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RESEARCH ARTICLE

SEX RATIO AND REPRODUCTIVE PERFORMANCE OF THE FEMALE MUD CRAB SCYLLA SERRATA (FORSKAL) IN CORINGA MANGROVES, ANDHRA PRADESH, INDIA

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ABSTRACT

Sex ratio and reproductive performance of the female crab, *Scylla serrata* was studied for two years in Coringa mangroves. The crab was a continuous breeder with peak season in winter months (October, November and December). The overall sex ratio of male to female was 1:1.09 with the highest ratio of 1:1.8 in December and the lowest (1:0.84) in May. Males were more in number in the size groups of 2.0-3.9cm, 10.0-11.9cm and 12.0-13.9cm with 1:0.67, 1:0.70 and 1:0.20 male to female ratios respectively. The size at first maturity of female crab was 8.3 cm (carapace length). Gonado-somatic index in female ranged between 3.26 (May) to 9.24 (December) corroborating with peak breeding of female in winter and spent phases in summer months. The maturity stages in females were distinguished into immature, early maturing, late maturing, mature and spent. The fecundity varied from 0.327 million to 3.41 millions in the size range of 8.7cm to11.4.cm carapace length and 160gm to 375gms of body weight. A linear relationship was found between the logarithmic relationship of fecundity and carapace length, carapace width, total weight and ovary weight. The fecundity against ovary weight was found to be a better index than total weight, carapace length and width.

INTRODUCTION

Reproduction in mud crab is continuous throughout the year with peak period during winter months. Food availability, temperature & salinity of the environment and the internal factors like metabolism, age, sex, hormones and stage of maturity influence the development (Bal and Rao, 1984). Reproductive potential of a species as represented by sex ratio, size at first maturity, spawning frequency and fecundity is important to estimate the stock and the ideal size of the fishery and management strategies to increase production will be formulated for sustainability of the fishery (Bal and Rao, 1984). The reproductive biology of mud crab *S. serrata* has been studied by several researchers. (Bhattachary, 1931; Du Plessis, 1971; Brick, 1974; Shanmugam and Bensam, 1980; Poovachiranon, 1992; Hill, 1994; Bromage and Roberts, 1995; LeVey, 2001; Onyago, 2002; Davis, 2004; Quinitio *et al.* 2001, 2007; John Samuel and Soundrapandian, 2010; Mohapatra *et al.,* 2010; Sherazul Islam and Hisashi, 2013; Ikwanuddin *et al.,* 2014). An attempt is made in the present study on reproductive parameters such as sex-ratio and size at first maturity, gonado-somatic index (GSI), maturity stages and fecundity in male crab.

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MATERIALS AND METHODS

Samples of mud crab *S. serrata* were collected from the Pedavalasala landing center (16° 46'45.93"N; 82°15'42.05"E) for two years *i.e.* from 2007 to Dec 2008. Out of 1475 crabs collected 693 were males and 782 were females. Both males and females were separated into 6 size classes basing on the length of carapace in cm: 2-3.9; 4-5.9; 6-7.9; 8-9.9; 10-11.9 and 12 to 13.9. The males and females of different size classes collected in every month were also counted. The respective reproductive parameters were assessed by the following standard methods.

Sex ratio

Sex ratio was determined from the number of specimens of each sex sampled every month in every size group. To study the homogeneity of the distribution of males and females, the values of sex ratio obtained were subjected to chi-square test (Sokal and Rohit, 1981) by employing the formula.

$X^2 = \sum [(o-e)^2/e]$, where o = observed number and e = expected number.

Sex ratio= No. of female crabs / No. of male crabs

Size at first maturity

The size at first maturity was derived by plotting the percentage occurrence of mature crabs against the total length following Somerton & MacIntosh (1983).

Maturity stages

The stages of ovarian maturation were determined by external morphological observation of the gonads in 782 female crabs following Quinitio *et al* (2007) every month.

Gonado-somatic Index (GSI)

Gonado-somatic index of female crabs was calculated using the equation proposed by June (1953) and Yeun (1955). It was expressed as percentage of the ovarian weight relative to the body weight *i.e.*,

GSI (%) = ovary weight / total body weight X 100
The GSI in different months and in different size classes were estimated.

Fecundity

The fecundity was calculated following Anderson *et al.* (1949).

$$\text{Fecundity} = \frac{\text{No. of eggs in sub sample}}{\text{Wt. of sub sample}} \times \text{Weight of the ovary}$$

The fecundity was regressed against carapace length (CL), carapace width (CW), body weight (BW) and ovary weight (OW) and was also calculated for ovary weight (OW) and body weight (BW) by the method of least squares (Snedecor and Cochran, 1968).

RESULTS

Sex- ratio

Of 1475 crabs collected in the overall study period 693 (46.98%) were males and 782 (53.12%) were females. Highest percentage of females (68) was found in December and the lowest (43.33) in April. The overall sex ratio of male to female was 1:1.13. Highest ratio of male to female *i.e.,* 1:1.94 was recorded in December whereas lowest 1:0.92 in November followed by 1: 0.93 in May (Fig.1). The males were more in the size groups of 2.0-3.9cm, 10.0-11.9cm and 12.0-13.9 cm with 1:0.67, 1:0.70 and 1:0.20 male to female ratios respectively. In 4.0-5.9 cm, 6.0-7.9 cm and 8.0-9.9 cm size classes female were dominant. Highest number of females to males was recorded in 8.0-9.9cm size class was shown (Fig.2).

Size at first maturity

The minimum size at first maturity (50%) for females was 8.3cm (Fig.3).

Maturity stages (Fig.4a to 4e)

Maturity stages in females of *S. serrata*

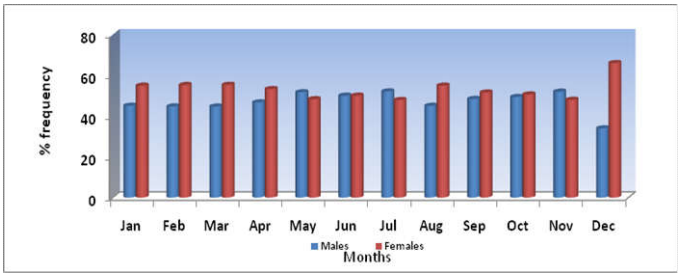


Fig. 1. Month-wise sex ratio of males and females of *S. serrata*.

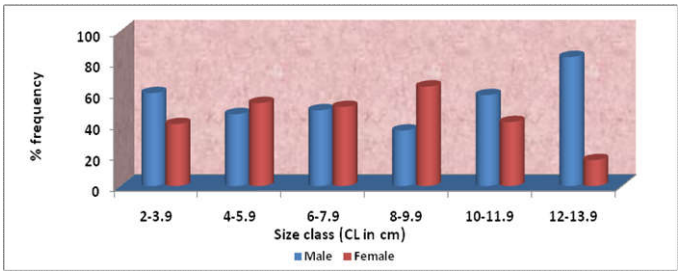


Fig. 2. Size-group wise sex ratio of males and females of *S. serrata*.

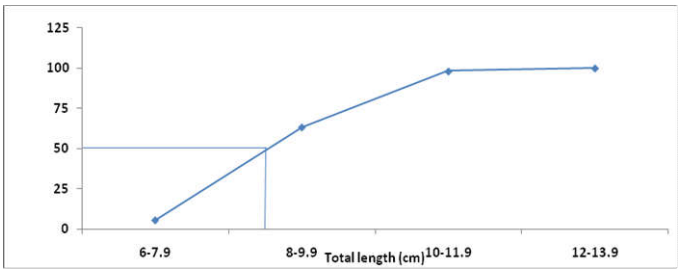


Fig. 3. Size at first sexual maturity in females of *S. serrata*.

Immature: Ovaries were translucent and thread like and sometimes difficult to recognize from the other tissues (Fig. 4a).

Early Maturing: Increased ovary size with yellow in colour occupying ¼ or 1/3 of the body cavity were found (Fig. 4b).

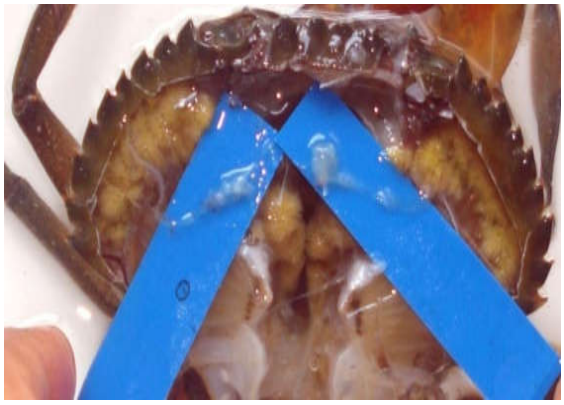
Late Maturing: Massive increase in ovaries with orange in colour occupying the full body cavity were found. Lobules were apparent (Fig. 4c).

Mature: Ovary occupied the whole body cavity and the colour was changed from orange to dark orange. The ovaries were swollen with large ova (Fig. 4d).

Spent: Ovary similar to early mature stage or smaller than late maturing stage, colour of the ovary was yellow to light orange and with dark orange in some parts of ovary and was flaccid (Fig. 4e).

Maturity stages (%) in different months

The highest percentage of immature females was recorded in May (80.00) followed by April (77.03) and the lowest percentage was noticed in December (38.56) followed by November (43.50). Highest percentage (30.84) of females in early maturing stage was observed in August and highest percentage of late maturity and mature in December with 23.53 and 25.66 respectively whereas the highest percentage of spent females was found in June (9.26) (Fig. 5).



(a) Immature

(b) Early maturing

(c) Late maturing

(d) Mature

(e) Spent

Fig. 4. Maturity stages of *Scylla serrata* (Female)

Maturity stages (%) in different size groups

Immature females were found in 2.0-3.9cm and 4.0-5.9cm size classes. Early maturing females were high (29.6%) in the size group of 8.0-9.9cm size class and low(7.1%) in the 10-11.9cm, and late maturing size group were maximum(43.6%) in 10.0-11.9cm size class and low (16.4%) in 8.0-9.9cm size class whereas mature females were high(36.4%) in 12.0-13.9cm size class and low(6.3%) in 8.0-9.9cm size group. Spent females were high in 12.0-13.9cm size class and low in 8.0-9.9cm size group (Fig.6).

Gonado-somatic index

Gonado-somatic index varied from a minimum of 3.01(±1.26) in April to a maximum of 9.93 (±2.86) in the month of December 2007. In the second year 2008 it varied from minimum of 3.39 (±2.10) in May to a maximum of 9.35 (±2.12) in December (Fig.7).

Fecundity

The fecundity of *S. serrata* was observed from 60 ovaries of late maturing and mature females.

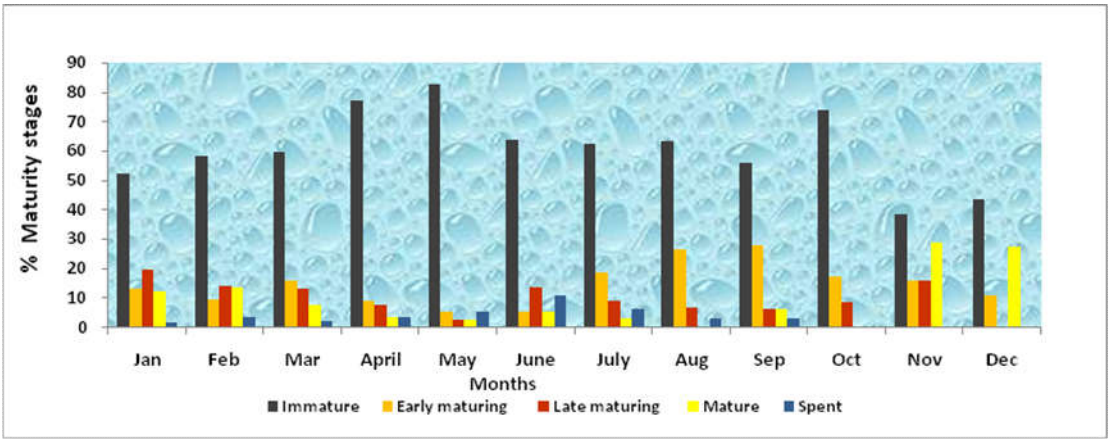


Fig. 5. Month-wise percentage maturity in females of *S. serrata*

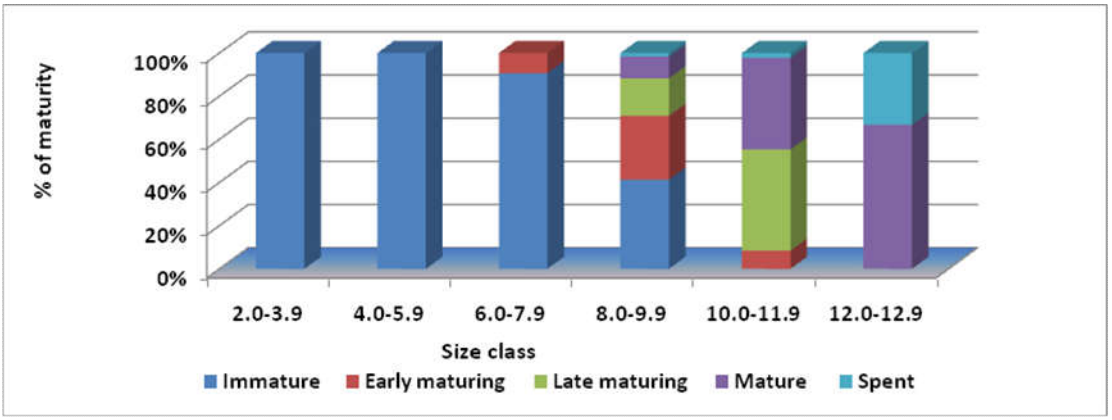


Fig. 6. Size-group wise percentage maturity in females of *S. serrata*

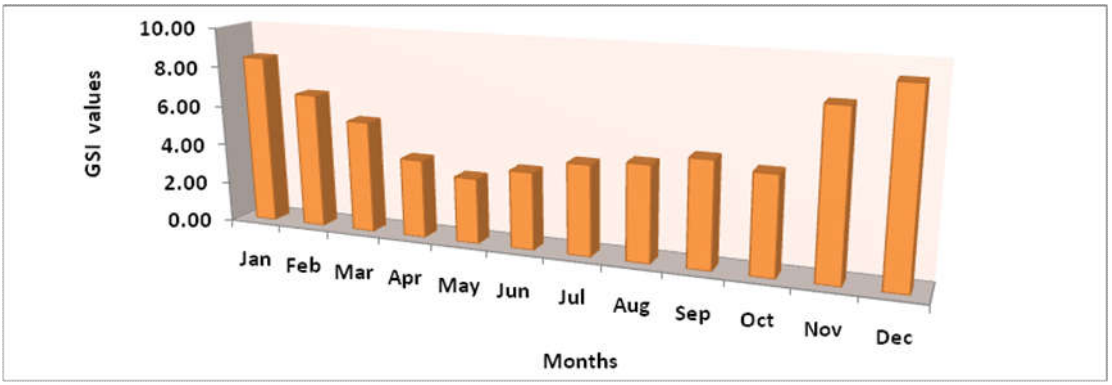


Fig. 7. Gonadosomatic index of females of *S. serrata*

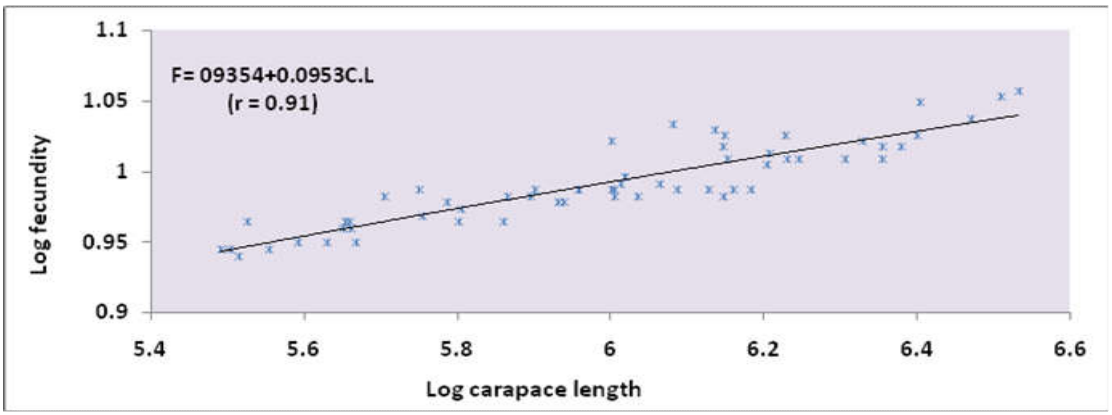


Fig. 8. Logarithmic relationship between carapace length (CL) and fecundity(F) of *S. serrata*.

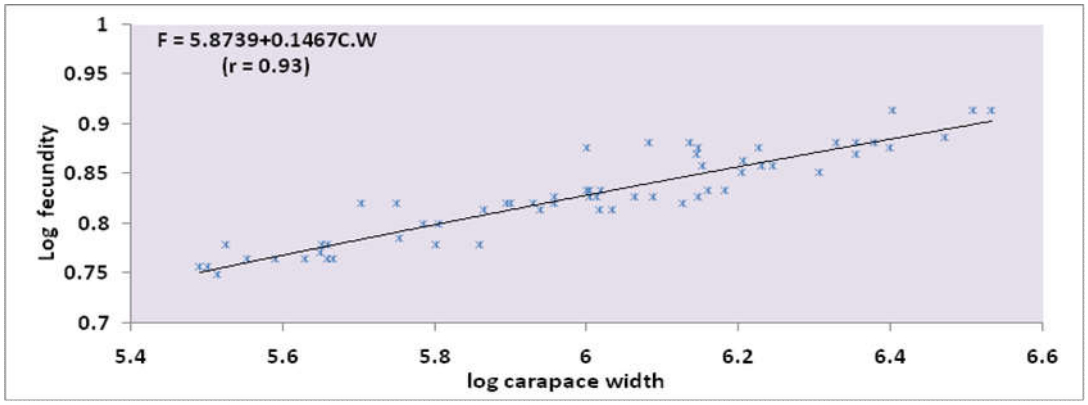


Fig. 9. Logarithmic relationship between carapace width (CW) and fecundity (F) of *S. serrata*.

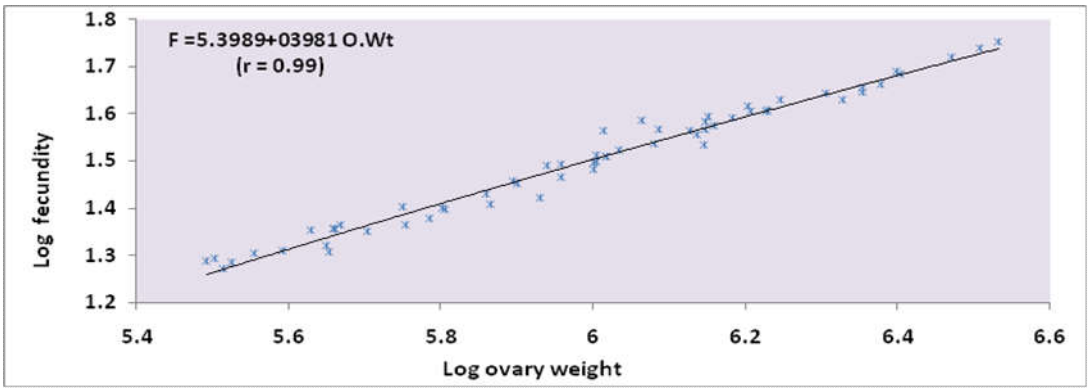


Fig. 10. Logarithmic relationship between ovary weight (OW) and fecundity (F) of *S. serrata*.

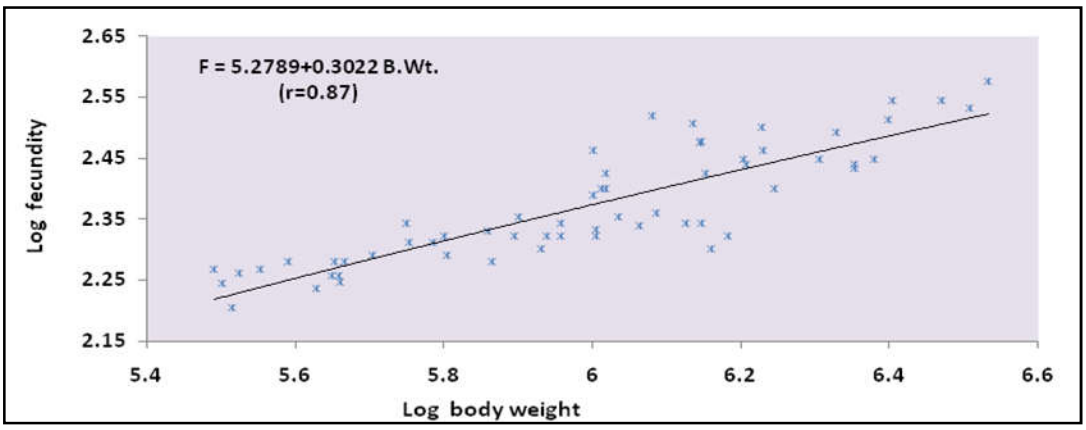


Fig. 11. Logarithmic relationship between body weight (BW) and fecundity (F) of *S. serrata.*

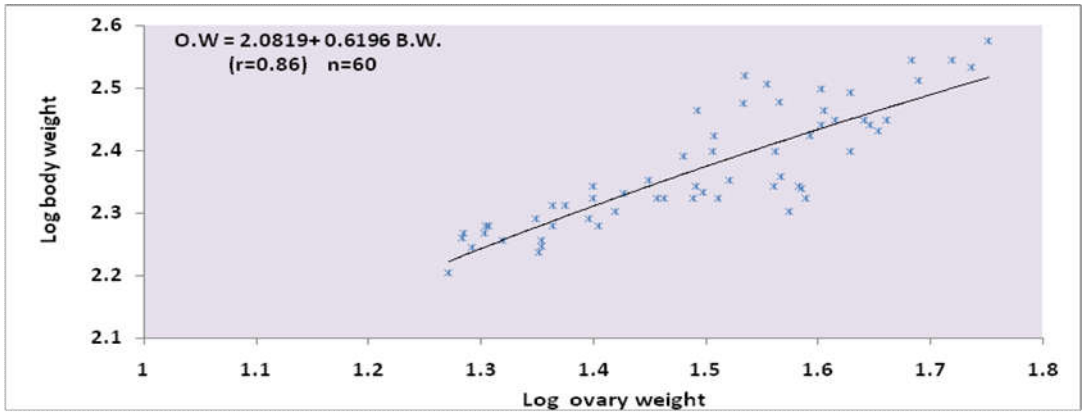


Fig. 12. Logarithmic relationship between ovary weight (OW) and body weight (BW) of *S. serrata*.

The fecundity varied from minimum of 0.327 million to 3.41 millions in the size range of 8.7cm to11.4.cm carapace length and 160g to 375g of body weight. A linear relationship between fecundity (F) and the carapace length (CL) of the crab was obtained and regression equation derived was Log F = 0.93537+0.0953 Log CL (r= 0.91, P< 0.001) (Fig.8). The correlation coefficient (r) between fecundity and total length was highly significant. The logarithmic relationship between fecundity (F) and other variables like carapace width (CW), ovary weight (OW) and body weight (BW) was linear and significant. The regression equations for the above were

Log F = 5.8739+0.1467 Log CW (r = 0.93, P<0.001) (Fig.9)
Log F = 5.3989 + 0.3981 Log OW (r= 0.99, P< 0.001) (Fig.10)
Log F= 5.2789 + 0.3022 Log BW (r= 0.87, P< 0.001) (Fig.11)

Similarly a significant linear relationship was found between ovary weight (OW) of crab and the body weight(BW) and the regression equation was

Log OW= 2.0819 + 0.6196 Log BW (r = 0.86, P< 0.001) (Fig.12)

DISCUSSION

Sex ratio is important to understand the population structure and reproductive performance in crustaceans and it may vary from 1:1 ratio depending on the environmental conditions, maturity stage of the animal, migratory behaviour and so on (Cheewasedtham, 1990). Shanmugam and Bensam (1980) have observed the sex ratio in mud crab is more or less equal during May and September but disproportionate in all the other months, with females dominant during June and July and January to March, and males during August and October-December. The dominance of females in the catches of mud crabs from Natravati estuary was observed by Ram and Chandramohan (1978). The same phenomenon is noticed by several workers Kathirvel (1981) in Cochin backwaters, Srinivasagam (1975) in Killai backwaters, Srinivasagam and Raman (1985) in Pulicat lake and Lalitha Devi (1985) in Kakinada mangroves. Ali *et al* (2004) have observed the 1: 0.94 male to female ratio in Sundarban mangrove ecosystem. Qinn and Kojis (1987) have also reported a variation in sex ratio of *S. serrata* by size and season in Labu estuary of New-Guinea.

Onyango (2002) has also observed significant difference in overall sex ratio in *S. serrata* with male dominance in the size of 8-9 cm except in December and June, whereas females dominance in 9 cm size class in March to April and June to September. Aktar (2003) has found the overall sex ratio of 1:081(M: F) in *S. serrata* in Sathkhira region of Bangladesh from October to February. Sex ratio of 1.3:1 (male/female) has been noticed by Jirapunpipat (2008) in *S. olivacea* in Ranong province. Koolkalya *et al* (2006) have observed a female to male ratio 0.79:1 in *S. olivecia*. Males of *S. serrata* have outnumbered the females in the studies made by Bonine *et al*., (2008). Fondo *et al.*, (2010) have observed the domination of males with a significant difference from normal ratio of 1:1. Mohapatra *et al* (2010) have reported the dominance of males over females in *S. serrata.* In the present study females have outnumbered males in the size groups of 4.0-5.9 cm, 6.0-7.9 cm and in 8.0-9.9 cm whereas males in 2.0-3.9 cm, 10.0-11.9 cm and 12.0-13.9 cm size groups. Highest male to female ratio 1:1.79 has been observed in the size group of 8.0-9.9 cm. The large females are more in summer except May while large males have outnumbered females in the winter. The same has also been observed by Nandi and Pramanik (1994) in mud crabs of Sundarbans. The seasonal trends in sex ratio may be linked with migration patterns in particular to the offshore migration of mature females for spawning (Jirapunpipat, 2008). Lalitha Devi (1985) has noticed berried crabs during November-April reaching peak numbers in December and February. According to Mahapatra *et al* (1996) the monthly distribution of sex is disproportionate since female crabs migrate towards deeper zone for egg laying in March to September. Mating takes place in the estuarine environment and the female crabs migrate to the sea afterwards for spawning (Arriola, 1940; Ong, 1966). Berried *S. serrata* females have been caught in trawl nets up to 80 km from the shore in Australia (Poovichiranon, 1992; Hill, 1994). Hyland *et al* (1984) have also found an offshore migration of female crabs in Queenlands waters.

Size at first maturity is considered as a mark to assess the minimum catch size of the female crabs. Female *S. Serrata* matures between 80 and 120 mm carapace width (Heasman *et al.,* 1985, Prasad *et al.,* 1990, Robertson and Kruger, 1994). In the present study the females have attained maturity at 8.3 cm carapace width. It can be corroborated with the findings of Poovachiranon (1992) that *S. serrata* mature at a smaller size in the tropics compared to the subtropical areas. The size at first maturity was 8.94 cm carapace width in the Andaman islands. Bhaskar Reddy (1982) has also observed that *S. serrata* mature at 75 to 80mm carapace width. Hill (1975) has reported that *S. serrata* mature at 83 to 144mm carapace width in South Africa whereas Heasman *et al* (1985) have reported 128 mm carapace width as the size of maturity in femalt. MacIntosh *et al* (1993) have observed 123 mm as the size of first maturity in *S. serrata.* In case of *S. olivacea* the size at first maturity is 9.4 cm but 8.3 cm is the minimum size for first maturity and the mean size is 9.55 cm in *S. olivacea* (Koolklya *et al*., 2006). The size at maturity of mud crab in the present study is more or less similar with the findings of the Kathirvel, (1981), Joel and Sanjeev Raj, (1982), Kathirvel *et al* (2004) and Mohanty *et al* (2006). The females attain first maturity at a size of 39 mm in carapace length (Lalitha Devi, 1985). Tongdee (2001) has found that median size for first maturity of female crabs is about 8.6 cm in Ranong. Mahopatra (2006) has recorded that the females with carapace width ranging from 79 to 159 mm as the size of first maturity. It has been reported that size at first maturity in female *S. serrata* is about 80mm of carapace width (Anon., 1997) and 84mm carapace width by Anil (1997). Anon (2000) has reported that the size range at first maturity for female is 85-96 mm. Higher water temperatures in the tropics has probably increased the crab's growth rate and decrease time to maturity and the size at first maturity observed is 70 mm (Quinn and Kojis 1987).

Maturation and spawning in *Scylla* species is continuous throughout the year (Le vay, 2001). Five maturity stages have been recorded in the present study as immature, early maturing, late maturing, mature and spent in females as per Quinitio, (2007) with 58.8%, 15.3%, 12.7%, 9.7% and 3.5% respectively. Highest number of immature females has been observed in May, while early maturing female number is high in August. Highest number of late maturing and mature

females have been observed in December and spent females in June. Fondo *et al* (2010) have also observed the dominance of immature *S. serrata* in Kenyan coast in May. Three maturity classes in females have been reported in *S. paramomasain* based on the shape of abdominal flap as immature, pre-pubertal and mature by Walton (2006). Koolkalya *et al* (2006) have observed four stages in female based on the external observations of the ovary. Shanmugam and Bensam (1980) have reported three stages of maturity basing on external observation of ovary with inshore population of *S. serrata* comprising Immature and maturing ones and fully mature or berried specimens in the gill net operations off Tuticorin at 15 to 20 m depth during April to July. According to them immature females constituted 55% in June, January and March and maturing females 21.5% during July, while Williams and Prakasam (2004) have reported four stages in *S. tranquebarica* immature, maturing, mature and spent with immature females high (46.7%) in July, maturing in May and June with 42.5%, and mature in August (63.2%) and with high percentage (60.0%) of spent females in March.

Onyango (2002) has observed the females with activated ovaries of stage I to III throughout the sampling period. In the present study also females with early, late maturing and mature stages have been observed throughout the study period. It has been found that the juvenile crabs are available throughout the year with peak in the months March, April and May. Mohanty *et al* (2006) has also made similar observations in Chilika lake. Anil (1997) has recorded berried *Scylla* spp. in the catches throughout the year except during monsoon. Krishnapillai and Nair (1976) have observed the berried *S. serrata* during November-April with peaks in December-February.

The gonado-somatic index is the percentage ratio of gonad weight to the total body weight. Generally it is positively correlated with the development o the gonads. This index gradually decreases with the progress of the spawning season and is useful for determining the intensity and the spawning duration. Ali *et al* (2004) have reported that the gonado-somatic index has been maximum in May and gradually decrease up to February. In the present study the gonado-somatic index has shown a peak in the last quarter (November to January) in both years and gradually decreases in summer months (April and May). Higher gonado-somatic index in October, November, December and January matched with the high ratio of male to female and more number of matured females during that period. Further the high value of GSI confirmed the onset of spawning period of *S. serrata* with fully matured stage of ovaries during winter season and in January. The low value of GSI in the dry months *i.e.,* during April, May and June of both the years indicates the migration of matured individuals to the off shore for spawning. This confirms with the less and non availability of fully matured crabs during this period in near shore waters. It correlates with the findings of Mohapatra *et al* (2010) wherein in Chilka lagoon the gonado-somatic index has shown a single oscillation having peak during the months of September to November in both years. According to them the GSI of *S. serrata* varied between 2.6 to 6.2. Satapathy (2007) has reported 1.5 to 6.3 gonado somatic index in *S. serrata* and higher values in the months of September to November. Koolkalya *et al* (2006) have observed 1.9 in December to 8.2 in November which has synchronized with the maturity stages of the gonads in *S.olivacea*. Tongdee (2001) has observed two peaks of gonadosomatic index in June with 4.17 and the other in August, September and October with 5.50, 6.43 and 6.70 respectively. Pripanapong (1993) has also observed two seasonal peaks coinciding with those of Tongdee (2001). Poovachiranon (1992) has noticed the absence of mature females in mangrove areas coinciding with high gonado-somatic index in crabs caught at sea. Islam *et al* (2010) have reported that crabs at stage I and II has low gonado-somatic index and began to increase from stage III with highest mean gonado-somatic index more than 10% at stage V. These findings are in correlation with the present study wherein the females of late maturing (stage III) and mature (stage IV) are more in November and December.

Fecundity represents the reproductive output of the animal and generally it is used to describe the number of eggs produced by individual female (Lagler, 1949). According to Arshad *et al* (2006) fecundity of crabs varies from species to species and also within the same species due to different factors such as age, size, nourishment, ecological conditions of the water body etc and variation in fecundity was primarily a reflection of variation in the size of the crab at maturity. In the present study it is observed that the mud crab *S. serrata* is highly fecund. Fecundity in *S. serrata* seems to be more than other *Scylla* species (Srinivasagam *et al*., 2000; Marichamy and Rajapackiam, 1992; Jayamanna and Jinadasa, 1993; Bin Jamari, 1992; Dat, 1999; Hai *et al*., 2001; Millamena and Bangcaya, 2001; Quinitio *et al*., 2001; Djunaidah *et al*., 2001). In the present study the average fecundity noticed is 1.202 millions. The observation in the present study is in correlation with the reports of Srinivasagam *et al* (2000) and Jayamanna and Jinadasa (1993). Millamena and Quinitio (2000) have reported that there is no reduction in fecundity with repeated spawning of the mud crab. Prasad and Neelakantan (1989) have reported a direct relationship between size and fecundity in *S. serrata* up to a size of 140 mm carapace width. A significant positive relationship between carapace width and total fecundity has been noticed by Churchill (2003) and further observed that larger crabs have higher total fecundities and reported crabs between 131 and 144mm carapace width produce (4.03 ± 1.17 million eggs on average with 146 to 181 mm carapace width produce 7.98 ± 1.79 million eggs.

Davis (2004) has noticed that *S. serrata* is highly fecund with 5.17$\pm$1.93 million eggs per mature female within the size range 116 to 200mm carapace width and the mean relative fecundity is 10,655$\pm$ 4,069 eggs /g. Koolkalya *et al* (2006) has observed 1,229,472 to 4,787,967 range with an average of 2,585,098 (± 864,351) fecundity in *S. olivacea* in Andaman sea. In the present study also a linear relationship has been recorded between the carapace length and fecundity and carapace width and fecundity with eggs ranging from 0.3274 million to 3.41 million in females of 8.7-11.4 cm carapace length. Higher "b" values were observed in the present study between fecundity and ovary weight and fecundity and body weight than the carapace length and carapace width indicating that the egg production relates to ovary weight or body weight but not to total length.

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