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The mud crab fishery of the Sundarbans mangrove of Satkhira district (south-western Bangladesh); biological traits to manage the resource

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Key words: Mud crab, relative abundance, biological traits, Sundarbans mangrove forest, livelihood.

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Abstract

Mud crab is one of the important commodities in the coastal region of Bangladesh but less understood about their abundance and biological traits. The present study described the relative abundance and the biological traits like size distribution, ovarian maturity size, breeding periodicity, etc. of mud crab (*Scylla olivacea*) to propose a suitable management guideline. Samples were taken between October 2017 and October 2018 from different stations of Satkhira district. The average mud crab density was estimated 481.57 ± 221.34 crabs/ha which represent the average biomass as 28.85 ± 12.88 kg/ha. The crab density was higher in the deeper mangroves than the nearby mangroves and rivers. A total of 874 individuals were assessed and sample individuals showed mostly under the size-class of 70-79 mm internal carapace width (ICW). The female crabs were dominated (57%) throughout the study period and the sex ratio was 1: 1.33. The 47% individuals were mature (U-shape) according to their abdominal flap shape and this finding also reaffirmed by the internal observation of ovaries. The 50% females attain ovarian maturation at the size of 84.98 mm ICW. The species breed round the year but according to their gonadal development frequencies (%) and gonad somatic index (GSI), it was noticed that they might have two peak breeding seasons i.e. winter (November to February) and rainy season (June to July). Thus, it may be suggested that the female mud crab should not be harvested<85mm ICW and the season restriction time might be revised for the coastal areas of Bangladesh.

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Introduction

The Sundarbans is the largest single block mangrove forest in the world (Curtis, 1933) which is not only famous for the Royal Bengal Tiger, Spotted dear, and biodiversity but also for mud crab. Among the 6017 km² of Sundarbans (Bangladesh part), about 1874 km² is water body. This vast water body consisting of 450 rivers-canals and vast inundated land is enriched with about 120 euryhaline fishes and crustaceans (Naskarand Chakraborty, 1984). The mud crab (*Scylla olivacea*formerly known as *Scylla serrata* in Bangladesh) is widely abounded and economically important crabs in Sundarbans mangroves in Bangladesh and India. The species occur abundantly in the estuaries, tidal rivers of the Sundarbans mangrove swamps and coastal shrimp farms (Khan and Alam, 1992).

Mud crab fishing has been practiced for many years in coastal region, particularly in the southwest region of the country (Khulna, Bagerhat and Satkhira) based primarily on capture from the wild. The main source of mud crab (almost 60%) is in the Sundarbans (Islam, 2018). Export of mud crab started in 1977-78, and became a stable business in 1982. The export of live mud crabs from Bangladesh has increased many times in the last decade (BEPB, 2004) and ranked third among frozen foods exported from Bangladesh (Ali *et al*., 2004). Bangladesh exported 7707 tons of hard-shell live crabs to international markets during 2013-14 and earned US$ 21.1 million (DoF, 2015).However, Rosenberry (2015) mentioned the annual mud crab production of the country is about 10,000 tons.

Millions of locals are directly or indirectly dependent on crab fishery in Bangladesh (Zafar and Siddiqui, 2006; Molla *et al*., 2009; Rosenberry, 2015). There are various types of livelihood in the coastal areas of Bangladesh like fishing, shrimp culture, wood collections, honey collections, crab harvesting and fattening, etc. However, the crab harvesting, fattening and grow out culture are on the increase. The disease outbreak in shrimp farming and the last few catastrophic disasters have caused a lot of change in coastal habitat and the livelihood pattern. In addition, last few catastrophic natural disasters (like AILA, SIDRE) also have overstated the changes in coastal habitat and the livelihood pattern of the marginal people.

Considering the increasing demand of mud crab in the local and international markets, it has been gaining popularity among the coastal communities in greater Khulna regions (Azam *et al*., 1998). Therefore, the entry of new fishers in crab harvesting from coastal waters has increased manifolds. As a result, the natural populations of mud crab are declining throughout the Southeast Asia due to (i) over-exploitation, (ii) loss of mangrove habitat, and (iii) coastal environmental degradation. In addition, catching of small crabs due to high demand of recent crab fattening hampered biological reproduction as most of the individuals caught before maturity. The two very recent study in Bangladesh mentioned that the total catch is decreasing, especially female and large-size crabs (Islam, 2018; Chakraborty *et al*., 2018). An experiment in Thailand, it is reported that >80% populations are being caught before getting the size of first maturity (Islam, 2012).

So, a comprehensive management activity is urgently needed for the mud crab fishery to sustain the harvesting from natural habitat and hence to ensure continuous livelihood of the coastal marginal people who have rare alternative livelihood. However, to set a fruitful management strategy, it is essential to know the present abundance and details biology such as size-class distribution, population maturity size, breeding season, etc. which are lack in this area. Thus, the present study was conducted to figure out the management strategies on the basis of abundance assessment and biological information in a coastal district, Satkhira, Bangladesh.

Materials and methods

Study site

Year-round monthly samples were collected (October 2017 to October 2018) from different Sundarbans mangrove adjacent locations of Satkhira district of

south-western Bangladesh (Fig. 1). Among the seven sub-districts, Shyamnagar and Kaliganj are adjacent to the Sundarbans where focused in the present study. Shyamnagar is the most Sundarbans adjacent area and we collected samples from three stations of this sub-districts. On the other hand, from up-stream of the Sundarbans associated river, samples were collected from Kakshiali river, Kaliganj, Satkhira.

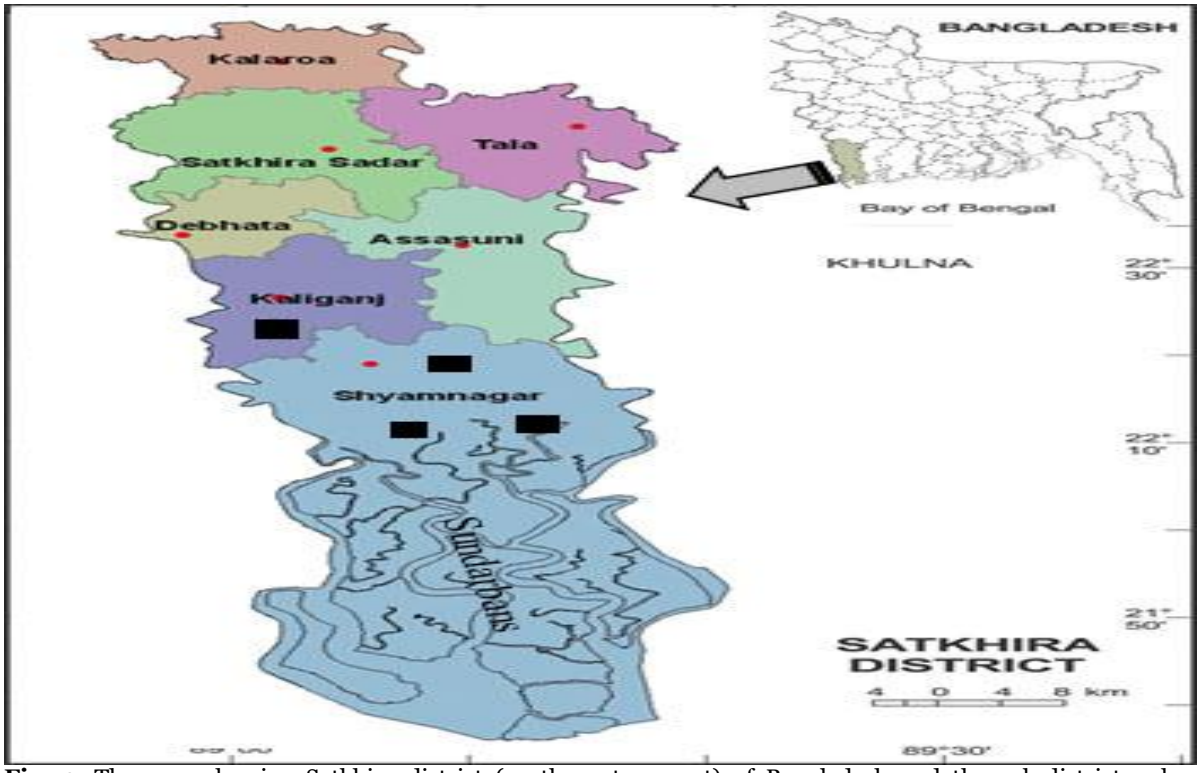


Fig. 1. The map showing Satkhira district (south-western part) of Bangladesh and the sub-districts where samples were collected (in black block). One station from Kaliganj and three from Shyamnagar.

Abundance and production trends

Some crab fishers were contracted to undertake standardized fishing every selected time frame (particularly during spring tide) of each month for a period of one year to estimate the mud crab abundance. The four fishing sites were selected across the Satkhira district (3 from Shyamnagar and 1 from Kaliganj sub-districts) on the basis of mangrove vegetation, fishing pressure and different habitats. The selected crab harvesters were trained up to harvest crab in the designed manner, how to collect data and keep records. The gathered information was used to estimate crab density by extrapolating the relationship between the harvest area and crab removal over a fixed period of time. In the station, Kaliganj, collapsible bamboo traps and in other three stations, long line was used to estimate abundance as a prime gear. At each station, the relative abundance (catch per unit effort; CPUE) of mud crabs was estimated in terms of number of crabs caught per trap/line in a day. Then the CPUE was considered the number and biomass of the respective area they covered. The production trends were estimated according to the crab collector's perception. Forty-five collectors' perception was taken to estimate the production trends from five years back to present study. Among the respondents, almost half of them were small scale crab collectors who usually collect crabs in nearby mangrove area and sell daily and the others were large-scale collectors as they used long-line and usually go to deeper area of mangroves for several days at a stretch.

Sampling and measurements

Scylla olivacea were collected directly from fishermen in monthly basis to ensure that samples were collected from all the gears used in the study area. The collected crabs were brought to the

laboratory of Fisheries and Marine Bioscience, Jashore University of Science and Technology, Bangladesh where further study was done. The sexes of the crabs were determined according to their abdominal flap shape (Islam *et al*., 2012). The length, internal carapace width (ICW), and weight of individuals were measured. The female with mature abdomen shape (U-shape) was separated and dissected for ovarian development study and measuring ovary for the calculation of gonadosomatic index (GSI) to identify the maturity cycle.

Ovarian development and estimation of maturity size

The gonad of female was dissected out to observe the development stages and to ensure the maturity of the species. The colour and sizes of the ovaries were examined visually and categorized into five development stages according to Islam *et al.* (2010) and Islam (2012). On the basis of mature individuals regarding their size, it was determined the size at which 50% of females reach sexual maturity (ICW_{50}) (Robertson and Kruger, 1994) by fitting the linear curve. This is the proportion of female with ovary stages III-V to total number of females in each ICW class (10 mm interval).

Management strategies

The population sexual maturity size (50% maturation of population) could be one of the regulations for catching of the mud crab. The legal size imposed for a particular population is widely used regulation, especially for wild stock. In addition, on the basis of peak breeding cycle, it was tried to justify the season which may be imposed to manage the population.

Statistical analysis

All the statistical analysis in the present study was done in Microsoft Excel 2007.

Results

Abundance and production trends

The average crab catches (kg/day), average number of crab harvesting (day/fishermen) and the abundance of mud crab (number/500 f^2) at different sampling stations of Satkhira district is presented in Table 1.

Table 1. The average catch (kg/day), average number of crab fishing (day/fishermen) and the abundance of mud crab (number/500 square feet) at different sampling stations of Satkhira district.

Sampling Station	Average catch (kg/day) ± SD	Average catch (No/day/Fishermen) ± SD	Average catch (kg/day/500 f^2) ± SD
Kaliganj	0.8 ± 0.36	7.0 ± 3.0	7.0 ± 3.0
Nildumur	3.8 ± 0.44	56.0 ± 6.0	19.0 ± 2.0
Kadamtola	3.8 ± 2.04	40.0 ± 28.0	13.0 ± 9.0
Munshiganj	7.2 ± 3.80	172 ± 80.0	57.0 ± 26.0
Average	3.9 ± 1.66	69 ± 29	24.0 ± 10.0

It is estimated that the average catch 3.9 ± 1.66 (kg/day/500f^2) which represent 24.0 ± 10.0 crabs/day/500 f^2 from Sundarbans area of Satkhira district. The average catch at upstream Sundarbans (Kaliganj) is 0.85 kg/day/30 traps (7 crabs/day/30 traps). This could represent 7 crabs/500 f^2 as 30 traps usually cover 500 f^2.

Table 2. Density and biomass of mud crab *Scylla olivacea*of different stations in Sundarbans mangrove forest, Satkhira, Bangladesh.

Sampling stations	Average density (m^2)	Average density (ha)	Average biomass (kg/m^2)	Average biomass (kg/ha)
Kaligonj	0.014 ± 0.005	137.81 ± 48.26	0.0017 ± 0.0007	16.5 ± 7.25
Nildumur	0.037 ± 0.004	373.3 ± 42.3	0.0026 ± 0.0003	25.53 ± 2.95
Kadamtola	0.027 ± 0.021	268.6 ± 208.0	0.003 ± 0.001	25.3 ± 13.58
Munshigonj	0.11 ± 0.06	1146.6 ± 586.8	0.005 ± 0.003	48.1 ± 27.77
Average	0.47 ± 0.022	481.57 ± 221.34	0.005 ± 0.001	28.85 ± 12.89

The average mud crab biomass calculated 28.85 ± 12.89 kg/ha with the highest 48.1 ± 27.77 kg/ha from Munshiganj stations (Table 2). The average crab densities calculated 482 ± 221 crabs/ha.

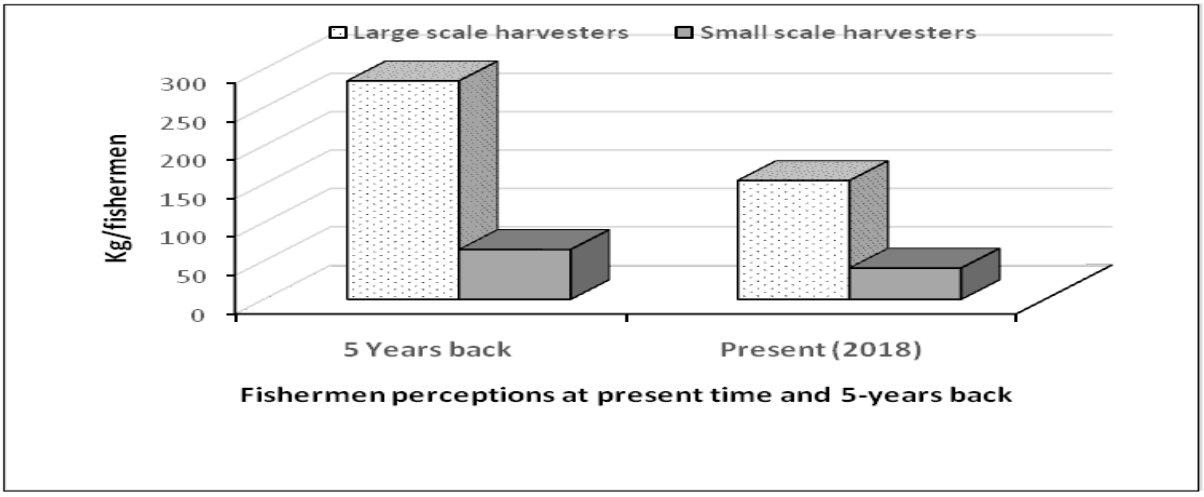


Fig. 2. The mud crab production trends according to the harvester's perception from the district Satkhira, South-western Bangladesh.

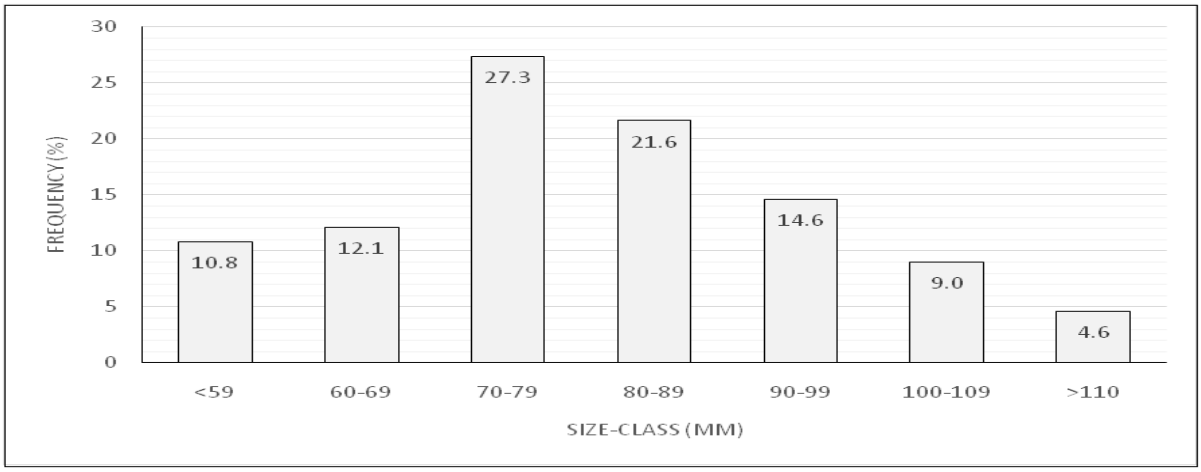


Fig. 3. The size-class (mm) distribution of mud crab *S. olivacea* collected from the district Satkhira, South-western Bangladesh during October 2017 to October 2018.

According to the mud crab harvester's perception, the harvesting amount has decreased in the area.

It is showed that 45.6% catch decreased for a large-scale crab harvester from five years back to present time. In the same time, 37.1% decreased in case of small-scale crab fishers (Fig. 2).

Population demography

A total of 874 crabs were sampled during the study period and the size ranged from 50.0-130.0 mm internal carapace width (ICW) to the average size of 82.43 ± 16.0 mm ICW. In case of size-class distribution, it is noticed that most species (27%) belonged to the size group 70-79mm ICW. Almost 50% crabs belonged to the size group 70-90 mm ICW (Fig.3). Female was dominant (57%) over male (Fig. 4) in almost throughout the sampling months (Fig.5) and the sex ratio was 1: 1.33.

Ovarian development

The ovarian development or maturity status was assessed in two different ways which are external observation i.e. observe the shape of abdominal flap to know whether they are mature or not. On the other hand, ovary was dissected out and observed their

development status by physical observation. In the present study, it was found that 47% females (Fig. 6) were mature according to their abdominal flap shape. However, about 26% female recorded as hermaphrodite (intermediate stage between mature and immature; locally called 'hijra').

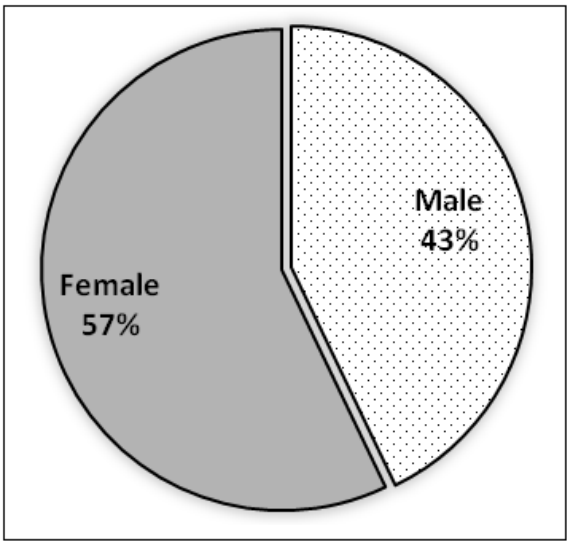


Fig. 4. The sex ratio of mud crab *S. olivacea* collected from the district Satkhira, South-western Bangladesh during October 2017 to October 2018.

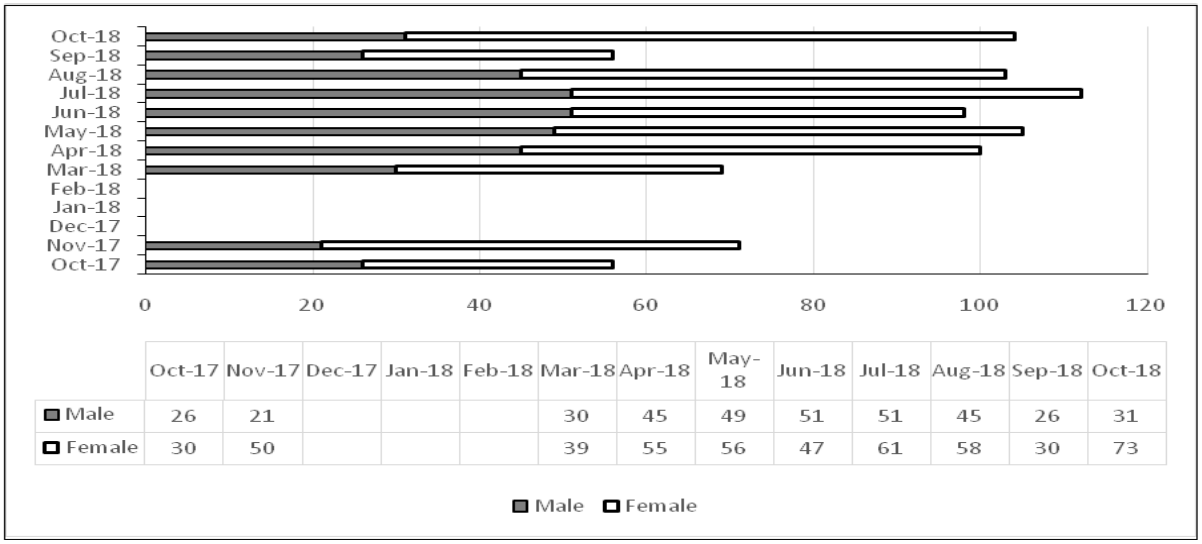
The ovarian maturation was classified into five stages according to their internal ovarian observation like immature ovary, under developed, early developed, late developed and mature respectively.

In the present study, it was found that >21% individuals were at the maturation stage. However, if we consider, from the vitellogenesis i.e. from the stage 3 (yellow coloration of the ovary), >50% of individuals were mature (Fig. 7).

Regarding the abdominal shape, it is noticed that U-shaped female crabs occurred at smallest size group (>59 mm ICW)but they increased in number at the size of 70mm ICW (Fig.8). More than 90% female was U-shaped abdomen at the size-class of 90mm ICW.

Breeding cycle

It is found that the U-shaped female crab (mature crab) encountered each of the sampling months (Fig.9). This is the indication of continuous breeders of *S. olivacea* in the coastal area of Bangladesh. This result got more authentication as the mature stages of ovary (stage III to V) noticed throughout the sampling months (Fig. 10) by the internal observation of the ovaries.



	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18
Male	26	21				30	45	49	51	51	45	26	31
Female	30	50				39	55	56	47	61	58	30	73

Fig. 5. The male-female mud crab, *S. olivacea* in different sampling months from the district Satkhira, South-western Bangladesh.

Management aspects

In the present study, we noticed higher percentage of mature female crabs in October and November. In addition, during June and July we also recorded higher percentage of mature crabs in the study area (Fig. 11). The gonadosomatic index (GSI) values (%)

also showed higher in winter and rainy season (Fig. 12). Thus, we may say that the species might have two peak breeding seasons which are winter and the rainy season.

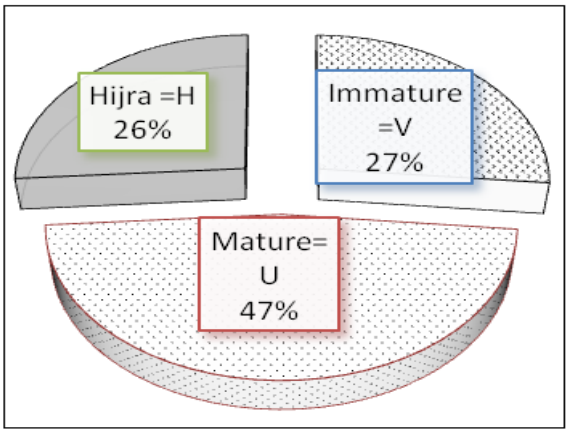


Fig. 6. The maturity index of female regarding their external abdominal flap shape from Satkhira, Bangladesh during October 2017 to October 2018. U=Mature, V=Immature and H=Hijra (underdeveloped female).

In addition, the ovarian development pattern regarding to their size group, it is noticed that the mature stage (stages III-V) started from 60-69mm size class but frequency of mature stages increased at the body crab size of about 80mm ICW (Fig. 13). However, the maturity size of an open water organisms usually denoted as the maturity of the 50% of their population. In the present research, it is found that the 50% female reach maturity at the size of 84.98 mm ICW (Fig. 14).

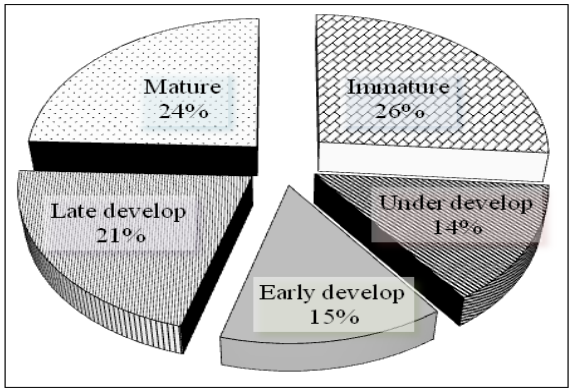


Fig. 7. The percentage of ovarian development stages of *Scylla olivacea* collected from district Satkhira, South-western Bangladesh.

Discussion

Mud crab abundance

Since there was no information on the abundance of mud crab (*S. olivacea*) from South-western Sundarbans before this study, catch per unit effort (CPUE) value was used as an index of abundance even though it is not representative of the entire population.

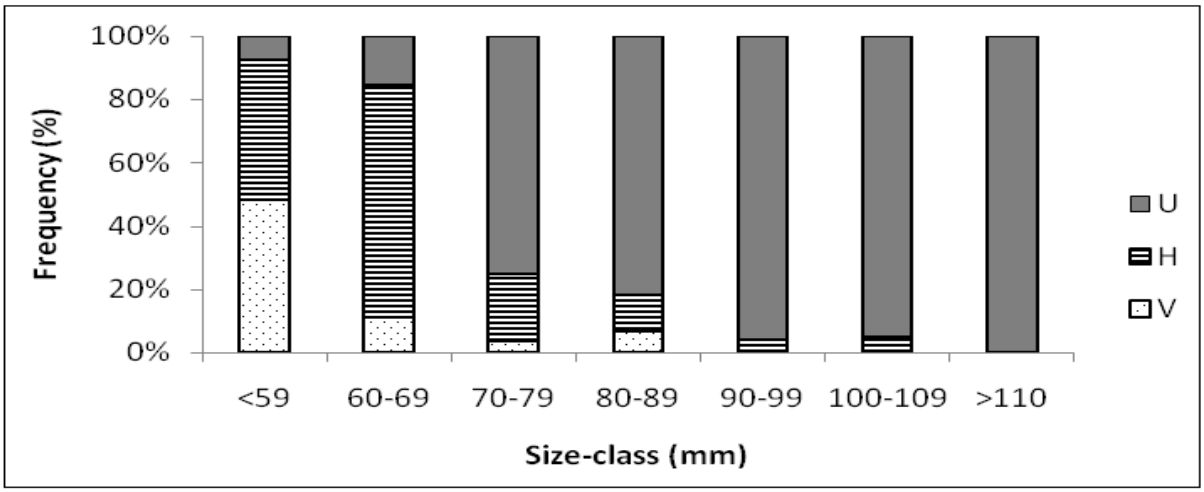


Fig. 8. The maturity distribution (according to their abdominal shape) in different size-classes of *Scylla olivacea* from Satkhira district, Bangladesh.

In the present study, the collapsible bamboo traps for the site of Kaliganj and long-line for the other three sites of Shyamnagar sub-districts were used as the best estimation of CPUE as they are the main gears for harvesting mud crab in the respective sites. As different gears were used at two sub-districts to

estimate the CPUE, it was not possible to compare the CPUE between two sub-districts. However, the CPUE was different from three stations of Shyamnagar sub-districtranged 56.0 ± 6 to172 ± 80 crabs/day/fishermen. The CPUE was very low in Kaliganj sub-district where it was only 7 ± 3 crabs/day/fishermen.

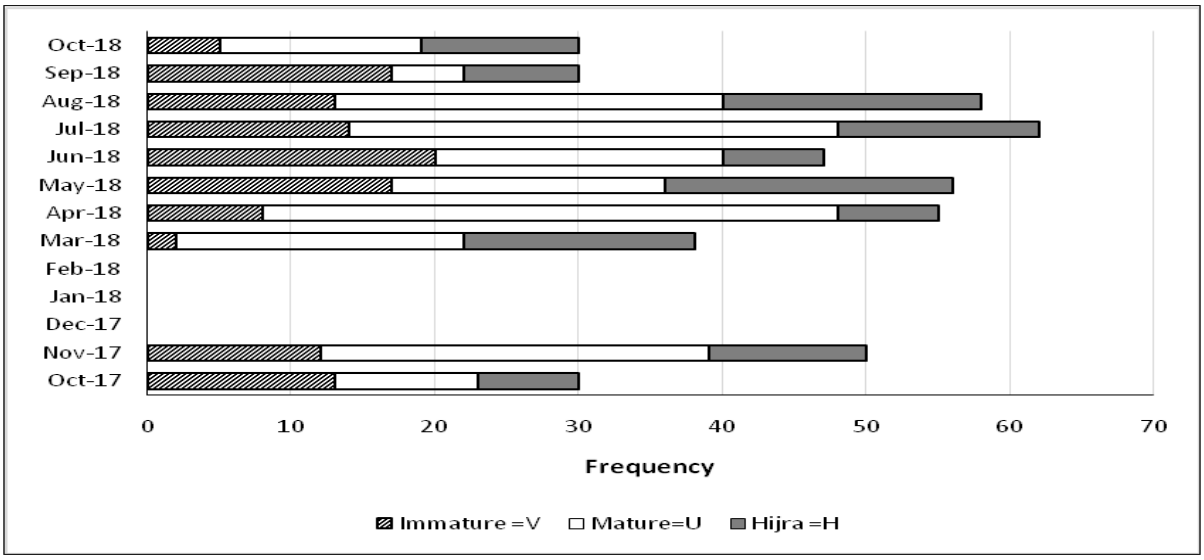


Fig. 9. The different types of abdominal flap-shaped mud crab collected from Sathakhira, Bangladesh. The U-shaped (mature) crab noticed all the sampling months. No samples were collected during January and February due to restriction of harvest.

The most crab density and biomass were recorded inMunshiganj of Shyamnagar and it was 1146.6 ± 586.8 crabs/ha and 48.1 ± 27.77 kg/ha respectively. The crab collectors of Munshiganj usually harvest crabs from deep mangroves. So, we may say that the density is higher in deep mangroves than the nearby mangroves. The present abundance of mud crab was much higher than other studies like Dumas *et al.* (2012) recorded 13.7-19.3 crabs/ha from Voh-Kone area of New Caledonia with the biomass of 9.2-9.9 kg/ha and Nand *et al.* (2016) reported 2.3-12.5 crabs/ha from Bua Mangrove forest of Fiji.

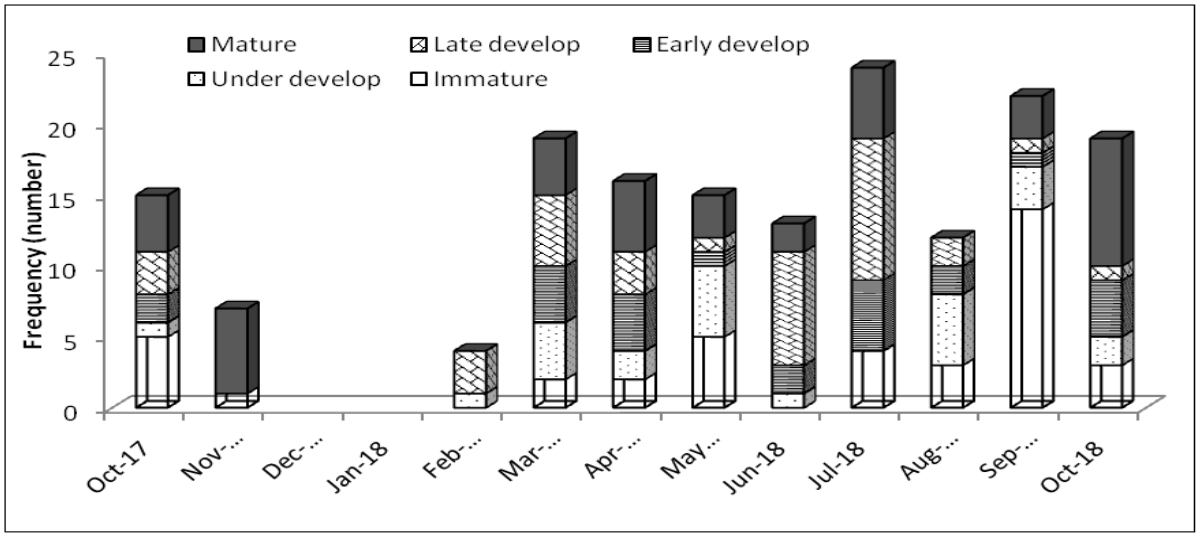


Fig. 10. The ovarian development stages of mud crab collected from Sathakhira, Bangladesh during October 2017 to October 2018. The mature-stage ovaries noticed throughout the sampling months. No samples were collected during December, January and February due to restriction of harvest.

Biological traits

Though different gears were used into sub-districts, there was no significant difference in the size class distribution between two places. The size of crabs recorded ranged from 50 to 130 mm internal carapace width (ICW). Almost similar size 40 to 140 mm carapace with (CW; CW is usually 10 mm higher than ICW) was reported from Klong Ngao mangrove swamps, Ranong Province, Thailand (Jirapunpipat *et al.*, 2007). However, the larger size ranged 87-181 mm CW was recorded from Voh-Kone area of New Caledonia (Dumas *et al.*, 2012).

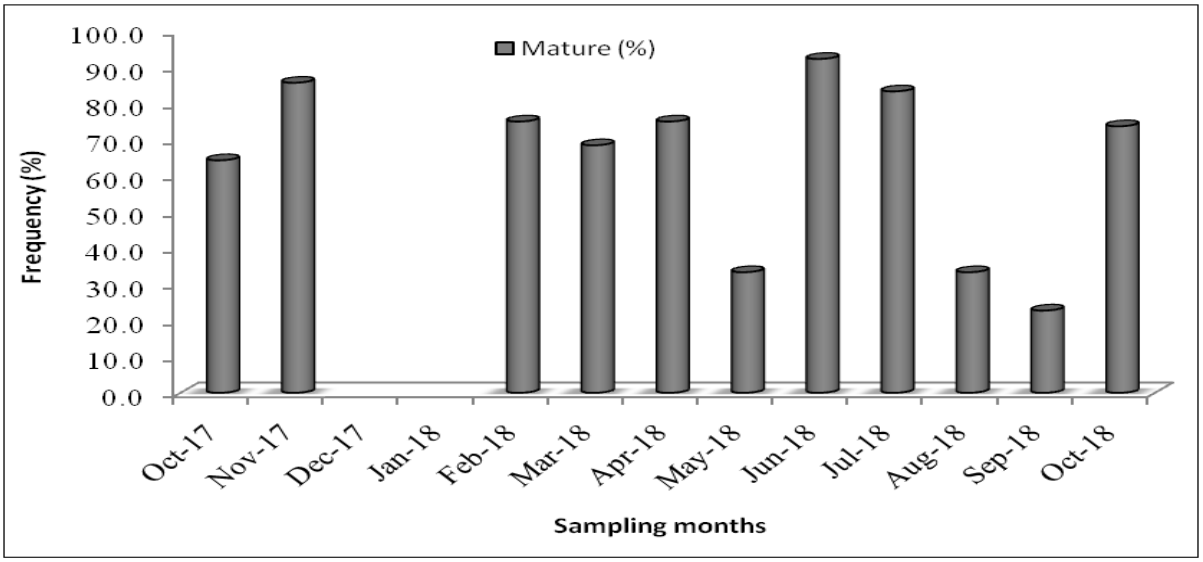


Fig. 11. The mature mud crab (ovary stage III-V) collected from Satkhira, Bangladesh during October 2017 to October 2018. No samples were collected during January and February due to restriction of harvest.

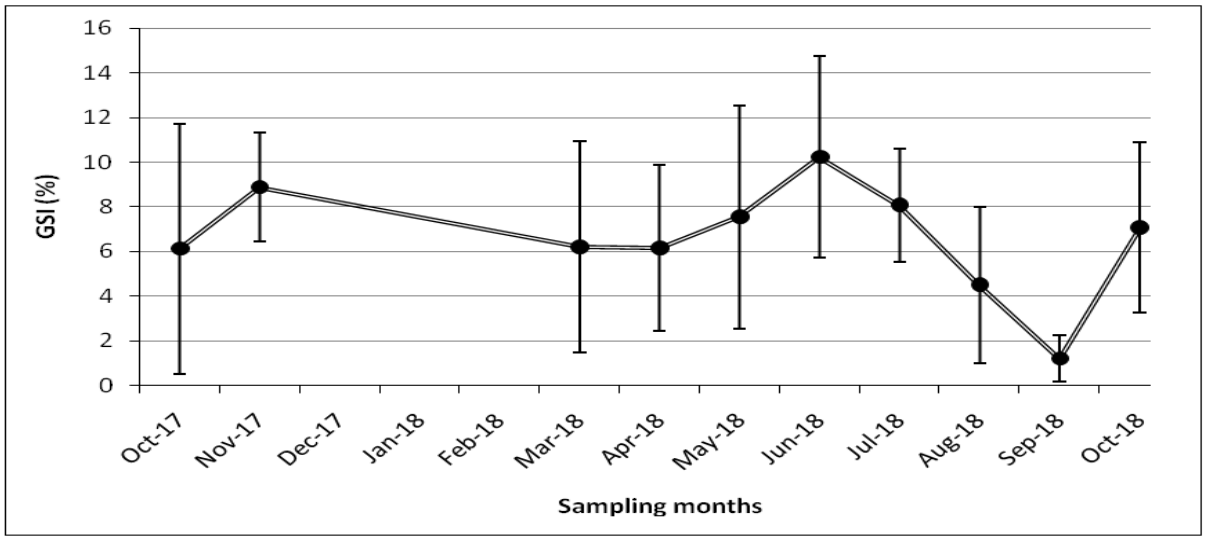


Fig. 12. The GSI indexes of *Scylla olivacea* in different sampling months from Satkhira, Bangladesh.

The wide range like 20.8 to 140 mm CW was reported from Ibajay mangroves, Aklan, Philippines (Lebata *et al.*, 2007).

The size-class distribution showed that the most of the individuals (27%) from the study area belonged to 70-79mm ICW. The same predominant smaller size-class was reported by Sana (2017 unpublished data collected personally) from Koyra, Khulna, Bangladesh. However, in 2004 the most individuals were recorded in the size-class 81-90 mm ICW from Khulna region, another coastal area of Bangladesh (Ali *et al.*, 2004). Thus, it may be said that the population is under threat for over fishing. The

average crab size was recorded 82.43 ± 16.09 mm ICW that is smaller than those found in other such reports. The average size was recorded 134mm CW by Dumas *et al.* (2012) from Voh-Kone area of New Caledonia and 130 ± 16.09 mm CW by Nand *et al.* (2016) from Bua Mangrove forest of Fiji.

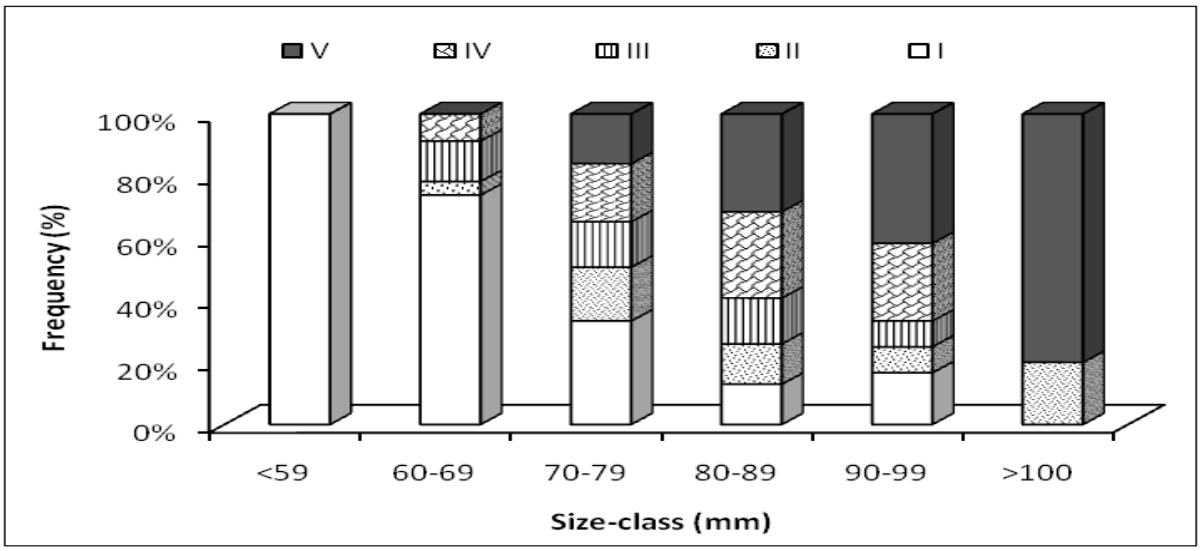


Fig. 13. The ovarian development stages regarding their size-class distribution collected from Satkhira, Bangladesh during October 2017 to October 2018. Mature crab reported mostly at the size of about 80mm ICW.

The female *S. olivacea* was dominated (M: F=1: 1.33) in the study area which is different from other studies except those of Kannathasan and Rajendran (2011) who recorded the sex ratio 1: 1.01 in the south-east coast of the Bay of Bengal of India. Others reported male dominancy like 1: 0.94 from Khulna Sundarbans area, Bangladesh (Ali *et al.*, 2004), 1: 0.89 from Mangroves Sarawak, Malaysia (Ikhwanuddin *et al.*, 2011) and 1:0.81 reported from Voh-Kone area of New Caledonia (Dumas *et al.*, 2012).

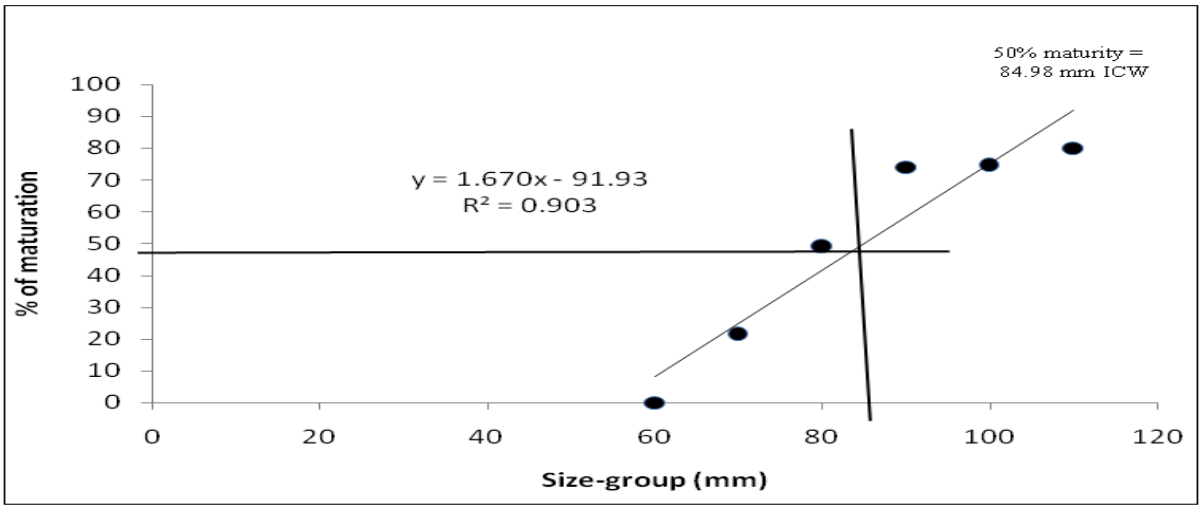


Fig. 14. The estimation of 50% maturation of *Scylla olivacea* from Satkhira, Bangladesh. The 50% maturity was 84.98 mm ICW.

In the present study, the 50% female attained ovarian maturity at the size of 84.98 mm ICW which is smaller than any other reports on *S. olivacea*. The late maturation like 95.5 mm ICW reported from Klong Ngao mangrove swamps, Ranong Province, Thailand (Jirapunpipat *et al.*, 2007) and 99.1 mm ICW reported from Pak Phanang mangrove, Thailand (Islam *et al.*, 2010). Another unpublished data (Sana,

2017; personal communication) mentioned that 50% female getting maturity at about 78 mm ICW from Sundarbans of Khulna, Bangladesh. Thus, early maturation is the clear indication of biological threats of the population and hence we can suggest that in the coastal area of Bangladesh, female mud crab should not harvest <85 mm ICW.

As we could not collect crabs during winter (January-February) due to Government fishing restriction, it is not possible to draw the exact peak breeding season of the species. However, in the present study, it is noticed that *S. olivacea* breed round the year but female maturity percentage and the their GSI index indicated that there might be two peak breeding seasons namely winter (October and November) and rainy season (June-July). Thus, the present restriction season, winter (January-February) by the Government of Bangladesh is questionable.

It is needed further study throughout the mangroves of Bangladesh and confirms the peak breeding season of the species.

Conclusion

The abundance of the mud crab species of Sundarbans mangrove forest is higher than other reports from other countries. However, the early maturity of the *S. olivacea* in the study area indicated that the population is under threat.

The present season restriction needs to be revised as they may have another peak breeding season. In addition, the size restriction may imply in the region to manage the mud crab population. If, we could manage properly this resource, it may provide continue livelihood to the local community.

Acknowledgement

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