II: Gray colour egg mass with eyes visible as spot in eggs. Stage III: Black colour egg mass, with visible eye spots (Fig. 3).



Fig. 3. Egg stages of berried female crab of *P. segnis*. Stage I: The egg mass light yellow to deep yellow. Stage II: Gray colour egg mass. Stage III: Black colour egg mass.

Pleopods of female crabs on which the eggs were attached carefully separated and then complete egg mass (pleopods with eggs) weighted and then taken to the adjacent weight of 0.01 g on the top loading electronic

balance (Denver Instrument TP-214). Three samples were collected from each egg mass (from 0.01 to 0.02 g). Number of eggs were counted on a counting tray under the stereomicroscope, using hand tally counter. Average total number of eggs found in samples was calculated. To estimate the total weight of egg mass alone, egg mass was weighed with pleopods, then eggs were detached from the pleopods and pleopods washed-out with distilled water then weight of only pleopods was taken which was subtracted from the weight of eggmass with pleopods. Fecundity of females was then calculated by the following formula (Kumar *et al.*, 2003).

$$N = \frac{W \times n}{w}$$

where N is cumulative amount of eggs (Fecundity), W is for whole amount of egg mass, n is amount of experimental eggs on average, w is weight of three sub sample of egg mass.

The egg mass index was calculated as follows.

Egg mass index = (average weight of egg mass/ mean weight of crab) × 100

RESULTS

Gonadal developments

A total of 110 male crabs with a short carapace width of 48 to 135 mm (mean ±SD 94.86 ± 20.61) and 125 female crabs with a short carapace width of 38 to 140 mm (mean ±SD 91.95 ± 27.20) were measured for study of development of the gonads.

Table I shows the distribution of immature and adult crabs in multiple size categories on the basis of gonads. In the case of male *P. segnis*, the size groups of 38-50 mm, 51-62 mm and 63-74 mm SCW have only immature crabs, while the SCW of the size groups 75-86 and 87-98 mm have immature as well as mature crabs. 100% matured crabs were in the remaining four bigger size groups from 99-110 to 135-146 mm SCW. The first two groups of 38-50 and 51-62 mm SCW had 100 percent immature crabs in the case of female *P. segnis*, while the next three groups of 63-74, 75-86 and 87-98 mm had both mature and immature females. The preceding four larger size classes with a SCW of 99-110 to 135-146 mm had 100 percent mature crabs.

Male crabs

Ripe testis was found in smallest mature male (in which testis and vasa-differential was swollen and white in colour) was found in crabs acquiring 76 mm SCW, while immature testis of largest male crab found in 90 mm thick carapace (in which testis and vasa-differential was not visible by naked eye due to their pale colour and difficult to find).

Table I. Distribution of mature and immature crabs of both sexes of *Portunus segnis* in various size classes.

Size group SCW (mm)	Male			Female		
	N	Immature (%)	Mature (%)	N	Immature (%)	Mature (%)
38-50	4	100	0	7	100	0
51-62	5	100	0	8	100	0
63-74	10	100	0	15	80	20
75-86	32	37.5	62.5	38	39.47	60.52
87-98	31	14.63	90.24	30	10	90
99-110	10	0	100	12	0	100
111-122	8	0	100	8	0	100
123-134	6	0	100	4	0	100
135-146	4	0	100	3	0	100

Percentage of all three stages of male testis development were observed during the entire study period (Fig. 4). Highest percentage of stage I was 50% in February 2018 and 46.15% in May 2018. Lowest testis development of this stage was 12.5% in September 2017 and March 2018. Moreover, 0% was observed in August, November and December 2017. Highest percentage of testis development of second stage II was recorded in September 2017 and January 2018 which was 50% while the lowest percentage 7.69 % was observed in May 2018 and 0% in August 2017 and December 2017. The highest percentage stage III was 100% in August 2017 and November 2017 and the lowest was found 33.33% in January 2018 and February 2018.

Female crabs

The smallest mature crabs of 70 mm SCW in case of female *P. segnis* have large ovary, nodulated and bright yellow in colour, while off white in appearance, compressed and small ovary of 92 mm SCW was the largest immature crab. Throughout the study period, four stages of female ovarian development were described as shown in Figure 4. Stage I Immature stage were found every monthly collection and the highest percentage of occurring were found in October 2017 (62.5%) and 41.18% in April 2018. The lowest rate was observed in February 2018 (6.66%). Second stage II which is maturing stage, was recorded in highest percentage with 30% and 25% in the month of March 2018 and August 2017, respectively. However, the lowest percentage of 7.69% occurred in November 2017. Moreover, this stage was not found in October 2017, December 2017 and January 2018. Mature stage which is third stage III was also found in every month of collection. The highest percentage was 70% in the month of January

2018 while the lowest percentage was 20% in March 2018. Fourth stage of ovarian development is spent ovaries which were highly found in 35% that was observed in May 2018 and the lowest ovarian development was observed 5.88% in April 2018. Moreover, none of the spent ovaries were found from August to October 2017.

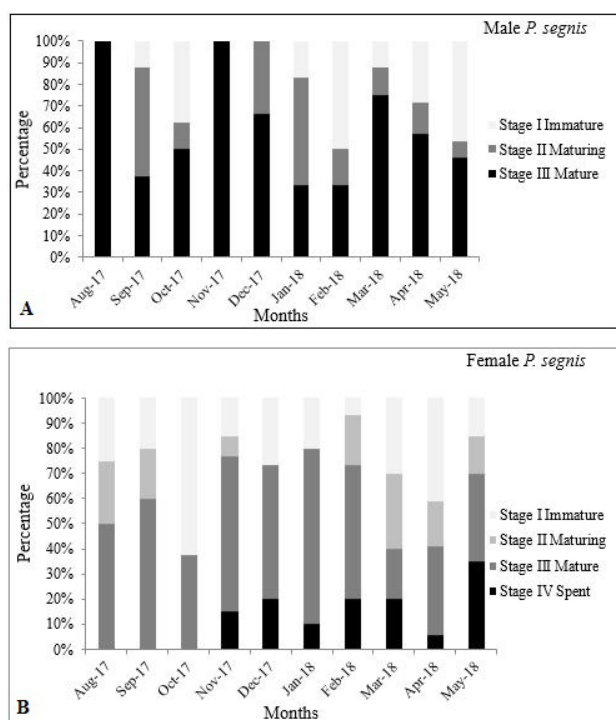


Fig. 4. Percentage of gonad maturity stages in male (A) and female (B) *P. segnis*.

Figure 5 shows 50% maturity of male and female crabs. The male maturity of 50% is 78.5 mm and female crabs achieved scale of sexually mature at a width of short carapace of 74.5 mm.

Gonadosomatic index (GSI)

GSI mean values of male and female swimming *P. segnis* crabs are presented in Table II. For the study of GSI values, a total of 110 male crabs were dissected, GSI varied from 0.70 to 6.20 having an average of 3.80 ± 1.08 S.D. The lowest GSI mean value was recorded 3.27 ± 0.48 in August. After the month of August, the mean value was increased to 3.73 ± 1.66 , 3.99 ± 1.23 in the month of October and September. However, the highest GSI mean value was observed 4.52 ± 0.85 in the month of November but it declined in December. Again, the mean value increased 4.02 ± 0.82 in the month of January. In the last four months the means values decreased from February to May.

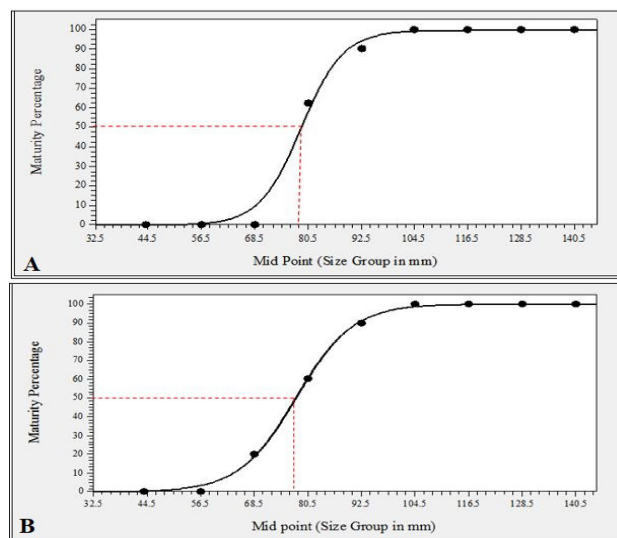


Fig. 5. The logistic curves of 50% maturity in various size classes of the male (A) and female (B) *Portunus segnis* (N = 110).

Logistic model: $y = a / (1 + b \times \exp(-cx))$

Coefficient data: Male; $a = 9.95274370365E+001$; $b = 1.95578686191E+007$; $c = 2.12857746078E-001$; Standard error: 4.7234002; Correlation Coefficient: 0.9962958.

Female; $a = 1.00217211735E+002$; $b = 2.01356887217E+005$; $c = 1.56928940609E-001$; Standard error: 1.6418724; Correlation coefficient: 0.9994943.

Table II. Gonadosomatic indices (GSI) of male and female *P. segnis*.

Month	Male	Female
August 2017	3.27 ± 0.48	5.09 ± 1.27
September 2017	3.99 ± 1.23	6.33 ± 3.25
October 2017	3.73 ± 1.66	3.69 ± 3.76
November 2017	4.52 ± 0.85	7.35 ± 3.75
December 2017	3.77 ± 1.55	4.44 ± 2.27
January 2018	4.02 ± 0.82	5.91 ± 2.77
February 2018	3.87 ± 0.57	7.04 ± 3.80
March 2018	3.43 ± 0.95	5.71 ± 3.72
April 2018	3.72 ± 1.03	4.89 ± 3.07
May 2018	3.55 ± 1.07	4.28 ± 2.58

In the case of female crabs, GSI values of samples ranged from 0.71 to 13.33 having a mean of 5.46 ± 3.25 S.D. GSI mean values increased to 5.09 ± 1.27 , 6.33 ± 3.25 in August and September. The lowest GSI mean value 3.69 ± 3.76 was recorded in October. The peak GSI mean value 7.35 ± 3.75 was observed in November. It was

again decreased in December and January. Once again the peak GSI mean value was recorded in February in the last month the mean GSI value was decreased to 5.71 ± 3.72 in March. Moreover, the GSI mean value of females was significantly greater than that of the males.

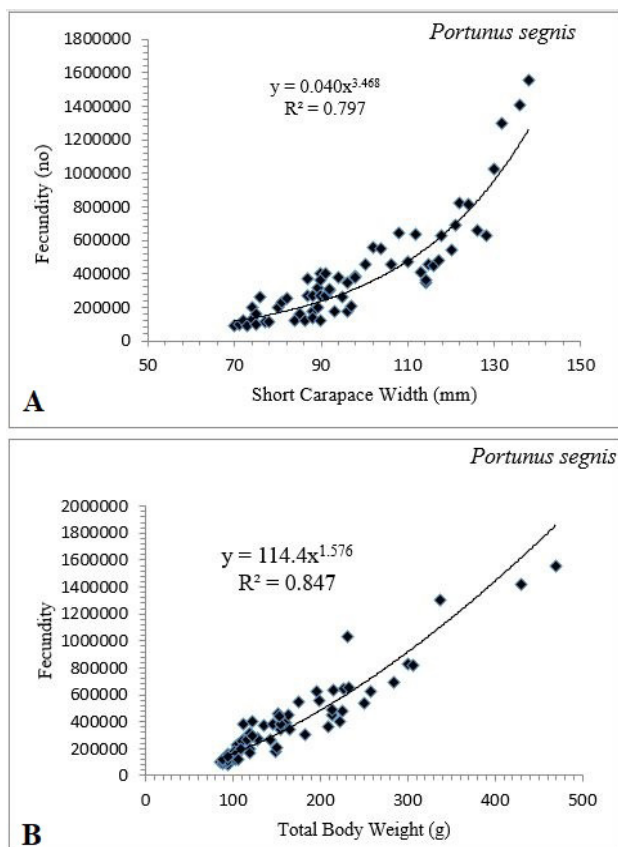


Fig. 6. Comparison between short carapace width (SCW) (A) and total body weight (B) and fecundity of *Portunus segnis*.

Fecundity

Study of fecundity was carried out on 65 berried females of *P. segnis* having SCW from 70 to 138 mm (mean 97.47 ± 18.04 SD) and TBW from 95 to 470 g (mean 164.04 ± 79.70 SD). The relationships of SCW with Fecundity (F) are shown in Figure 6 and correspondence between total weight of body TBW with F is shown in Figure 6. Smallest amount of fecundity was observed in a berried female at SCW of 70 mm and TBW was 95 g. However, the highest fecundity was recorded in 138 mm SCW and TBW was 470 g. The numbers of eggs were determined in the clutch of female *P. segnis* ranged from 86,392-1,555,820 eggs in various sizes of SCW from 70 to 138 mm. A few smaller crabs were also found to bear greater number of eggs than larger crabs, as approximately 119,705 eggs were found

to have a smaller female measuring 72 mm SCW, while about 97,470 eggs were borne by another measuring 75 mm SCW. Likewise, some crabs bore slightly less eggs than others, while the size of the crabs remained the same.

Table III. *P. segnis* egg stages and fecundity of different berried crabs.

Egg colour	Number (n)	Fecundity Mean \pm SD (Range)
Yellow	28	479218 \pm 380131 (130,357-1,555,820)
Brown	13	319,931 \pm 21,3294 (86,392-813,054)
Black	24	332,386 \pm 230389 (89030-1030142)

Fecundity of different egg stages

The egg stages and fecundity of *P. segnis* are displayed in Table III. First stage (yellow colour egg mass, no eyespot was observable in the eggs) was found in 28 berried females with fecundity range 130357 to 1,555,820 (mean $479,218 \pm 380,131$ S.D). Thirteen berried crabs of second stage (orange to brown colour egg mass with small eyespot was visible in the eggs) were observed. This stage having maximum numbers of eggs were 813,054 and minimum numbers of eggs were 86,392 (mean $319,931 \pm 213,294$ S.D). Third stage (brown to black colour egg mass and big eyespot was visible in the eggs) were observed in 24 berried females. In this stage, maximum numbers of eggs were 1,030,142 and minimum numbers of eggs were 89,030 (mean $332,386 \pm 230,389$ S.D).

Different sizes of *P. segnis* were sampled and among these crabs, their size range estimated to find out the more frequent SCW size for fecundity and other biological aspects. Table IV presents the total number of eggs for different size groups. The more frequent size range 16 was observed at 90-99 mm SCW. The highest number of 1,323,466 egg, body weight average 367 ± 106.75 , egg mass average weight 89.7 ± 20.68 and egg mass index 24.44 were observed at 130-139 mm SCW. However, the minimum number of 133,755 eggs, body weight average 97.09 ± 8.58 , egg mass average weight 11.05 ± 4.53 and egg mass index 11.38 were observed at 70-79 mm SCW.

DISCUSSION

Fifty percent of the inhabitants of male and female crabs achieved full mature sexuality at 76.5 mm and 74.5 mm width of short carapace, respectively. Current research results agree with Sumpton *et al.* (1989), who established physiological maturities in both male and female *P. sanguinolentus*, who stated that both males and females

Table IV. Fecundity, weight of egg mass and index of egg mass in various size classes of *P. segnis*.

Size range (mm)	Sample (no)	Short carapace width (mm)	Mean body weight (g)	Mean egg mass weight (g)	Average fecundity	Egg mass index
70-79	11	74.09 ± 2.46	97.09 ± 8.58	11.05 ± 4.53	133,755	11.38
80-89	14	85.85 ± 3.00	107.57 ± 11.29	16.70 ± 6.18	213,380	15.52
90-99	16	93.31 ± 2.98	141.25 ± 19.70	25.16 ± 9.27	297,403	17.81
100-109	5	104 ± 3.16	183.6 ± 30.03	37.8 ± 11.77	533,485	20.58
110-119	9	114.33 ± 2.5	201.33 ± 25.57	32.87 ± 3.84	469,081	16.32
120-129	6	123.5 ± 3.08	271.83 ± 28.93	52.98 ± 10.23	692,406	19.49
130-139	4	134 ± 3.65	367 ± 106.75	89.7 ± 20.68	1,323,466	24.44

± indicated standard deviation.

had maturities of 83 and 74 mm LCW, respectively. [Reeby *et al.* \(1990a\)](#) recorded that male *P. sanguinolentus* had a complete sexual maturity (both functional and physiological) of 81 to 85 mm LCW. [Chu \(1999\)](#) provided an estimation of gonad growth study on 50 percent gonad maturity at 42 and 36 mm carapace width for females and males of *Charybdis affinis* crabs, respectively. [Hosseini *et al.* \(2014\)](#) observed that 50 percent of female *P. segnis* had sexual maturity at 75 mm CW.

[Rasheed and Mustaqim \(2010\)](#) recorded that fifty percent male *P. sanguinolentus* matured at 60.8 mm SCW, while 50 percent female *P. sanguinolentus* matured at 63.5 mm SCW. [Yang *et al.* \(2014\)](#) recorded that 50 percent of males and females of *P. sanguinolentus* had reached maturity at 76.4 and 82.2 mm CW, respectively. [Potter and De-lestang \(2000\)](#) studied *P. pelagicus*, which showed that 50 percent of females had sexual maturity while they were 97 mm CW, while male crabs were 84 mm CW. The present findings are not comparable to those of [Wardiatno and Fahrudin \(2015\)](#) who reported that 50 per cent of males and females *P. pelagicus* sexual maturity at 98 mm and 103 mm carapace width (CW), respectively; [Tureli and Yesilyurt \(2017\)](#) who reported 50 per cent of females *P. segnis* sexual maturity at 115 and 119.99 mm CW; [Safaie *et al.* \(2013\)](#) who and recorded 50% of females sexual maturity *P. segnis* at size of 113 mm CW; [Soundarapandian *et al.* \(2013\)](#) who reported 50 percent of male crabs sexual maturity in *P. pelagicus* at the size of 106 to 110 mm of carapace width; and [Wimalasiri and Dissanayake \(2016\)](#) who estimated the size of *P. sanguinolentus* at first sexual maturity, in males with 97 mm CW, and females at 94 mm CW.

The average values of GSI for females were slightly higher than for males in this study. The present observation is close to [Wardiatno and Fahrudin \(2015\)](#) who recorded that the mean monthly GSI of matured female also displayed cyclic trends, although the lowest GSI mean value was 3.3 percent ± 0.5 in April and September, the highest GSI mean was 4.0 percent ± 0.3SE in December.

[Tureli and Yesilyurt \(2017\)](#) analyzed *P. segnis*, which determined that the values of GSI differed from 0.13 to 13.60 percent with a mean of 2.21 ± 2.67 S.D. for the 113 female specimens. The GSI of *P. sanguinolentus* females were significantly higher than that of males, estimated by [Wimalasiri and Dissanayake \(2016\)](#). Present findings are not comparable to those of [Sahoo *et al.* \(2011\)](#) who *P. pelagicus* reported that in the GSI was less than 0.5 in December to February while in May to July the GSI was increased from 2.0 to 2.5. [Wimalasiri and Dissanayake \(2016\)](#) recorded GSI ranging from 0.02 to 3.69 for males (mean 0.75 ± 0.58 S.D) and from 0.12 to 9.44 for females (mean 3.29 ± 2.13 S.D).

Sixty five berried crabs were analyzed for the study of fecundity, sizes from 70 to 138 mm (mean 97.47 ± 18.04 SD). Number of eggs estimated in the female *P. segnis* clutch ranged from 86,392 to 1,555,820 eggs. Minimum fertility of 70 mm SCW and total body weight of 95 g was observed in berried females, while maximum fertility of 138 SCW mm and total body weight of 470 g was also reported. Few smaller crabs that hold more eggs than larger crabs have also been identified. The present findings are similar to [Wimalasiri and Dissanayake \(2016\)](#) who estimated the fecundity range of *P. sanguinolentus* between 112017 and 1380223 number of eggs. [Kamrani *et al.* \(2010\)](#) reported that females of *P. pelagicus* at ranged from 32 to 173 mm CW produce 277421 to 1114348 eggs and their mean fecundity was 662978 eggs. [Hermanto \(2004\)](#) studied on *P. pelagicus* to find out their fecundity in Subang, West Java. The results show that the berried females can produces 81,000 to 1,343,000 number of eggs. [Rasheed and Mustaqim \(2010\)](#) recorded 272,000 to 1,395,000 eggs at 63 to 120 mm CW in *P. sanguinolentus* from Karachi, Pakistan. [Rasheed *et al.* \(2021\)](#) found average fecundity in *P. pelagicus* $523,773 \pm 279,304$ (S.D) at mean SCW 98.53 ± 18.05 mm.

Fecundity outcomes of present study are greater than those of [Yang *et al.* \(2014\)](#), who fecundity and recorded a total of 58,600 to 565,000 berried female eggs

P. sanguinolentus, with female fecundity being strongly associated with CW, with the smallest berried female being 77.1 mm CW and the largest berried female and 139.6 mm CW. The average number of egg batches produced by *P. pelagicus* female crabs as reported by Arshad *et al.* (2006) produces eggs from the 148,897 to 835,401. In south western India, Sukumaran and Neelakantan (1997) 56,000 to 1,070,000 eggs produced by berried females of *P. pelagicus*. Sukumaran *et al.* (1986) observed that *P. sanguinolentus* fecundity ranged in South Kanara India from 300,000 to 700,000 (83 mm to 113 mm SCW). At 79 to 126 mm SCW of *P. pelagicus* in Karawar India, Reeby *et al.* (1990b) recorded 158,608 to 712,526 eggs.

The current fecundity values are less than the results of Safaie *et al.* (2013) who recorded 521,027 to 6,656,599 eggs in *P. segnis* ovigerous crabs, and the mean fertility of 2,397,967 eggs. The fecundity values ranged from 229,468 to 2,236,355 numbers of eggs in *P. pelagicus* with (mean $926,638 \pm 30,975$ S.D) stated by Zairion and Fahrudin (2015) and the fecundity was positively and linearly associated with width of carapace. Tureli and Yesilyurt (2017) classified 44 ovigerous crabs of *P. segnis* ranging from 101.4 to 154 mm CW and recorded 139,379 to 2,745,236 egg development figures.

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CONCLUSIONS

Different sizes of *P. segnis* were sampled and among these their range were estimated to find out the SCW for fecundity and other biological aspects. The highest number of 1,323,466 egg, body weight average 367 ± 106.75 , egg mass average weight 89.7 ± 20.68 and egg mass index 24.44 were observed at 130-139 mm SCW. However, the minimum number of 133,755 eggs, body weight average 97.09 ± 8.58 , egg mass average weight 11.05 ± 4.53 and egg mass index 11.38 were observed at 70-79 mm SCW.

Statement of conflict of interest

The authors have declared no conflict of interest.

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