Pakistan J. Zool., pp 1-9, 2021. DOI: https://dx.doi.org/10.17582/journal.pjz/20170427100439

Size at Sexual Maturity and Fecundity of the Blue Swimmer Crab, *Portunus pelagicus* (Linnaeus, 1758) along the Coast of Karachi, Pakistan

Shazia Rasheed[1]*, Javed Mustaquim[2] and Khalil Hasni[1]

[1]*Lasbela University of Agriculture, Waters and Marine Sciences, Uthal, Balochistan*
[2]*Centre of Excellence in Marine Biology, University of Karachi, Karachi*

Article Information
Received 27 April 2017
Revised 29 July 2018
Accepted 13 November 2019
Available online 18 June 2020

Authors' Contribution
JM supervised and design the study. SR executed the experimental work, analyzed the data and wrote the article. KH helped in statistical work and page proof.

Key words
Sexual maturity, Fecundity, Berried crab, *Portunus pelagicus*

ABSTRACT

In the present paper, size at sexual maturity was determined by relative growth (functional) as well as by examining the condition of gonads (physiological) in both sexes of *Portunus pelagicus*. During the study it was observed that the physiological and functional maturities occur almost at the same size which was from 68 to 75 mm short carapace width or 86 to 94 mm long carapace width. Male *P. pelagicus* matures earlier than the females. The size at which females attains full sexual maturity is 74-86 mm short carapace width (or 93 to 108 mm long carapace width). The size at 50% sexual maturity for male and female crabs was 63.57 mm and 83.55 short carapace width, respectively. The minimum number of eggs was 1, 72, 963 in a crab of 84 mm short carapace width whereas maximum number of eggs was found to be 11, 27,796 in a crab of 135 mm short carapace width. The average fecundity was 523773 ± 279204 (S.D) for a berried crab with a mean short carapace width of 98.53± 18.05 mm.

INTRODUCTION

Portunus pelagicus is commonly known as 'blue swimming crab' (Carpenter *et al*., 1997) or 'flower crab' (Carpenter and Niem, 1998) due to its appearance. Local fisher called it "Neela Kekra". Biology of *Portunus pelagicus* has been studied extensively in various countries of Southeast Asia and Australia for the proper management of their crab fisheries and sustainable utilization of the resource.

Usually two types of criteria are applied to determine the size at which sexual maturity is attained (Rasheed and Mustaquim, 2010). In *Portunus* species both types of maturity have been worked out from different countries. From Australia, Campbell and Fielder (1986) and Xiao and Kumar (2004) have studied size at sexual maturity in *P. pelagicus* by relative growth. Weng (1992) determined the size of sexual maturity in *P. pelagicus* on the basis of gonadal development from Queensland. de Lestang *et al.* (2003) applied both criteria to examine the size at which maturity is attained by male and female *P. pelagicus* from the west coast of Australia. From India, Reeby *et al*. (1990) investigated size at sexual maturity in male *P. pelagicus* and *P. sanguinolentus* by relative growth of chela whereas Sukumaran and Neelakantan (1996) studied relative growth and sexual maturity in the two species of *Portunus* from Southwest coast of India. From Philippines Ingles and Braum (1989) studied size at sexual maturity by relative growth in *P. pelagicus.*

Size at which male and female brachyuran crabs attain sexual maturity has been worked out by several researchers in crabs like *Portunus pelagicus* (Fielder and Eales, 1972; Campbell and Fielder, 1986; Batoy *et al*., 1987; Ingles and Braum, 1989; Reeby *et al*., 1990; Weng, 1992; Sumpton *et al*., 1994; Sukumaran and Neelakantan, 1996; de Lestang *et al*., 2003; Xiao and Kumar, 2004), *P. sanguinolentus* (Wimalasiri and Dissanayake, 2016; Campbell and Fielder, 1986; Reeby *et al*., 1990; Sukumaran and Neelakantan, 1996), *Liocarcinus depurator* (Mori and Zunino, 1987; Muino *et al*., 1999), *Ovalipes punctatus* (Du Preez and McLachalan, 1984), *O. stephensoni* (Haefner, 1985), *Charybdis feriatus* (Campbell and Fielder, 1986), *C. natator* (Sumpton, 1990), *Scylla serrata* (Imtiaz *et al*., 1998), *Callinectes ornatus* (Haefner, 1990), *Chionectes bairdi* (Brown and Powell, 1972), *Ocypoda quagratea* (Haley, 1972) and *Sesarma rectum* (Leme, 2005).

Size at sexual maturity, breeding season and fecundity are important aspects of reproductive biology of crab. This information is often required to manage crab fisheries on sustainable basis. The study of fecundity is important to have a full understanding of the population dynamics.

* Corresponding author: shaziarasheed_22@hotmail.com; shaazz_22@yahoo.com
0030-9923/2021/0001-0001 $ 9.00/0

From Pakistan no work has been done so far to determine the size at which male and female *P. pelagicus* attain sexual maturity, knowledge of which may have important implications on the resources management. In this paper size at sexual maturity (determined by relative growth and condition of the gonad) and fecundity are described for *Portunus pelagicus*. Size at sexual maturity and fecundity are important aspects of reproductive biology of crab.

MATERIALS AND METHODS

A total of 941 male and 1027 female crabs of *P. pelagicus* for the present study were collected from the commercial landing at Korangi Fish harbour (24° 48′ 50″ N; 67° 13′ 45″ E), Karachi. The sampling was done twice in a month for a period of two years.

For relative growth of chela, abdomen and male pleopod, measurements were taken as described in Rasheed and Mustaquim, 2010. For gonadal maturity crab's carapace was removed to examine gonad macroscopically. Male crabs having anterior and middle vas deferentia enlarged and white in colour were regarded as mature (de Lestang *et al*., 2003; Wimalasiri and Dissanayake, 2016; Zhang *et al*., 2020). In case of female crabs, if the ovary was large, orange, and nodulated then crabs were considered as mature (de Lestang *et al*., 2003). In mature female crabs the ovary displaces the hepatopancreas and occupies the anterior region. The middle and the posterior lobes of the ovary are well developed and fill the gastric, posterior and intestinal cavities. Mature female with spent ovary were easily recognized by the swollen spermatheca and translucent ovary.

For fecundity, only those berried crabs were used which had bright yellow or bright orange colored eggs indicating that the eggs had been deposited recently. Pleopods bearing eggs were removed carefully and the weight of the whole egg mass (eggs + pleopods) was taken to the nearest 0.01 g on a top loading electronic balance. Three samples (from 0.20 to 0.30 g) were taken from egg mass. Number of eggs in these samples was counted in a counting tray under stereomicroscope. Average number of eggs present in the samples was then calculated. In order to find out total weight of the egg mass only, eggs were removed from the pleopods and the weight of the pleopods was taken. This was subtracted from the weight of the whole egg mass. Fecundity was then calculated by method described by Rasheed and Mustaquim (2010). Student *t*-test (Zar, 1996) was used to find out significance of the observed values.

The statistical analysis was done with the help of MINITAB (Version 15) and Curve Expert statistical software and Microsoft Excel.

In relative growth, changes in proportions of different parts of an organism, as a result of growth, are studied. Usually relationship of two dimensions is compared at a time by the simple linear regression equation:

$$Y = a + b.X$$

One is the reference dimension which represents the body size and is considered as independent variable such as carapace length or width in brachyuran crabs. The other is the dimension whose relative growth is under study and is considered as dependent variable such as pleopod length or cheliped width. The relative growth is represented by the formula:

$$Y = a X^b$$

Where y is the relative dependent variable, a is the y-intercept, x is the independent variable and b is the relative growth rate or allometric growth constant. A log transformation of the relative growth equation produces:

$$Log\ Y = log\ a + b.\ log\ X$$

If log y plotted against log x it will give a straight line whose slope has the value of b. If the value of b is greater than 1 then there is a positive allometry, which means that the organ is growing faster than the body. If b is less than 1 then there is a negative allometry with the organ growing slower than the body. When the value of b is equal to 1 then there is isometry and the organ and the body are growing at the same rate (Hartnoll, 1982).

RESULTS

Size at which sexual maturity is attained by the male and female crabs of *Portunus pelagicus* was determined by relative growth (or allometry) which also mentions as functional method. Size at sexual maturity also determined by examining the condition of gonads (physiological method). The results are presented below.

Size at sexual maturity by functional method

Chela allometry

A total of 260 male crabs having 23 mm to 134 mm (mean 76.64 mm ± 24.08 SD) short carapace width and 314 female crabs having 26 mm to 148 mm (mean 74.01 mm ± 22.44 SD) short carapace width were measured for the relative growth of chela. The relationship between chelar propodus length and short carapace width is shown in Figure 1A for male and Figure 1B for female crabs. The regression equations for each of the two phases (separated by visual mean) are given in Table I while in Table IV analysis of covariance (ANCOVA) carried out to test the significance of simple linear regressions are given. The value of regression coefficient b was found to be 1.1163 for immature male and 1.4024 for mature male.

Table I. *Portunus pelagicus*: Summary of linear regressions and log-transformed regression analysis.

Y-vari ble	Sex	Size-range (SCW)	Regression equations	R^2	b	S. E. b	t (b=1)	AL	t (compa-ring two slopes)
CPL	Immature Male	23-67 mm	CPL = - 3.9823 + 0.7967 SCW	0.98	1.1163	0.0156	7.440*	+Ve	39.178*
			Log CPL = log-0.34 + 1.116log SCW	0.979					
	Mature Male	75-134 mm	CPL = - 37.178+ 1.2985 SCW	0.988	1.4024	0.0103	38.94*	+Ve	
			Log CPL = log- 0.84+ 1.40 log SCW	0.987					
	Female (Imma-ture & mature)	26 -148 mm	CPL = - 2.8733 + 0.7538 SCW	0.991	1.0591	0.014	4.191*	+Ve	…
			Log CPL= log -0.25 + 1.059log SCW	0.991					

*significant (α=0.05); AL, allometry; b, regression coefficient (slope of the line); CPL, chelar propodus length; iso, isometric; R^2, coefficient of determination; SCW, short carapace width; S.E. b, standard error of b; t, student's *t*-test.

Table II. *Portunus pelagicus*: Summary of linear regressions and log-transformed regression analysis.

Y- vari ble	Sex	Size-range (SCW)	Regression equations	R^2	b	S. E. b	t (b=1)	AL	t (compa-ring two slopes)
LP	Immature Male	23-66 mm	LP = -4.009+ 0.389 SCW	0.975	1.3123	0.0187	16.64*	+Ve	42.280*
			Log LP = log -1.04+ 1.312log SCW	0.98					
	Mature Male	76-134 mm	LP = -0.1375+ 0.309 SCW	0.981	0.9952	0.0101	0.475	iso.	
			Log LP = log -0.502+ 0.995 log SCW	0.978					

*significant (α=0.05); For abbreviations and statistical details, see Table I.

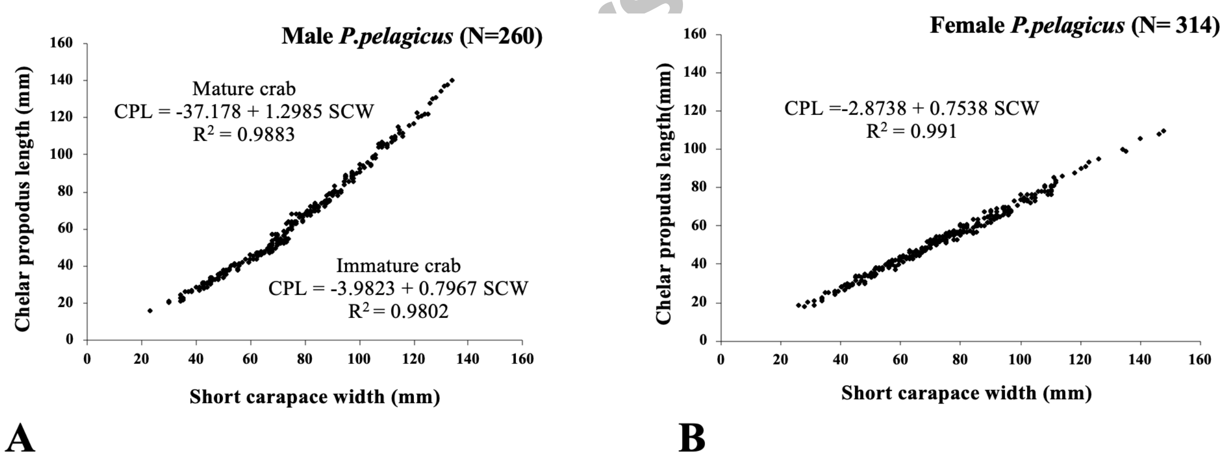

Fig. 1. Relationship between short carapace width (SCW) and chelar propodus length (CPL) in (A) male (n=260) and (B) female (N=314) of *Portunus pelagicus*.

These values were found significantly different from 1 (t = 7.440 for immature male and 38.940 for mature male, α = 0.05), which shows that the growth was positive in both phases. The difference between immature and mature male b values were also found significant (t = 39.178, α = 0.05). In male crabs chela allometry is slightly positive in first phase (crabs having <66 mm short carapace width) and then allometry changes and chela grows more positively in second phase (crabs having > 74 mm short carapace width). This shows that the puberty moult occurs between 66-74 mm short carapace width in male crabs. On the other hand, relative growth of the chela of female *P. pelagicus* was found positive but no sudden change was observed. The regression equations which are given in Table I and the value b obtained for female is significantly different from 1 (t = 4.191; α = 0.05).

Pleopod allometry

The relationship between short carapace width and first pleopod length of male crabs is shown in Figure 2.

The regressions were computed separately for each of the two resulting phases which are given in Table II while in Table V analysis of covariance (ANCOVA) carried out to test the significance of simple linear regressions. The regression equations show that the growth of pleopod in the first phase was positive and in the second phase it was isometric with respect to short carapace width. The value of regression coefficient b was significantly different from 1 for immature male ($t = 16.638$; $\alpha = 0.05$) and insignificant for mature ($t = 0.475$; $\alpha = 0.05$) male crab. Student's *t*-test also revealed that the difference between immature and mature male b values was significant ($t = 42.280$; $\alpha = 0.05$). The pleopod length shows positive allometry in first phase (crabs <66 mm short carapace width) and in second phase (crabs >75 mm short carapace width) the allometry becomes isometric. This shows that the puberty moult occurs between 66-75 mm short carapace width in male crabs.

Abdomen allometry

Figure 3A shows the relationship between short carapace width and abdomen width in 314 female crabs ranging from 26 mm to 148 mm short carapace width (mean 74.23 mm ± 22.44 S.D.). The width of female abdomen shows allometry up to 72 mm short carapace width. At this stage the relative growth of abdomen is changed and

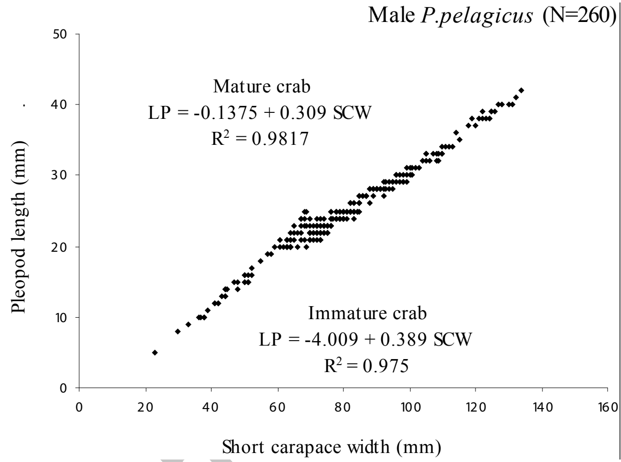

Fig. 2. *Portunus pelagicus*: Relationship between short carapace width (SCW) and pleopod length (LP) in male crabs (N=260).

Table III. *Portunus pelagicus*: Summary of linear regressions and log-transformed regression analysis.

Y- vari ble	Sex	Size-range (SCW)	Regression equations	R^2	b	S. E. b	T (b=1)	AL	T (compa-ring two slopes)
AW	Immature Female	26-73 mm	AW = - 3.8201 + 0.3718 SCW	0.971	1.2698	0.019	13.84*	+Ve	9.017*
			Log AW= -0.9933 + 1.2698 log SCW	0.978					
	Mature Female	86-148 mm	AW= -7.8834 + 0.5011 SCW	0.976	1.1799	0.011	16.20*	+Ve	
			Log AW= -0.7352 + 1.1799 log SCW	0.972					
	Male (Imma-ture & mature)	23 -134 mm	AW= 0.7755 + 0.3038 SCW	0.992	0.9586	0.013	3.084*	-Ve	…
			Log AW= -0.4247 + 0.9586 log SCW	0.991					

*significant (α=0.05); For abbreviations and statistical details see Table I.

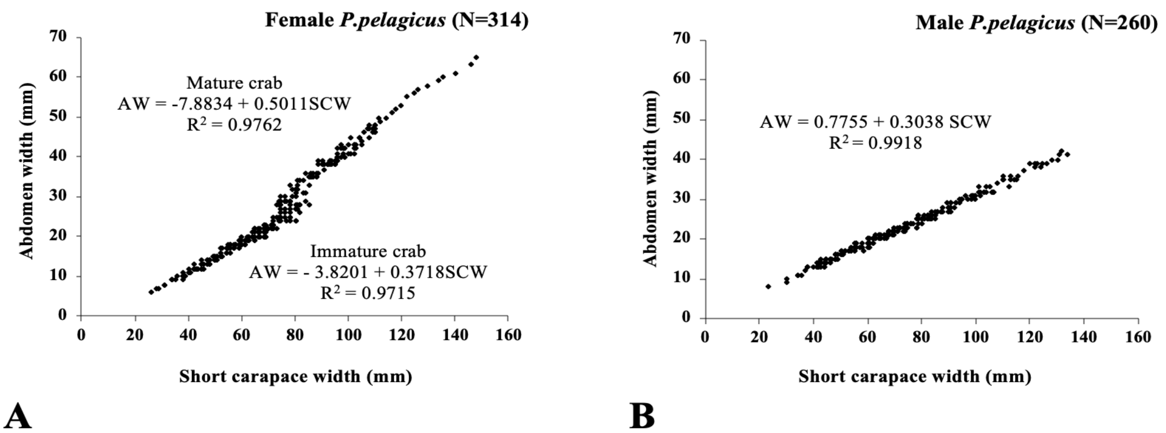

Fig. 3. Relationship between short carapace width (SCW) and abdomen width (AW) in (A) female (N=314) and (B) male (n=260) of *Portunus pelagicus*.

becomes less positive in second phase (85 mm and above). This shows that the puberty moult occurs between 72-85 mm short carapace width in female crabs. The regressions equations for the two phases are given in Table III and in Table VI, analysis of covariance (ANCOVA) are carried out. The value of regression coefficient 'b' was found to be 1.2698 for immature female and 1.1799 for mature female. These values were found significantly greater than 1 (t = 13.842 for immature female and 16.207 for mature female, α = 0.05), which shows that the growth was positive. The difference between immature and mature female b values were also found significant (t = 9.017, α = 0.05).

Abdomen width of 260 male crabs was also measured and the relationship with short carapace width is shown in Figure 3B. The value of b was found to be 0.9586 which is significantly less than 1 (t = 3.084; α = 0.05). The abdomen width increases negatively with the short carapace width and there is no sudden change in the relative growth of male abdomen.

Table IV. *Portunus pelagicus*: Analysis of covariance (ANCOVA) carried out to test the significance of simple linear regressions.

Variables	Source of variance	df	SS	MS	F
CPL	Male (Immature=0)				
	Regression	1	6001.7	600.17	4205.28*
	Residual	86	122.7	1.4	
	Total	87	6124.4		
	Male (Mature=1)				
	Regression	1	51200	51200	11122.02*
	Residual	132	608	5	
	Total	133	51808		

CPL, chelar propodus length; df, degree of freedom; F, F-test (*significant, P< 0.001); MS, mean squares; SS, sum of squares.

Size at sexual maturity by physiological method

Study of gonads

A total of 941 male and 1027 female *P. pelagicus* having short carapace width from 23 mm to 135 mm and 26 mm to 148 mm, respectively, were dissected and the condition of gonads was examined.

The short carapace width of the smallest male having ripe testis (testis and vasa- differentia swollen and white in colour) was found to be 64 mm whereas the largest male crab having immature testis (testis and vasa- differentia not detectable by naked eye and difficult to locate due to their pale colour) had 72 mm wide carapace. In case of female *P. pelagicus*, the smallest mature crab (large ovary, deep yellow in colour and nodulated) had 70 mm short carapace width while the largest immature crab (small ovary, flattened and off white in colour) had 86 mm short carapace width. The smallest berried crab was 78 mm in short carapace width.

Table V. *Portunus pelagicus*: Analysis of covariance (ANCOVA) carried out to test the significance of simple linear regressions.

Variables	Source of variance	df	SS	MS	F
LP	Male (Immature=0)				
	Regression	1	1043.7	1043.7	2223.39*
	Residual	57	26.8	0.5	
	Total	58	1070.4		
	Male (Mature=1)				
	Regression	1	3257.4	3257.4	7560.41*
	Residual	141	60.7	0.4	
	Total	142	3318.2		

df, degree of freedom; F, F-test (*significant, P< 0.001); LP, length of pleopod; MS, mean squares; SS, sum of squares.

Table VI. *Portunus pelagicus*: Analysis of covariance (ANCOVA) carried out to test the significance of simple linear regressions.

Variables	Source of variance	df	SS	MS	F
AW	Female (Immature=0)				
	Regression	1	3057.3	3057.3	5218.3*
	Residual	153	89.6	0.6	
	Total	154	3147		
	Female (Mature=1)				
	Regression	1	4318.1	4318.1	3561.37*
	Residual	87	105	1.2	
	Total	88	4423		
	Male				
	Regression	1	13405	13405	31294.36*
	Residual	258	111	0.428	
	Total	259	13515		

AW, abdomen width; df, degree of freedom; F, F-test (*significant, P< 0.001); MS, mean squares; SS, sum of squares.

Figures 4A and B shows that the 50% population of male and female crabs attains sexual maturity at 63.57 mm and 83.55 mm short carapace width, respectively.

Fecundity

Numbers of un-eyed eggs were counted in 26 females ranging from 76 mm to 145 mm in short carapace width. The minimum number of eggs was 1, 72, 963 in a crab of 84 mm

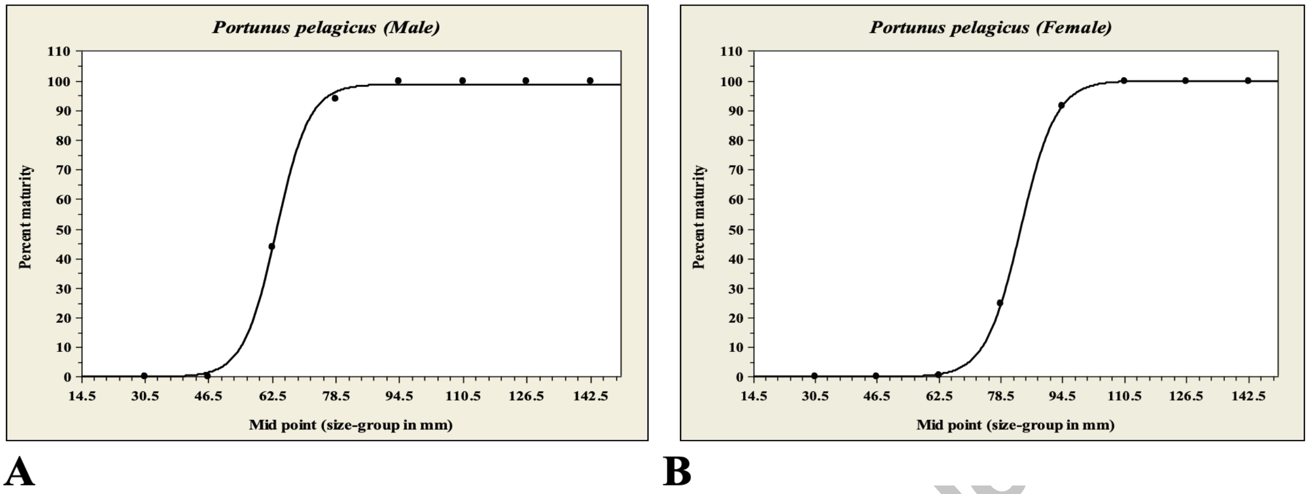

Fig. 4. Size of 50% maturity in different size groups of (A) male (n=941) and (B) female (n=1057) of *Portunus pelagicus* estimated by evaluating the logistic curve.

short carapace width whereas maximum number of eggs was found to be 11, 27,796 in a crab of 135 mm short carapace width. The average fecundity was 523773 ± 279204 (S.D) for a berried crab with a mean short carapace width of 98.53± 18.05 mm.

The relationship between fecundity and short carapace width is given in Figure 5, which shows that egg number increases with increase in short carapace width. The scattered plot shows a trend by power function: egg number = 0.8063 SCW $^{2.8946}$ and the two variables are strongly co-related. (R^2 = 0.8756).

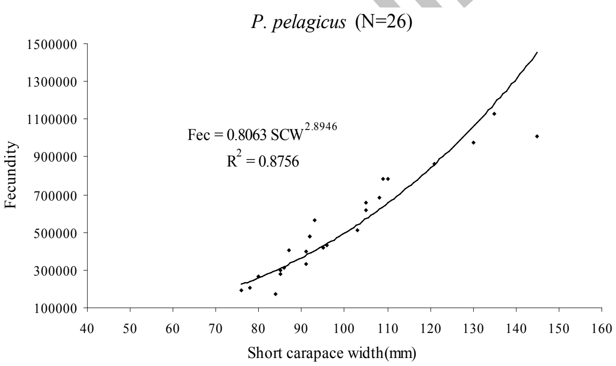

Fig. 5. *Portunus pelagicus*: Relationship between fecundity (Fec) and short carapace width (SCW).

DISCUSSION

Chela of male crab and abdomen in females are considered as secondary sexual characters because of their function in reproduction (Hartnoll, 1978). The male crab uses its chela for territorial defense, combat, mating and courtship as well as in carrying and holding the female during copulation. The abdomen in adult females forms an incubation chamber for the developing eggs, which are attached to the setose pleopods. The increase in relative growth of the male chela and female abdomen at the puberty moult brings these structures to fully functional size at sexual maturity. Hence the relative growth of chela in males and abdomen in females has been used to determine size at which puberty moult occurs or functional maturity attained. Another character frequently used in determining functional maturity in male crabs is the relative growth of 1st pleopod, which is used as interomittant organ during copulation. The relative growth of first pleopod decreases after puberty moult, which enables the male crabs to copulate even with small female crabs, as well (Warner, 1977).

During present investigation it was observed that the physiological and functional maturities occur almost at the same size in *Portunus pelagicus*. This finding agrees with that of Reeby *et al*. (1990a) who studied sexual maturity in male *P. pelagicus* and *P. sanguinolentus* from Karwar, west coast of India and Leme (2005) who determined the size at sexual maturity of female grapsid crab *Sesarma rectum* from Brazil. Similar results have been presented by de Lestang *et al*. (2003a) for male and female *P. pelagicus* from west coast of Australia.

The size at which male *P. pelagicus* attains full sexual maturity (physiological and functional) in Karachi waters varies from 68 to 75 mm short carapace width or 86 to 94 mm long carapace width according to present investigation. This is very close to the size 86-90 mm long carapace width reported by Reeby *et al*. (1990a) for male *P. pelagicus* from Karwar. From the west coast of Australia, de Lestang *et al*. (2003a) reported that the male *P. pelagicus* attains sexual maturity at a size of 86 - 87.2 mm long carapace width. Ingles and Braum (1989) determined sexual maturity on the basis of morphometry and reported that 96.4 mm long carapace width is the size at which male *P. pelagicus* attains sexual maturity in Ragay Gulf, Philippines. From Cockburn Sound, Australia Hall *et al*. (2006) stated that the male *P. pelagicus* attains morphometric (=functional) maturity at 82 mm long carapace width. Weng (1992), who studied two populations of *P. pelagicus* from Australia, found that the male *P. pelagicus* in the Gulf of Carpentaria matures at 70 mm long carapace width while in Moreton Bay the males mature at 80 mm long carapace width.

It was also observed during present investigation that male *P. pelagicus* matures earlier than the females. The size at which females attains full sexual maturity is 74-86 mm short carapace width (or 93 to 108 mm long carapace width). This is in accord with those of Ingles and Braum (1989) and Weng (1992). From the Ragay Gulf, Philippines, Ingles and Braum (1989) reported that male and female *P. pelagicus* attain functional maturity at 96.4 and 106 mm long carapace width, respectively. Similarly, from Australia, Weng (1992) observed that male and female *P. pelagicus* in Gulf of Carpentaria attain physiological maturity at 70 mm and 80 mm long carapace width, respectively. He also reported that the male and female *P. pelagicus* in Moreton Bay attain sexual maturity at the same size that is 80 mm long carapace width. However, de Lestang *et al*. (2003a) reported that female *P. pelagicus* attains sexual maturity earlier than the males in the west coast of Australia. According to them the size at which female and male attain sexual maturity is 61-84 mm and 86-87.2 mm long carapace width, respectively.

It is well known that the size at which sexual maturity is attained by brachyuran crabs may vary from place to place. Hines (1989) compared geographic variation in size of sexually mature females in five species of crabs along the east and west coast of North America. Four of the five species show significant geographic variation in size at onset of maturity. The differences in size at maturity among populations of the same species of crab may be attributed to variation in moult increment and in the number of moults (Hines, 1989). Environmental factors such as temperature and salinity can also affect size at sexual maturity in crabs. Fisher (1999), who investigated effect of temperature and salinity on size at sexual maturity of female blue crab *Callinectes sapidus* from nine Texas bay systems stated that size at maturity can vary along the Texas coast, as temperature and salinity vary from bay to bay. He also mentioned that seasonal and annual variation in temperature and salinity in the bay could also affect size at onset of maturity. According to him crabs may mature “at smaller-sizes during late summer-early fall and at large sizes during winter-spring. Crabs would also be expected to mature at smaller sizes during drought years, with larger mature crab occurring during years of high rainfall. A single hurricane could increase size at maturity by several millimeters.

ACKNOWLEDGMENT

Thanks are due to Pakistan Science Foundation for providing the financial support for this study. The present study was carried out within the Research Project No. PSF/Res/S - KU/ Bio (342).

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Batoy, C.B., Sarmago, J.F. and Pilapil, B.C., 1987. Breeding season, sexual maturity and fecundity of blue crab, *Portunus pelagicus* in selected coastal waters in Leyte and Vicinity, Philipines. *Annls Trop. Res*., **9**: 157-177.

Brown, R.B. and Powell, G.C., 1972. Size at maturity in the male Alaskan Tanner crab, *Chionoecetes bairdi*, as determined by chela allometry, reproductive tract weights and size of pre copulatory males. *J. Fish. Res. Bd. Can.*, **29**: 423-427. https://doi.org/10.1139/f72-069

Campbell, G.R. and Fielder, D.R., 1986. Size at sexual maturity and occurence of Ovigerous females in three species of commercially exploited portunid crabs in S.E. Queensland. *Proc. R. Soc. Qld*, **97**: 79-87.

Campbell, G.R. and Fielder, D.R., 1987. Occurrence of a prezoea in two species of commercially exploited portunid crabs (Decapoda, Brachyura). *Crustaceana,* **52:** 202- 206. https://doi.org/10.1163/156854087X00240

Campbell, G.R. and Fielder, D.R., 1988. Egg extrusion and egg development in three speciesof commercially important portunid crabs from S.E. Queensland. *Proc. R. Soc. Qld,* **99**: 93-100.

Carpenter, K.E. and Niem, V.H. (eds.) 1998. *FAO species identification guide for fishing purpose. The living marine resources of the Western Central Pacific*. Vol. **2**, *Cephalopds, Crustaceans, Holothurian and Sharks*. FAO Rome: **687**: 1-139

Carpenter, K.E., Krupp, F., Jones, D.A. and Zajonz, U.,

1997. *The living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. FAO species identification field guide for fishery purpose*. FAO Report, **7**: 293.

De Lestang, S., Hall, N.G. and Potter, I.C., 2003. Reproductive biology of the blue swimmer crab (*Portunus pelagicus*, Decapoda: Portunidae) in five bodies water on the west coast of Australia. *Fish. Bull.*, **101**: 745-757.

Du Preez, H.H. and Mclachalan, A., 1984. Biology of the three- spot swimming crab, *Ovalipes punctatus*, I. Morphometrics and relative growth (Decapoda: Portunidae) *Crustaceana*, **47**: 72-82. https://doi.org/10.1163/156854084X00324

Fielder, D.R. and Eales, A.J., 1972. Observations on courtship, mating and sexual maturity in *Portunus pelagicus* (L. 1766) (Crustacea, Portunidae). *J. nat. Hist.,* **6**: 273-277. https://doi.org/10.1080/00222937200770261

Fisher, M.R., 1999. Effect of temperature and salinity on size at maturity of female blue crabs. *Trans. Am. Fish. Soc.,* **128**: 499–506. https://doi.org/10.1577/1548-8659(1999)128<0499:EOTASO>2.0.CO;2

Haefner, P.A., 1985. Morphometry, reproduction, diet, and epizoites of *Ovalipes stephensoni* Williams, 1976 (Decapoda, Brachyura). *J. Crust. Biol.*, **5**: 658-672. https://doi.org/10.2307/1548243

Haefner, P.A., 1990. Morphometry and size at maturity of *Callinectes ornatus* (Brachyura: Portunidae) in Bermuda. *Bull. mar. Sci.*, **46**: 274-286.

Haley, S.R., 1972. Reproductive cycling in the ghost crab *Ocypoda quagratea* (Fabr.) (Brachyura: Ocypodidae). *Crustaceana*, **23**: 1-11. https://doi.org/10.1163/156854072X00011

Hall, N.G., Smith, K.D., De Lestang, S. and Potter, I.C., 2006. Does the largest chela of males of three crab species undergo an allometric change that can be used to determine morphometric maturity? *Int. Counc. Explor. Sea J.,* **63**: 140- 150. https://doi.org/10.1016/j.icesjms.2005.07.007

Hartnoll, R.G. 1978. The determination of relative growth in crustacean. *Crustaceana*, **34**: 281-293. https://doi.org/10.1163/156854078X00844

Hartnoll, R.G., 1982. Growth. In: *The biology of Crustacea* (ed. L.G. Abele). Academic Press, New York, pp. 111-196.

Hines, A.H., 1988. Fecundity and reproductive output in two species of deep-sea crabs, *Geryonfenneri* and *G. quinquedens* (Decapod: Brachyura). *J. Crust. Biol.*, **10**: 14-19.

Hines, A.H., 1989. Geographic variation in size at maturity in Brachyuran crabs. *Bull. mar. Sci.*, **45**: 356-368.

Imtiaz, R., Mustaquim, J. and Sultana R., 1998. Size at sexual maturity in the mudcrab *Scylla serrata* (Crustacea: Portunidae) as determined by relative growth. *Pak. J. mar. Sci.,* **7**: 117-122.

Ingles, J.A. and Braum, E., 1989. Reproduction and larval ecology of the blue swimmingcrab, *Portunus pelagicus* in Ragay Gulf, Philippines. *Int. Rev. Gess. Hydrobiol.*, 5: 471- 490. https://doi.org/10.1002/iroh.19890740503

Leme, M.H.A., 2005. Size at sexual maturity of female crabs *Sesarma rectum* Randall (Crustacea: Brachyura) and ontogenetic variation in the abdomen relative growth. *Rev. Brasil. Zool.*, **22**: 433-437. https://doi.org/10.1590/S0101-81752005000200020

Mori, M. and Zunino, P., 1987. Aspects of the biology of *Liocarcinus depurator* (L.) in the Ligurian Sea. *Inv. Pesq*., **51** (Supl. 1): 135-145.

Muiňo, R., Fernández, L., González-Gurriarán, E., Freire, J. and Vilar, J.A., 1999. Size at maturity of *Liocarcinus depurator* (Brachyura: Portunidae): a reproductive and morphometric study. *J. mar. Biol. Assoc. U.K.*, **79**: 295-303. https://doi.org/10.1017/S0025315498000320

Rasheed, S. and mustaquim, J., 2010. Size at sexual maturity, breeding season and fecundity of three-spot swimming crab *Portunus sanguinolentus* (Herbst, 1783) (Decapoda, Brachyura, Portunidae) occurring in the coastal waters of Karachi, Pakistan. *Fish. Res.,* **103**: 56-62. https://doi.org/10.1016/j.fishres.2010.02.002

Reeby, J., Prasad, P.N. and Kusuma, N., 1990. Size at sexual maturity in the male crabs of *Portunus sanguinolentus* and *P. pelagicus*. *Fish. Tech.*, **27**: 115-119.

Sukumaran, K.K. and Neelakantan, B., 1996. Relative growth and sexual maturity in the marine crabs, *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) along the southwest coast of India. *Indian J. Fish.,* **43**: 215-223.

Sumpton, W.D., 1990. Biology of the rock crab *Charybdis natator* (Herbst) (Brachyura: Portunidae). *Bull. mar. Sci.,* **46**: 425-431.

Sumpton, W.D., Potter M.A. and Smith, G.S., 1994. Reproduction and growth of the commercial sand crab, *Portunus pelagicus* (L.) in Moreton bay, Queensland. *Asian Fish. Sci.*, **7**: 103-113.

Warner, G.F., 1977. *The biology of crabs*. Paul Elek (Scientific Books) Ltd. London. pp. 1-170.

Weng, H.T., 1992. The sand crab (*Portunus pelagicus* (Linnaeus)) population of two different environments in Queensland. *Fish. Res.*, **13**: 407-422. https://doi.org/10.1016/0165-7836(92)90061-W

Wimalasiri, H.B.U.G.M, and Dissanayake, D.C.T., 2016. Reproductive biology of the three-spot swimming crab (*Portunus sanguinolentus*) from the west coast of Sri Lanka with a novel approach to determine the maturity stages of male gonads. *Inverteb. Reprod. Dev.*, **60**: 243-353. https://doi.org/10.1080/07924259.2016.1202337

Xiao, Y. and Kumar, M., 2004. Sex ratio and probability of sexual maturity of females at size, of the blue swimmer crab, *Portunus pelagicus* (Linnaeus) off southern Australia. *Fish. Res.*, **68**: 271-282. https://doi.org/10.1016/j.fishres.2003.11.012

Zar, J.H., 1996. *Biostatistical analysis*. 3rd Edition. Prentice-Hall, Upper Saddle River, New Jersey. pp. 790.

Zhang, J., Zhang, K., Chen, Z., Jiang, Y., Cai, Y., Gong Y. and Yu, W., 2020. Length-weight relationship parameters of tropical coral reef fishes in the South China Sea. *Pakistan J. Zool.,* **52**: 821-824.