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Research Article

Nursery Rearing of Orange Mud Crab, *Scylla olivacea* (Herbst, 1896): Optimizing Pond Habitat and Stocking Density

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ABSTRACT

Orange mud crab, a species of the genus *Scylla* is a seafood product having a high demand for local and international trade. Traders supply live crab regularly from the wild to the domestic and foreign markets however, its commercial seed production has not been started yet. Knowledge production from different nursery rearing strategies is essential for successful commercial seed production of orange mud crab. This study aimed to optimize the stocking densities and pond habitats for better survival, intactness and growth during the nursery management of orange mud crab juveniles. Here, the first experiment (E1) was designed with three treatments depending on nursery habitats i.e., T1 (nursery in pond bottom without shelter), T2 (nursery in hapa), and T3 (nursery in pond bottom with shelters). In contrast, the second experiment (E2) was designed with stocking densities such as T1 (30 crablet.m^{-2}), T2 (50 crablet.m^{-2}), and T3 (70 crablet.m^{-2}). Water quality was monitored regularly and we found all water quality parameters (e.g., salinity, temperature, pH, dissolved oxygen, alkalinity, and total ammonia) within the desirable range for farming of *S. olivacea*. The observed crab growth was higher in T3 of E1 and in T1 of E2. Similarly, the crab survival (64.0±5.0 %) and intactness (82.0±5.0 %) were significantly ($p<0.05$) higher in T3 of E1 than T1 and T2. Besides, the survival (68±4.0 %) and intactness (85±6.0 %) in T1 of E2 were significantly ($p<0.05$) higher than T2 and T3. In summary, keeping crabs on pond bottom with sufficient shelters in low stocking density showed better survival and intactness for *S. olivacea*. The findings of this study will be a cornerstone in rearing of juvenile orange mud crab at coastal crab hatcheries and nurseries for supplying inputs to grow out crab farms in Bangladesh.

Introduction

Orange mud crab (*Scylla olivacea*) is one of the most popular and expensive seafood items for the Southeast Asians (Viswanathan and Raffi, 2015). This single aquaculture species contributes remarkably to the world's seafood production (FAO, 2020). A notable contribution of orange mud crab in foreign exchange earnings and livelihood opportunities has turned the sector as an independent industry in Bangladesh (Shamsuzzaman et al., 2020). In recent years, developments of soft-shell crab farming strategies have opened up a new field in Bangladesh's orange mud crab aquaculture along with the fattening of hard-shell crabs (Rahman et al., 2020a; Islam et al., 2021). In the South-east and South-west coastal areas, there are a few commercial soft-shell crab shedding farms which are struggling to run their business due to lack of adequate supply of crablets (Lahiri et al., 2021).

Nowadays, both hard-shell and soft-shell fattening has become popular in coastal farms simultaneously. However, orange orange mud crab aquaculture still is not well developed in Bangladesh despite its potential contribution to the national economy and improvement of livelihoods (Islam et al., 2021; Lahiri et al., 2021). Crab industry has been continuing the conventional crab farming practices with the wild stock in an unsustainable way (Bhuiyan et al., 2021). Apart from aquaculture, the main challenging factor is the lack of technical knowledge of crab growers to combat against the existing limiting factors that constraint orange mud crab farming in Bangladesh (Rahman et al., 2020b). Furthermore, as orange mud crabs are a valuable item in many nations' small-scale coastal fisheries in tropical and sub-tropical Asia, there has been a consistent trend of increasing the exploitation rate in the past (Angell,

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1992; Keenan, 1999). Orange mud crabs are in high demand as a luxury food item in the international market (Azra and Ikhwanuddin, 2016, Karniati et al., 2021), and their popularity is rapidly growing as an alternative species for aquaculture (Abol-Munafi and Azra, 2018), as the coastal, brackishwater, and marine shrimp aquaculture industries are negatively affected by disease outbreaks and environmental degradations (Holme et al., 2006).

Orange mud crabs live in brackishwater farms, tide-fed shallow lagoons, estuaries, and mangrove swamps in Bangladesh (Shelley, 2008). Currently, orange mud crab farming relies only on natural seed stock, with the lack of hatchery-reared seed being one of the most significant barriers to development (Ali et al., 2020). In order to promote the growth of the orange mud crab aquaculture business, effective hatching technique must be developed (Ikhwanuddin et al., 2015; Gunarto et al., 2016).

Larval rearing and nursery rearing techniques, disease outbreak and nutritional composition are the major areas of research which support the commercial production of marine finfish and crustacean larvae (Sorgeloos and Leger, 1992; Rodriguez et al., 2001; Ye et al., 2011). Thus, developing nursery rearing strategies for orange mud crabs is very essential to bridge the gap between hatchery and farm grows out (Syafaat et al., 2021). In addition, optimum stocking density is also a key factor for the survival and growth of orange mud crab (Van et al., 2021). The appropriate nursery techniques should be tailored for *S. olivacea* in terms of specific environmental requirements such as the modification of pond atmosphere and nursery management for local crab farm fellows. Considering stated facts, this study aimed to develop a suitable nursery strategy by providing comfortable shelter to juvenile crabs in a pond and optimizing stocking density for maximizing survival, growth, and quality of *S. olivacea* seed.

Materials and Methods

Animal Ethics

The authors were aware of animal ethics clearance from the concerned authorities. However, the protocol of the experiment was approved by Bangladesh Fisheries Research Institute (BFRI) and the research was conducted by considering the guidelines of the 'Animal Welfare Act 2019' approved by the National Parliament of Bangladesh.

Study area and animals

Standardizing the nature of crab shelters and optimizing the stocking density in the earthen pond, the nursery management of mud crab juveniles were done in the brackishwater ponds for 30 days. This study was conducted at Bangladesh Fisheries Research Institute (BFRI), Brackishwater Station, Paikgacha, Khulna-9280, Bangladesh. The experimental organisms were the juveniles of orange mud crab picked from the crablet stage of their life cycle. *S. olivacea* juveniles (0.3±0.1 g) were collected from the crab hatchery of Brackishwater Station of BFRI.

Experimental design

The study was designed with two experiments with three different treatments and each of which was replicated thrice to standardize the pond habitat and to optimize stocking density for the nursery management of crablet. In experiment 1 (E1), the study was performed for the evaluation of suitable pond habitat with different juvenile crab shelters in the nursery rearing. The first treatment (T1) was executed in the pond bottom without shelter. In contrast, second treatment (T2) of nursery rearing for crablets were implemented with 40 micro-meshed hapa nets and the size of each hapa was 1×1×1.5 m^3. Besides, different shelters such as nylon nets and 30 cm long plastic pipes were given at the nursery pond bottom in the third treatment (T3). Stocking density of 50 crablet.m^{-2} was maintained for all the treatments under this experiment. In experiment 2 (E2), the entire research was done for optimizing the stocking density of crablets in the nursery pond. The first treatment (T1) was implemented with 30 crablet.m^{-2} in the pond. In the second treatment (T2), the stocking density was maintained at the rate of 50 crablet.m^{-2}. In addition, for third treatment (T3) crablet were stocked at a density of 70 crablet.m^{-2} in the brackishwater earthen ponds. Hanging nets, shrinking nets and pieces of plastic pipes were used as a shelter in all the treatments of experiment 2.

Pond preparation

The brackishwater earthen ponds of 0.01 hectare capacity were selected for this study. The clay and organic substances were removed from the pond bottom after draining out the water. Agricultural lime ($CaCO_3$) at the rate of 250 kg.ha^{-1} was applied in the pond. Afterwards, the pond was sun dried for five days and filled with tidal water. Thereafter, Triple Super Phosphate (TSP) at the rate of 25 kg.ha^{-1} and Urea at the rate of 20 kg.ha^{-1} were applied about 7 days before stocking orange mud crab juvenile.

Feeding

Trash fish like small tilapia was chopped into pieces and used as a feed for the crablets in the nursery ponds at the rate of 10 % body weight. Feeding was administered twice daily in the morning (07:00 am) and evening (07:00 pm).

Monitoring and sampling

During the experiment, crablets were checked regularly in each nursery pond. The orange mud crab juveniles were also monitored randomly from the open pond area by keeping up the crablets against strong sun light or electric light. The intactness and gained weight data were kept in weekly basis. Survival rate of crablet was calculated with formula as mentioned by Khan et al. (2017):

$S = N_t / N_o \times 100$

Where S = Survival rate (%), N_o = number of crablet stocked, N_t = number of crabs harvested

Moreover, the monitoring of salinity, temperature, pH, dissolved oxygen (DO), alkalinity and total ammonia nitrogen (TAN) concentration were done daily at early in the morning (at 07:00 am) by following the standard procedures of AOAC (1990) and APHA (1992).

Statistical analysis

The collected data on crablet viz. weight increment, survival, intactness and water quality parameters were compiled, categorized, computed and tabulated using a computer program, Microsoft Office Professional Plus 2016. Furthermore, some statistical tests were executed by using another computer program, Statistical Product and Service Solutions (SPSS) ver. 25. One-way ANOVA and Duncan's Multiple Range Test (Duncan, 1955) were employed to observe the differences in growth parameters, survival rates and intactness of crablets among the treatments. The analyzed data are presented in tabular and graphical forms to describe them elaborately for extracting the information accurately.

Results

Water quality parameters

The recorded water quality parameters viz. salinity, temperature, pH, dissolved oxygen concentration, alkalinity and total ammonia concentration of water during the nursery period in this study are presented in Table 1. Interestingly, all the physico-chemical parameters of the experimental ponds were within the suitable ranges for brackish water nursery management of juvenile orange mud crab. Salinity is considered as one of the most fundamental factors that affects the survival and development of orange mud crab.

The salinity level in different experimental ponds varied between 10 ppt and 18 ppt. Temperature is one of the key physical regulators that affects the growth, energy flow and biological effects of marine organisms specially crustaceans like orange mud crab. There were very little temperature fluctuations in experimental ponds. The temperature of the experimental ponds ranged between 26 ºC and 32 ºC. The recorded pH of this study ranged from 7.56 to 8.95. Dissolved oxygen concentration, alkalinity and total ammonia levels of the experimental ponds ranged between 5.10-7.85, 86-164 and 0-1.1 ppm, respectively.

Table 1. Ranges of different water quality parameters during the study period

Variables	Treatments						Optimum level †Shelley and Lovatelli (2011)
	T1		T2		T3		
	E 1	E 2	E 1	E 2	E 1	E 2	
Salinity (ppt)	17.0↑	16.0↑	17.0↑	17.0↑	18.0↑	16.0↑	10–25
	11.0↓	11.0↓	10.0↓	11.0↓	11.0↓	11.0↓	
Temperature (ºC)	31.0↑	30.4↑	30.6↑	31.5↑	32.0↑	31.5↑	25–35
	26.0↓	27.5↓	26.5↓	26.7↓	26.5↓	27.0↓	
Water pH	8.27↑	8.68↑	8.65↑	8.66↑	8.69↑	8.95↑	7.5-9.0
	7.65↓	7.76↓	7.56↓	7.75↓	7.66↓	7.68↓	
DO (ppm)	7.25↑	6.80↑	7.85↑	7.67↑	7.63↑	7.25↑	>5
	5.35↓	5.10↓	5.48↓	5.25↓	5.12↓	5.14↓	
Alkalinity (ppm)	146↑	138↑	135↑	164↑	126↑	156↑	>80
	86↓	98↓	96↓	102↓	96↓	98↓	
TAN (ppm)	0.8↑	1.1↑	0.5↑	0.9↑	0.7↑	0.6↑	<3
	0.0↓	0.1↓	0.0↓	0.1↓	0.0↓	0.1↓	

E1 = Experiment 1; E2 = Experiment 2; ↑ = Maximum; ↓ = Minimum; †Source

Growth performance

Growth increment of crablet under different stocking density and nursery habitat were presented in Table 2. The average gained weight was quite slow in the first 14 days after stocking for both E1 and E2. Thereafter, the growth appeared speedy in the last two weeks. The average initial weight of crablets in different treatments was 0.3±0.10 g for both E1 and E2. During first 14 days of rearing, the juvenile crabs raised up to 3.5±0.26 g, 2.9±0.80 g, 5.3±1.10 g and 8.1±0.33 g, 5.8±1.50 g, 4.8±1.20 g in T1, T2 and T3 for E1 and E2, respectively. On 30th day, the final average weight of E1 was recorded as 20.6±4.10 g, 16.4±4.00 g and 24.2±6.25 g in T1, T2 and T3, respectively. In general, the growth values of T1 and T3 were found higher than the growth value of T2 in E1. Here, T3 performed significantly (p<0.05) better in growth than two other treatments until the 14th day of rearing. Also, the average growth values of T3 were observed higher than the values of T1 and T2 in last two weeks of nursery rearing. In experiment 2, the recorded average final weights were 29.8±3.40 g, 24.3±4.10 g and 18.9±4.25 g for T1, T2 and T3, respectively. During four weeks, the growths of T1 showed higher than two other treatments (T2 and T3) in the nursery pond. Moreover, T1 performed significantly (p<0.05) better than T2 and T3 until the 14th day of rearing, by following the pattern of experiment 1. Besides, T1 and T2 showed better growth than the T3 in last two weeks of rearing juvenile orange mud crab in the nursery. Overall, the juvenile orange mud crab growths were higher in T3 and T1 of E1 and E2, respectively, during the entire nursing period.

Table 2. Weekly weight gain of juvenile crabs in E1 and E2

Days of rearing	Weight gain (g)					
	E1			E2		
	T1	T2	T3	T1	T2	T3
1	0.3±0.10	0.3±0.10	0.3±0.10	0.3±0.10	0.3±0.10	0.3±0.10
7	1.0±0.12^{b}	0.7±0.11^{c}	1.8±0.14^{a}	2.6±0.15^{a}	1.9±0.12^{b}	1.5±0.10^{c}
14	3.5±0.26^{b}	2.9±0.80^{b}	5.3±1.10^{a}	8.1±0.33^{a}	5.8±1.50^{b}	4.8±1.20^{b}
21	11.9±2.10^{ab}	9.8±1.80^{b}	14.9±2.50^{a}	18.7±1.40^{a}	15.1±1.60^{ab}	11.8±2.60^{b}
30	20.6±4.10^{a}	16.4±4.00^{a}	24.2±6.25^{a}	29.8±3.40^{a}	24.3±4.10^{ab}	18.9±4.25^{b}

p<0.05; E1 = Experiment 1; E2 = Experiment 2

Survival and intactness

Survival and intactness of crablet in E1 and E2 were presented in Table 3. Survival (64.0±5.0 %) and intactness (82.0±5.0 %) in T3 of E1 were significantly (p<0.05) higher than T1 and T2. Whereas, for the E2, the survival (68±4.0 %) and intactness (85±6.0 %) of T1 were significantly higher than T2 and T3. Result of E1 focused density dependent survival and weight gain and intactness. However, result of E2 indicated that adequate shelter along with soil attachment is necessary for nursery to achieve better survival and intact crablets. On the other hand, better performance was obtained from the lowest density of stocking crablets.

Table 3. Survival and intactness of juvenile crabs in E1 and E2

Treatments	Survival (%)		Intactness (%)	
	E1	E2	E1	E2
T1	52.0±3.0^{b}	68±5.0^{a}	68.0±4.0^{b}	85±6.0^{a}
T2	42.0±6.0^{c}	58±4.0^{b}	54.0±9.0^{c}	68±5.0^{b}
T3	64.0±5.0^{a}	40±4.0^{c}	82.0±5.0^{a}	48±7.0^{c}

p<0.05; E1 = Experiment 1; E2 = Experiment 2

Discussions

Nursery, a concept which was coined as a shelter of juvenile that can contribute greater than other habitats used by juveniles of a particular species (Gaikwad et al., 2021). Even in the wild, it is important to maintain a high ecological quality of essential nursery habitat in coastal and estuarine areas in order to sustain marine populations and fisheries (Pape and Bonhommeau, 2015). Therefore, specific criteria for the habitat of orange mud crab nursery pond are required for a successful and sustainable farming of juveniles (Ye et al., 2011).

Optimum water quality parameters provide all necessary nutrients to grow phytoplankton, zooplankton and other arthropods to feed the cultured fish and shell-fish. Proper nutrition in the waterbody ensures high growth and low mortality indeed. Therefore, ideal water quality is very important for fish culture (Ojwala et al., 2018). Suitable and congenial water quality variables ensure higher growth rate, survivability and production by keeping a friendly culture environment (Deswati et al., in press). The temperature of water in this study varied within the range of 26-32 °C. The range of salinity levels in the study fluctuated between 10 ppt and 18 ppt. Hereafter, water pH and dissolved oxygen (DO) were recorded within a range of 7.58-8.95 and 5.10-7.85 ppm, respectively. Furthermore, alkalinity (86-164 ppm) and total ammonia (0-1.1 ppm) were observed during the experiments. In crab farming, all water quality parameters were found within the optimum range in accordance with Shelley and Lovatelli (2011).

In crab culture system, a negative effect of high stocking on crab production performance was discovered (Dai et al., 2020). Also, there are many benefits of artificial substrates were observed in farming of crustaceans (Da Silveira et al., 2022). Here, the final average weight of E1 was recorded as 20.6±4.1 g, 16.4±4.0 g and 24.2±6.25 g in T1, T2 and T3, respectively. In contrast, the revealed average final weights in E2 were recorded

29.8±3.4 g, 24.3±4.1 g and 18.9±4.25 g from T1, T2 and T3, respectively (Table 2). Thus, the lowest stocking density (30 crablet.m^{-2}) was revealed as an optimum limit for stocking in the nursery. For growth, third treatment and first treatment performed well in E1 and E2, respectively. However, the orange mud crab is mainly found wild, aggressive and cannibalistic in nature and has a tendency to escape through burrowing (Rahman et al., 2020a). In general, the survival rate of aquatic organisms mainly depends on the culture environment, stocking density and the nature of the cultured organism (Hastuti et al., 2020). In this study, survival (64.0±5.0 %) and intactness (82.0±5.0 %) in T3 of E1 were significantly ($p<0.05$) higher than T1 and T2. Whereas, for the E2, the survival (68±4.0 %) and intactness (85±6.0 %) of T1 were significantly higher than T2 and T3 (Table 2). Minimizing stress and fighting among the crab individuals, shelters play a remarkable role by providing refuge for the crabs (Shelley and Lotvatelli, 2011). In terms of survival rate of crab population, shelter gives a good result by reducing the mortality due to antagonistic effect between rival crabs (Triño et al., 1999).

Conclusion

Mud crab is a common shell-fish for coastal aquaculture on the south of Bangladesh. However, lower survival and intactness are the major threats to the commercial seed production of *S. olivacea*. Hence, optimizing the stocking density and nursery habitats for better growth of juvenile crabs, minimize mortality and improving the intactness during the nursery rearing of orange mud crab were the main goals of the study. The water quality parameters were within the acceptable limit throughout the study. The highest growth, survival and intactness were observed in T3 of E1. In contrast, E2 was displayed the best results in T1. To sum up, orange mud crab nursery with sufficient shelter on the pond bottom and the lowest stocking density (30 crablet.m^{-2}) brought a positive effect to enhance the growth, survival and intactness in farming of juvenile *S. olivacea*. This study will be a benchmark for juvenile crab nursing at coastal farms and also drops some clues for other crab species in domestication for artificial propagation on coming days.

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Competing interests

The authors have declared that no competing interests exist.

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