EFFECTS OF WATER QUALITY ON THE GROWTH, MOLTING AND MORTALITY OF MUD CRAB, *Scylla serrata* Forskal (DECAPODA: PORTUNIDAE) FROM COX'S BAZAR

Dutta, J., M. Nasiruddin and M. A. Azadi

Department of Zoology, University of Chittagong, Chattogram-4331, Bangladesh

Abstract

The important decapod crustacean, the soft-shell crab, *Scylla serrata* is in great demand in different countries due to its taste next to shrimp and nutritional value, for which its farm is growing day by day as a source of income generation. This experiment was conducted for one year from January 2016 to December 2016 in Chaufaldandi, Cox's Bazar, Bangladesh to study the growth, molting and mortality rates of the soft shell crab and water quality of the crab culture pond. During the three experiments in a year, matured male crab showed highest growth performance (28.00±7.02g to 32.15±3.87g). Mature female crab showed maximum molting (60%) during the 3rd experimental period (September to December), while immature crab depicted the highest rate of molting (75%) in the 2nd (May-August) and 3rd experimental periods (September-December). Mortality rate was found highest in mature male during the 1st experimental period (60%). The female crab showed maximum mortality rate (40%) during the 1st experimental period. The survival rate was best for female and immature *S. serrata*. The growth of *S. serrata* showed significant positive relationships with water temperature, salinity, water pH, soil pH, and alkalinity during the all three experimental periods. The 2nd and 3rd experimental periods were found to be the most favorable time to produce soft-shell crab due to suitable weather conditions.

***Key words*:** Soft shell mud crab *Scylla serrata*; Growth; Molting; Mortality; Cox's Bazar.

INTRODUCTION

Soft-shell mud crab consumers have been increased around the world throughout the last few decades leading to a more profitable investment option (Aldon and Dagoon 1997). Due to its high demand in international markets, it is acknowledged as one of the most industrially valuable shellfish species in Bangladesh, ranking second to only shrimp and prawn in export earnings (Rahman *et al*. 2017). Thirteen marine and three freshwater crab species were identified from the coastal water of Khulna, Chattogram, Barisal, Satkhira, Bagerhat and Cox's Bazar of Bangladesh (Siddiqui and Zafar 2002). Among these species, the mud crab, *Scylla serrata* possesses a very important place due to its high export, nutritional and economic value (Jahan *et al*. 2016).

Among the available practices of crab culture, soft-shell mud crab culture is regarded as one of the most valuable forms of crab culture for commercial marketing of mud crab (Hungria *et al*. 2017). Mud crab shed their hard exoskeleton to grow and remain soft for a few hours until the reformation of the shell. Crab farmers collect the mud crab during this time as soft shell crab (Oesterling and Moore 1995). Soft shell crabs are in high demand in international markets due to their easy edibility in comparison to hard shell crabs and their high nutritional value (Chakraborty 2019). The commonly cultivated soft shell crabs are blue swimmer crab (*Portunus pelagicus*) and mud crab (*Scylla serrata*) (Niswar *et al*. 2018), while *Scylla sp.* has got special attention in Bangladesh (Jahan *et al*. 2016). Hence, the study of the growth and production techniques of mud crab, *S. serrata* becomes inevitable.

Scylla serrata has an exoskeleton like other Decapod crustaceans. Molting is an essential feature of crab to grow and reach maturation, especially in female to become soft shell for insemination (Alberts-Hubatsch *et al*. 2016). In juvenile stage mortality rate is high due to their vulnerability to predators as juvenile tends to molt more frequently than the adults (Fatihah *et al*. 2017).

Water quality parameters like temperature, salinity, water and soil pH and alkalinity affect the growth and mortality rate of *Scylla spp.* (Ruscoe *et al*. 2004, Pavasovic *et al*. 2004, Pedapoli and Ramudu 2014). Temperature can affect the growth rate, carapace width, and molting intervals in *S. serrata*, while salinity affects the mortality rate of the species along with other factors (Ruscoe *et al*. 2004). For crab farmers, it becomes tougher to achieve a consistent production rate as climate change can be a great challenge. Therefore, assessing the water quality can help in determining the most suitable time for commercial production, as well as minimizing the economic loss.

It is important to have some useful information on the production system of mud crab. So, the present investigation was undertaken in a mud crab culture pond at Chaufaldandi, Cox's Bazar to study the growth, molting, and mortality rates of *Scylla serrata* Forskal (Decapoda: Portunidae) with relation to water quality of the culture pond. This study may be useful to crab farmers optimizing their production.

MATERIAL AND METHODS

The study area is situated in Chaufaldandi, Cox's Bazaar Sadar Upazila (21°50'27"N latitude and 92°0'0"E longitude) Chattogram Division, Bangladesh (Fig. 1). The experiment was conducted in the SS Crab Farm, Chaufaldandi, Cox's Bazar from January 2016 to December 2016.

Fig. 1. Map showing the study area (square red mark) of mud crab culture at Chaufaldandi, Cox's Bazar.

The experimental year was divided into three periods, i.e. experimental period 1 (January 2016 to April 2016), experimental period 2 (May 2016 to August 2016), and experimental period 3 (September 2016 to December 2016). Female, male and immature mud crab samples were collected from the suppliers and collectors of crab from the different shrimp 'Ghers' of the coastal region of Cox's Bazar and Maheshkhali Channel. For each experimental period, a random sample (60-70 crabs) was taken from where 15 female, 15 male and 20 immature crabs were taken (n=50) for the experimental purpose. The male, female, and immature crabs were identified based on the shape of their abdomen as suggested by Keenan *et al*. (1998) (Fig. 2a, b). The experimental pond size was 170m in length, 70m in width, 5.0m slope and 1.0 to 1.5 meters in depth. The experimental mud crabs were kept in rectangular plastic cages (10×20 cm with a lid on the top), set on a floating platform (Fig. 3a). Before placing the crabs in the plastic cages, their weight was taken with the aid of a digital balance (Shinko, 300g/0.01g). The carapace length and width of the hard-shell crabs were measured using a slide caliper. The cages were numbered to keep proper record until the completion of the experiment. The temperature, salinity, and pH of water and soil were recorded using Celsius thermometer, Refractometer (Osaka, Japan), and digital pH meters (Hanna, Italy), respectively, and total alkalinity was determined by following the titrimetric method (APHA 2012). Water quality was measured regularly at 10 day interval.

Fig. 2a. Mud crab, *Scylla serrata* (dorsal view).

Fig. 2b. Mud crab, *Scylla serrata* (ventral view).

Fig. 3a. Plastic cages on the floating platform in the mud crab culture pond.

Fig. 3b. Molted crab after ecdysis inside the plastic cage.

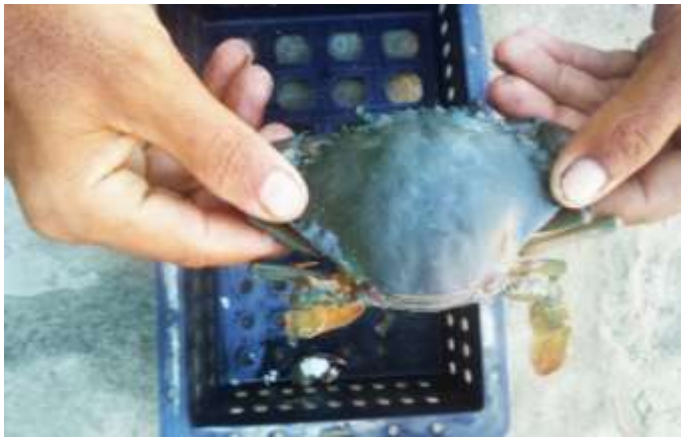
Fig. 3c. Soft shell mud crab just after molting.


Fig. 3d. Soft-shell mud crab just after harvesting.

The feeding of crab was started from the first day of stocking. The crabs were fed with sole fish about 10% of their body weight at one-day interval. Harvesting was done just after the crabs molted (Figs. 3b, c and d). The dead crab was checked and removed. Some crabs did not go through molting during the experimental period and were considered as non-molted after the end of the experimental period. Their carapace length, carapace width, and weight of the body of the male, female and immature crabs were taken at the beginning and at the end of the experiments. The water of the experimental pond was changed regularly at seven day interval to maintain a healthy environment in the water. Water exchange was done during the high tides. The brackish water of the Chaufaldandi canal was used for this water exchange.

Statistical analysis

The relationships between the growth of female, male and immature crabs with the water quality parameters, i.e. water temperature, salinity, water pH, soil pH, and alkalinity in the three experimental periods were calculated through Pearson's corelation test.

RESULTS AND DISCUSSION

Growth of Scylla serrata during three experimental periods

During the experimental period 1, mean growths in carapace length were 0.78±0.07cm for female, 0.90±0.21cm for male and 0.87±0.10cm for immature and the mean growths of carapace width were 0.80±0.08cm for female, 0.77±0.03 cm for male and 0.72±0.08cm for immature (Table 1).

The mean growths in weight of the mud crab were 21.66±1.94g for female, 28.00±7.02g for male and 19.91±2.25g for immature and the mean daily growth rates were 1.47±0.68g for female, 0.68±0.19g for male and 0.60±0.11g for immature (Table 2). During the experimental period 1, the mean growth of carapace length of the male and immature *S. serrata* showed higher than that of the mean growth of the female crab (Table 1). The female and male crabs showed almost the same growth in carapace width, but the immature crab showed lesser growth in carapace width (Table 1). In case of mean growth in weight, males showed higher growth rate than that of the female and immature *S. serrata* (Table 2).

During the experimental period 2, the mean growths in carapace length were 0.79±0.07cm for female, 0.80±0.04cm for male and 0.98±0.07cm for immature, and the mean growth of carapace width

were 0.87±0.07cm for female, 0.97±0.06cm for male and 1.00±0.05cm for immature (Table 1). The mean growths in weight of the mud crab were 18.49±2.71g for female, 31.05±2.63g for male and 28.57±2.24g for immature and the mean daily growth rates were 2.37±0.69g for female, 2.24±0.60g for male and 2.97±0.66g for immature (Table 2). During the experimental period 2, the immature *S. serrata* showed higher growth in carapace length than that of the male and female crabs while the female showed less growth in carapace width than that of the male and immature crabs. The male and immature *S. serrata* showed a higher growth in weight during this period in comparison to the female growth (Table 2).

Table 1. Data on the growth of carapace length (CL) and carapace width (CW) of female, male and immature *Scylla serrata* during the experimental periods.

Experiment periods	Sample	Initial CL (cm)	Final CL (cm)	Mean±SE growth in CL (cm)	Days taken for Increment	% of growth increment
Period 1	Female	6.48±0.15	7.26±0.20	0.78±0.07	39.2±14.52	12.00
	Male	5.47±0.20	6.37±0.26	0.90±0.21	44.33±9.02	16.56
	Immature	5.92±0.11	6.78±0.14	0.87±0.10	39.50±7.97	14.69
	Female	4.30±0.08	5.10±0.12	0.80±0.08	39.20±14.52	18.62
	Male	3.43±0.12	4.20±0.10	0.77±0.03	44.33±9.02	22.43
	Immature	3.80±0.08	4.52±0.12	0.72±0.08	39.50±7.97	18.87
Period 2	Female	7.09±0.07	7.87±0.07	0.79±0.07	16.57±6.98	11.12
	Male	6.30±0.11	7.10±0.10	0.80±0.04	20.00±5.79	12.74
	Immature	6.09±0.11	7.07±0.09	0.98±0.07	18.27±4.12	16.34
	Female	4.64±0.11	5.51±0.11	0.87±0.07	16.57±6.98	18.88
	Male	4.08±0.08	5.05±0.06	0.97±0.06	20.00±5.79	23.83
	Immature	3.91±0.11	4.91±0.10	1.00±0.05	18.27±4.12	26.14
Period 3	Female	6.83±0.18	7.80±0.28	0.97±0.15	38.89±7.55	0.14
	Male	6.50±0.10	7.40±0.11	0.90±0.05	48.25±14.02	13.87
	Immature	6.27±0.12	6.97±0.11	0.69±0.05	36.33±6.34	11.20
	Female	4.37±0.13	5.26±0.15	0.89±0.07	38.89±7.55	20.52
	Male	3.98±0.05	5.06±0.07	1.09±0.06	48.25±14.02	27.42
	Immature	3.83±0.08	4.81±0.10	0.97±0.05	36.33±6.34	25.43

During the experimental period 3, the mean growths in carapace length were 0.97±0.15cm for female, 0.90±0.05cm for male and 0.69±0.05cm for immature and the mean growths of carapace width were 0.89±0.07cm for female, 1.09±0.06cm for male and 0.97±0.05cm for immature (Table 1). The mean growths in weight of the mud crab were 27.10±4.29g for female, 32.15±3.87g for male and 21.23±1.27g for immature and the mean daily growth rates were 2.00±1.15g for female, 2.44±0.98g for male and 1.71±0.58g for immature (Table 2). During the experimental period 3, the female and male crabs showed higher growth in carapace length than that of the immature crabs, while the male and immature crabs showed higher growth in carapace width than that of the female crab (Table 1). The males showed a higher growth in average weight than that of the female and immature *S. serrata* (Table 2).

Molting and mortality of Scylla serrata

During the experimental period 1 (Table 3), the female had a higher rate of molting (33.33%) than that of the male (20.00%) and immature (30.00%) crabs. The male *S. serrata* showed lesser non-molting rate (20.00%) than that of the female (26.67%) and immature (25.00%) crabs. The highest mortality rate (60%) was

found in the male. The male crab took longer period for molting (44.33 days) than the female (39 days) and immature (39.50 days) *S. serrata.*

Table 2. Growth in weight of female, male and immature *Scylla serrata* during the experimental periods.

Experiment periods	Sample	Mean±SE initial weight (g)	Mean±SE final weight (g)	Mean±SE growth weight (g)	Duration±SE time (Days)	Mean±SE daily growth rate (g)
Period 1	Female n=5	80.79±4.63	102.45±5.85	21.66±1.94	40.00±14.01	1.47±0.68
	Male n=3	63.94±2.37	91.94±6.98	28.00±7.02	44.33±9.02	0.68±0.19
	Immature n=6	65.10±1.70	85.00±3.21	19.91±2.25	39.50±7.97	0.60±0.11
Period 2	Female n=7	92.95±3.02	111.44±4.00	18.49±2.71	17.00±6.84	2.37± 0.69
	Male n=6	81.02±3.97	112.06±4.66	31.05±2.63	20.00±5.79	2.24±0.60
	Immature n=15	70.14±3.89	98.71±4.16	28.57±2.24	18.40± 4.09	2.97± 0.66
Period 3	Female n=9	84.65±6.47	111.75±9.14	27.10±4.29	38.89±7.55	2.00±1.15
	Male n=8	85.96±4.00	118.11±6.08	32.15±3.87	49.37±13.50	2.44 ±0.98
	Immature n=15	70.08±2.63	91.32±2.50	21.23±1.27	36.33±6.34	1.71±0.58

During the experimental period 2 (Table 3), the immature *S. serrata* showed the highest rate of molting (75.00%) than that of the male (40.00%) and female (46.67%), while the male and female *S. serrata* showed the same rate of non-molting (13.33%). The male *S. serrata* showed high mortality rate (46.67%) and needed longer period (20 days) for molting. During the experimental period 3 (Table 3), the immature *S. serrata* showed higher rate of molting (75%) than that of the female (60.00%) and male (53.33%). The males showed the highest rate of non-molting (20%) followed by the female (6.67%). The female showed the highest rate of mortality (33.33%) than that of the male (26.67%) and immature (25.00%). The males needed longer period (48.25) for molting than that of the female (38.89 days) and immature (36.33 days) crabs. From the study it is observed that the experimental periods 2 and 3 were the better periods for the molting of the crabs, whereas non-molting and mortality mostly occurred during the experimental period 1. Of the crabs, males took longer days to molt than the female and immature crabs in all the three experimental periods.

Table 3. Percentage of molting, non-molting, mortality and survival rate and average days taken for the molting of *Scylla serrata* during the three experimental periods.

Sample	Experimental period 1				Experimental period 2				Experimental period 3			
	Molted (%)	Non-molted (%)	Mortality/ Survival rate (%)	Average days for molting	Molted (%)	Non-molted (%)	Mortality/ Survival rate (%)	Average days for molting	Molted (%)	Non-molted (%)	Mortality/ Survival rate (%)	Average days for molting
Female	33.33	26.67	40.00/ 60.00	39.00	46.67	13.33	33.33/ 66.66	16.57	60.00	6.67	33.33/ 66.66	38.89
Male	20.00	20.00	60.00/ 40.00	44.33	40.00	13.33	46.67/ 53.33	20.00	53.33	20.00	26.67/ 73.33	48.25
Immature	30.00	25.00	45.00/ 55.00	39.50	75.00	5.00	20.00/ 80.00	18.27	75.00	0.00	25.00/ 75.00	36.33

Quality of the pond water during the experimental periods

During the experimental period 1 (Table 4), water temperature ranged from 20.5 to 32.0°C with a mean of 26.5±0.97°C, salinity from 25 to 34ppt with a mean of 28.92±0.72ppt, water pH from 7.2 to 8.1

with a mean of 7.74±0.08, soil pH from 4.1 to 5.5 with a mean of 4.90±0.98 and alkalinity from 114 to 133mg/l with a mean of 125.25±1.56mg/l. During the experimental period 2 (Table 4), water temperature from 23.0 to 32.0°C with a mean of 27.25±0.78°C, salinity from 8 to 27ppt with a mean of 15.25±1.97ppt, water pH from 5.1 to 7.3 with a mean of 6.21±0.22, soil pH from 5.8 to 6.7 with a mean of 6.10±0.10 and alkalinity from 50 to 127 mg/l with a mean of 82.08±7.52mg/l. During the experimental period 3 (Table 4), water temperature from 19.0 to 32.0°C with a mean of 24.75±1.28°C, salinity from 12 to 27ppt with a mean of 20.67±1.67ppt, water pH from 6.3 to 7.2 with a mean of 6.68±0.11, soil pH from 4.0 to 5.8 with a mean of 4.57±0.19, and alkalinity from 77 to 125 mg/l with a mean of 106.25±4.36mg/l.

Relationship between growth and water quality

During the experimental period 1, the growth of *S. serrata* showed significant relationship with water temperature (r=0.950, P<0.01), water pH (r=0.874, P<0.05), soil pH (r=0.992, P<0.001) and alkalinity (r=0.874, P<0.05). During the experimental period 2, the growth of *S. serrata* showed significant relationship with water temperature (r=0.989, P<0.001), water pH (r=0.865, P<0.05), soil pH (r=0.867, P<0.05) and alkalinity (r=0.982, P<0.001). During the experimental period 3, the growth of *S. serrata* showed significant relationship with water temperature (r=0.973, P<0.01), salinity (r=0.965, P< 0.01), water pH(r=0.889, P<0.05), soil pH (r=0.887, P<0.05) and alkalinity (r=0.843, P<0.05).

Table 4. Monthly mean±SE values of water quality parameters of the experimental pond during the experimental periods.

	Month	Water Temp. (°C)		Salinity (ppt)		Water pH		Soil pH		Alkalinty (mg/l)	
		Monthly mean	Mean of four months	Monthly mean	Mean of four months	Monthly mean	Mean of four months	Monthly mean	Mean of four months	Monthly Mean	Mean of four months
Exp. pd.-1	Jan 16	22±0.76		26±0.58		7.5±0.18		4.5±0.21		120±3.21	
	Feb.16	26±1.04	26.50	28±0.58	28.92	7.8±0.09	7.74	4.9±0.05	4.90	130±2.52	125.25
	Mar 16	30±1.15	±0.97	32±1.20	±0.72	8.0±0.03	±0.08	5.0±0.10	±0.98	125±1.53	±1.56
	Apr 16	28±0.28		30±0.58		7.8±0.21		5.2±0.15		126±3.06	
Exp. pd.-2	May 16	26±1.32		25±1.0		6.7±0.12		5.7±0.15		120±4.04	
	Jun 16	28±1.04	27.25	12±3.06	15.25	5.6±0.26	6.21	6.2±0.10	6.10	80±5.78	82.08
	Jul 16	25±1.32	±0.78	15±1.53	±1.97	5.5±0.20	±0.22	6.5±0.12	±0.10	60±10.00	±7.52
	Aug 16	30±1.15		9±0.58		7.0±0.15		6.0±0.05		70±6.00	
Exp. pd.-3	Sep 16	31±0.57		13±1.0		7.2±0.03		5.6±0.12		95±9.64	
	Oct 16	25±1.52	24.75	20±1.76	20.67	6.4±0.10	6.68	4.5±0.15	4.57	100±7.64	106.25
	Nov 16	23±0.58	±1.28	25±1.15	±1.67	6.8±0.21	±0.11	4.1±0.03	±0.19	110±8.67	±4.36
	Dec 16	20±0.76		26±0.58		6.4±0.10		4.1±0.03		120±2.89	
Mean±SE		**26.17 ±0.98**		**21.75 ±2.22**		**6.89 ±0.24**		**5.19 ±0.23**		**104.67 ±6.83**	

Growth of Scylla serrata

The growth rates of female, male and immature *S. serrata* were recorded as 21.66±1.94g, 28.00±7.02g and 19.91±2.25g, respectively during the experimental period 1, where the males showed higher growth. Molting was found to be higher in the female (33.33%) than that of the male (20.00%) and immature (30%) crabs. The highest mortality rate was recorded for the male (60%), followed by the immature (45%) and female (40%). In the experimental period 2, the growth rate of male was also found

to be higher (31.05±2.63g) than that of the female (18.49±2.71g) and immature (28.57±2.24g) crabs. Here, molting was higher in the immature crab (75%) than that of the mature female (46.67%) and male (40.00%) crabs. The male and immature crabs showed a satisfactory growth during this period than the female crabs. Mortality rate was highest in the male (46.67%) followed by the female (33.33%) and immature (20%) crabs. Here, molting rate was highest in the immature crab (75%), which would be beneficial for crab farmers for getting better quality soft shell product. In the experimental period 3, the male crab also showed highest growth rate (32.15±3.87 g) than the growth of the female (27.10±4.29 g) and immature (21.23±1.27 g) crabs. Like the experiment 2, the immature crab showed highest molting rate (75%) than that of the female (60%) and male (53.33%) crabs. Here, the highest mortality rate was seen in the female (33.33%) followed by the male (26.67%) and the immature (25.00%) crabs.

The mean daily growth rates of the female, male and immature crabs in the experimental period 1 were 1.47±0.68g, 0.68±0.19g and 0.60±0.11g, respectively, while in the experimental period 2, the mean daily growth rates were 2.37±0.69g for female, 2.24±0.60g for male and 2.97±0.66g for immature crabs, and subsequently in the experimental period 3 the mean daily growth rates were 2.00±1.15g, 2.44±0.98g and 1.71±0.58g for female, male and immature crabs, respectively. The highest mean daily growth rate 2.97±0.66g was recorded for the immature crab in the experimental period 2 and lowest mean daily growth rate 0.60±0.1g was also for the immature crab in the experimental period 1. Samarasinghe *et al.* (1992) recorded 2.17g daily growth of *S. serrata* in a pond of Sri Lanka. David (2009) recorded a growth rate of 1.25 g/day of the mud crab *S. serrata* in the north coast, Kenya. Yulianto *et al*. (2019) recorded absolute growth of *S. serrata* between 0.68 and 1.58 g per day after the culture period in Indonesia. Uddin (2004) recorded the daily mean growth rate of mud crab, *S. serrata* as 1.18 and 1.37 g/day for two stations in Satkhira, Sundarban. The present findings on the daily average growth of crab showed similarities with the findings of the above-mentioned authors.

Water quality

Temperature is considered as an important abiotic factor that affects survival, growth and molting (Aslamyah and Fujaya 2014). During the study period, water temperature varied from 19°C to 32°C with a mean of 26.17±0.98°C in the experimental pond, with the highest in March, August and September (32°C) and the lowest in December (19°C). Hubatsch *et al*. (2015) reported that mangrove crabs, *S. serrata* lived and grew well at temperature 23-32^{0}C, thus agreeing with the present findings. According to Hamasaki (2003) optimum temperature for larval rearing and molting of *S. serrata* was 29ºC. Results of other studies showed that the optimal growth for *S. serrata* was 30°C, with good growth from 26 - 32°C (Aslamyah and Fujaya 2010), and 25-30°C (Shelly and Lovatelli 2011, Herlinah and Septiningsih 2016), which showed relevancy with the present findings. Hence, the temperature fluctuation range of the present study was found to be suitable for the growth of *S. serrata*.

Salinity directly affects the growth and molting of shell fish (Ikhwanuddin *et al*. 2012). In the present study, salinity varied from 8 to 34 ppt with the highest in March (34ppt) and lowest in June and August (8ppt). Rainfall was found to be directly related for decreasing the salinity level in the experimental periods 2 and 3. Mahmood (1977) also opined similar view. The optimal salinity for survival of *S. serrata* larva as obtained by Baylon *et al.* (2001) was 32 ppt. Sitaba *et al.* (2017) opined

that mangrove crabs *S. serrata* live and grow in salinity ranges between 10-30 ppt. Optimal growth of *S. serrata* was recorded in the salinity range of 15-30‰ (Aslamyah and Fujaya 2010), 10-25‰ (Shelley and Lovatelli 2011), 15-25‰ (Setiawan and Triyanto 2012), 29-33‰ (Herlinah and Septiningsih 2016), 15-32‰ (Yulianto *et al.*, 2019) and 10-20 ppt (Sushanty *et al*. 2019; Suyano, 2021) in the different experiments by different authors. Furthermore, Pedapoli and Ramudu (2014) reported a daily growth rate of 2.3 g/day at salinity 10 ppt and 0.97-1.25 g/day at 29-30 ppt. Daily growth rate for mangrove crabs obtained by Hastui *et al*. (2016) was 1% at salinity 25ppt and 0.4% at 15 ppt. In the present study, salinity varied from 8-34 ppt with a mean of 21.75±2.22ppt which was found to be suitable for the growth of *S. serrata*, and bearing close similarities with the findings of the above-mentioned authors.

The water pH ranged from 5.1 to 8.1 with a mean of 6.89±0.24. Highest pH 8.1 was observed in April and lowest pH 5.1 was in June and July. Almost similar acidic to alkaline pH range (6.2 to 8.52) was also observed by Obayed (1998) in the Khulna region. However, only alkaline range of pH 7.5-8.5 (Shelley and Lovatelli 2011), 7.1-8.5 (Herlinah and Septiningsih 2016) and 7.0-8.0 (Yulianto *et al*. 2019) were recorded by some researchers in the culture media of *S. serrata* in different regions of the world. The soil pH ranged from 4.1 to 6.7 with a mean of 5.19±0.23. Hossain (2007) also found the soil pH value <7.0 in a crab culture area of the mangrove swamp of Chakaria, Sundarban. The soil pH was found to be acidic in the present study area for *Scylla serrata.*

In this study, the range of alkalinity in the culture pond of *Scylla serrata* was found in between 50 and 133 mg/l with a mean of 104.67±6.83mg/l. Chakraborty (2019) recorded water alkalinity ranging from 127.48±7.14 to 136.08±8.44mg/l in the three crab culture earthen ponds in the South west region of Bangladesh which is a little bit higher than the present study. However, Hossain (2007) recorded the soil alkalinity values of 41.10 ppm and 69.70 ppm in the two experimental stations of the mangrove swamp forest of Chakaria, Sundarban, Bangladesh, while Zafar and Hasan (2005) recorded the values of soil alkalinity from 49.0 to 52.5 ppm at Poshur River mangrove fringe, Sundarban.

Based on the findings of the present study, the experimental periods 2 and 3 were found to be the favorable time for survival and growth of the mud crab *S. serrata* at the water temperature range of 19-32°C, salinity 8-34ppt, water pH 5.1-8.1, soil pH 4.1-6.7 and alkalinity 50-133mg/l. The results thus obtained for water physico-chemical parameters, such as the temperature, salinity, water and soil pH and alkalinity provided suitable conditions for the growth and molting of the mud crab *S. serrata*. Further studies are needed with more water quality parameters related to the growth, survival and molting of the mud crab (*Scylla serrata*) for getting more information to increase the mud crab production.

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