Nursing Management and Economics of Mud Crablets Produced in the Hatchery at Kolbari in Satkhira

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Declaration

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The results submitted in this thesis are entirely the candidate's own investigations and no part of the results has been accepted for any degree, nor is it being concurrently submitted for any degree.

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Dedicated to

My Beloved Parents

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ABSTRACT

The thesis work was aimed at understanding the present scenario of production and economics of crablets production at Kolbari, Satkhira. The investigation was conducted on three different crablets nursery through a structured questionnaire. The study was based on reconnaissance survey from July to December, 2017. The survey discovered that this crablets nursing business gives a very good economic benefit with a minimum investment at a short period of culture. The average total areas of pond were found as 36 decimal with average water depth 1-2m. Dyke condition of most of the pond was very good. Fertilizer mainly urea was used at the rate of 150g/decimal and TSP at the rate of 100g/decimal. $CaCO_3$ was used as lime at the rate of 1kg/decimal. The stocking density of crablets was found 1000 piece/decimal. Average growth performance was found 15.95 ± 1.21 g after 22 days nursing. For feeding the crablets, mainly blending tilapia 10kg/decimal was used. The average Salinity, Temperature, pH and DO were found at 16.49 ± 0.03 ppt, 26.01 ± 0.45 ^{0}C, 7.58 ± 0.04 and 7.36 ± 0.04 mg^{-1}, respectively. The average production was found 520.83 ± 46.92 piece/decimal. The average net return was estimated at TK 586 ± 61.98/decimal and the average rate of return on operating cost was estimated at 21.54% and the average benefit cost ratio was estimated at 0.82. So it can be assumed from the study that crablets nursing business can give a good economic benefit with a minimum investment at a short period of culture, and can be a potential and profitable business at the region where crab aquaculture is predominant. However, further coherent research is needed for generating data and suggestions regarding mud crab larvae production, nursing system, farming practices.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

CHAPTER ONE

INTRODUCTION

1.0. Introduction

1.1. Background of the study

The geographical position and climate condition have made Bangladesh one of the highly productive areas of the world for producing fishes. Bangladesh has achieved remarkable progress in the fisheries sector since its independence in 1971. The fisheries sector has been playing a very significant role, and deserves potential for future development in the agrarian economy of Bangladesh. The total fish production of Bangladesh was about 3.7 million MT (in FY2015-16) of which marine fisheries accounted for only about 16.3 per cent (share of artisanal fishing was 14 per cent and commercial fishing was 2.3 per cent) (Basu and Roy, 2018). This sector contributes 3.61 percent to our national GDP and around one-fourth (24.41 percent) to the agricultural GDP. More than 11 percent of total population of Bangladesh are engaged with this sector on full time and part time basis for their livelihoods. Last 10 years average growth performance of this sector is almost 5.43 percent (Annual Report 2016-17).

The coastal belt of Bangladesh endowed with diverse resources bears a significant scope in ensuring the security of food and livelihood of the coastal poor people. But this region is highly pruned to the effect of climate change. The effect of climate change is deteriorating food security and livelihood of coastal resources poor people. Fortunately, the perpetual sea-level rise and salinity intrusion is making the coastal waters of this area economically and environmentally feasible for coastal aquaculture. Among the edible shrimps, lobsters and crabs the large clawed mud crabs are considered as one of the important seafood items for aquaculture in southwest coastal region of Bangladesh due to their esteemed delicacy, medicinal value and demand for local and export trades (Ali *et al.*, 2004).

There are thirteen marine and three fresh water species of crabs reported in the coastal waters of Bangladesh covering the districts of Khulna, Chittagong, Barishal, Satkhira, Bagerhat and Cox's Bazar (Siddiqui and Zafar, 2002). Six important genera that are considered as food crabs are Scylla, Portunus, Charybdis, Matuta, Varuna and Sartorina (Shafi and Quddus, 1982). Mud crabs are less susceptible to disease and more resistant to adverse more environmental conditions and climate change effects due to which many of the small-scale shrimp farmers are transferring to mud crab farming.

After the disease outbreak in shrimp farming, Mud crabs, locally called as "*Habba kakra*", "*Silla kakra*" or "*Kankra*", have become candidate species for aquaculture because of their export potential. Mud crab of genus *scylla,* also known as green crab or mangrove crab constitute an important crop in the Asian Aquaculture. Four species of mud crabs like *Scylla serrata, S. olivacea, S. paramamosain* and *S. tranquibarica* are of great commercial importance out of which the former two occur abundantly in the coastal areas of Bangladesh. The mud crabs are widely distributed in the pacific and Indians oceans, and are available in brackish coastal waters and estuaries and have a great potential for aquaculture.

In Bangladesh, mud crab aquaculture, based primarily on capture and fattening of juvenile crabs from the wild, has been practiced for many years. In recent years, there has been increasing interest in mud crab farming due to growing markets and international demand (Hasanuzzaman *et al.*, 2014).

Live crab production is considered as a profitable and feasible business by most of the marketing operators. Due to religious myth on eating crabs, the mud crab (*Scylla* spp.) is not popular in Bangladesh even though they have commercial importance in the world market. It occupies the third position among the frozen foods exported from Bangladesh. Thus, mud crab being agricultural product, can be identified as a significant product in the economy of Bangladesh for its noteworthy contribution in augmenting the foreign exchanges earnings. There is an increasing demand for mud crab in Asia, Europe and America, which has been resulting in increased trend in mud crab production. Bangladesh started exporting crab in 1977 and the first consignment was worth $2,000 only. The crab exports increased over the years to 2,973 tons in 2008-09 Fiscal Year, 4,416 tons in 2011-12 FY and 8,520 tons in 2013-14 FY. During 2005-06, Bangladesh earned US$ 3,668,000 compared with 2006-07, when the total export value increased by 65%. The export of live mud crabs from Bangladesh has increased many folds in the last decade. The country earned $15.83 million from crab exports in 2012-13 FY. Crab exports fetched $22.91 million in 2013-14 FY. The country exported crabs worth $23.82 million in 2015-16, which was $7.2 million in 2010-11(Jahan and Islam, 2016).

The present culture system of mud crab mostly involves fattening of immature and/or underweight crab to produce market size hard shell crabs which are exported alive. The fattening operation includes stocking of the targeted crabs in brackish water ponds/*ghers* for a very short period of time with supplementary feeding. Different types of locally available trash fish are used as feed. Another culture system includes producing soft shell crabs which are exported as frozen food. The soft shell crabs are produced by keeping crabs individually in plastic boxes in brackish water ponds with supplementary feeding and harvesting just after molting when the exoskeleton is removed. Soft shell crab production is very new in Bangladesh and is being done in a very limited scale in Satkhira and Cox's Bazar region.

The mud crab fishery is absolutely based on wild catch mainly from the swamps of the Sundarbans and vast areas of the traditional shrimp *ghers* along the coastal region of Bangladesh (Chandra, 2012). Due to rapid expansion of mud crab fattening and increased numbers of mud crab farmers, a huge quantity of mud crab seeds are being caught from the wild. There is an unmet demand for mud crabs, and this has led to over-exploitation in many years. Thus mud crab farming is putting intense pressure on the wild stock for which declining in the natural stock size is of major concern. Present size of mud crab wild stock and yearly increment are unknown; this is why, we do not know whether the natural wild stock is over exploited or under exploited; discussion with the crab collectors and traders, however, reveals that they do not get as many crabs as before which is an indication of declining in the wild stock. Thus indiscriminate catching of mud crab from the wild is not sustainable and has a potential risk of damaging the wild population.

Like any other aquaculture species, hatchery produced seeds can only be the option for sustainable development of mud crab aquaculture. Hatchery production of mud crab has been done in a number of countries like India, Philippines, Vietnam, China, Japan and Australia (https://www.shrimpnews.com/FreeReportsFolder/CrabFolder/MudCrabFarmingInBangladesh.html). Considering the potentiality and sustainability of mud crab aquaculture, mud crab hatcheries should be developed in Bangladesh. As mud crab farming is becoming very popular in the coastal districts of Bangladesh owing to the good demand and better price of mud crab in the international market, the private sectors may succeed in mud crab seed production in hatcheries, and it will reduce pressure on the natural crab population as well as ensure regular and sustainable supply of crab seed for grow out, fattening and soft-shell farming for better production, better export and better income. Recently, a NGO has developed a mud crab hatchery where comprehensive efforts have given to produce crablets, and rear them in the nursery system. The present study was conducted with the following objectives:

1.2. Objectives of the study

- To understand the nursery system of mud crablets produced in the Nowabeki Gonomukhi Foundation crab hatchery.
- To asssess the economical indicators associated with the crablets production and nursing management.

CHAPTER TWO

LITERATURE REVIEW

2.0. Literature Review

2.1. Taxonomy

The taxonomy of the mud crabs has been clarified using allozyme electrophoresis, DNA sequencing and morphometrics to identify four Scylla species from crabs collected throughout their distribution from the Red Sea to the Indo-Pacific. The species are *S. serrata* (Forskal, 1775), *S. olivacea* (Herbst, 1796), *S. tranquebarica* (Fabricius, 1798), and *S. paramamosain* (Estampador, 1949) (Shelley and Lovatelli, 2011).

Classification of *Scylla* spp.:

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Crustacea

Class: Malacostraca

Order: Decapoda

Infraorder: Brachyura

Family: Portunidae

Genus: *Scylla*

Species: *S. serrata*

2.2. Ecology and distribution

Scylla species are widely found in the Indian Ocean, Red Sea, Pacific Ocean. It can associate with mangrove forests inundated with full salinity oceanic water for the greater part of the year. It can tolerate reduced salinity. *S. paramamosain* found in the South China Sea, Java Sea. It is an abundant species where it occurs. It can associate with various habitats including shallow coral rubble; shallow subtidal flats and estuarine ponds; mangrove forests. *S. olivacea* found in South China Sea, Indian Ocean, Pacific Ocean. It is moderately widespread, often associated with *S.*

tranquebarica. It can associated with mangrove forests and coastlines inundated with reduced salinity seawater during the wet season. *S. tranquebarica* found in the South China Sea, Pacific Ocean, Indian Ocean. It is a widespread species, often associated with *S. olivacea*. It can associated with mangrove forests and coastlines inundated with reduced salinity seawater for part of year (Davie and Mann, 1998).

2.3. Life cycle

While mud crab megalopae appear not to be selective among estuarine habitats (seagrass, mud or sand), crablets (juvenile mud crabs) strongly select for a seagrass habitat, indicating that living within seagrass beds likely increases their survival. The maturation of mud crabs is their apparently step-wise maturation process, where they pass through an apparent physiological maturation, before becoming functionally mature. In *S. serrata*, the first stage of maturation for a male occurs from carapace width 90–110 mm, while from carapace width 140–160 mm males develop their characteristic "large-claw" and mating scars on their sternum and front walking legs become apparent. In female mud crabs, the characteristic U shape of their abdominal flap, together with a well-developed fringe of setae around it, is a more obvious sign of maturation, together with their heavily pigmented abdomen and highly setose pleopods. Males guard mature females, cradling them prior to their moult. The male carries the female underneath him using three pairs of walking legs. The male can successfully mate and transfer spermatophores (packets of sperm) into the female's spermathecum once she has moulted and is soft shelled (Shelley and Lovatelli, 2011).

2.4. Food and feeding

Mud crab diet in the wild consists mainly of marine detritus, molluscs, crustaceans and fish. Mud crabs are capable of catching live fish and shrimps, seizing them with their chelae. Mud crabs have high apparent digestibility coefficient for cellulose, soybean and rice bran in formulated diets, together with their ability to readily consume starches, indicating that the marine detritus component of their diets in the wild may be more significant. Feeding on algae, decaying wood and bamboo sticks, mud crabs can probably best be described as omnivores (Shelley and Lovatelli, 2011).

2.5. Mud crab aquaculture

2.5.1. Crablets production (Hatchery phase)

2.5.1.1 Site selection

The hatchery is a compromise based on land availability, cost, existing infrastructure and proximity or logistical connections to grow-out areas. The basic attributes required for a mud crab hatchery site include an unpolluted source of marine seawater and freshwater; ability to discharge treated hatchery wastewater streams; a site with land suitable for construction of hatchery buildings; access to reasonable transport arrangements for staff and products. The more oceanic the source of marine water, the better, as this reflects the offshore water conditions under which mud crab eggs hatch naturally (Shelley and Lovatelli, 2011) .

2.5.1.2. Water parameter treatment

A range of water treatments can be used in mud crab hatcheries to minimize the risk of water-borne pathogens in water supplied to stock including filtration, ultraviolet (UV) sterilization, chemical treatment, ageing of water and ozone treatment. Often, more than one treatment method is used. Water treatment requirements can vary with local conditions and the use of the water. In areas prone to bacterial or other water-borne issues, the treatment system needs to achieve a high level of water remediation. In this case, filtration should be followed by another step that eliminates the microbiological community, such as chlorination/dechlorination, microbial conditioning by ageing or UV or ozone treatment. All water sources, both freshwater and seawater, entering a mud crab hatchery need to be filtered. Domestic freshwater supply should be carbon filtered to ensure that any chemicals (e.g. chlorine) used to treat the domestic supply are removed (Shelley and Lovatelli, 2011) .

2.5.1.3. Broodstock conditioning

The broodstock are typically held in a maturation tank for a period of several weeks or more. Under adequate conditions, the broodstock can be held communally at up to 1.5/m^2 and typically large (>10 m^3), shallow (80–100 cm deep) tanks are used. Broodstock need to be housed in facilities constructed light levels can be kept low, or existing facilities need to use shade cloth or other similar interventions to enable a low light regime to be established. Broodstock areas have some sort of fencing around them to ensure that valuable broodstock cannot walk out of the facility if they escape from the tanks. Maintenance of hygiene is very important to successful broodstock maturation; uneaten feed and waste material need to be regularly removed. Mud crab broodstock consume a large quantity of diets, so a high level of water renewal per day is required in order to maintain water quality conditions (Shelley and Lovatelli, 2011).

2.5.1.4. Larval rearing : water quality and feeding microalgae, rotifer, artemia

Water treatment for mud crab larval rearing varies with location and availability of filtration equipment. Where the water quality of incoming seawater available to hatcheries is suboptimal, treatment by chlorination can be used, followed either by chemical de-chlorination, or aeration for 2–3 days to remove residues. Other water treatment options for mud crab larval rearing water include ozone treatment (followed by carbon filtration), UV sterilization, microfiltration and microbial conditioning.

Microalgae regularly used in mud crab larval culture systems include *Tetraselmis* and *Nannochloropsis*. While crab larvae may consume microalgae, their nutritional value is relatively low compared with the rotifers or artemia that the larvae consume. However, eicosapentaetonic acid (EPA) (20:5n3) and docosahexaenoic acid (DHA) (22.6n3) have been shown to be essential fatty acids for mud crab larval development (Shelley and Lovatelli, 2011).

Among different culture systems, the density at which rotifers are recommended for early stage mud crab zoea (z1–z2) varies from 10 to 60 per millilitre. For larval culture of *S. paramamosain* in Viet Nam, most operators do not use rotifers, preferring to use umbrella stage artemia, while in China, feeding rotifers at 60 per millilitre is recommended for the same species and *S. serrata*.

Artemia is commonly used to feed them from z2 or z3 through the megalopa stage to settlement. They are provided to larvae at densities from 0.5 per milliltre to 15 per millilitre. In Viet Nam, umbrella stage artemia are used in place of rotifers for z1–z2 larvae. Larger larvae that have been hatched and grown for 5–7 days can be fed to advanced zoea (z5) and early megalopae, although newly hatched nauplii can also be used. Typically, feeding density of artemia is increased with increasing larval stage, e.g. 0.5 per millilitre at z2, increasing to 3.0 per millilitre at z5 to megalopa. Megalopae can also feed on adult-sized artemia (Shelley and Lovatelli, 2011).

2.5.2. Nursery system

2.5.2.1 Tanks, hapa nets, earthen ponds

In nursery tanks exposed to the elements, overheating of tank water can be an issue, especially in summer months, which can lead to high mortalities of crablets. To counter this, nursery tank systems are typically covered with an overhead awning or roof to filter out direct sunlight and also prevent rain entering the tanks. Rapid changes in salinity from heavy rain could also stress crablets and potentially lead to increased mortality rates, if uncontrolled.

Square or rectangular net cages (or Hapa nets), typically of 1–2 mm mesh opening, are set in earthen ponds, the base of the net buried into the bottom of the pond. Ponds should be used or designed so that a water depth of 80–120 cm of water can be maintained to support moderate water temperature fluctuations and steady plankton populations. Zooplankton populations should be established in the ponds to provide feed for the megalopae once they are stocked.

Ponds may be stocked with Gracilaria, netting, straw or other shelters to provide habitat for crablets. In China, mud is considered the best surface for megalopae to settle on to become crablets. As for net cage nursery culture of megalopae, mixed zooplankton population developed within the pond is the primary food source for the megalopae (Shelley and Lovatelli, 2011) .

2.5.2.2. Stocking

Megalopae are stocked either into tanks, net cages or earthen ponds at densities of 1–50 per litre, although some prefer to stock at a density linked to the surface area available for megalopae to settle into crablets on, e.g. 1–2 000 megalopae/m^2. It is recommended that 50–70 megalopae/m^2 be stocked into net cages in ponds. The main determinant on optimum stocking density is the size at which the crablets is harvested. The larger the crablets being harvested from the nursery system, the fewer that should be stocked, as the cannibalism rate is strongly correlated with density and rapidly increases with crab size during the early crablets stages (Shelley and Lovatelli, 2011) .

Gunarto and Sulaeman (2017) have reported that the stocking density during early life stages is proposed to influence the crablets production in the larvae rearing tanks. The stocking density of 75 ind./L is optimum for *S. tranquebarica* larvae and recommended to be applied for commercial larvae production in the hatchery. The highest larvae development index (LDI) and Megalopa occurrences index (MOI) was found with the stocking density of 45 and 75 individual/ L compared to 30 and 60 individual/L. Furthermore, the highest crablet production was obtained with the stocking density of 75 ind./L.

2.5.2.3. Management: shelter, drying, using chemicals, filtering

Netting, mussel shells or artificial seagrass are often put in tanks as shelter. The shelter materials provide a three-dimensional habitat that assists in minimizing inter-crablets antagonistic behaviour, providing more areas for newly moulted crabs to hide from other crabs. The addition of habitat to nursery systems appears to improve survival at all crab densities, but has little effect on growth. Nursery systems do not generally require a high level of water treatment by filtration or disinfection as late-stage megalops and crablets are tougher than the zoeal larval stages (Shelley and Lovatelli, 2011) .

2.5.2.4. Water quality parameter

While juvenile mud crabs (crablets) can be grown successfully across a wide range of temperatures and salinities, optimal conditions for their growth and survival appear to be at 30 ^{0}C, and salinities of 10–25 ppt, while salinities of 36 ppt and 48 ppt have been reported to have a detrimental effect on crablets growth. The duration of the megalopa stage of *S. serrata* has been reported to be shortest at a salinity of 20 ppt and a temperature of 31 °C. Mud crabs are highly tolerant to varying salinity conditions ranging between 10 ppt and 34 ppt, pH 8.0 to 8.5, Temperature 23 °C to 30 °C and dissolved oxygen (DO) content should be more than 3 ppm (Chou and Lee, 1997).

Gunarto and Parenrengi (2014) conducted the study to know the effectiveness of crablets rearing at the different salinity regimes in floating plastic glass individually to minimize canibalism. Crablets were stocked inside of the plastic glass individually, then set in a floating cage constructed with bamboo fenced, where a piece of styrofoam make them floated in surface water in the aquarium. Nine aquariums (each size 29×60×34.5 cm) were randomly filled 30 L saline water with different salinity regimes, i. e. (A) 5 ppt, (B) 10 ppt, (C) 20 ppt, (D) 30 ppt. The highest growth increment of crablets was obtained in A treatment (0.74 ± 0.13 g) compared to B (0.57 ± 0.10 g) C treatment (0.61 ± 0.15 g) and D (0.48 ± 0.9 g). The carapace width was significantly different ($P<0.05$) between A and B, A and D, B and C, B and D, C and D. The highest of survival rate was obtained in C treatment (100%) compared to A treatment (73.3 ± 11.55%).

2.5.2.5. Food and feeding

On-grown artemia, up to adult size, can also be fed throughout the megalopa and early crablet stages. Advanced artemia (5 days old) at 20–25 per millilitre and formulated shrimp larval feeds are provided to the megalopa stage mud crab larvae, prior to settlement. Once settled, formulated feeds (at present, formulated prawn starter diets as few crab-specific diets have been developed), or diets of trash fish, and/or molluscs can be used to feed crablets. Diets of 45–55 percent crude protein and 9–15 percent lipid appear to support optimal growth in crablets of *S. serrata* (Shelley and Lovatelli, 2011).

Gunarto *et al.* (2016) conducted the study to know the influence of enriched *Artemia nauplii* using *Nannochloropsis sp.* on the different stages of larvae *Scylla olivacea* and crablets production in tanks of 250 L filled with saline water of 30 ppt., hatched mud crab larvae zoea-1 was stocked at the density 100 ind./L. The larvae zoea-1 were fed rotifer, *Brachionus sp.* and after zoea-3, the larvae were fed with *Artemia naupli,* beside fed with rotifer. The highest LDI and MOI was obtained by feeding larvae zoea-3 stage until megalop stage with *Artemia nauplii* enriched using *Nannochloropsis* sp., compared to using *Artemia nauplii* larvae for zoea-3 until megalop stage, and using *Nannochloropsis* sp. enriched *Artemia nauplii* for zoea-4 stage, zoea-5 stage until megalop stage. The use of *Artemia nauplii* enriched by *Nannochloropsis sp.* for feeding larvae, *S. olivacea* stage zoea-3 to zoea-5 until the megalop stage development is one of the key factor to enhance the crablets production.

2.5.2.6. Harvest

Crablets are typically harvested from nursery systems after a 3–4-week period and moved to grow-out systems having grown to over 1 cm and to weights up to 0.3 g, at the C3–C4 stage. In net cages, lift nets with feed on them can be used to attract and harvest crablets. For the final harvest from a net cage, one end of the cage can be lifted and crablets scooped from the other (Shelley and Lovatelli, 2011).

2.5.2.7.Transport

Crablets can be transported with or without water. Cooling crablets before transport is recommended to prevent both moulting and lower oxygen consumption during transport. Crablets can also be transported in water using the same method as used for post-larval shrimp or juvenile fish. Out of water, crablets can be transported in containers on moist sand or damp cloth, in containers that are lined and covered to minimize evaporation and resulting desiccation, while ventilated to ensure they can respire adequately. It is recommended that transport of crablets out of water should not exceed 30 hours (Shelley and Lovatelli, 2011).

2.5.3. Grow-out

2.5.3.1 Water quality

Mud crabs are extremely tolerant of salinity variation and can survive in a salinity range from 2 to 50 ppt. Mud crabs are extremely tolerant of temperature variation that is 12 °C to 35 °C (Bhuyian and Islam, 1991). Cholik and Hanafi (1988) recommended pH 7.5 to 8.5 for crab culture practice.

2.5.3.2. Fattening in pens, ponds, cages, tanks

Various structures, including cages, floating cages, ponds or tanks, can be utilized to hold mud crabs for relatively short periods of time for fattening. As long as the mud crabs are held in water of suitable quality, fed regularly and precautions are taken to minimize disease, crabs for fattening can be held at reasonably high densities. Fattening operations may be constructed within an existing pond or pen, a tidal river or creek (Shelley and Lovatelli, 2011).

Pen is located in the intertidal area, and usually with area of 800 m^2. Pen is constructed and fenced using uzio (fish trap) material made of mangrove poles and wood. Stocking of the pen with seed crabs collected from local sources. The crabs are fed with trash fish obtained from local sources, and feeding is conducted once or twice daily, preferably at high tide. Salinity of the pond ranges from 12.8 to 35 ‰; temperature between 25 and 36 °C, pH from 7.95–8.25 and dissolved oxygen (DO) from 2.65–4.00 mg/l. Harvesting of the crabs started after 4 months from date of stocking (Chang 1997).

2.5.3.3. Silviculture

In many Asian and Indo-Pacific nations, significant areas of mangrove forests have been damaged, removed or degraded over the decades. To counter this, large areas of new mangrove forests have been planted in many countries, including Indonesia, the Philippines and Viet Nam. In addition to the lumber they will produce in time, these new forests are often constructed around canal systems to ensure adequate circulation and drainage. Such systems have also provided an opportunity for low-intensity culture of mud crabs, both in canals and within the new mangrove forests themselves. Areas of the forest may be fenced to minimize escape of mud crabs stocked into the area, or if a communal approach is taken to the culture of crabs within the forest, there may be no structures to retain stock. This is because it is assumed that the community will share the benefits of stocking the area with crabs (Shelley and Lovatelli, 2011) .

2.5.3.4. Stoking density and feeding rate

As no supplementary feed is provided to mud crabs in these systems, they are dependent on natural productivity. As such, stocking rates are typically very low (0.05 crabs/m^2) (Shelley and Lovatelli, 2011) .

2.5.4. Economics

Mud crab is one of the most important coastal aquatic crustacean species among 12 marine/brackish water species in Bangladesh. The mud crab plays an important role in the national economy by earning from export (Istiak, 2018). The contribution of crabs is 0.34% into the total fish production of Bangladesh in 2015-16 (Mustafa *et al.*, 2017). Gaillard (2009) reported that in the Philippines the mud crab represents between 20 and 30% of the value of the production against 20 - 50% for the shrimp (Salam *et al.* 2003). Crab fattening is widely practiced in Thailand, Taiwan, Malaysia, Singapore, India, Indonesia and Bangladesh (Begum *et al.*, 2009). According to Sudhakar (2009) and Yousuf *et al.* (2017) mud crab has been well-accepted as a good source of protein and antioxidant properties, scrumptious and demandable crustacean in the world. Live crab marketing is a profitable business. China, USA, Japan, South Korea and Thailand are the top five consumers. In recent years, crab business has been increasing due to buyers demand (Kamata *et al.* 2012). About 2.5 - 3.00 lakh people are directly involved in crab value chain (Jahan and Islam, 2016). Bangladesh started exporting crab in

1977 and earned US $2,000 (Jahan and Islam, 2016) and in 2015-16 earned US $23.82 million by exporting live and frozen crabs to 17 countries. China is the single largest crab importer. In the southwest coastal belt of Bangladesh, millions of poor fishers, traders, and transporters are directly or indirectly dependent on live crab catching and collection. In Bangladesh, about 19,408 hectare water bodies have been used to produce crab and in 2015 -16 produced 13,160 MT crabs (Mustafa *et al.*, 2017). The production of mud crab has attracted several private sectors into this emerging and profitable sector.

Begum *et al.* (2009) conducted to compare the survival, production and economics of mud crab fattening in cage with fattening in encircled earthen brackish water pond. Mud crab fattening in cage and in encircled earthen area were considered as Treatment-1 and Treatment-2, respectively with three replications each. Single adult non-gravid female crab (204.42 ± 2.58g) was stocked into each compartment of the cages and 80 crabs (204.42 ± 2.58g) were also stocked into earthen pond at the stocking density of 2 indiv./ m^2. The crabs were fed with chopped tilapia at the rate of 8% of body weight twice daily. The survival rate of crab was found 93.75 ± 6.25% and 86.12 ± 2.16% respectively in cages and encircled earthen area. The significant higher production of crab from cages (3.30 ± 0.08 kg/m^2) was recorded than the encircled earthen area (0.37 ± 0.01 kg/m^2). The comparative benefit-cost analysis showed that bamboo cage fattening attained higher net profit (Tk 91,630.00) than crab fattening in encircled earthen area (Tk 9,345.00) from 12 crops (12-16 days per crop) fattening period.

Jahan and Islam (2016) aimed to examine the economics of collecting and fattening of live crab (*Scylla serrata*) at Paikgachha upazila under Khulna district of southwest region of Bangladesh. A total of 50 crab farmers were randomly selected from Paikgachha upazila of which 20 were crab collectors and 30 were crab fatteners. The study determined costs, returns and profitability of mud crab production in respect of crab collection and fattening. The demand of live crab was higher in winter season (November-March) when the production and catch were relatively higher. The results from profitability analysis revealed that the total cost and gross return of crab collecting in one season (Sept-Feb) were about Taka 277,197 and Tk. 416,706 respectively whereas in one culture period (Nov-Feb) of fattening, per acre total cost and gross return were Tk. 729,619 and Tk. 864,314 respectively. Net returns of crab collecting and crab fattening were Tk. 139,510 per season and 134,95 per acre respectively and there corresponding benefit cost ratio were about 1.5 and 1.18 respectively. The average benefit-cost ratio (BCR) of crab collecting (1.5) and crab fattening (1.18) revealed that there is a great business potentiality in mud crab collection and fattening.

Chandra *et al.* (2012) conducted to estimate approximate production and assess the marketing of mud crab in the south-western region of Bangladesh. Crab culture was done by hardening and fattening collected from the natural source. Most of the fattening farms were 0.2 to 2 acres. Fattening and hardening period varied from 10 to 30 days. The Sundarban mangrove, tidal rivers, estuaries, canals, shrimp farms and fattening ponds were the sources of mud crabs. The total number of mud crab depots was 328. Three types of physical conditions of the crab depots were recorded, Kacha (110), Semi-pacca (150) and Pacca (68). The grading system of crabs varied depending on sex and size. The total production of mud crab was 6945.62 (t) in Khulna-Satkhira-Bagerhat districts. The maximum (2655.91 t) mud crab was produced in Bagerhat district and the minimum (1777.15) in Satkhira. The production was maximum (3567.86) in the monsoon and the lowest (1306.95) in summer season.

CHAPTER THREE

MATERIALS and METHODS

3.0. Materials and Methods

3.1. Selection of the study area

The study area was conducted at the Nowabeki Gonomukhi Foundation crab hatchery of Kolbari in Shyamnagar Upazila, Satkhira, in the southeast part of Bangladesh. This study site was selected on the basis of the availability of the crab hatchery and crablets nursing practice in the region.

3.2. Study period

The data collection was carried out from the month of July to December in 2017.

3.3. Data collection

The necessary data were collected from both primary and secondary sources (Fig.2.1). Primary data was collected through field survey by using a questionnaire. Secondary data was collected from different books, journals and reports.

3.4. Primary sources

Primary data such as salinity, temperature, pH and DO were mainly collected through field survey. For collection of data a questionnaire was prepared (Appendix). Before formulating the questionnaire, visits were made in the study area. Various information about crab hatchery were collected during the visit. After finalizing the structured questionnaire, relevant data were collected by interviewing the crab hatchery farm manager and technicians directly.

3.5. Secondary sources

For supporting primary data, secondary data were also collected from different sources. The sources were follows:

i. Publications report from Bangladesh Fisheries Research Institute (BFRI).
ii. Publications report from Department of Fisheries (DOF).
iii. Other related published books and journals.

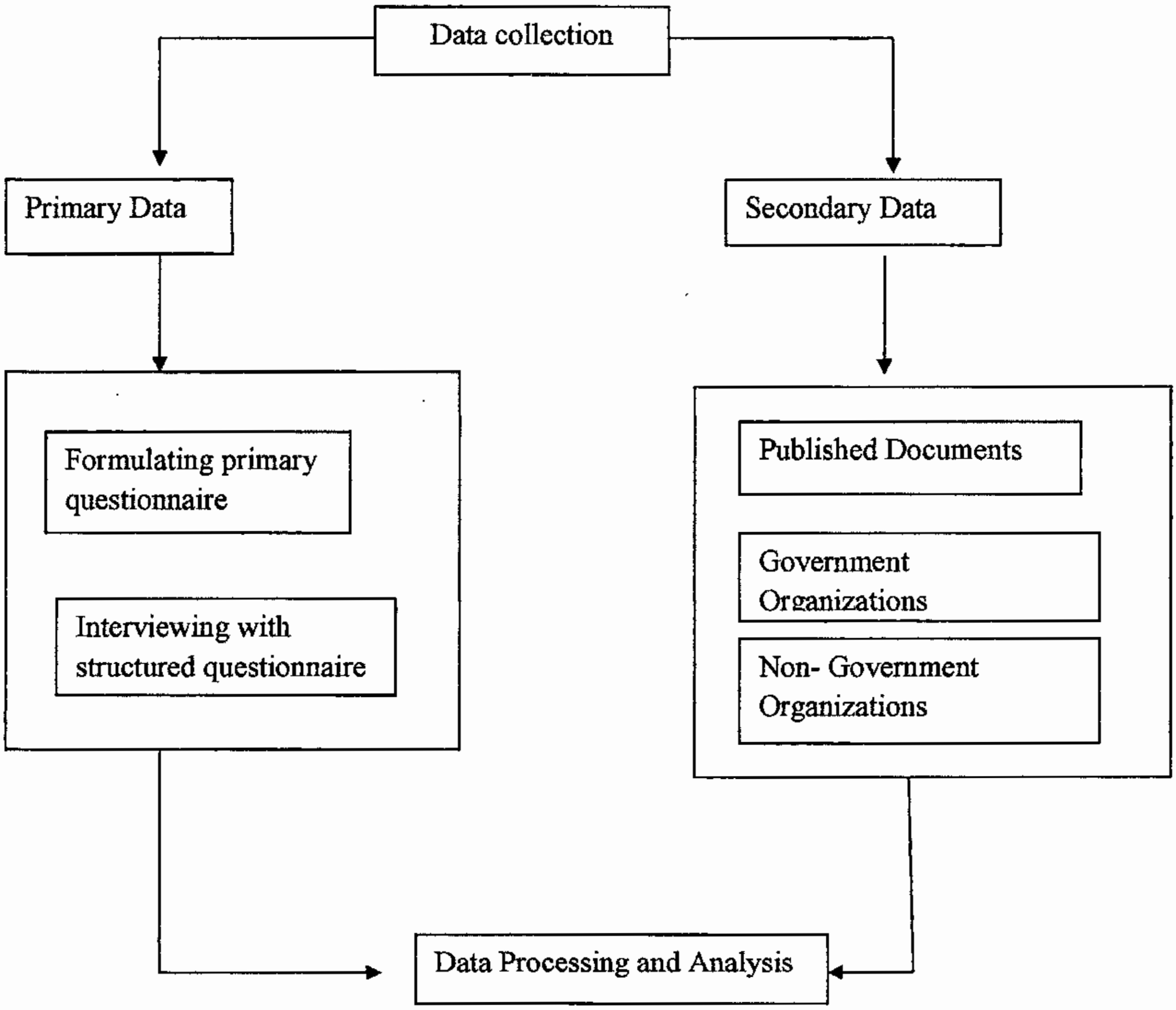

Fig.2.1: Flow chart of the standard data collecting approach

3.6. Data analysis:

All data collected from questionnaire interviews were complied, rearranged and presented as descriptive statistics using Microsoft word and Microsoft Excel software-2007. The analysis of data was mainly based on tabular, diagram and descriptive techniques.

CHAPTER FOUR

RESULTS

4.0. Result

In the Nowabeki Gonomukhi Foundation crab hatchery, crablets were nursed in the three nursery ponds having size of 16 decimal, 10 decimal, 10 decimal and water depth of 1-2 m (Table 1).

Table 1: General information about Nursery

Feature	Nursery 1	Nursery 2	Nursery 3
Soil type	Sandy clay	Sandy clay	Sandy clay
Water depth	1-2m	1-2m	1-2m
Water source	River water	River water	River water
Pond size	16 decimal	10 decimal	10 decimal
Water Quality			
Salinity(ppt)	16.49 ± 0.67	16.52 ± 0.77	16.46 ± 0.82
Temperature(^{0}c)	26.04 ± 3.01	25.55 ± 2.31	26.45 ± 2.31
pH	7.54 ± 0.39	7.61 ± 0.34	7.61 ± 0.34
DO	7.4 ± 0.20	7.31 ± 0.21	7.37 ± 0.24

4.1. Water quality parameters

Various water quality parameters were recorded during the culture period. In nursery 1, salinity was observed between 31 to 15.8 ppt. Temperature was observed between 28.3 ^{0}c to 20.4 ^{0}c.The range of pH varied from 8.5 to 7.1 and DO 7.8 to 7.0. In nursery 2, the range of salinity varied from 28.6 to 15.3 ppt. Temperature was measured from 29.5 ^{0}c to 22.4 ^{0}c. pH was recorded as 8.1 to 7.2 and DO from 7.8 to 7.0. In nursery 3, salinity rang varied from 29.5 to 15.2 ppt. Temperature was varied from 29.6 ^{0}c to 22.4 ^{0}c. pH was observed from 8.5 to 7.2 and DO was between 7.8 to 7.0.

4.2. Production management description

4.2.1. Pond preparation

At the beginning of the nursing season in every year, the nursery operators prepare their nursing pond for nursing crablets and fully dried up by pumping and exposed to the sun for seven days.

4.2.2. Liming

$CaCO_3$ was applied as lime. Liming was done at the rate of 1 kg/decimal.

4.2.3. Water filling and water depth

The pond is filled with water by pump machine. Pumping of water is done till the water becomes 1-2m in depth. Water level fall its average during winter. Then, supplementary water is supplied by ground water by pump. The salinity of underground water is 21 ppt. In rainy season it rise or overflow. Fencing or netting around the ponds was given.

4.2.4. Insecticide

After fertilization different types of insects were grown in the ponds. Insecticides were applied to kill insects. But farmers do not use any insecticide in this time.

4.2.5. Fertilization

Fertilizer was given after filling the pond with water or while pouring ponds with water. In the nursery ponds TSP was used at the rate of 100g/decimal, but if the ponds were new then TSP were used double in amount. Urea was used at the rate of 150g/decimal. 2-3 days after applying fertilizers water color become greenish or light brownish green.

4.2.6. Stocking

4.2.6.1. Source of crablets

Crablets were mainly collected from the Nowabeki Gonomukhi Foundation crab hatchery at Kolbari in Satkhira.

4.2.6.2. Stocking in nursery

After pond preparation, crablets were mainly stocked in different nursery ponds in 1000 piece per decimal. The crablets were stocked in the ponds at afternoon.

4.2.7. Foods and feeding management

Generally blending tilapia was applied for feeding crablets. The nursery operators had weekly monitoring on growth and health checking for crablets. In general feeds such as blending tilapia are given once in a day. Crabs are fed with trash fish at 10% of body weight in a week.

4.2.8. Disease and control

The crablets production system takes only 20-22 days to produce it. Water is changed within a few days in a consecutive process in each time of nursing. But they do not found any disease in this time.

4.3. Harvesting

4.3.1. Crab harvesting

Crabs were harvested after 20-22 days with seine net. It was mainly done in the early morning. It was reported that 520.83 ± 56.96 piece/decimal of crab can be produced. After harvesting, crabs were stocked in a double walled cloth named Hapa.

4.3.2. Growth observation

The data about growth were mainly collected through field survey and the observation of crablets growth are shown in table 2.

Table 2: Growth performance of crablets in different nursery

Nursing Farm	Weight on stock (gm)	Weight during harvest (gm)	Average Weight(gm)
Nursery 1	11.06 ± 0.79	16.006 ± 0.80	
Nursery 2	11 ± 0.82	16.11 ± 0.72	16.022 ± 0.081
Nursery 3	11.1 ± 0.77	15.95 ± 0.83	

Table 3: Survival rate of crablets in different nursery

Nursing Farm	Stocking time	Number on harvest time	Survival rate (%)	Average survival rate (%)
Nursery 1	16000	8200	51.25	
Nursery 2	10000	5300	53	52.25 ± 0.90
Nursery 3	10000	5250	52.5	

4.4. Economics

In the Nowabeki Gonomukhi Foundation crab hatchery, crablets were nursed in the three nursery ponds and their fixed cost, operating cost, average cost, average production value and profit are shown in table 4, 5, 6, 7 and 8, respectively.

Table 4: Cost estimation (Fixed cost)

Features	Quantity (Decimal)			Unit Price (TK/Decimal)			Cost (TK)		
	Nursery 1	Nursery 2	Nursery 3	Nursery 1	Nursery 2	Nursery 3	Nursery 1	Nursery 2	Nursery 3
Land Rent	16	10	10	300	320	250	5100	3200	2500
Pond Construction	16	10	10	70	80	50	1120	800	500
Pond repairing	16	10	10	30	35	25	480	350	250
Dyke Construction	16	10	10	-	-	-	-	-	-
Gate	16	10	10	-	-	-	-	-	-
Fencing &Netting	16	10	10	-	-	-	-	-	-
Labour	16	10	10	70	70	70	1120	700	700
Depreciation Cost	16	10	10		-	-	-	-	-

Interest (Bank/NGO Loan)	16	10	10	-	-	-	-	-	-
Pump	16	10	10	20	22	15	320	220	150
Grant Total	16	10	10	490	527	410	8140 ± 1974.8	5270 ± 1223.3	4100 ± 963.45

Table 5: Cost estimation (Operating cost)

Type of crops features	Cost in nursery 1(16 decimal, TK)	Cost in nursery 2(10 decimal, TK)	Cost in nursery 3(10 decimal, TK)
Pest Eradication	-	-	-
Liming	300	200	200
Feed	3000	2000	2000
Fertilizers			
a. Urea	150	100	100
b. TSP	150	150	150
c. Potash	-	-	-
d. Pesticides	-	-	-
Total	3600 ± 1401.7	2450 ± 925.9	2450 ± 925.9

Table 6: Average cost

Nursery	Cost (TK)		Total cost (Fixed+Operating) (TK)	Total cost/decimal (TK)	Average cost/decimal (TK)
	Fixed	Operating			
Nursery-01	8140 ±1974.8	3600 ± 1401.7	11740 ± 3210.26	733.75	

Nursery-02	5270 ± 1223.3	2450 ± 925.9	7720 ± 1994.04	772	720.25 ± 59.65
Nursery-03	4100 ± 963.4	2450 ± 925.9	6550 ± 1166.72	655	

Table 7: Average production value

Nursing farms	Total production (piece)	Buying price /piece	Selling price /piece	profit	Total selling (TK)	Total production/decimal (TK)	Average production value/decimal (TK)
Nursery 1	8200	1.00	3.50	2.50	20500	1281.25	
Nursery 2	5300	1.00	3.50	2.50	13250	1325	1306.25 ± 22.54
Nursery 3	5250	1.00	3.50	2.50	13125	1312.5	

4.4.1. Profit

Table 8: Profit of the nursery

Nursing farms	Profit/decimal (TK)	Average profit/decimal (TK)
Nursery 1	547.5	
Nursery 2	553	586 ± 61.98
Nursery 3	657.5	

Table 9: Economic indicators of the nursery

Nursing farms	Nursery 1	Nursery 2	Nursery 3
Profit	547.5	553	657.5
Rate of return on initial cost	6.73%	10.5%	16.03%
Rate of return on operating cost	15.20 %	22.57%	26.84%
Benefit cost ratio	0.75	0.72	1.0

CHAPTER FIVE

DISCUSSION

5.0. Discussion

In shyamnagar under the southern district of satkhira, the country's first crab hatchery started crablets production. The hatchery was established by Nowabeki Gonomukhi Foundation, a partner organization of PKSF, under a project titled 'Promoting Agricultural Commercialisation and Enterprises. Now more than 50,000 people are engaged in collecting crabs in the country's coastal areas, including Satkhira, Khulna and Bagerhat (Molla *et al*., 2009). Some 30,250 crab farmers are cultivating crabs together with shrimps on 3,500 hectares of lads in the country. The number of crab farmers is going up day by day as many small shrimp cultivators are now interested in crab farming as it is three-four times more profitable. There is now the demand for 30 million crablets in the country's coastal crab farmers. According to one study, mud crab activities provide jobs for around 300,000 farmers, collectors, trades, brokers, transporters and exporters (Islam *et al*., 2015).

The thesis work was aimed at understanding the present scenario of production and economics of crab production at Kolbari in Satkhira. The investigation was conducted in three different crablets nursery operator through a structured questionnaire. The study was based on reconnaissance survey from the month of July to December in 2017. The objective of the study was to know the present scenario of crablets production, analyze the economics of crablets nursing, treading and identify the problems associated with the business. The survey discovered that this crablets nursing business gives a very good economic benefit with a minimum investment at a short period of culture. The average total areas of nursery were found as 36 decimal with average water depth 1-3m. Dyke condition of most of the pond was very good. Fertilizer mainly Urea, TSP were used by the nursery operators on the basis of their assumption and water color. $CaCO_3$ mainly used as lime. The stocking density of crablets was found 1000 piece/decimal. Average growth performance found 16.022 ± 0.081 after 22 days nursing.

The average salinity was recorded at 16.49 ± 0.67, 16.52 ± 0.77 and 16.46 ± 0.82 in nursery 1, nursery 2 and nursery 3, respectively. Salinity has significant effect on survival and growth of crablets. According to Romano and Zheng (2012), a minor increase in salinity level may weaken decapods ability to tolerate high ammonia stressor that interferes with the osmoregulatory system.

Mud crabs are highly tolerant to varying salinity conditions ranging between Salinity 10 to 34 ppt, pH 8.0 to 8.5, Temperature 23 to 30 °C (Chou and Lee, 1997). The average temperature was observed at 26.04 ± 3.01 °C, 25.55 ± 2.31 °C and 26.45 ± 2.31 °C in nursery 1, nursery 2 and nursery 3, respectively. Some authors also have reported higher temperature which enhances the growth (Yuan *et al.*, 2017, Ruscoe, Shelley and Williams, 2018). Higher temperature (>32 ^{0}C) can be detrimental as reported by Hewitt and Duncan (2001) in the survival of *Marsupenaeus japonicus* juveniles due to cause of physiological damages, such as failure of enzyme systems, denaturation of proteins, respiratory stress or deterioration in membrane structures. As the main objective for farming or stocking is to increase the number of crablets, survival is more important than growth during the nursing period. Therefore, low temperatures such as 25 to 26 ^{0}C can be suggested based on the present study.

The average pH was noticed at 7.54 ± 0.39, 7.61 ± 0.34 and 7.61 ± 0.34 in nursery 1, nursery 2 and nursery 3, respectively. pH was likely playing an important role in ammonia production and it could be a required factor for higher survival. In addition, pH also plays vital role in culture system which can directly affect the organism's well-being in terms of metabolism and physiological processes. A slight change in pH would give negative effects on crabs because the changes often take place due to residual feed and excretion product of organisms (Talpur and Ikhwanuddin, 2012).

The average dissolved oxygen was observed at 7.4 ± 0.20, 7.31 ± 0.21 and 7.34 ± 0.24 in nursery 1, nursery 2 and nursery 3, respectively. Chou and Lee, 1997 have also reported that dissolved oxygen content should be more than 3 ppm. While juvenile mud crabs (crablets) can be grown successfully across a wide range of temperatures and salinities, optimal conditions for their growth and survival appear to be at 30 °C, and salinities of 10–25 ppt, while salinities of 36 ppt and 48 ppt have been reported to have a detrimental effect on crablets growth. The duration of the megalopa stage of *S. serrata* has been reported to be shortest at a salinity of 20 ppt and a temperature of 31 °C (Shelley and Lovatelli, 2011).

Crablets were mainly stocked in different nursery ponds in 1000 piece per decimal in this study. Megalopae are stocked either into tanks, net cages or earthen ponds at densities of 1–50 per litre, although some prefer to stock at a density linked to the surface area available for megalopae to settle into crablets on, e.g. 1–2000 megalopae/m^2. It is recommended that 50–70 megalopae/m^2 be stocked into net cages in ponds (Shelley and Lovatelli, 2011).

The survival rate was reported at 51.25%, 53% and 52.5% in nursery 1, nursery 2 and nursery 3, respectively in this study. The survival rate of crablets that were fed three experimental diets were determined at the end of 6 weeks feeding trial. Crablets fed with Diet 3 (trash fish) had the highest survival rate (58.33 ± 7.4%) which was significantly higher ($p<0.05$) from those of Diet 2 (commercial shrimp feed) and Diet 1 (commercial crab feed), although crablets fed actively on all diets. At the end of the study, crablets fed with Diet 3 showed the higher daily growth rate, body weight gain (Khan *et al* 2017). Regardless of stocking density, survival in net cages was higher (77.11 ± 6.62%) than in ponds (40.41 ± 3.59%). Growth, however, was significantly higher for crab juveniles reared in earthen ponds (Rodriguez *et al.* 2007). The growth performances of crablets that were nursed in three different nursery at the end of 22 days.

In case of fattening, the estimated average net return was found to be Tk. 11,626 for a crab collector in 12-15 days. The stocking density varied from 2000 pieces of crablet/acre and fed at 10 percent of body weight once in a day during evening hours. The benefit-cost ratio (BCR) of crab farming was found to be 1.5 implying that Tk. 1.5 would be earned by investing every Tk. 1.00 for crab production. Therefore, it can be said that crab collection is profitable for crab collector (Jahan and Islam, 2016). The fattening per cycle in the south-west regions of Bangladesh has a wide duration of 12 – 75 days. The mean cycle is reported as 32 ± 19.19, 14.31 ± 1.26, and 18.91 ± 6.73 days in Bagerhat, Satkhira, and Khulna districts, respectively. The average duration of fattening cycle lie in the typical range of 14 -60 days reported by Shelley and Lovatelli (2011); Agbayani (2001) and Trino and Rodriguez (2002).The net return was higher in Satkhira (US$ 147.77) while US$ 118.32 in Bagerhat and US$ 75.14 in Khulna. The benefit cost ratio (BCR) was estimated at 1.07, 1.34 and 1.06 in Bagerhat, Satkhira and Khulna, respectively (Hasanuzzaman *et al.*, 2014). Begum *et al.* (2009) reported BCR of 1.22 for earthen-pen fattening and Khatun *et al.* (2009) estimated at 1.77 for mixed-sex mud crab culture in bamboo pens installed in mangrove tidal flats.

The economic analysis summarized that the net return was higher in nursery 3(TK 657.5) while TK 547.5 in nursery 1 and TK 553 in nursery 2. The rate of return on initial cost was estimated at

6.73%, 10.5% and 16.03% in nursery 1, nursery 2 and nursery 3, respectively. The rate of return on operating cost was estimated at 15.20 %, 22.57% and 26.84% in nursery 1, nursery 2 and nursery 3, respectively. The benefit cost ratio was higher in nursery 3 (1.0) while 0.75 in nursery 1 and 0.72 in nursery 2.

So it can be assumed from the experiment that by using nursery of crab desirable production can be achieved and the crab production is economically profitable. However, further coherent research is needed for developing good management practice of crablet nursing system augmenting survival of crablets and thus contributing to achieve sustainable mud crab aquaculture in Bangladesh.

CHAPTER SIX

CONCLUSION

6.0. Conclusion

Availability of seed crab is the most important factor in determining the success of mud crab aquaculture. In Satkhira District, crablet nursery trade playing a role in the mud crab production systems. The study showed that the average production in the nursery was 520.83 ± 46.92 piece/decimal and the average weight in three different nursery was 16.022 ± 0.081gm. The average cost in three different nursery was 720.25 ± 59.65TK/decimal. The average profit in three different nursery was 586 ± 61.98TK/decimal. It has now become a potential and profitable business at the region. However, there are some factors that act as a barrier to nursery trade at this region such as lack of sufficient crablet supply, credit facility, technical knowledge and modern equipments etc. The Government should give spatial attention in providing training and credit support for the development of the culture and trade. Studies of crab farming intensification, transportation, export and hatchery operation policy should be carried out.

CHAPTER SEVEN

REFERENCES

7.0. References

7.1. Books and journals references

Agbayani, R. F. (2001). Production economics and marketing of mud crabs in the Philippines. *Asian Fisheries Science*, *14*(2), 201-210.

Ali, M. Y., Kamal, D., Hossain, S. M. M., Azam, M. A., Sabbir, W., Murshida, Ahmed, B., & Azam, K. (2004). Biological studies of the mud crab, Scylla serrata (Forskal) of the Sundarbans mangrove ecosystem in Khulna region of Bangladesh. *Pakistan Journal of Biological Sciences*, *7*(11), 1981-1987.

Annual Report 2016-17. Bangladesh Fisheries Research Institute, Mymensingh. 2201. 170 p.

Basu, S., & Roy, A. (2018). Economic assessment of mud crab (Scylla Serrata) culture as an adaptation strategy to salinity intrusion in south-west region of Bangladesh. *International Journal of Environmental Studies*, *75*(6), 891-902.

Begum, M., Shah, M. M. R., Mamun, A. A., & Alam, M. J. (2009). Comparative study of mud crab (Scylla serrata) fattening practices between two different systems in Bangladesh. *Journal of the Bangladesh Agricultural University*, *7*(1), 151-156.

Begum, M., Shah, M. M. R., Mamun, A. A., & Alam, M. J. (2009). Comparative study of mud crab (Scylla serrata) fattening practices between two different systems in Bangladesh. *Journal of the Bangladesh Agricultural University*, *7*(1), 151-156.

Bhiyan, A. L., & Islam, M. J. (1981). Tolerance and distribution of Scylla serrata in response to salinity of Karnafully River estuary. *Bangl. J. Agric*, *6*, 7-15.

Chandra, K. J. (2012). A survey on the production and marketing of mud crab, scylla serrata (forskal, 1755) in the south-west part of Bangladesh. *International Research Journal of Applied Life Sciences*, *1*(3).

Chandra, K. J. (2012). A survey on the production and marketing of mud crab, scylla serrata (forskal, 1755) in the south-west part of Bangladesh. *International Research Journal of Applied Life Sciences*, *1*(3).

Chang, W. W. (1997). Pen culture of mud crabs in the mangrove ecosystems in Sarawak (East Malaysia). *Aqua. Asia*, 3-5.

Cholik, F., & Hanafi, A. (1992). A review of the status of the mud crab (Scylla sp.) fishery and culture in Indonesia. In *Report of the seminar on mud crab culture and trade. Bay of Bengal Programme, Madras. BOBP/REP/51: pp* (pp. 13-27).

Chou, R., & Lee, H. B. (1997). Commercial marine fish farming in Singapore. *Aquaculture Research, 28*(10), 767-776.

Davie, P. J., & Mann, D. L. (1998). A revision of the genus Scylla de Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). *The Raffles Bulletin of Zoology, 46*, 217-245.

GAILLARD, J. (2009). Development of the mud crab sector in three provinces of the Philippines. *Constraints and Prospects. CEARCA in Collaboration with Cirad and World Fish Center, 54*.

Gunarto and Parenrengi, A. 2014. *Research and Development for Coastal Aquaculture, Maros,* South Sulawesi, Indonesia. *J Aquac Res Development* 5:5.

Gunarto, G., & Parenrengi, A. (2016). Crablet of Mud Crab Scylla Olivacea Production from the Different Stages of Larvae fed Artemia Nauplii Enriched Using Nannochloropsis sp. *International Journal of Agriculture System, 4*(2), 132-146.

Gunarto, G., & Sulaeman, S. (2017). Rearing of Mud Crab, Scylla tranquebarica Larvae with Different Stocking Densities. *Omni-Akuatika, 13*(2).

Hasanuzzaman, A. F. M., Arafat, S. T., & Huqa, K. A. (2014). Mud Crab (Scylla spp.) Aquaculture in the South-West Sundarbans Region of Bangladesh. *Iraqi J. Aquacult, 11*(1), 57-83.

Hewitt, D. R., & Duncan, P. F. (2001). Effect of high water temperature on the survival, moulting and food consumption of Penaeus (Marsupenaeus) japonicus (Bate, 1888). *Aquaculture Research, 32*(4), 305-313.

Islam, M.S., Aleem, N.A. and Rahman, M.M. 2015. Mud Crab Aquaculture: Present status, Prospectsand Sustainability in Bangladesh. Volume 46, Number 3, Page 58, September 2015.

Istiak, S. M. (2018). Study for assessing mud crab (Scylla serrata, Forskal, 1755) market chain and value-added products development in Bangladesh. *Bangladesh Journal of Zoology, 46*(2), 263-273.

Jahan, H., & Islam, M. S. (2016). Economic performance of live crab (Scylla Serrata) business in the southwest coastal region of Bangladesh. *International Journal of Fisheries and Aquatic Studies*, *4*(1), 453-457.

Jahan, H., & Islam, M. S. (2016). Economic performance of live crab (Scylla Serrata) business in the southwest coastal region of Bangladesh. *International Journal of Fisheries and Aquatic Studies*, *4*(1), 453-457.

Kamata, E. L., Lamtane, H. A., Abdallah, J. M., Kalinga, M. E., Books, R. U. F. O. R. U. M., OER, R., ... & Tenders, R. U. F. O. R. U. M. (2012). The impact of climate change on mud crab fishery and fattening to the communities livelihood in Pangani and Rufiji estuaries in Tanzania.

Khan, M. S. K., Haque, M. M., Islam, M. M., & Hoq, M. E. NURSERY REARING OF WILD SEEDS OF MUD CRAB (SCYLLA SP.) IN SALINE WATER EARTHEN POND.

Khatun, M. M., Kamal, D., Ikejima, K., & Yi, Y. (2009). Comparisons of growth and economic performance among monosex and mixed-sex culture of red mud crab (Scylla olivacea Herbst, 1796) in bamboo pens in the tidal flats of mangrove forests, Bangladesh. *Aquaculture research*, *40*(4), 473-485.

Molla, M. A. G., Islam, M. R., Islam, S., & Salam, M. A. (2009). Socio-economic status of crab collectors and fatteners in the southwest region of Bangladesh. *Journal of the Bangladesh Agricultural University*, *7*(2), 411-419.

Mustafa, M. G., Firoz Khan, A. K. M., & Mohsin, S. K. M. (2017). Community-based resources management approaches adopted in the three tributaries of river Surma, North-East Bangladesh. *J. Fish. Aquat. Sci*, *12*, 54-63.

Rodriguez, E. M., Parado-Estepa, F. D., & Quinitio, E. T. (2007). Extension of nursery culture of Scylla serrata (Forsskål) juveniles in net cages and ponds. *Aquaculture research*, *38*(14), 1588-1592.

Romano, N., & Zeng, C. (2012). Osmoregulation in decapod crustaceans: implications to aquaculture productivity, methods for potential improvement and interactions with elevated ammonia exposure. *Aquaculture*, *334*, 12-23.

Ruscoe, I. M., Shelley, C. C., & Williams, G. R. (2004). The combined effects of temperature and salinity on growth and survival of juvenile mud crabs (Scylla serrata Forskål). *Aquaculture*, *238*(1-4), 239-247.

Salam, M. A., Ross, L. G., & Beveridge, C. M. (2003). A comparison of development opportunities for crab and shrimp aquaculture in southwestern Bangladesh, using GIS modelling. *Aquaculture, 220*(1-4), 477-494.

Shafi, M., & Quddus, M. A. A. (1982). Bangladesher Matshya Sampad (in Bengeli). *Bangla Academy, Dhaka*, 1-444.

Shelley, C., & Lovatelli, A. (2011). Mud crab aquaculture: a practical manual. *FAO Fisheries and aquaculture technical paper*, (567), I.

Siddiqui, M. Z. H., & Zafar, M. (2002). Crabs in the Chakaria Sundarban area of Bangladesh. *J. NOAMI, 19*(2), 61-77.

Sudhakar, M., Manivannan, K., & Soundrapandian, P. (2009). Nutritive value of hard and soft shell crabs of Portunus sanguinolentus (Herbst). *Journal Animal and Veterinary Advances, 1*(2), 44-48.

Talpur, A. D., & Ikhwanuddin, M. (2012). Effects of stress tests on larvae of blue swimming crab, Portunus pelagicus (Linnaeus, 1758). *Advances in Environmental Biology*, 1909-1916.

Triño, A. T., & Rodriguez, E. M. (2002). Pen culture of mud crab Scylla serrata in tidal flats reforested with mangrove trees. *Aquaculture, 211*(1-4), 125-134.

Yuan, Q., Wang, Q., Zhang, T., Li, Z., & Liu, J. (2017). Effects of water temperature on growth, feeding and molting of juvenile Chinese mitten crab Eriocheir sinensis. *Aquaculture, 468*, 169-174.

Yusof, W. R., Badruddin Ahmad, F., & Swamy, M. (2017). A brief review on the antioxidants and antimicrobial peptides revealed in mud crabs from the genus of Scylla. *Journal of Marine Biology, 2017*.

7.2. Website references

https://www.shrimpnews.com/FreeReportsFolder/CrabFolder/MudCrabFarmingInBangladesh.html

CHAPTER EIGHT

APPENDIX

Chapter Eight **Appendix**

Questionnaire

1. Name of the hatchery

2. Date of interview

Table 1: General information about Nursery

Feature	Nursery 1	Nursery 2	Nursery 3
Soil type			
Water depth			
Water source			
Pond size			
Water Quality			
Salinity(ppt)			
Temperature(^{0}c)			
pH			
DO			

Growth Observation

Table 2: Growth performance of crablets in different nursery

Nursing Farm	Weight on stock (gm)	Weight during harvest (gm)	Average Weight(gm)
Nursery 1			
Nursery 2			
Nursery 3			

Table 3: Survival rate of crablets in different nursery

Nursing Farm	Stocking time	Production on harvest time	Survival rate (%)	Average survival rate (%)
Nursery 1				
Nursery 2				
Nursery 3				

Table 4: Cost Estimation (Fixed Cost)

Features	Quantity (Decimal)			Unit Price (TK/Decimal)			Cost (TK)		
	Nursery 1	Nursery 2	Nursery 3	Nursery 1	Nursery 2	Nursery 3	Nursery 1	Nursery 2	Nursery 3
Land Rent									
Pond Construction									
Pond repairing									
Dyke Construction									
Gate									
Fencing &Netting									
Labour									
Depreciation Cost									
Interest (Bank/NGO Loan)									
Pump									
Grant Total									

Table 5: Cost Estimation (Operating Cost)

Type of Crops Features	Cost in Nursery 1(16 Decimal, TK)	Cost in Nursery 1(10 Decimal, TK)	Cost in Nursery 1(10 Decimal, TK)
Pest Eradication			
Liming			
Feed			
Fertilizers a. Urea			
b. TSP			
c. Potash			
d. Pesticides			
Total			

Table 6: Average Cost

Nursery	Cost (TK)		Total Cost (Fixed+Operating) (TK)	Total Cost/Decimal (TK)	Average Cost/Decimal (TK)
	Fixed	Operating			
Nursery-01					
Nursery-02					
Nursery-03					

Table 7: Average Production Value

Nursing farms	Total production (piece)	Buying price /piece	Selling price /piece	profit	Total selling (TK	Total production/decimal (TK)	Average production value/decimal (TK)
Nursery 1							
Nursery 2							
Nursery 3							

4.4.1. Profit

Table 8: Profit of the nursery

Nursing farms	Profit/decimal (TK)	Average profit/decimal (TK)
Nursery 1		
Nursery 2		
Nursery 3		

Table 9: Economic indicators of the nursery

Nursing farms	Nursery 1	Nursery 2	Nursery 3
Profit			
Rate of return on			

initial cost			
Rate of return on operating cost			
Benefit cost ratio			