INT. J. BIOL. BIOTECH., 11 (2-3): 177-190, 2014.

SOME BIOLOGICAL ASPECTS OF THE PORTUNID CRAB *SCYLLA SERRATA* (FORSKÅL, 1775) FROM COASTAL WATERS OF KARACHI, PAKISTAN

Muhammad Atiqullah Khan[1], D. Khan[2] and Javed Mustaqeem[3]

[1]*Department of Zoology, University of Karachi, Karachi, Pakistan.*
[2]*Department of Botany, University of Karachi, Karachi, Pakistan.*
[3]*Department of Environment, University of Karachi, Karachi, Pakistan.*

ABSTRACT

Variations in morphometric parameters in 488 males and 450 female individuals of *Scylla serrata* (Forskal, 1775) are presented. Males were larger than females. The male: female sex ratio was 1.1038 ± 0.08468 in 2009 and 1.1462 ± 0.09722 in 2010. The carapace width (CW) varied from 50 to 170 mm in males and 40 to 169 mm in females averaging to 103.8 ± 0.81 mm and 100.8 ± 0.87mm, respectively. The size-based compositional similarity amongst the various size classes of male and female crabs, as per Czekanowski (1913) index, was 93.2%. Sex ratio was uneven amongst the months. The overall male: female ratio was 1.1249± 0.0632. Male outnumbered the female in August, October and November in 2009 and in October and November only in 2010. The gonadal weight was quite low in males (6.57 ± 0.21g) than females (50.26 ± 0.25g). There was sexual dimorphism in *S. serrata.* It was evident from the analysis that females had larger abdominal length and width and larger gonadal size than that of the males. In other characters viz. CW, carapace length (CL), 3-Merus length, 5th dactylus length, left and right propodus lengths and widths, and left and right claw merus lengths and weights, the males had superiority over females. The condition factor of male mud crab averaged to 0.09831 ± 0.00108 varying from 0.0303 to 0.3375 (CV: 24.23%). The condition factor of female specimens (N= 449; one outlier sample excluded) averaged to 0.17115 ± 0.00138 varying from 0.0736 to 0.3640 (CV: 17.18%). The condition factor in both sexes related with carapace width in a model of cubic equation.

Key-words: ***S****cylla serrata*, Size morphometry, Sexual dimorphism, Condition factor.

INTRODUCTION

Scylla serrata (Forskål, 1775), commonly called mud crab, inhabits muddy mangrove marshes and river mouth estuarine environments (Motoh, 1979; Oshiro, 1991). *S. serrata* is a voracious carnivore, preying on small invertebrates such as molluscs, crustaceans, polychaetes, and on small quantities of detritus and plant material (Azam *et al.,* 1998; Eldredge and Smith, 2001). Hill *et al.* (1982) found that the distribution and abundance of *S. serrata* depend on the development stage: juveniles up to 8 cm carapace width were most abundant on intertidal flats, while sub – adult and adult crabs were more Subtidal. In Tanzania, mud crab density estimates using burrow density and burrow occupancy in three mangrove habitats were less than 1 per 25 m^2 in open channel, 3 per 25 m^2 in mangrove fringe and 1 per 25m^2 in the inner forest (Barnes *et al*., 2002). Chandrasekaran and Natarajan (1994) found that newly recruited juveniles prefer sheltered and shallow water habitats amongst sea grasses, algae and mangrove roots. In this study, no juvenile crabs were found in the catch. The catches came mainly from channels in the mangroves, where crabs are abundant. The habitat selection by *Scylla* species thus differs with respect to the life cycle stages. Usually, megalopa larvae of *Scylla* sp. prefer a structurally complex habitat rich with refuge and food. But crablets of *S. serrata* strongly prefer sea grass habitat (Webley *et al*., 2009). The nature of substratum for benthic life in estuaries in Indian coast for *Scylla* sp. varies from sandy to sandy muddy or totally muddy with wide fluctuating hydro-biological factors. The environmental factors for *Scylla* in India may vary with a wide range of temperature (13 - 40 ºC) and from a low dissolved oxygen to over saturated dissolved oxygen content 4-10 mg/L (Mohapatra *et al.*, 2007). The shell width in *S. serrata* may grow maximally up to 300mm and body may weigh around 2.5 kg (DOF, 2013). According to DOF (2013) the growth of *S. serrata* is not a continuous process, but results from a series of moults, which is under strict hormonal control. The width of the mud crab's carapace may reach 100 mm within a year. In the beginning of its life history, it lives as a larva called Zoea which is c 1mm, floats with planktons in clusters. With time (10-12 days) it changes to Magalopa by moulting five times, Megalopa has functional claws. It settles in the bottom and gives rise to juvenile which is a miniature version of the adult crab and admeasures c 4 mm in width. In about a month of hatching it attains a size of 10-12 mm. It moves to estuary and settles in a sheltered place. Crab reaches to sexual maturity in about 18-24 months when its carapace attains a width of c 110 mm. The first moult of sexual maturation is reported to be at 83 mm by Kathirvel (1966). The females are reported to reach sexual maturity at carapace width of 79 mm in Chilika lagoon of India (Mohanty *et al*., 2006).

S. serrata is an economically important species. It is harvested by both artisanal and commercial fishermen in many countries for example India (Menon, 1952; Kathirvel & Srinivasagam 1992), Pakistan (Ahmed, 1980; Saleem *et al.,* 2013; Khan and Mustaqeem, 2013), Bangladesh (Khan & Alam 1992), Sri Lanka (Jayamanne 1992), Thailand (Tookwinas *et al.,* 1992), Australia (Heasman & Fielder 1977; Hill 1982; Lee 1992; Sumpton, 1990), Indonesia (Cholik & Hanafi 1992), Taiwan, Hong Kong (Lui *et al.*, 2007); the Philippines (Ladra & Mondragon 1992), and in most of the countries along the east coast of Africa (Mutagyera 1981; Piatek 1981; Robertson, 1996; Fondo *et al.*, 2010). It provides meat with protein from 17.69 and 19.39% of fresh weight of male and female mud crabs, respectively and fat as low as 0.59 and 0.61% of the fresh weight in male and female mud crabs, respectively (Zafar *et al.,* 2004). It is recommended for the patients of atherosclerosis symptoms. There are marked differences in the body meat and claw meat in relation to flavour (George and Gopakumar, 1987).

The population of *S. serrata* is gonochoristic i.e., male and female individuals in the same population). The females are often called “jennies” and males “bucks” (DOF, 2013). It is under intense human pressure – being exploited for meat delicacy in countries of its occurrence where its population is declining substantially (FAO, 2011). In Pakistan, it has been studied from Sonmiani (Balochistan) (Saleem *et al.,* 2013) and Indus Delta (Khan and Mustaqeem, 2013). Saleem *et al.* (2013) reported it to be contaminated with organo-chloride pesticides and Khan and Mustaqeem, 2013) reported on carapace width-weight relations of this edible crab. In this paper some aspects of this valuable Portunid crab are described. The data on size of males and females and their morphometric differences and the condition factor, based on its collections from coastal waters of Karachi (Arabian Sea), Pakistan, are presented for two consecutive years (2009 and 2010). Such data is imperatively crucial in the conservation and management of this species (Keenan *et al.,* 1998).

MATERIALS AND METHODS

In monthly collections for two years (2009 and 2010), 938 specimens of *Scylla serrata* (Fig. 1) were collected from the Creeks of Karachi, Pakistan. Of these specimens 488 were male and 450 female. The collected specimens were brought to the laboratory in ice box and immediately preserved. Each specimen was weighed afresh and various organs were measured with precision of 0.1 cm. The size parameters included Carapace Width, Body Weight, Carapace Length, Abdomen Length, Abdomen Width; Third Merus Length, Fifth Dactylus Length, Propodus Left Length, Propodus Right Length, Propodus Width Left, Propodus Width Right); Claw Merus Left Length. Claw Merus Right Length, Claw Weight Left, Claw Weight Right, and Gonad Weight (testes and ovary weight). The data was analyzed statistically (Zar, 2010). The seasons in a calendar year were defined according to Latif *et al.* (2013). The physico-chemical characteristics of the Seawater were determined by recording temperature, pH and dissolved Oxygen on monthly basis. The data collected was subjected to statistical analysis using SPSS version 12.

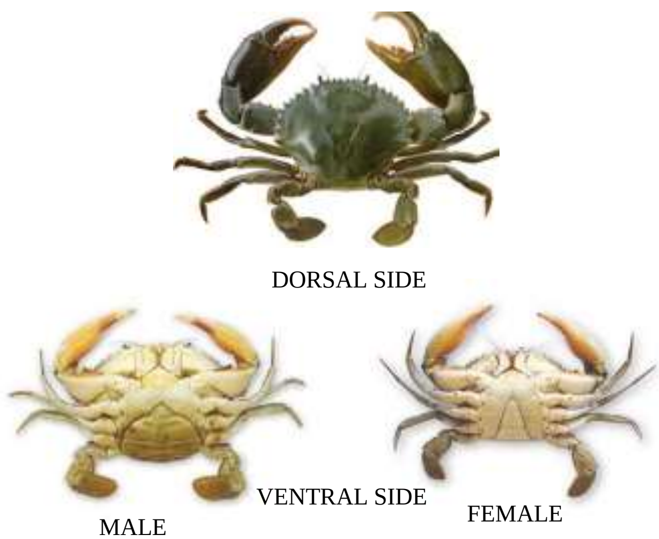

Fig. 1.Habit of *Scylla serrata* (source: Williams, 2002).

The condition factor was calculated as $K = 100\ W / CW^b$ (Bagenal and Tesch, 1978) where W is the body weight of the crab, CW, the Carapace width and b the regression coefficient. The value of ‘b’ was 2.632 and 2.481 in case of male and female crabs, respectively as given by Khan and Mustaqeem (2013).

RESULTS AND DISCUSSION

Physico-Chemical Characteristics of the Seawater

The physico-chemical properties of Seawater for 2009 and 2010 are outlined in Table 1. Arabian Sea is a warm water body. The temperature of water averaged to 28.82 ± 0.914 ^{o}C in 2009 and 28.95 ± 1.235 ^{o}C in 2010 – not varying significantly between the years (t = 0.096, NS). Temperature remained the lowest in winter. Salinity averaged to 37.03 ± 1.588 ‰ in 2009 and 38.49 ± 0.502 ‰ in 2010 which were non-significantly different from each other (t = 0.877, NS). Salinity was low in rainy season. Similarly, dissolved O_2 and pH didn't vary significantly between years (t = 0.242 and 0.173, respectively, non-significant in each case. The lowest variation was found in pH (4.41 - 6.25 %) and largest variation was found in dissolved oxygen (13.59 – 24.83%). pH averaged to 7.5 ± 0.135 in 2009 and 7.65 ± 0.108 in 2010. Dissolved oxygen averaged to 5.12 ± 0.201 in 2009 and 4.82 ± 0.345 ppm in 2010.

Table 1. Physico-chemical properties of Seawater of during 2009 and 2010.

Month	2009				2010			
	Temp. (^{o}C)	Salinity (‰)	Dissolved O_2 (ppm)	pH	Temp. (^{o}C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
Jan	21.2	38	6.1	8	23.7	38	6.2	8
Feb	27.5	40	5.8	7.4	26.2	36.6	6	8.1
March	29.5	38.2	5.4	7.2	27	37.8	6.1	8
April	31	39.4	5.2	8	31.2	37	4.6	7.1
May	30	37.4	4.8	8	33.7	38.7	3.9	7.3
June	33	38.2	4	8	33.7	38.1	3	7.1
July	29.2	20.2	4.9	7.4	31.5	38.6	3.3	7.6
Aug	31.7	34.8	4.2	7.9	32.5	37.8	3.5	7.5
Sept	31.5	40.1	4.9	7.2	32.2	37.1	4.4	7.4
Oct	28	40	4.8	6.6	28.2	39.1	5.7	8
Nov	29.2	39.5	5	7.1	27.5	41.5	5.8	8
Dec	25	38.5	6.3	7.2	20	42.3	6.3	7.8
Minimum	21.2	20.2	4	6.6	20	36.6	3	7.1
Maximum	33	40.1	6.3	8.0	33.7	42.3	6.3	8.0
Mean	28.82	37.03	5.12	7.50	28.95	38.49	4.82	7.65
SE	0.914	1.588	0.201	0.135	1.236	0.502	0.345	0.108
CV (%)	10.98	14.86	13.59	6.25	14.79	5.02	24.83	4.41

Population Structure of *Scylla serrata* (Sex Ratio)

The population of *S. serrata* in coastal waters of Karachi (Arabian Sea) was studied for its morphometric characteristics by its monthly collection for two years (2009 & 2010). *In toto,* 938 specimens were studied of which 488 were male and 450 females. As per developmental classification of mud crab proposed by DOF (2013), on the basis of carapace width, all crabs collected were young, young-maturing and mature individuals irrespective of their gender.

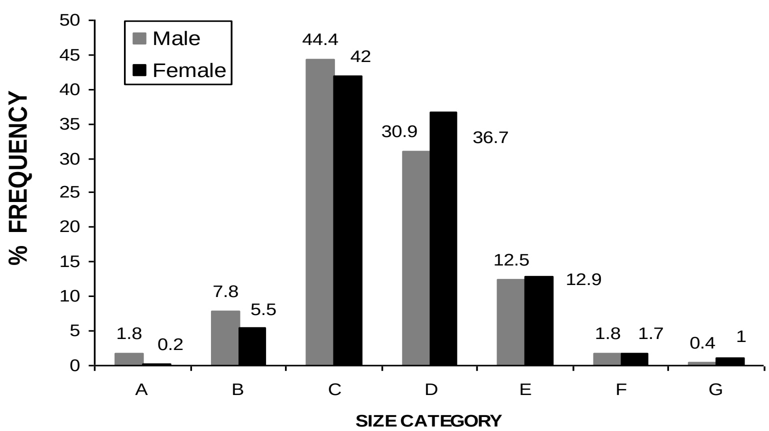

Fig. 2. Percent frequency of size (carapace width) of male and female crabs studied. Size category: A, ≤ 60 mm; B, 61-80; C, 81-100; D, 101-120; E, 121-140; F, 141-160; G, > 160 mm. There was 93.2% size compositional similarity between male and female populations studied.

The distribution of male and female mud crabs into various size categories is presented in Fig. 2. Distribution pattern in the two genders was remarkably similar (the compositional similarity amongst the various classes, as per Czekanowski (1913) index, was 93.2%. There was no individual of juvenile category (carapace width 4-20 mm). There were 47.7% young and maturing crabs (20-100 mm Carapace width, size classes A, B and C) amongst males and 52.3% mature (> 100mm carapace width) ones. Amongst females, there were 54.4% young and maturing individuals and 45.6% the mature individuals. Minimum size at sexual maturity for the species is estimated 10-12 cm (carapace width) for female crab and 12-14 cm for male crab. (Overton and Mcintosh, 2002). Robertson (1996) reported that Female crabs mature between 130 and 140 mm carapace width (CW) in KwaZulu-Natal (South Africa) and some male crabs between 120 and 130 mm CW and they were capable of mating. Crabs mature at smaller size in KwaZulu Natal than those in the Eastern Cape (Robertson, 1996).

All females were ovigerous. Sex ratio was uneven amongst the months. The male: female sex ratio was 1.1038 ± 0.08468 in 2009 and 1.1462 ± 0.09722 in 2010 (Table 2; Fig. 3) which were not statistically different from each other significantly ($t = 0.372$; $p < 0.717$). The overall male: female ratio was 1.1249± 0.0632. The over all sex ratio of male to female in *S. serrata* was found to be 1.094 in Sundarban mangrove ecosystem in Khulna region of Bangladesh (Ali *et al.*, 2004). Sallam and Gab-Alla (2010) have also reported overall male: female sex ratio of 1: 1.1 but male outnumbering female during September to November in case of a portunid crab *Charybdis natator* in the Gulf of Suez, Red Sea. This is similar to our results – male outnumbered the female in August, October and November in 2009 and in October and November only in 2010. This period corresponded with the autumn inter-monsoon season (Fig. 4). The breeding period was extended from August to November in *S. serrata* in Chilika lagoon of Orissa, India (Mohapatra et al., 2010). Kathirvel (1966), however, reports that mud crab breeds from June to July and November to February. The size of fist maturity was at 81-91 mm carapace width.

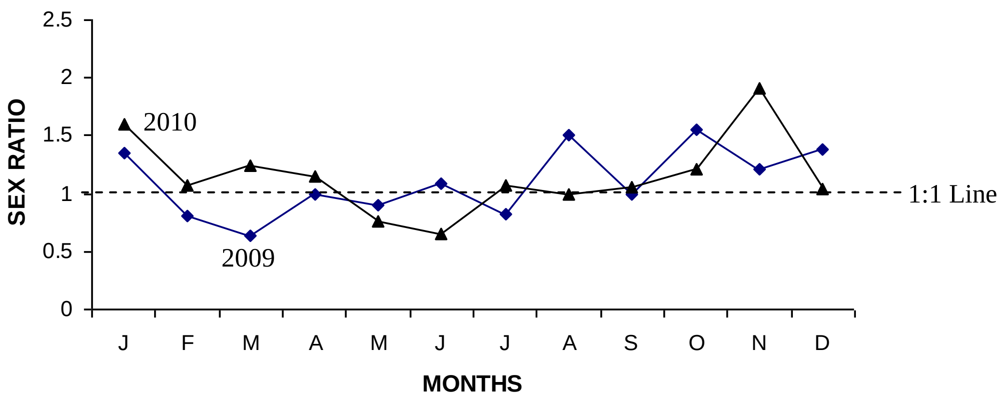

Fig. 3. Monthly variation in male: female sex ratio of mud crab collected during 2009 and 2010.

Morphometry

The location and dispersion parameters of various body organs of *S. serrata* – male, female and sexes combined – are presented in Tables 3, 4, and 5, respectively, for 488, 450, and 938 respective specimens studied during 2009 and 2010. The carapace width (CW) varied from 50 to 170 mm in males and 40 to 169 in females averaging to 103.8 ± 0.81 mm and 100.8 ± 0.87mm, respectively. The size of mud crab caught in Kenya by Fondo *et al.* (2010) ranged from 50 to 125 mm carapace length (CL) with individuals of 75 mm CL dominating. The size of the first maturity was 75 and 70 mm CL for male and female crabs, respectively. .The size disparity between male and female mud crabs is also reported from Chilika lagoon, India (Mohapatra *et al.*, 2010). The size of the first maturity was 75 and 70 mm CL for male and female crabs, respectively. Here air temperature is 28 -32 ^{o}C and salinity 34 to 35.5 ppt although rainfall is high (508-1150mm) – mainly from March to July. Short rains are there in October to December. The model class of size was reported to be 81-90 mm in Sundarban ecosystem in Khulna (Ali *et al.*, 2004). In our studies, CW varied 17.22% in males and 18.2% in females. Maximum variation was observed in the fresh weight of left and right claws of males (90.12 and 83.16%, respectively). Such a variation was comparatively, however, low (55.57 and 54.70%, respectively) in females left and right claws fresh weight. Other body parts had low variation in size around 15-24% in males and 17-21% in females. Carapace length (CL) was shorter than Carapace width in both sexes (68.69 ± 0.46 and 67.45 ± 0.56 mm, respectively). The larger part of the body was propodus. The left propodus in male which measured 83.47 ± 0.93 mm was more or less comparable to the right one (84.61 ± 0.93). In females, the propodus was relatively shorter (left: 68.70 ± 0.67 and right: 69.13 ± 0.69 mm).

Table 2. Comparing the male: female sex ratio for the year 2009 and 2010.

Parameter	2009	2010	Years Pooled
N	12	12	24
Mean ± SE	1.1038 ± 0 .08468	1.1462 ± 0.09722	1.1249 ± 0.06321
Minimum	0.6429	0.6500	0.6429
Maximum	1.550	1.9091	1.9091
CV (%)	36.58	29.38	27.53
t	0.372 (df : 11; p < 0.717)		-

Table 3. Location and dispersion parameters of morphometric measurements of male mud Crab. (N = 488).

Parameters	Mean	S.E	CV%	Q_2	g1	g2	KS-z	p	Min.	Max.
Carp. Wid (mm)	103.811	0.809	17.22	102	0.679	1.18	1.497	0.023	50	170
B. Wt (g)	203.444	3.879	44.07	185	1.019	0.744	2.391	0.001	60	500
Carp. Lth (mm)	68.687	0.459	14.71	68	0.393	0.294	1.172	0.128	43	104
Abd. Lth (mm)	39.119	0.277	15.69	39	0.19	0.059	1.184	0.121	24	60
Abd.Wid (mm)	31.194	0.33	23.40	32	-0.142	-0.387	2.049	0.001	15	52
3Mer. Lth (mm)	38.225	0.294	17.03	38	0.494	0.53	1.754	0.004	23	64
5Dact Lth (mm)	32.487	0.256	17.47	32	0.311	-0.085	1.843	0.001	19	50
Pro. L.Lth (mm)	83.469	0.929	24.60	80	0.85	1.143	1.822	0.003	45	170
Pro. R. Lth (mm)	84.614	0.927	24.21	82	0.85	1.143	1.738	0.005	46	176
Pro. Wd. L (mm)	24.797	0.257	22.92	24	0.541	0.161	1.88	0.002	13	50
Pro. Wd. R (mm)	26.465	0.27	22.55	26	0.421	-0.218	1.682	0.007	14	46
Cla. Me L. L (mm)	52.579	0.562	46.98	51	0.642	0.549	1.74	0.005	28	105
Cla. Me R.L (mm)	53.28	0.575	23.85	52	0.384	0.55	1.707	0.006	2.0	105
Claw Wt. L (mm)	15.017	0.612	90.12	11.1	3.328	17.344	3.926	0.001	2.2	118
Claw Wt. R (mm)	16.321	0.614	83.16	12.2	2.555	9.918	3.946	0.001	2.4	115
Gonad Wt (g)	6.566	0.211	71.14	5.4	1.641	4.030	3.193	0.001	.30	30

Symbols:

S.E = standard error, g1= Skewness, g2 = Kurtosis, CV= coefficient of variance, KS-z = Kolmogorov-Smirnov Z. Sg1= SE of Skewness (0.111), Sg2= SE of Kurtosis (0.221), Min. = Minimum; Max = Maximum.

Acronyms:

Carapace Width (Carp. Wid), Body Weight (B. Wt), Carapace Length (Carp. Lth); Abdomen Length (Abd. Lth); Abdomen Width (Abd. Wid); Third Merus Length (3Mer.Lth); Fifth Dactylus Length (5 Dact. Lth); Propodus Left Length (Pro. L. Lth); Propodus Right Length (Pro. R. Lth), Propodus Width Left (Pro.Wd. L), Propodus Width Right (Pro.Wd. R); Claw Merus Left Length (Claw Me L.L); Claw Merus Right Length (Claw.Me R. L); Claw Weight Left (Claw.Wt. L); Claw Weight Right (Claw.Wt. R); Gonad Weight (Gonad. Wt).

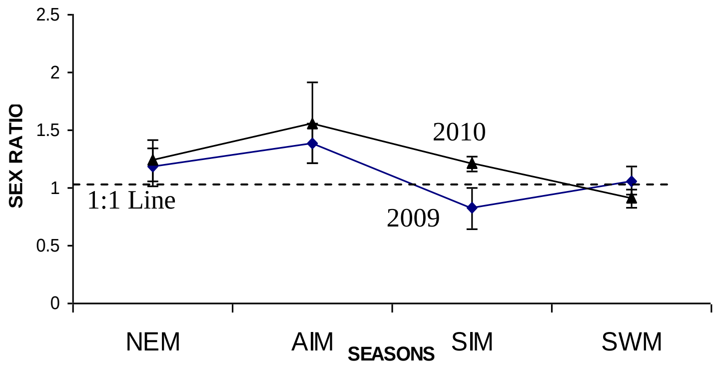

Fig.4. Seasonal variation of male: female sex ratio of mud crab. Key to the acronyms: AIM, autumn inter-monsoon (October-November); NEM, Northeast monsoon (December, January, February), SIM, spring inter-monsoon (March, April) and SWM (Southwest monsoon (May, June, July, August and September).

Table 4. Location and dispersion parameters of morphometric measurements of female mud crab (N = 450).

Parameter	Mean	S.E	CV %	Q_2	g1	g2	KS-z	p	Min.	Max.
Carp.Wid (mm)	100.980	0.866	18.20	100	0.282	1.09	1.744	0.005	40	169
B.Wt (g)	168.48	3.5	44.07	156	0.863	0.85	2.703	0.001	22	450
Carp.Lth(mm)	67.447	0.563	17.72	67	0.173	1.05	1.543	0.017	23	109
Abd.Lth(mm)	42.938	0.477	23.58	42	0.876	2.54	1.85	0.002	12	89
Abd.Wid(mm)	42.711	0.44	21.85	43	0.231	1.43	1.568	0.015	13	78
3Mer. Lth(mm)	33.198	0.265	16.93	33	0.073	0.3	1.665	0.008	11	49
5Dact Lth(mm)	27.947	0.233	17.67	28	0.108	0.34	1.696	0.006	9	42
Pro.L.Lth(mm)	68.698	0.666	20.58	68	-0.001	2.02	1.936	0.001	17	116
Pro.R.Lth(mm)	69.129	0.689	21.13	68	0.123	1.84	3.891	0.001	19	120
Pro.Wd.L(mm)	22.378	0.209	19.78	22	0.166	0.43	1.664	0.008	7	37
Pro.Wd.R(mm)	23.88	0.241	21.40	24	0.482	1.08	1.554	0.016	7	44
Cla.Me L.L(mm)	41.322	0.405	20.80	40	0.445	0.13	1.627	0.01	22	71
Cla.Me R.L(mm)	41.687	0.398	20.23	41	0.433	0.18	1.351	0.052	22	72
ClawWt.L(mm)	10.146	0.267	55.77	9	1.781	6.25	2.473	0.001	0.6	42
ClawWt.R(mm)	11.096	0.286	54.70	10	1.342	2.87	2.327	0.001	0.7	40.5
GonadeWt(g)	50.258	0.248	10.50	48	1.142	1.005	3.891	0.001	42	69

S.E= Standard Error, CV= coefficient variance (%), g1= Skewness, g2= Kurtosis, KS-z= Kolmogorov-Smirnov Z , Sg1= SE of Skewness (0.115), Sg2 = SE of Kurtosis (0.230); Acronyms: As in Table 3.

The average total fresh body weight of male crab was 203.44 ± 3.88g – significantly higher than that of females (168.48 ± 3.5g). Body weight varied almost equally (44%) in both sexes. Any male individual weighed maximally to 500g and female 450g. Males being larger and heavier than females are the expected pattern to many brachyuran crabs (Olmi and Bishop, 1983; Baptista *et al*., 2003; Baptista-Metri *et al*., 2005; Pinheiro and Fiscarelli, 2009). It may occur for the differential reproductive effort between sexes. Males present a mate-guarding behavior during and after copulation, providing protection to the recent post-molt female (Pinheiro and Fransozo, 1999). In fact, adult males may have to be stronger to be able of such behavior. On the other hand, females utilize a large portion of the energy to the eggs production (Kotiaho and Simmons, 2003). Therefore, the somatic growth is reduced (Ferkau and Fischer, 2006). It's important to state that ovigerous females are usually heavier than non-ovigerous in many species of crabs (Moura and Coelho, 2004; Araújo *et al*., 2012), even though in many studies they are commonly grouped as total females (Branco and Thives, 1991; Pinheiro and Taddei, 2005; Pinheiro and Fiscarelli, 2009), as treated in the present paper.

The gonadal weight was quite low in males (6.57 ± 0.21g) than females (50.26 ± 0.25g) i.e. ovaries occupied c. a proportion of 29.83% of the total body weight and male gonads only 5.23 % of the body weight. Male gonadal weight varied around 71% amongst the males whereas such a variation was merely 10.50% amongst the female individuals. High variation of gonadal weight in males may probably be due to differential sexual maturation of them.

None of the body parts in males, except carapace length (CL) and abdominal length (AL) were distributed normally as given by the Kolmogorov-Smirnoff test. None of the morphometric parameters were found to distribute normally in female specimens. In males, all morphometric parameters except CL and AL were positively skewed and showed leptokurtosis. In females, all morphometric also exhibited positive skewness and leptokurtosis. That is to say that distribution pattern of nearly all morphometric parameters was more or less similar in males and females. When the sexes were pooled, CL and AL, similar to males distributed normally.

Table 5. Location and dispersion parameters of morphometric measurements of combine (M+F) mud crab (N = 938)

Parameter	Mean	S.E	CV (%)	Q_2	g1	g2	KS-z	p	Min	Max
Carp.Wid (mm)	102.451	0.593	17.73	100	0.47	1.16	2.275	0.001	40	170
B.Wt (g)	186.672	2.685	44.06	166.5	0.987	0.983	3.589	0.001	22	500
Carp.Lth (mm)	102.451	0.593	16.25	100	0.234	0.869	1.756	0.004	23	109
Abd.Lth (mm)	40.951	0.277	20.77	40	1.046	0.6	2.298	0.001	12	89
Abd.Wid (mm)	36.719	0.33	27.58	36	0.355	0.6	1.477	0.025	13	78
3Mer. Lth (mm)	35.813	0.215	18.14	35	0.405	0.657	2.124	0.001	11	64
5Dact Lth (mm)	30.309	0.189	19.12	30	0.316	0.203	2.513	0.001	9	50
Pro.L.Lth (mm)	76.382	0.627	25.17	73	0.879	2.049	3.182	0.001	17	170
Pro.R.Lth (mm)	77.185	0.636	25.26	74	0.864	2.011	3.081	0.001	19	176
Pro.Wd.L (mm)	23.636	0.171	22.25	23	0.56	0.627	2.665	0.001	7	50
Pro.Wd.R (mm)	25.224	0.186	22.67	25	0.51	0.304	2.369	0.001	7	46
Cla.Me L.L (mm)	47.179	0.396	25.73	45	0.805	0.921	2.752	0.001	22	105
Cla.MeR.L (mm)	47.718	0.402	25.81	46	0.698	0.742	2.908	0.001	2	105
Claw Wt.L (mm)	12.68	0.352	85.11	10	3.966	26.47	5.378	0.001	0.6	118
Claw Wt.R (mm)	13.814	0.358	79.37	10.9	3.059	15.46	5.308	0.001	0.7	115
Gonad Wt (g)	61.479	0.484	24.15	57	0.922	0.231	4.24	0.001	42	111

S.E= standard Error, CV= coefficient variance, g1= Skewness, g2= Kurtosis, KS-z= Kolmogorov-Smirnov Z ; Sg1= SE of Skewness (0.080), Sg2= SE of Kurtosis (0.160); Q2, Median.. Acronyms: As in Table 3.

Table 6. Comparison of morphometric parameters of male and female mud crabs.

S.NO	Parameter	Mean (Male)	Mean (Female)	t
1	Carp. Width (mm)	103.811 ± 0.809	100.980± 0.866	2.391 ($p<0.0001$)
2	B. Wt(g)	203.444 ± 3.879	168.48 ± 3.500	6.690 ($p<0.0001$)
3	Carp. Length (mm)	68.687 ± 0.459	67.447 ± 0.563	1.710 ($p<0.0001$)
4	Abd. Length (mm)	39.119 ± 0.277	42.938 ± 0.477	-6.942 ($p<0.0001$)
5	Abd.Wid (mm)	31.194 ± 0.330	42.711 ± 0.440	-21.016 ($p < 0.0001$)
6	3Mer. Lth (mm)	38.225 ± 0.294	33.198 ± 0.265	12.726 ($p<0.0001$)
7	5Dact Lth (mm)	32.487 ± 0.256	27.947 ± 0.233	13.159 ($p<0.0001$)
8	Pro.L.Lth (mm)	83.469 ± 0.929	68.698 ± 0.666	12.923 ($p<0.0001$)
9	Pro.R.Lth (mm)	84.614 ± 0.927	69.129 ± 0.689	13.148 ($p<0.0001$)
10	Pro.Wd.L (mm)	24.797 ± 0.257	22.378 ± 0.209	7.299 ($p<0.0001$)
11	Pro.Wd.R (mm)	26.465 ± 0.270	23.88 ± 0.241	2.914 ($p<0.0001$)
12	Claw. Me L.L (mm)	52.579 ± 0.562	41.322 ± 0.405	16.267 ($p < 0.0001$)
13	Claw. Me R.L(mm)	53.280 ± 0.572	41.687 ± 0.398	16.608 ($p < 0.0001$)
14	Claw Wt.L (mm)	15.017 ± 0.612	10.146 ± 0.267	7.303 ($p<0.0001$)
15	Claw Wt.R (mm)	16.321 ± 0.614	11.096 ± 0.286	7.729 ($p<0.0001$)
16	Gonad Wt (g)	6.5662 ± 0.211	50.258 ± 0.248	-134.85 ($p < 0.0001$)

Acronyms for morphometric parameters: As in Table 3.

Morphometric comparison of male and female *S. serrata*

Table 6 compares sizes of various body parts of bucks and Jennies populations by means of pair comparison t-test. There is sexual dimorphism in *S. serrata.* It was evident from the analysis that Jennies had larger abdominal length and width and larger gonadal size than that of the bucks. In other characters viz. CW, CL, 3-Merus length, 5th dactylus length, left and right propodus lengths and widths, and left and right claw merus lengths and weights, the bucks had superiority over Jennies. A single Jenny in laboratory is known to produce 1.5 million eggs in one season (Mohanty *et al.*, 2006). Very large gonadal size and abdominal capacity of Jennies may be considered interrelated in view of the immense fecundity of female mud crab. The larger propodus and appendages of male may be thought to facilitate capturing female during copulation which may last for several hours.

Table 7. Pair comparison (t-test) of left and right counterpart components.

Pairs for comparison	Mean Paired Difference	SE (Mean)	t	p
Male *Scylla serrata* (df = 487)				
Propodus left – Propodus right (Length, mm)	-1.14590	0.12506	- 9.16	0.0001
Propodus left – Propodus right (Weight, g))	- 1.66803	0.05566	- 29.97	0.0001
Left Claw Merus- Right Claw Merus (Length, mm)	- 0.70082	0.11429	- 6.132	0.0001
Left Claw Merus- Right Claw Merus (Weight, g)	-1.30348	0.30605	- 4.259	0.0001
Female *Scylla serrata* (df = 449)				
Propodus left – Propodus right (Length, mm)	- 0.43111	0.13083	- 3.295	0.0001
Propodus left – Propodus right (Weight, g))	- 1.50222	0.10412	-14.428	0.0001
Left Claw Merus- Right Claw Merus (Length, mm)	- 0.36444	0.08390	-4.344	0.0001
Left Claw Merus- Right Claw Merus (Weight, g)	- 0.94978	0.10614	-8.948	0.0001

Table 7 compares lengths and weights of left and right propodus and claw merus in male and female specimens. The length and weight of right Propodus and right Claw Merus were found to be significantly larger than the left side counterparts in both male as well as female *Scylla serrata* collected from Karachi waters.

Table 8. Location and dispersion of condition factor of male and female mud crabs.

Statistics	Male	Female	Female *
N	488	450	449
Mean	0.09831	0.1725	0.17114
SE	0.0010784	0.01905	0.0013813
Median	0.093411	0.1725	0.172425
Mode	0.0895	0.1746	0.1746
CV (%)	24.23	23.43	17.18
g1	3.423	7.087	0.407
Sg1	0.111	0.115	0.115
g2	25.948	102.40	5.912
Sg2	0.221	0.230	0.230
Minimum	0.0303	0.0736	0.0736
Maximum	0.3375	0.7632	0.3640
KS-z	3.323	3.036	1.509
p	0.0001	0.0001	0.021

*, Excluding an outlier.

Condition Factor

The concentration and dispersion of condition factor of male and female specimens as calculated after Bagenal and Tesch (1978) is outlined in Table 8. The condition factor of male mud crab averaged to 0.09831 ± 0.00108 varying from 0.0303 to 0.3375 (CV: 24.23%). The condition factor of female specimens (N= 449; one outlier sample excluded) averaged to 0.17115 ± 0.00138 varying from 0.0736 to 0.3640 (CV: 17.18%) [An outlier is shown enclosed within a circle in Fig. 6]. It follows from the results that condition factor was quite higher in females (female: male ratio = 1.741) than that in male population. The condition factor varied with the age of the mud crab. It related with carapace width in a cubic equation model (Fig. 5, 6, and 7) in both male and female populations. In both sexes carapace width defined around 35 % of the variance in the condition factor (Fig. 5 and 7). It is obvious from Fig. 6 and 8 that in male as well as in female, the condition factor is somewhat higher in young crabs of 40-60 mm CW. It remains more or less asymptotic in crabs of 60 to 140 mm CW and then declines in larger crabs (> 140 mm CW).

The condition factor of the females was higher than that of males. Araújo and Lira (2012) have also reported significant variation of condition factor between sexes – being significantly higher in females of *Callinestes danae*. The mean condition factor in males was $8.0 \times 10^{-5} \pm 1.5 \times 10^{-5}$ and that in females $11.5 \times 10^{-5} \pm 2.8 \times 10^{-5}$. It may be due to the reason that female gonads are heavier than that of males, and it has been observed in many species of Brachyura, as *Callinestes danae* (Araújo and Lira (2012), *C. sapidus* (Atar and Seçer, 2003), *Dilocarcinus pagei* (Pinheiro and Taddei, 2005) and *Ucides cordatus* (Pinheiro and Fiscarelli, 2009). However, Branco and Thives (1991) have observed higher condition factor in *C. danae* and Pinheiro and Fransozo (1993) observed that males presented higher condition factor in *Arenaeus cribrarius.* The condition factor, on the other hand, has also been reported neither sex nor season dependent. There was no significant variation in condition factor between sexes of *Callinestes amicola* (Abowei and George, 2009). It is, however, important to note that a small difference in the regression coefficient between sexes could generate great differences in the condition factor. Besides, sexual dimorphism in the metabolic rates, nutritional aspects, stage of maturity, time of recruitment and selective fisheries might also affect sexual differences of the condition factor (Rodríguez, 1987). The condition factor is strongly influenced by the environment factors (exogenous parameters) and by the gonad development, the rate of feeding and growth and the degree of parasitism (endogenous parameters) and may vary among seasons and populations (LeCren, 1951; Rodriguez, 1987; Vazzoler, 1996; Froese, 2006; Pinheiro and Fiscarelli, 2009). Males are larger but their condition factor is low. There is also significant difference in condition factor between sexes of *Callinestes pallidus* (Oluwatoyin *et al.,* 2013). Females have higher condition factor.

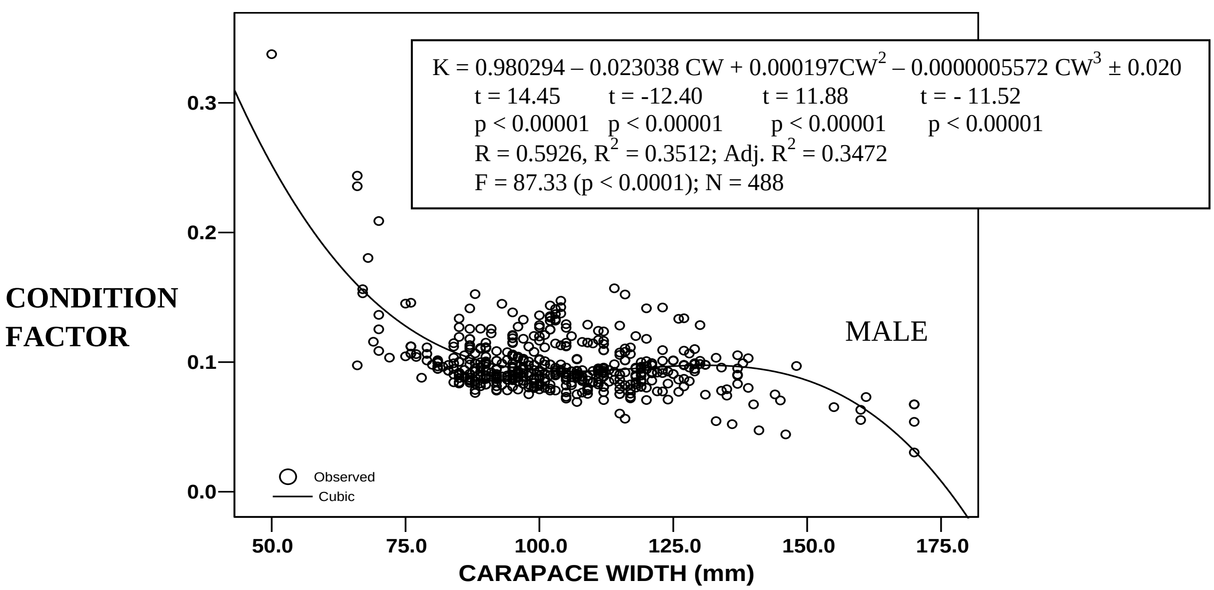

Fig. 5. Relationship of condition factor with carapace width in male crabs. Cubic model. N = 488.

Salinity relations of Mud crabs

The salinity tolerance of *S. serrata* has been investigated for various life history stages e.g., Zoea (Hill, 1974), Zoea and Megalopa (Porado-Estepa and Quintinio, 1999; Babylon *et al.,* 2001), juvenile and adults (Chen and Chia, 1997). It can survive under wide range of salinity (Porado-Estepa and Quintinio, 2011; Chen and Chia, 1997; Ruscoe *et al.,* 2004). The optimum salinity, however, appears to be around 8-24 $g.L^{-1}$. Sudden decline in salinity causes higher mortalities (FRDC, 2008). The interaction of high salinity with high temperature is deleterious. Under high salinity Scylla expend more energy for osmotic regulation that could have been directed towards growth (Chen and Chia, 1997). This may be the reason of predominance of relatively low size ranges of S. serrata in coastal waters of Karachi for its higher temperature and salinity regime creating relatively somewhat sub-optimal conditions. At least, in part, it may also be due to exploitation of large size crabs for economic purpose.

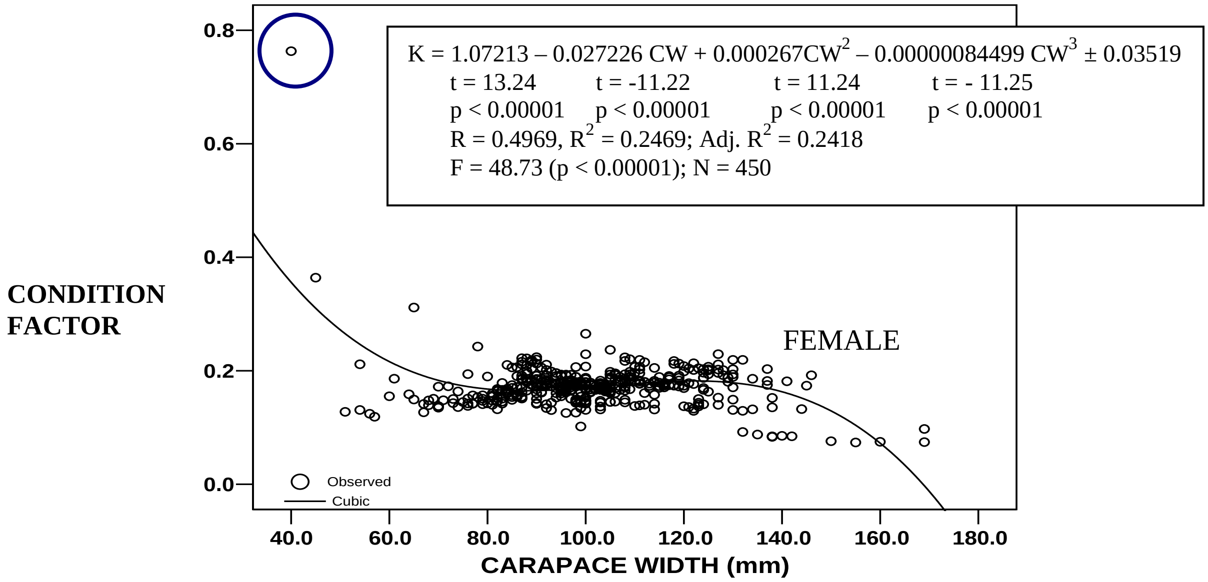

Fig. 6 Relationship of condition factor with carapace width in female crabs. Cubic model. N = 450. An outlier sample is shown enclosed within a circle.

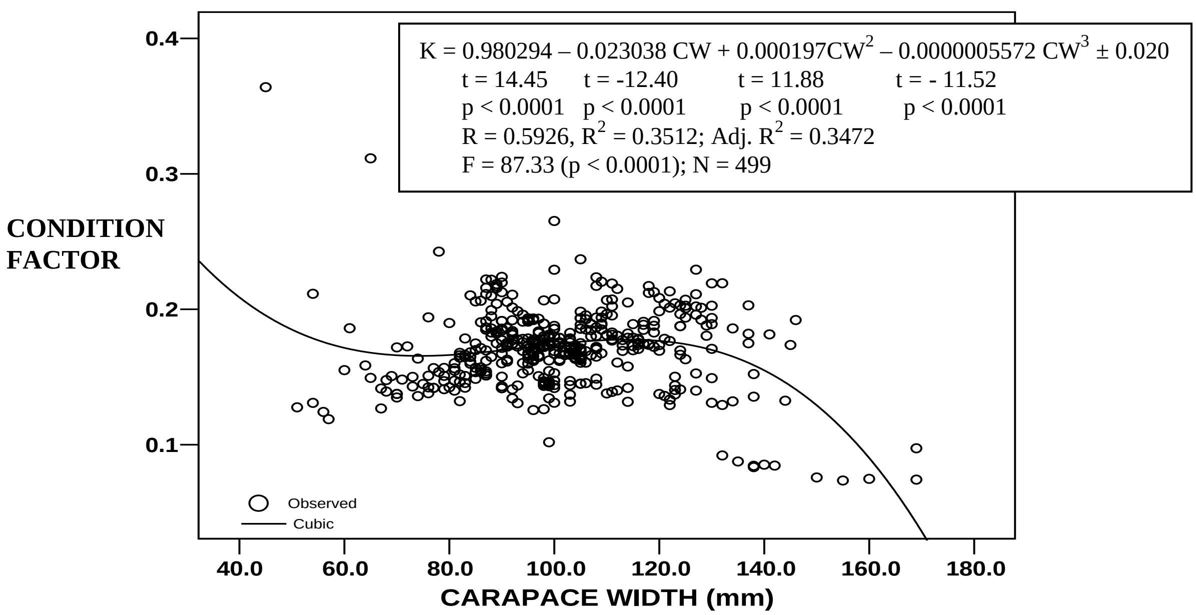

Fig. 7. Relationship of condition factor with carapace width in female crabs. Cubic relationship. Exclusion of the Outlier (N = 449) improved the explanatory power of the equation by around 10%.

Being associated with mangrove forests inundated with full salinity oceanic water for the greater part of the year on Karachi coast, *S. serrata* should remain under stressful conditions of salinity and pollution (Mashiatullah *et al.*, 2013). It can tolerate reduced salinity (Keenan *et al*, 1998). *Scylla serrata* cannot tolerate salinities below 2 ppt or above 60 ppt (Hill 1979). The survival rate of the crablings was found to be highest (46.67 %) at 25 ppt and lowest (2.67, 2.85%) at 5 ppt where the specific growth rate was low at 5 and 10 ppt which increased in 15 ppt and it didn't differ in 20 and 25 ppt water significantly (Mia and Shah, 2010). FAO (2011) has proposed optimum conditions for culturing mud crab (Temperature 25-35°C; pH 7.5-9.0; dissolved oxygen > 5 ppm; Sacchi disk turbidity 20-30 cm; H_2S < 0.1 ppm; hardness > 2000ppm and total ammonia Nitrogen < 3 ppm). Comparing conditions existing on our coast, it is apparent that temperature, pH and dissolved oxygen were within the tolerance limits throughout the year. The salinity of our Seawater was, however, quite higher (37.03 ± 1.588 ‰ in 2009 and 38.49 ± 0.502 ‰ in 2010 than that proposed optimum (10-25 ppt) (FAO, 2011; Mia and Shah, 2010). The size of mud crab caught in Kenya living under comparatively low Seawater salinity of 34 to 35.5 ppt (Fondo *et al.* (2010) are smaller in size (50-125 mm CL with dominating class of individuals of 75 mm) than those reported in the present studies. Since, the size of an organism may depend upon a great number of environmental and hereditary factors and should be determined by the holistic nature of internal and external environment, a great deal of research is needed to elucidate the ecology of *S. serrata* with respect to the in our coastal waters.

REFERENCES

Abowei, J.F.N. and A.D.I. George (2009). A study of length-weight relationship and condition factor of *Callinestes amicola* (De Rochebruner, 1883). From Okpoka Creek, Niger Delta, Nigeria. *Int. J. Animal & Veterinary Advances* 1(2): 66-72.

Ahmed, M. (1980). The breeding and recruitment of marine animals of the coast of Pakistan bordering the Arabian Sea. *Proc. First Pak. Confr. Zool*. PP 55-96.

Ali, M.Y., D. Kamal, S.M.M. Hussain, M.A. Azam, W. Sabbir, A. Murshida, B. Ahmed and K. Azam (2004). Biological studies of the mud crab, Scylla serrata (Forskal) of the Sundarbans mangrove ecosystem in Khulna region, *Bangladesh. Pak. J. Biol. Sci.* 7 (11): 1981 – 1987.

Araújo, M.S.L.C.; Barreto, A.V.; Negromonte, A.O. and R. Schwamborn (2012). Population ecology of the blue crab *Callinectes danae* (Crustacea: Portunidae) in a Brazilian tropical estuary. *Anais da Academia Brasileira de Ciências*, 84(1): 129-138.

Araújo, M.S.L.C, and J.S.P.R. Lira (2012). Condition factor and carapace width vs. wet weight relationship in the swimming crab (*Collinetes danae* Smith 1869 (Decapoda: Portunidae) at the Santa Cruz Channel, Pernambuco State, Brazil, *Napluis* 20(1): 41-50.

Atar, H.H.S. and Seçer, S. 2003. Width/ length-weight relationships of the blue crab (*Callinectes sapidus* Rathbun, 1896) population living in Beymelek Lagoon Lake. *Turkish Journal of Veterinary and Animal Sciences*, 27: 443-447.

Azam, K., D. Kamal and M. Mostafa (1998). Status and potential of mud crab in Bangladesh. In: *Proc. Of the National Seminar on Integrated Management of Ganges Flood Plains and Sundarbans Ecosystem*. Khulna Univ., Khulna, Bangladesh 16-18 July, 1994. pp. 150-160.

Babylon, J.C., A.N. Failaman and E.L. Vengano (2001). Effect of salinity on survival and metamorphosis from Zoea to Megalopa of the mud crab Scylla serrata Forskal (Crustacea; Portunidae). *Asian Fish. Sci.* 14: 143-151.

Bagenal, T.B. and F.W. Tesch (1978). Age and growth In: *Methods for Assessment of Fish Production in Freshwater* (Bagenal, T. B., Ed.). pp. 101-136.

Baptista, C.; Pinheiro, M.A.A.; Blankensteyn A. and Borzone, C.A. 2003. Estrutura populacional de *Callinectes ornatus* Ordway (Crustacea, Portunidae) no Balneário de Shangri-lá, Pontal do Paraná, Paraná, Brasil. *Revista Brasileira de Zoologia*, 20(4): 661-666.

Baptista-Metri, C.; Pinheiro, M.A.A.; Blankensteyn, A. and Borzone, C.A. 2005. Biologia populacional e reprodutiva de *Callinectes danae* Smith (Crustacea, Portunidae) no Balneário de Shangri-lá. Pontal do Paraná, Paraná, Brasil. *Revista Brasileira de Zoologia*, 22(2): 446-453.

Barnes DKA, N.K. Dulvy, S.H. Priestley, W.R.T. Darwall, V. Choisel and M. Whittington (2002). Fishery characteristics and abundance estimates of the mangrove crab Scylla serrata in southern Tanzania and northern Mozambique. South Afr. J. Marine Sci. 24(1): 19-25.

Branco, J.O. and Thives, A. 1991. Relação peso/largura, fator de condição e tamanho de primeira maturação de *Callinectes danae* Smith, 1869 (Crustacea, Portunidae) no manguezal do Itacorubi, SC, Brasil. *Arquivos de Biologia e Tecnologia*, 34(3/4): 415-424.

Chandrasekaran VS and Natarajan R (1994). Seasonal abundance and distribution of seeds of mud crab *Scylla serrata* in Pichavaran Mangrove, Southeast India. J. Aquac. Trop., 9: 343-350.

Chen, J.C. and P.G. Chia (1997). Osmotic and ionic concentrations of *Scylla serrata* (Forskal) subjected to different salinity levels. *Comp. Biochem. Physiol* A 117: 239-244.

Cholik. F. & A. Hanfl. (1992). A review of the status of the mud crab *(Scylla* sp.) fishery and culture in Indonesia. In: Report of the seminar on the mud crab culture and trade held at Surat Thani, Thailand. November 5-8, 1991. (Ed.) C.A. Angell. Bay of Bengal Programme. Madras. pp. 13-27.

Czekanowski, J (1913). Zarys method statystycznych. (Die Grunduge der Statischjen Methoden) Warsaw.

DOF (Department of Fisheries (2013). Mud Crab: Fisheries Fact sheet. # 28, Govt. of Western Australia. (www.nt.gov.au/d.fisheries).

Eldredge, L. G. and C. Smith (Eds.) (2001). *Guidebook to the introduced Marine Introduced Species in Hawaiian Waters*. Bishop Museum Technical report 21. Honolulu.

FAO (2011). *Mud Crab Aquaculture: A Practical Manual.* FAO Fisheries and Aquaculture Tech. Paper # 567. (Shelley, C and Lovatelli, A., Consultants) FAO Rome. Xviii + 78 Pp.

Ferkau, C. and Fischer, K. 2006. Costs of Reproduction in Male *Bicyclus anynana* and *Pieris napi* Butterflies: Effects of Mating History and Food Limitation. *Ethology*, 112: 1117-1127.

Fondo, E.N., E.N. Kimani and D.O. Odongo. (2010). The status of mangrove crab fishery in Kenya, east Africa. *Int. J. Fisheries and Aquaculture* 2(3): 79-86.

FRDC (Project 2008/012). (2010). *Evaluating the environmental drivers of mud crab (Scylla serrata) Catches in Australia*. (ISBn-978-0-646-536-1). Pp ii + 94.

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22: 241-253.

George, C. and Gopakumar (1987). Biochemical studies on crab Scylla serrata. *Fishery Technology* 24: 57-61.

Heasman, M.P. & D.R. Fiedler. (1977). The management and exploitation of the Queensland mud crab fishery. *Ausi. Fish.* 8: 36.

Hill, B.J. (1974). Salinity and temperature tolerance of Zoea of the Portunid crab *Scylla serrata. Mar. Biol*. 25: 21-25.

Hill BJ, Williams MJ, Lee CP (1982). Distribution of juvenile, sub-adult and adult Scylla serrata (Crustacea: Portunidae) on tidal flats in Australia. Marine Biol. 69: 117-120.

Hill, B.J. (1979). Aspects of the feeding strategy of the predatory crab *Scylla serrata. Mar. Biol.* 55: 209-214.

Hill, B.J. (Ed.) (1982). The Queensland mud crab fishery. *Qld. Fish. Inf. Ser.* FI820 I: 41 pp.

Jayamanne, S.C (1992). The mud crab fishery in Sri Lanka. In: Report of the seminar on the mud crab culture and trade held at Surat Thani, Thailand. November 5-8. 199 L (Ed.) CA. Bay of Bengal Programme, Madras. pp. 41-48.

Kathirvel, M (1966). *Mud crab: Handbook on Aqua-farming*. The marine Products Export Development Authority, Kochi, India) 72 pp.

Kathirvel, M. & S. Srinivasagam. (1992). Resource and exploitation of mud crab *Scylla serrata* (Forskal) in India. In: *Report on the seminar on the mud crab culture and trade held at Sural Thani, Thailand*. November 5-8, 1991. (Ed.) CA. Angell. Bay of Bengal Programme. Madras. pp. 85-94.

Keenan, C.P., Davie, P.J.F. & Mann, D.L. 1998. A revision of the genus *Scylla* de Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). *Raffles B. Zool.*, 46(1): 217–245.

Keenan, C.P., P.F.J. Davie and D.L. Mann (1998). A revision of genus Scylla De Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). *The Raffles Bull. Zool.* 46: 217-245.

Khan, M.A. and J. Mustaqeem (2013). Carapace width – weight relationship of mud crab Scylla serrata (Forskål, 1775) from Karachi coast. *Can. J. Pure and Applied sciences* 7 (2): 2381-2386.

Khan, M.G. and M.A. Alam. 1992. The Mud Crab (*Scylla serrata*) Fishery and Its Bio economics in Bangladesh. In: C.A. Angell (ed.), Report of the Seminar on the Mud Crab Culture and Trade. Surat Thani, Thailand, November 5-8, 1991. Bay of Bengal Programme, Brackish water Culture, BOBP/REP/51, Madras, India. 29-40.

Kotiaho, J.S. and Simmons, L.W. 2003. Longevity cost of reproduction for males but no longevity cost of mating or courtship for females in the male-dimorphic dung beetle *Onthophagus binodis*. *Journal of Insect Physiology*, 49: 817-822.

Ladra. D.E and S. Mondragon. (1992). An overview of the mud crab gear in the Philippines. In: Report of the seminar on the mud crab culture and trade held at Surat Thani, Thailand. November." 5-8, 1991 (Ed.) CA. Bay of Bengal Programme. Madras. pp. 71-79.

Latif, S., Z. Ayoub and G. Siddiqui (2013). Seasonal variability of phytoplankton in a coastal lagoon and adjacent open Sea in Pakistan. *Turk. J. Bot.* 37: 398-410.

LeCren, E.D. (1951). The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20(2): 201-219.

Lee, C. (1992). A brief overview of the ecology and fisheries of the mud crab. *Scylla serrata* in Queensland. In: Report of the seminar on the mud crab culture and trade held at Sural Thani. Thailand. November 5-8, 1991. (Ed.) CA. Angell, Bay of Bengal Programme. Madras. pp. 65-70.

Lui, K.K.Y, J.S.S. Ng and K.M.Y. Leung (2007). Spatio-temporal variations in diversity and abundance of commercially important Decapoda and Stomatopoda in subtropical Hong Kong waters. *Est. Coast Shelf Sci*. 72(4): 635-647.

Mashiatullah, A., R.M. Qureshi. N. Ahmad, T. Javed and Z. Khan (2004). Distribution of trace metals in inter-tidal, sediment along Karachi coast, Pakistan. *Geol. Bull. Univ. Peshawar* 37: 215-223.

Menon, M.K. (1952). A note on the bionomics and fishery of the swimming crab, *Neptunus sanguinolentus* (Herbst) on the Malabar Coast. *J. Zool. Soc. India* 4: 177-184.

Mia, M.Y. and M.M.R. Shah (2010) Effect of salinity on survival and growth of mud crabling, *Scylla serrata*. *Univ. J. Zool.* (Rajshahi University): 29: 29-32.

Mohanty, S,K, A. Mohapatra, R.K. Mohanty, K.S. Bhatta and A.K. Pattanaik (2006). Occurrence and biological outlines of two species of Scylla (De Haan) in Chilika Lagoon, *India. Ind. J. Fish.* 53: 191-202.

Mohopatra, A., R. K. Mohanty, S. K. Mohanty and S.K. Dey (2004). Carapace width and weight relationship, condition factor, relative condition factor and gonado-somatic index (GSI) of mud crab (*Scylla* spp.) from Chilika lagoon, India. *Indian J. Marine Sciences* 39 (1): 120-127.

Mohopatra, A., R. K. Mohanty, S.K. Mohanty, K.S. Bhatia and N.R. Das (2007). Fisheries enhancement and biodiversity assessment of fish, prawn and mud crab in Chilika lagoon after eco-restoration through hydrological intervention. *Wetlands Ecol. Mange.* 15: 229-251.

Motoh, H. (1979). Edible crustaceans in the Philippines. 11th in a series. Asian Aquaculture 2: 5.

Moura, N.F.O. and Coelho, P.A. 2004. Maturidade sexual fisiológica em *Goniopsis cruentata* (Latreille) (Crustacea, Brachyura, Grapsidae) no Estuário do Paripe, Pernambuco, Brasil. *Revista Brasileira de Zoologia*, 21(4): 1011-1015.

Mutagyera, WM. (1981). A review of past research on the edible crustaceans of the East African cost. In: Proceedings of the workshop of the Kenya Marine and Fisheries Research Institute on Aquatic Resource, of Kenya, July 13-19, 1981: pp . 56-74.

Olmi, E.J. III and J.M. Bishop (1983). Variations in total width-weight relationships of blue crabs, *Callinectes sapidus*, in relation to sex, maturity, molt stage, and carapace form. *Journal of Crustacean Biology, 3(4):* 575- 581.

Oluwatoyin, A., A. Akintade, C. Edwin, Kusemuja and Victor (2013). A study of length-weight relationship and condition factor of West African blue crab (*Callinestes pallidus*) from Ojo Creek, Logos, Nigeria. *Am. J. Res. Comm*. 1 (3): 102-114.

Oshiro, N. (1991). Mangrove crabs (*Scylla* spp.). In: *Aquaculture in Tropical Areas* (Eds. S. Shokita, K. Kakazu, A. Timori and T. Toma). Midori Shobo, Co. Ltd. Tokyo, Japan. Pp. 218-229.

Overton, J.L. and D.J. Mcintosh (2002). Estimated size at sexual maturity for female mud crabs (genus *Scylla*) from two sympatric species within Ban Don Bay, Thailand. *J. Crustacean Biol.* 22 (4): 790 – 797.

Piatek, M.A. (1981). Mangrove crab, *Scylla serrata* and its utilization with particular reference to Mozambique. A report prepared for the Research and Development of Inland Fisheries Project. FAO Field Document 3: 53 pp.

Pinheiro, M.A.A and Fiscarelli, A.G. 2009. Length-weight relationship and condition factor of the mangrove crab *Ucides cordatus* (Linnaeus, 1763) (Crustacea, Brachyura, Ucididae). *Brazilian Archives of Biology and Technology*, 52(2): 397-406.

Pinheiro, M.A.A and A. Fransozo (1999). Reproduction of the speckled swimming *Arenaeus cribrarius* (Brachyura: Portunidae) on the Brazilian coast near 23°30'S. *Journal of Crustacean Biology*, 22(2): 416-428.

Pinheiro, M.A.A. and A. Fransozo (1993). Análise da relação biométrica do peso úmido pela largura da carapaça para o siri *Arenaeus cribrarius* (Lamrck, 1818) (Crustacea, Brachyura, Portunidae). *Arquivos de Biologia e Tecnologia,* 36(2): 331-341.

Pinheiro, M.A.A. and F.G. Taddei (2005). Relação peso/largura da carapaça e fator de condição em *Dilocarcinus pagei* Stimpson (Crustacea, Trichodactylidae), em São José do Rio Preto, São Paulo, Brasil. *Revista Brasileira de Zoologia*, 22(4): 825-829.

Porado-Estepa, Fe D. and E.T. Quintinio (1999). Larval survival and megalopa production of *Scylla* sp. at different salinities. Pp. 174-177. In: *Mud crab Aquaculture and Biology* (Eds. Keenan, C.P. and A. Black Shaw) Proc. Intern. Forum: 21-24 April, 1997, Darwin, N. territory, Australia.

Porado-Estepa, Fe D. and E.T. Quintinio (2011). Influence of salinity on survival and molting in early stages of three species of *Scylla* crabs. *The Israeli J. Agriculture* – Bamidgen, II C.63.631: 1-6. (http://www.siamb.org.il).

Robertson, W.D. (1996). Abundance, population structure, and size at maturity of Scylla serrata (Forskal) (Decapoda: Portunidae) in Eastern Cape estuaries, South Africa. *S. Afr. J. Zool*. 31 (4): 177-185.

Rodriguez, A. (1987). Biologia del langostino *Penaeus kerathurus* (Forskal, 1775) Del Golfo de Cádiz. III. Biometría, edad y crecimiento. *Investigaciones Pesqueras*, 51(1): 23-37.

Ruscoe, I.M., C.C. Shelley and G.R. Williams (2004). The combined effect of temperature and salinity on growth and survival of juvenile mud crabs (*Scylla serrata* Forskal). *Aquaculture* 238: 239-247.

Saleem, M., S.H.N. Rizvi, J. Aftab, S. Kahkashan, A.A. Khan and m. Qammaruddin (2013). Short assessment survey of organochlorine [pesticides in marine environment of Damb (Sonmiani) Balochistan. *Pak. J. Chem*. 3(3): 107-115.

Sallam, W.S. and A.A. Gab-Alla (2010). Some biological aspects of the Portunid crab Charybdis notator from the Gulf of Suez, Red Sea. *Egypt J. Aquat. Biol. & Fish.* 14 (2): 39-51.

Sumpton, W.D. (1990). Morphometric growth and fisheries biology of the crab *Chrybdis natator* (Herbst) in Moreton Bay, Australia (Decapoda, Brachyura). *Crusaceana* 59 (2): 113-120.

Tookwinas, *S., N. S*richantulk and C. Kanchanavasil. (1992). Mud crab production in Thailand. In: Report of the seminar on the mud crab culture and trade held at Sural Thani Thailand. November 5-8, 1991, (Ed.) CA. Angell. Bay of Ber Programme, Madras. pp. 59-ocl.

Vazzoler, A.E.A.M. (1996). *Biologia da reprodução de peixes teleósteos: teoria e prática*. Maringá, Nupelia, 169p.

Webley, J.A.C., R.M. Connolly and R.A. Young (2009). Habitat selectivity of megalopa and juvenile mud crabs (Scylla serrata): Implications For Recruitment Mechanisms. *Mar. Biol.* 56: 861-899.

Williams, L.E. (2002). *Queensland's Fisheries Resources: Current Condition and recent Trends (1988 -2000).* Q102012 Dept. of Primary Industries, Queensland, Brisbane, Australia.

Williams, MJ. and B.J. Hill (1982). Factors influencing pot catches, and population estimates of the portunid crab *Scylla serrata. Mar. BioI.* 71: I H7-192.

Zafar, M., M.Z.H., Huda, and M.A. Haque (2004). Biochemical composition in *Scylla serrata* (Forskåll) of Chakaria, Sundarban area, Bangladesh. *Pak. J. Biol. Sci.* 7(2): 2182-2186.

Zar, J.H. (2010). *Biostatistical Analysis*. 5th Ed. Prentice-Hall, Englewood Cliffs. New Jersey, USA.

(*Accepted for publication April 2014*)