



Research article

Identifying peak breeding season and estimating size at first maturity of mud crab (*Scylla olivacea*) from a coastal region of Bangladesh

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ABSTRACT

Recently mud crab (*Scylla olivacea*) has emerged as a potential export commodity. Its farming is increasing rapidly in Bangladesh because of its lucrative price and high demand in international market. However, the farming or fattening of mud crab is totally dependent on capture of wild crablets. A huge quantity of mud crabs is being caught indiscriminately from nature and thus putting intense pressure on its wild stock, which is a major concern of conservation. Imposing ban at peak breeding season and setting a legal capture size are considered effective management tools for safe migration and spawning of berried females. There is contradictory information on breeding season of mud crab in Bangladesh. Thus, it is crucial to identify the peak breeding season of it and to formulate conservation policies to protect the berried crabs. Live crabs were collected year-round from the river adjacent to southwest part of Sundarbans. Although mud crab breeds throughout the year, March–April was identified as the peak breeding season of it. The second peak was observed in August–September. The highest abundance of crablets (1–2 months age) was recorded in May–June, and the lowest in January–February. Immature crablets were found all through the year that proves that mud crab is a continuous breeder. The highest amount of GSI value (11.6) was observed in February–March, which indicates that the breeding is very near. The size at first maturity (M_{50}) was estimated as 95.5 mm CW which lied at size class 91–100 mm (CW). The findings from the study will assist in fixing up the banning time and thus protecting the mother crabs; and will assist in formulating police to conserve and protect juvenile crabs in the sense that the minimum legal capture size of crabs will allow the adults to mate and spawn at least once before their capture.

1. Introduction

Farming of mud crab (*Scylla olivacea*) is gaining popularity among the coastal communities of Bangladesh because of its delicious taste, nutritional value, lucrative price and high demand in international market (Islam et al., 2015). Mud crab has emerged as a potential fisheries commodity that is being exported to many countries of the world, notably China, Taiwan, Singapore, Thailand, Hong Kong, Japan, USA and some parts of Europe (Ferdoushi & Xiang-guo 2010; Chakrabarty, 2017). The mud crab fishery supports the livelihood of a huge number of crab collectors, fatteners, growers, depot-holders, traders, brokers, transporters and exporters (Molla et al., 2009). According to a recent information of Department of Fisheries of Bangladesh, some 3,00,000 to 4,00,000 people are directly or indirectly involved with mud crab aquaculture for their sustenance (Chakrabarty, 2017).

Although mud crab aquaculture is expanding rapidly in recent years, till today, the culture practice of crab is only limited to fattening system; either fattening female juvenile crabs up to fully-matured gonad and then to export alive, or rearing of crablets up to a certain stage and to export frozen as a soft-shell product. As, there is no established crab hatchery in Bangladesh (except one at Shyamnagar in Satkhira which is at initial stage), mud crab farming in Bangladesh has become totally dependent on capture from wild stock, mostly from Sundarbans mangrove swamps and adjacent coastal areas. A huge quantity of mud crabs is being caught indiscriminately from the nature; and research findings reveals that annual catch has increased up to 375 T only from Sundarbans mangrove areas (Islam et al., 2015). Thus, mud crab collection from the nature is putting intense pressure on the wild stock, resulting in depletion of the stocks, which is a major concern from conservation point of view. It becomes worse when the berried crabs are caught at their breeding time

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and the immature crabs are caught from nature for growing them as soft-shell products. That is why, it is essential at the moment to formulate conservation policies to protect the mother crabs.

Imposing ban at peak breeding season is considered as one of the effective tools for allowing the berried females to migrate and spawn safely. The Bangladesh Department of Forests has put a ban on catching all types of crabs from January to February, but there is no scientific evidence in support of it. There are contradictory information on the breeding season of crab in Bangladesh; varying from December to April (Ali et al., 2004; Sana, 2017). However, all these works are based on only depot samples which do not reflect the true samples that exist in nature. Thus, it is essential to precisely identify the peak breeding season of the species, based on solid scientific evidence. Another important strategy in fisheries conservation and management is to set a minimum legal size of capture based on the size at first maturity of that particular species, which allows the adults to mate and spawn at least once before their capture (Stevens et al., 1993; Goshima et al., 2000). In Bangladesh, there is no minimum legal capture size (carapace width) for male and female crabs (*S. olivacea*). Though Bangladesh Department of Forest is exercising a thumb rule prohibiting the capture of male crabs below 200g and female crabs below 120g throughout the year, but this rule is very general for all species of crabs and without any scientific evidence in respect of Bangladesh. In addition, there is little enforcement of this rule (personal observation and discussion with crab collectors). Thus, it is of enormous importance to set a minimum legal size of capture for mud crab, based on proper scientific validation. Having considered all these, our study was conducted to identify the peak breeding season and to estimate the size at first maturity of mud crab (*S. olivacea*).

The main novelty of the present work is that this study is the only proper scientific study that describes the peak breeding season of Mud crab in Bangladesh with year-round data of natural crabs. In addition to gonadosomatic index value, back calculation of age of the small crabs by using age-length growth model is also a strong scientific method applied in our study to know the exact breeding time of the species. Although somewhat similar works were reported from few other countries, the present study adds new information in context of Bangladesh, because it is well known that breeding season of any aquatic species changes across geographical location and environmental parameters including temperature and salinity. The findings of the research will definitely assist in formulating any policies regarding conservation and management of the highly potential Mud crab fishery of the country.

2. Methodology

2.1. Sample collection and preparation

Live crabs were collected from the rivers adjacent to the Sundarbans forest at Shyamnagar under Satkhira district of Bangladesh (Figure 1). The geographical position of the sampling area is 22.26° North latitude and 89.20° East longitudes. Sampling was carried out monthly from June to December at every full moon during one high tide (approximately 5–6 h). Sampling was intensified at both full moon and new moon during January to May, the assumed breeding season of mud crab. Relatively bigger-size crabs were captured with long rope and bamboo traps and the crablets (<20g) were netted with nylon-made mosquito net. Crabs were transported alive to Biology and Histology lab of Fisheries and Marine Resources Technology in Khulna University. The samples were ice-shocked at the time of measurement for detailed biological study.

2.2. Study period

The study was carried out over a calendar year from June 2018 to May 2019. Samples were collected at every full moon and new moon from January to May; and at every full moon during the rest of the sampling period up to December.

2.3. Sex identification

For the determination of sex the abdomen of each crab was observed. Among the crab, the male abdomen was narrow and female abdomen was wider. The male and female crabs also had different abdominal flaps. In male *S. olivacea* only one abdominal shaped: narrow or triangular shaped (V-shaped) was observed and in female *S. olivacea* three categories of the abdominal shape were observed: a little bit narrow (V-shaped), wide and globular shaped abdomen with darkened color (U-shaped) and intermediate between the V and U-shaped (Intermediate) (Islam et al., 2010).

2.4. Methods to identify peak breeding season

Three methods were used in the study: i) Estimating abundance of crablets and age-determination (Ali et al., 2019; Hasan, 2019), ii) Observing monthly variation in GSI (Safaie et al., 2013; Fahimi et al.,

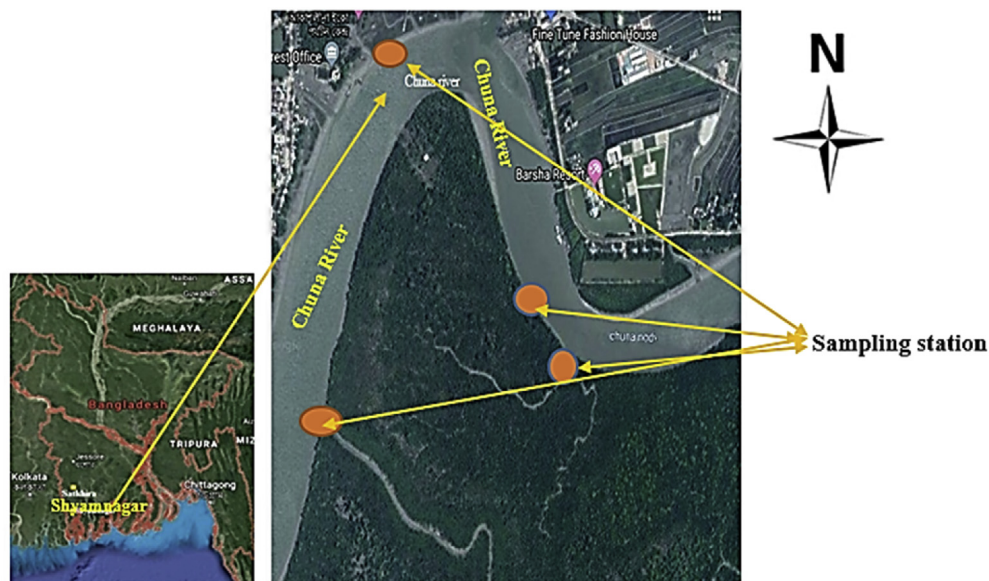


Figure 1. Sampling stations at Shyamnagar under Satkhira district of Bangladesh.

2017) and iii) Observing gonadal development stage or maturity stages (Islam et al., 2010).

All the methods used in our study are scientifically valid and well-documented in several published works (for example: Quinn and Kojis, 1987; Sukumaran, 1995; Islam et al., 2010; Jazayeri et al., 2011; Safaie et al., 2013; Hamid et al., 2015; Fahimi et al., 2017; Ali et al., 2019).

2.4.1. Estimating abundance of crablets and their age-determination

The high abundance of juveniles is an indicator of breeding season which has been well documented in fishes (Reynolds and Babb, 1978; Pope et al., 2010). This idea was utilized in our study to determine the breeding time of crabs. However, the back-calculation of ages of crabs applied in our study is a new approach through which we were able to precisely determine the ages of small crabs as described. The detailed procedure is described in our recent study (Hasan, 2019).

The abundance of small crabs or crablets (1–2 month age) was estimated at every month, and then the peak of the abundance was identified. By back-calculating the age of the crablets the peak breeding season was identified (Ali et al., 2019; Hasan, 2019).

For estimating crab age, hatchery-produced crablets and wild crablets of equal size were cultivated in ponds for six months, and then a growth model was developed from the length-weight data of the crabs. Using this model (general regression model) the ages of all the crabs in the experiment were determined as described in (Hasan, 2019).

2.4.2. Observing monthly variation in GSI

The Gonadosomatic Index (GSI) of female was determined by using the following formula

$GSI = 100 * GM / TW$, where GSI = Gonadosomatic Index, GW = Gonad weight, TW = Total body weight (Quinn and Kojis, 1987; Sukumaran, 1995; Jazayeri et al., 2011).

2.4.3. Observing gonadal development stage or maturity stage

To facilitate the removal of ovary, a cut was made in the carapace along and just ventral to the antero-lateralspines allowing the carapace easily to be lifted off exposing the ovary. The gonado-somatic index (GSI) (drained ovary weight as a percentage of total body weight) was then calculated for each crab. The progress of ovarian maturation was classified into five stages as immature ovary (stage I; transparent color), under-developed (stage II; off white color), early maturing (stage III; yellow color), late maturing (stage IV; orange color) and mature (stage V; deep orange color) based on external characters and observed the color of the ovary through dissection the crab (Figure 3) (De Lestang et al., 2003; Kumar et al., 2003; Rasheed and Mustaqim, 2010; Fahimi et al., 2017).

During the late maturing stage (stage IV), the lobules are developed prominently inside the carapace and upper digestive gland and this stages showed light orange coloration of the ovary. In the mature stages (stage V), the ovary enlarged to the maximum and eventually covered the hepatopancreas and majority of the cardiac stomach and these stages was defined as the deep orange coloration of the ovary (Figure 2).

2.5. Methods to estimate size at maturity

The size at maturity i.e. the size at which 50% of females reach sexual maturity (M_{50}) was measured by two methods; i) Probit analysis and ii). Logit analysis (Campbell, 1986; Overton and Macintosh, 2002). The data from the sampled crabs were allocated to 10-mm CW size classes.

The percentage of mature female mud crabs in each size class was calculated, then converted to a probit scale. The probit data were plotted against CW, and a regression line was fitted to the data points. The CW value equivalent to probit 5 was extrapolated as the median size (M_{50}) at sexual maturity (Overton and Macintosh, 2002).

In Logit analysis, percentage of mature females in each size class was calculated and converted to a Logit scale. The Logit data were plotted against CW, and a regression line was fitted. The value equivalent to Logit 0 was estimated as 50% maturity (M_{50}) or size at first sexual maturity.

2.6. Data analysis

All types of statistical analysis including Probit and Logit analysis were carried out with statistical software MINITAB, Version 17 (Minitab, 2014). Graphs were produced with MINITAB and Microsoft Excel.

2.7. Ethical approval

The experiment was approved by the Animal Ethics Committee of our university. The approval number is KRAEC-2020/04/08:28/04/2020.

3. Results

3.1. Monthly variation in abundance of crablets

The highest abundance of small crablets (1–2 month age) was observed in May–June, ranging from 45–90 crablets/CPUE; while the lowest was observed in January–February, ranging from 6–11 crablets/CPUE (Figure 3). The highest abundance in May–June indicates that the predicted breeding season is March–April. The crablets were spawned in March–April. In addition to the highest peak in May–June, another

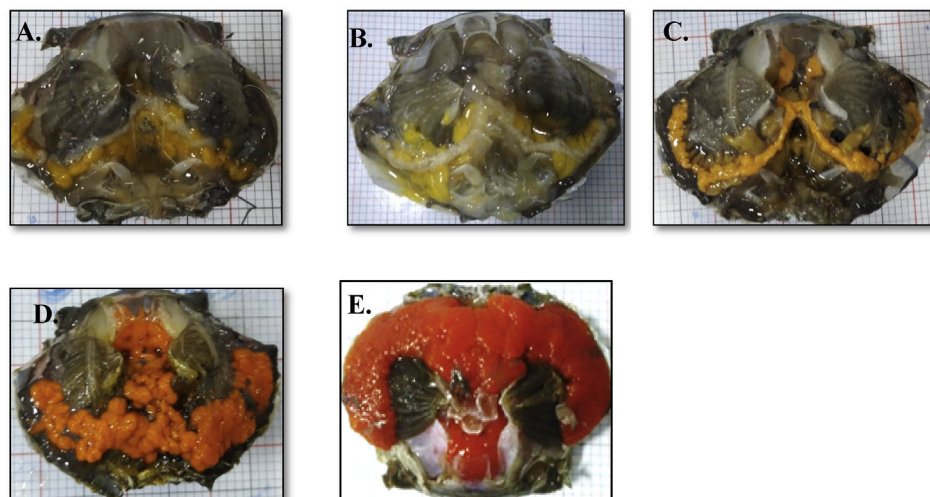


Figure 2. Observation of ovary development stages of mud crab *S. olivacea* collected from Satkhira coastal region of Bangladesh. A. Immature ovary (stage I), B. Under developed ovary (stage II), C. Early maturing ovary (stage III), D. Late maturing ovary (stage IV) and E. Mature ovary (stage V).

medium size peak was observed around November, indicating that September–October may be another peak of spawning. The availability of crablets was found in every month, which indicates that mud crab (*S. olivacea*) is a continuous breeder.

3.2. Monthly variation in GSI

The monthly variations in gonadosomatic index (GSI) of mud crab are shown in Figure 4. The results revealed that the highest amount of GSI was observed in February and March, ranging from 8.2 to 11.6 (% of body weight). The highest amount of GSI indicates that the breeding season is very near, i.e. they may breed either at the end of February or anytime in March or April. From the end of March to June the GSI values showed a downward trend, but in July–August a second peak of GSI (8.3) was observed. But the overall trend of GSI moved a little bit forward from the month of July which indicates that August–September would be another peak of breeding time. Relatively lower GSI was observed in October to December (2.6–3.26). Monthly observations of gonadal development depicted the prolific breeding nature of mud crabs (*S. olivacea*) possessing all maturity stages throughout the year but with a considerable seasonal variation.

3.3. Monthly variation in maturity stages

The monthly variation in maturity stages are presented in Figure 5; which shows that the highest number of fully mature crabs (58–60%) was observed in February–March indicating that breeding season is nearing. After March relative percentage of mature crabs started decreasing till the end of June. At the end of July another peak of maturity was found, which predicts that second peak breeding of mud crab is probably in August. The result also shows that a huge portion of crabs are immature.

3.4. Relationship between GSI and maturity stages

The relationship between Gonadosomatic index (GSI) and each ovarian development stage are shown in Table 1. GSI remained low at stages I and II and began to increase after yolk accumulation started at stages III. Mature ovaries showed the highest mean GSI of more than 11%.

3.5. Relationship between size class and maturity stage

The variation in maturity stages in different size classes for female mud crabs are shown in Figure 6. The figure depicts that the highest proportion of fully mature crabs (50%) was observed in size class >100 mm CW. The result also shows that the mud crab only attained full maturity after 70 mm CW.

3.6. Size at first maturity

Through probit analysis, the maturity size of the *Scylla olivacea* (M_{50}) was estimated as 95.5 mm carapace width (Figure 7), and through logit analysis 50% maturity was observed at 95.4 mm (Figure 8). The result of probit analysis was almost same as that of logit analysis.

4. Discussion

4.1. Peak breeding season

Through close observation of abundance of crablets, GSI and maturity stages, we observed two clear peaks of breeding, the highest one in March–April and another one in September–October (Figures 3, 4, and 5). However, the first peak was very clear that indicates the main breeding time of mud crabs; while the second one in September–October was relatively mild. Having two peaks of breeding is not wondering because there are some other marine and brackish crabs where two breeding peaks are prominent (Prasad et al., 1988; Rasheed and Mustaqim, 2010; Fahimi et al., 2017). In a study with mudcrab (*Scylla serrata*) two peaks of breeding were recorded in India; one in between December–March and another in September–November (Prasad and Neelakantan, 1989). The spawning season of crab *P. pelagicus* in India was reported as February–March (Dineshababu et al., 2008) and in south Australia it lasted for 3–4 months over the summer/autumn period (Svane and Hooper, 2004). A little bit difference was found between that study and our study. This may be due to different geographical area and different species, because the reproductive biology of species changes with seasons and environment (Martinelli et al., 2002; Cobo and Franco, 2003; Ali et al., 2004).

We recorded the salinity ranges of the river Chuna (Satkhira, Bangladesh) where we collected the samples from. The highest peak of gonadal development was observed between February–March where salinity started increasing from 20 ppt to 23 ppt. The salinity was quite

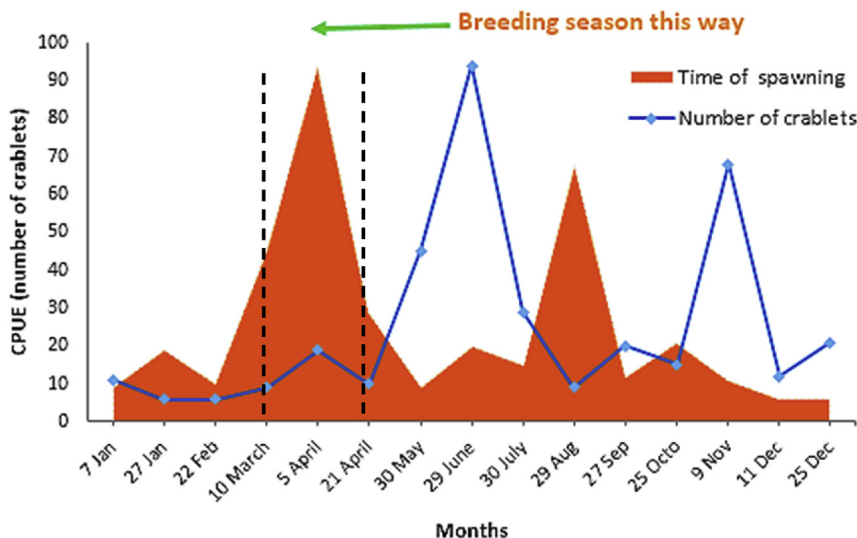


Figure 3. Monthly variation in abundance of 1–2 month-age crablets. The thin blue line indicates the exact number of crablets. The orange-colored shaded solid graph behind the line indicates the predicted birth-month of the crablets. CPUE means: number of crabs/1 boat plus 1 mosquito net during one high tide, approximately 5–6 h.

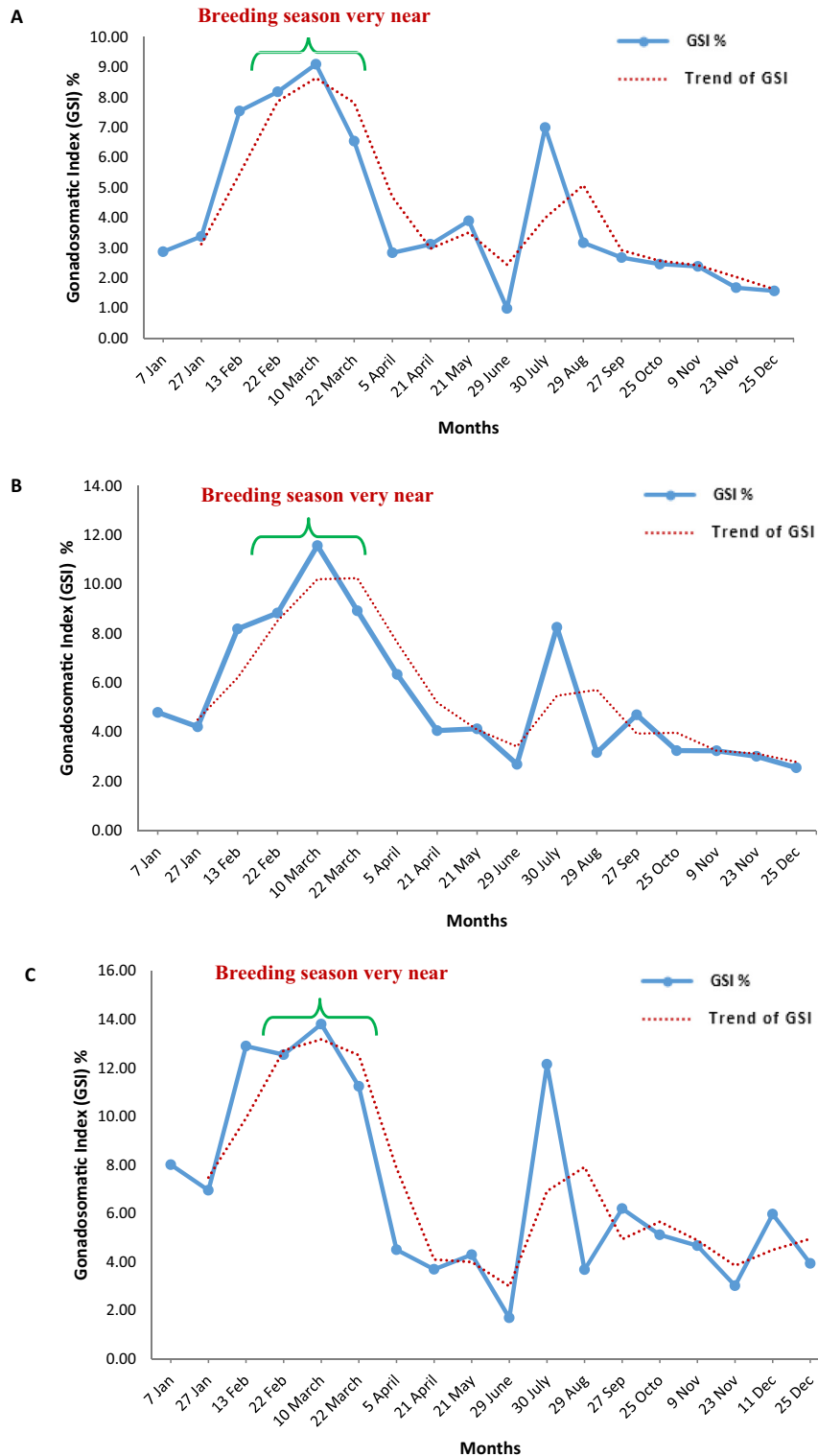


Figure 4. Seasonal variation in GSI (% of body weight) at different months. Data are presented as mean of GSI. The solid line indicates the average GSI of the month, and the dashed line is the overall trend of the data. A. Data of top ten gravid crabs based on highest gonadosomatic value. B. Data of top five gravid crabs based on highest gonadosomatic value C. Data of all crabs (developing, least developed and fully mature) as on highest gonadosomatic value.

low during the period August–December, ranging from 15 to 18 ppt. Between February–March average salinity was recorded as 23–26 ppt, which could be suitable for gonadal maturation. For gonadal development and maturation mud crabs usually need comparatively higher salinity, preferably 20–25 ppt. But for spawning and releasing larvae they need salinity more than 30 ppt, and that is why they migrate towards sea

before they spawn. However, salinity is not the only factor that triggers the breeding season of mud crabs; rather it depends on many environmental and nutritional factors. Chandran (1968) while working on breeding of marine crabs hypothesized that the salinity, temperature and supply of food material are some of the important factors which trigger the breeding behaviour of mud crabs. Haesman et al. (1985) in a review

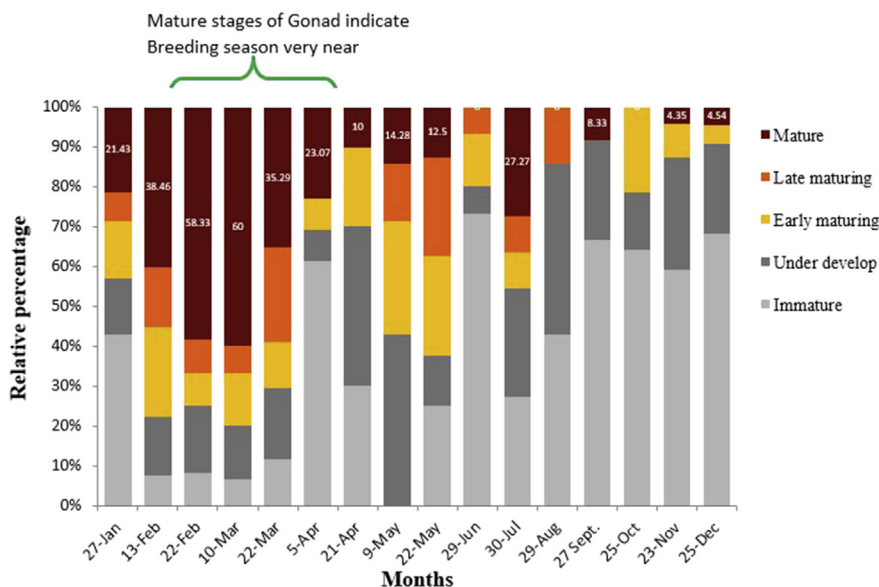


Figure 5. Maturity stages crab *S. olivacea* in different months of the year.

Table 1. Relationship between GSI and maturity stages of female mud crab (*S. olivacea*).

GSI (%)	Frequencies (%)				
	Stage I %	Stage II %	Stage III %	Stage IV %	Stage V %
<1	52.14	6.06	0	0.0	0.0
1 to 4	47.87	84.84	60.6	20.0	0.0
5 to 9	0	9.09	36.36	40.0	21.4
>10	0	0	1.51	40.0	78.6
No. of sample	117	66	33	15.0	42.0
Mean GSI (%)	1.2	2.29	4.6	8.6	11.3

of general trends of spawning activity of mud crab (*S. serrata*) suggested that the length of the spawning period varies with latitudes; and spawning period increases with the decreasing latitudes. One of the reasons accounted was the availability of food in different seasons. Like other brackish and marine water species, the breeding mechanism, spawning and migration of mud crab is dependent on lunar phases (Hill, 1975; Christy, 2011). Several reports show that mud crabs spawn in the sea and the young ones (crablets) migrate either to inshore waters or backwaters for their nourishment. However, in a nutshell, the breeding season, greatly vary in accordance with topographical features and existing hydrological conditions (Christy, 2011).

We are confident from the findings of our study that breeding months of mud crab are February, March and April, but between March and April is their peak time of spawning. The migration behaviour of mud crabs suggests that at the time of spawning they migrate from brackish water to deep sea of high saline water. That is why, catching of berried crabs in the estuarine areas should be restricted few weeks before they spawn. In that case we suggest revision of the existing banning period and it should be fixed in February and March if two months' ban is implemented; and February to April in case of three months' ban.

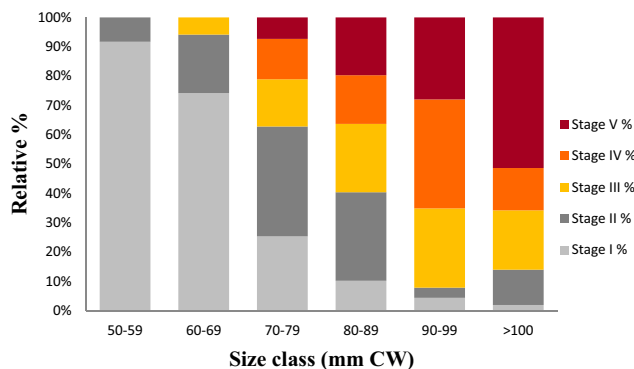


Figure 6. Variation in maturity stages in different size classes for female mud crabs (*S. olivacea*).

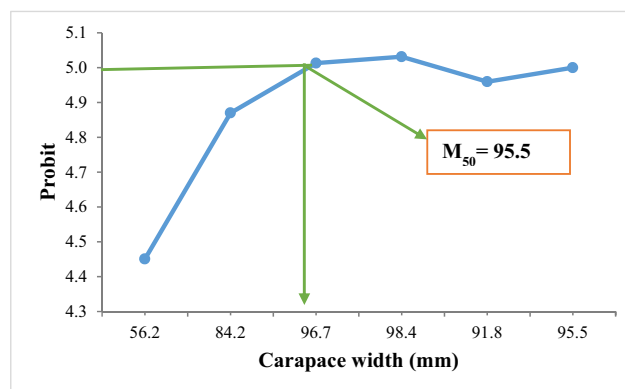


Figure 7. Probit values of percentage of mature female crabs against carapace width (mm).

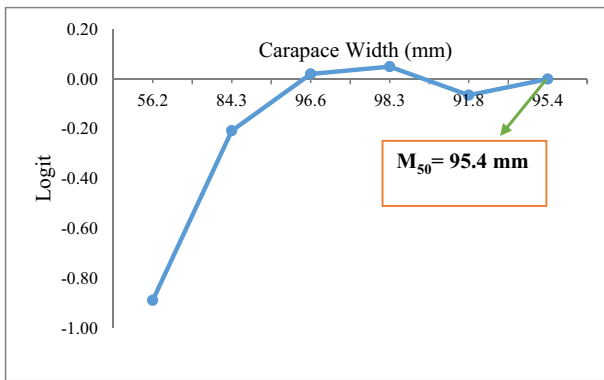


Figure 8. Logit values of percentage of mature female crabs against carapace width (mm).

4.2. Variation in maturity stages

In our study, we observed the availability of crablets (1–2 month age) and mature females all-round the year (Figures 3 and 4), which suggests that mud crab (*S. olivacea*) is a continuous breeder. Some other studies also confirmed that crab breeds continuously throughout the year (Fahimi et al., 2017; Hosseini et al., 2014; Safaie et al., 2013; Rasheed and Mustaqim, 2010; Norman, 1996; Prasad and Neelakantan, 1989). In a study, breeding seasons in brachyuran crabs were classified on the basis of the presence or absence of ovigerous females. Individuals of the crab *L. exaratus* were found ovigerous all year round, indicating its nature of being a continuous breeding. The findings of our study also agrees with the results from Safaie et al. (2013) in blue swimming crab *P. segnis*; Watanabe et al. (1990) in *L. exaratus* crab; Tomikawa and Watanabe (1992) in xanthoid crab *Eriphia smithii*; Latreille (1825) in *Tiarinia cornigera* crab; Tsuchida and Watatnabe (1991), Montgomery (1931) and Norman (1996) in portunid crab *Thalamita pelsarti*.

Interestingly, out of 778 female crabs examined in our study none of them was with a 'berry' (branch of eggs carried under the abdomen of mother crabs). Such absence of ovigerous females in the backwaters could be attributed to seaward migration of mature females for spawning purpose. Secondly ovigerous females, if any, might not have been accessible for 'don' (long lines), the gear mainly used in backwaters for catching *S. olivacea*. This phenomenon may be explained by the fact that the intensity of feeding in crabs declines during berried state (Edwards, 1979; Haesman et al., 1985; Prasad and Neelakantan, 1989). Thirdly, it could also be owing to protective behaviour towards the eggs, which is one kind of parental care the mud crabs exhibit for the welfare of their generations.

4.3. Relationship of GSI and size class with maturity

Maturity of any species depends on GSI and sizes of the species. The findings of our study reveals that GSI of the mud crab (*S. olivacea*) was low at stages I and II with white translucent female gonads; and began to increase when yolk accumulation started gradually to stages III with light orange colour (Table 1 and Figure 5). The highest mean of GSI (>11%) was observed in fully mature crabs with dark orange gonads. We can infer from the results that the female mud crabs (*S. olivacea*) with GSI below 4 are either immature or developing gonads; the ones with GSI more than 8 are late mature or fully mature. The variation in maturity stages in different size classes for female mud crabs reveals that the highest proportion of fully mature crabs (50%) was observed in size class around 100 mm CW. This size is very important from conservation point of view, because this is the minimum legal capture size of female mud crabs.

4.4. Size at maturity

In general, the mean size at first maturity is frequently used as a minimum legal size for the retention of the decapods species. The 50% maturity size is the common minimum legal size used in many open water mud crab fisheries but exclusively for female crab (Robertson and Kruger, 1994; Overton and Macintosh, 2002). Most of *S. olivacea* caught at Satkhira Mangrove region were composed of small sized crabs. In the present study the size at first maturity (50% maturity) of female *S. olivacea* was estimated at 95.5 mm carapace width. Macintosh et al. (2002) recommended that the minimum size of capture of mud crabs (*Scylla serrata*) in the Ranong fishery, situated on the western coast of Thailand, should be 100 mm ICW which is close to the present result. But the mean size at first maturity in this study was a little smaller than that of *S. paramamosain* in Bandon Bay in the Gulf of Thailand but similar to the same species caught in Bandon Bay (Overton and Macintosh, 2002). In South Australia *P. pelagicus* generally reach sexual maturity at a size of 70–80 mm in carapace width (Svane and Hooper, 2004) stated that 50% maturity in these crabs occurred at about 57 and 50 mm carapace width for males and females respectively in Spider Crab, *Chionoecetes opilio* which is not similar to the present study. The cause of difference of the result might be the different species. Size at maturity of the crabs *Portunus sanguinolentus* was determined by Rasheed and Mustaqim (2010) showed that in male crab's maturity was attained at a size of 64–70mm short carapace width and attain 50% maturity at 60.8 mm short carapace width. In females on the other hand size at maturity was recorded to be 63–71 mm CW and 50% maturity in females was attained at 63.5 mm CW. The size at first maturity varies with latitude or location and temperature (Campbell, 1986; Sukumaran and Neelakantan, 1996). For example, the minimum internal carapace width of female crabs that reach sexual maturity ranged from 61 mm in both the Peel-Harvey Estuary and Shark Bay and 84 mm in the Leschenault Estuary (De Lestang et al., 2003), Clarke and Ryan (2004) stated that about 82 mm ICW females in Australia can become sexually mature while in India, females at 80 mm ICW (Sukumaran and Neelkantan, 1996). Islam and Kurokura (2013) reported that the 50% maturation of male *S. paramamosain* was 110 mm internal carapace width where female *S. olivacea* at 100 mm ICW. Robertson and Kruger (1994) have shown that the size at sexual maturity in male and female *S. serrate* and Kanchana (2008) was showed that 50% of females were mature for the first time their carapace width was 95.5mm in *Scylla olivacea*, in Klong Ngao Mangrove Swamp, Ranong Province, Thailand as estimated from a logistic model which is similar to the present study. The mean size at first maturity (M_{50}) of *S. olivacea* in Satkhira mangrove region was 95.5 mm CW which lies in size class 91–100 mm CW. As the mean size at maturity lied in 91–100 mm CW size class, so the minimum legal size of capture for female mud crabs should be at least 100 mm CW that will help to conserve and protect the young crabs. The mean size at maturity was determined only for female so further research on sexual maturity of male mud crabs is recommended before we set up any legal capture size of mud crabs in Bangladesh. This finding indicates that maturity size does not vary widely but may vary with the species in the particular area. As this was conducted only in one area so the result in deep sea and other area can vary. That is why, further research on sexual maturity of mud crabs would be recommended before we set up any legal capture size of mud crabs in Bangladesh. About more than 74% of population is immature mud crabs so we should provide special management and conservation action for the mud crab population in Bangladesh.

5. Conclusion

Our study confirm that breeding season of mud crab (*Scylla olivacea*) is between February and April, but the peak spawning time is March–April. However, as the abundance of fully mature crabs starts increasing from the end of February, the month February should be included in the peak breeding season for precaution. Bangladesh government is now

implementing January and February as banning period for catching all types of natural crabs. Based on the findings of our study we would suggest that the existing banning period should be revised. If two months ban is enforced then we recommend February and March, and in case of three months' ban we propose February, March and April.

The present study suggests that the minimum legal size of capture for female mud crabs should be at least 100 mm CW that will help to conserve and protect the young crabs. However, this size might differ for male crabs because male crabs becomes larger than the female counterparts and may undergo sexual maturity at bigger size. Further research on sexual maturity of male mud crabs is recommended before we set up any legal capture size of mud crabs in Bangladesh.

The present study presents a solid scientific evidence on peak breeding season and size at first maturity of mud crab (*S. olivacea*). Thus, the finding of our study will definitely assist in formulating any law or policies regarding conservation and management of the natural population of mud crab in general and protection of mother crabs in particulars.

Declarations

Author contribution statement

Muhammad Yousuf Ali: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Md. Billal Hossain, Sattayjit Sana: Performed the experiments; Analyzed and interpreted the data.

Muhammad Abdur Rouf: Contributed reagents, materials, analysis tools or data.

Sajeda Yasmin: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Md. Golam Sarower: Conceived and designed the experiments; Wrote the paper.

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The authors declare no conflict of interest.

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No additional information is available for this paper.

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