Assessment of mud crab fattening and culture practices in coastal Bangladesh: understanding the current technologies and development perspectives

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Abstract. This investigation provides an assessment of existing techniques in crab culture from the sustainable development perspective. Our survey results divulged that crab fattener aged 34.56±8.29 years, culture experience spanning 7.64±5 years. The average pond size was 0.27±0.21 hectares, with a single crop of 32±12-46±15 days. The average stocking density was 1.0±0.5 (no m^{-2}), and stocking size of 86±21 to 179±62 grams. The average highest and lowest yields were 1383±67 and 815±22.6 kg ha^{-1} $crop^{-1}$, respectively. The total cost and gross returns were 316,654.00±37,042 and 514,748.00±32,056.00 BDT ha^{-1} $crop^{-1}$, respectively. The crab fattening net profit was 198,094.00± 8,387.00 BDT ha^{-1} $crop^{-1}$. The stocking of crab farming incurred 71% of the total farming cost. The other expenses include feed (12%), fencing (8%), land lease value (5%), and labor (4%). The main protein source of the crab feed was tilapia (95%), followed by snails and trash fish. Finally, the harvesting method consisted of hand angling with a scoop net (46.34%), while others (28.70%) used specialized traps. The 92.4% of the total harvested produce was sold at depots while only 7.6% to the intermediaries. In conclusion, our study shows how crab farmers execute the fattening operations at each growth stage, the current techniques, and the development potential to fetch higher profits.
Key Words: coastal Bangladesh, development, crab fattening, mud crab, aquaculture, profitable farming.

Introduction. The investigations in commercial crab fishery are rapidly growing worldwide. In 2015, the total production of crab from capture and culture expanded to 1300 thousand tons (Hungria et al 2017). Crab culture is commercially practiced in the USA and Asian countries as mud crab now recognized as one of the profitable aquaculture species. Likewise, Bangladesh is home to one of the most viable species that is commercially suitable for aquaculture, known as the mud crab (*Scylla serrata*) (Macintosh et al 2002; Marichamy & Rajapackiam 2001). However, the capture fisheries and trade have been developed from the abundance and availability of crabs in Sundarbans mangrove forests and adjoining coastal areas (Chandra et al 2012; Rouf et al 2016). The mud crab fisheries gained popularity in Southwestern Bangladesh since the 1990s (Azam et al 1998) and performed as a vital employment generation sector (Jahan & Islam 2016; Salam et al 2003).

The prospective mud crab farming is anticipated to be resilient to further expansion, particularly in brackish water (Baliao et al 1999). The high potential of the crab industry appears to hinge on high demand and fetch a premium price in local and international markets (Khan & Alam 1992; Marichamy & Rajapackiam 1999). The first-ever export of crab by Bangladesh was performed back in 1977-1978, and it was purely harvested from the wild stocks (Ali et al 2004). However, the fattening began in enclosed ponds in the early 1990s (Kamal 2002), while other forms of culture in bamboo cages, pens, and pots started in the 2000s (Khatun et al 2009). During 1995-96, disease outbreaks in shrimp farms shattered the overall interest in entire coastal aquaculture (Karim & Stellwagen 1998) that resulted in the conversion of some shrimp farmers to adopt crab culture. Comparable water quality and other features of available coastal waterbodies appeared well-matched to the requirements of crab culture. The soaring demand and higher price in the overseas markets further aggrandized the farmer's interest in ranching crabs (Rahman et al 2017). As a result, Bangladesh's government earned foreign currency amounting to 25.37 million US$ by exporting approximately 12,686 tons of live crabs from a total annual production of 14421 tons during 2016-2017 (DoF 2017).

Currently, there are three different culture systems (crab fattening, grow-out, and soft-shell crab production) in practice that target different tiers of the global crab market. Fattening is the predominant practice followed by grow-out culture and the recent trend of soft-shell crab production (Rahman et al 2017). All of these farming systems are entirely dependent on seed supply from the wild, as successful hatchery production has not been reported yet (Salam & Ross 2000; Rahman et al 2018). Bangladeshi crab business is highly export-oriented (Chandra et al 2012; Ferdoushi & Xiang-Guo 2013), and capture mainly supports it from the wild with a minuscule proportion from aquaculture. As a result, the seed shortage has tightly restricted the expansion of crab culture, particularly in Bangladesh (Marichamy & Rajapackiam 2001). Unfortunately, the technological development to support the commercial culture of mud crabs is at its nascent stages (Azra & Ikhwanuddin 2015).

However, crab farming has shown immense potential to support the vulnerable coastal populations by resilience and adaptability in the changing climate (Rahman et al 2017). By keeping the above points in mind, we commenced this study to explore the existing mud crab culture, crab fattening practices, and success. We further planned to identify the aspects hindering sustainable development and to recognize the necessary technological refinements that could help to enhance production, profitability, and sustainability of coastal crab culture practices in Bangladesh.

Material and Method

Study area and data collection. We selected three southwestern districts of Bangladesh viz. Khulna, Bagerhat, and Satkhira for this study, because these are the hub of dense crab culture and preponderance of them are the fattening farms (Figure 1). Secondly, this coastal zone is under the development of an informal marketing value chain. These Sundarbans mangrove forests and associated coastal water bodies are the most reliable sources of crab seed in Bangladesh. We used a semi-structured questionnaire method to interview the crab producers and fattening farmers to collect the data from randomly selected farmers from July to October 2017.

Questionnaire details. The survey targeted the assessment based on (i) age, religion, extent of experience, and training (if any); (ii) culture techniques used (e.g., pond size, culture period, stocking season, density and size of seed, male to female ratio, survival rates, production, farming cost and its involvement, income, feed types and feeding strategy, harvesting methods, and marketing information); (iii) best management practices (e.g., acclimatization before stocking, provision of shelters in the ponds); and (iv) other relevant issues (e.g., transformation from shrimp to crab culture, satisfaction level and family well-being). The intention was to ascertain the feasibility and sustainability of crab culture in the southwest coastal region of Bangladesh. We

interviewed 90 crab fatteners, 30 from each cluster in the districts selected (Table 1). Before the final validation, the questionnaire was pre-tested in the field and edited during preparation until we reached the final version. Additionally, nine focus group discussions (FGDs) were arranged at each point of study to cross-validate the obtained information during the interviews. Crab fatteners in Bangladesh seldom keep farming records, so respondents were required to inquire with family and associates for help in the recollection of farming costs, production economics, and relevant details.

Figure 1. The study area map showing the three districts (Satkhira, Khulna, and Bagerhat) in southwest coastal Bangladesh.

Table 1
Geographical distribution and number of crab farmers who use the fattening technique

Districts	*Upazila (Sub-District)*	*Village/Cluster*	*No. of fattening farmers*	*Data collection methods*
Khulna	Paikgacha	Kopilmoni	15	Interview and FGD
		Shibbati	15	Interview and FGD
Bagerhat	Rampal	Bujbunia	12	Interview and FGD
		Bhanga	8	Interview and FGD
	Mongla	Burirdanga	10	Interview and FGD
Satkhir	Debhata	Norarchalk	8	Interview and FGD
	Ashashuni	Shabdalpur	8	Interview and FGD
	Kaligonj	Balapota	7	Interview and FGD
	Shyamnagor	Horinagor	7	Interview and FGD

FGD = Focus Group Discussions.

Data analysis. Analysis of production economics and performance indicators was carried out following the methods described by Shang (1990). We compiled and logged the obtained information by the use of questionnaires into an MS Excel 2007-based database (Microsoft, Seattle, USA). Tabulation and analyses of data were performed with SPSS v16 software (SPSS, Chicago, IL, USA). Analytical endpoints included determination of mean, maximum and minimum values, calculation of percentages and ratios, and economic performance per fattening cycle.

Results and Discussion

Farmer's age, religion, experience, and training. Table 2 shows the details of the characteristic parameters studied during this study that highlight the salient outcomes about production economics and background information of crab fatteners.

A reasonable number of farmers got involved in mud crab collection and fattening business. Obtained records showed that the crab farmers' mean age is 34.56±8.29 years, with an age range of 31-40 years. Mud crab culture has enticed both young and experienced farmers and investors. Therefore, supporting initiatives such as the provision of professional training, credit supports, and other elements to enhance the value chain may have the possibility of more involvement of young farmers and enterprisers as a localized crab production industry. Up to 76% of the crab fatteners practice Hindu religion, while 24% are practicing Muslims. The religious practices and related factors may provide some meaningful inputs during the adoption of new policies in the area (Paudel & Thapa 2004). Hindus constitute the second large population in Bangladesh on a religious basis, with a relatively higher population (12.85%) living in Khulna division (BBS 2015). It is particularly important for the aptitude of the Hindu communities living in the coastal region, that are predominantly fishermen by profession and quickly take up progressive initiatives in aquaculture and fisheries sectors. The coastal landscape of Bangladesh has demonstrated significant growth of crab aquaculture during recent decades (Ferdoushi 2013; Kar et al 2016). The proliferation of crab culture began in the incidence of diseases in shrimp farms that partially brought economic impacts since 1995-96 (Karim & Stellwagen 1998). We found that crab fatteners have an average experience of 7.64±5 years with experience range between 2-21 years. On the other hand, only 38% of fatteners received formal training on mud crab culture conducted by government organizations and NGOs. Therefore, it could be inferred that the majority of the farmers practice the crab culture without professional and technical knowledge. Previous studies (Amutha 2016; Ferdoushi & Xiang-Guo 2013) have also reported inadequate knowledge of crab fattening farmers. Therefore, programs providing training and introducing farmers to the best management practices are strongly advised with higher potential to upgrade the performance of farmers.

Table 2

Parameters and characteristics of fatteners and production economics of the studied crab fattening practices

Characteristics	*Results of survey*			
	Average value	*Maximum value*	*Minimum value*	*Remarks*
Fattener age (years)	34.56±8.29			31–40 years
Experience (years)	7.64±5	21	2	
Respondent religion (%)	76% Hindus and 24 % Muslim			
Received training (%)	38%			
Pond size (ha)	0.27±0.21	0.91	0.04	
Fattening season (%)	68% wet season and 32% dry season			
Culture practice (%)	43% year-round and 57% seasonal			
Average crop period (days/crop)	46±15		32±12	7-70 days
Aquaculture type (%)	96% fattening and 4% grow-out farmers			
Production type (%)	94% polyculture and 6% crab monoculture			
Stocking density of crab (no. m^{-2})	1.0±0.5			
Average stocking size (g)	86±21 to 179±62 for both sexes		Female 60-100 and male 100-280	
Average survival rate (%)	64 to 68	87	40	
Average production (kg ha^{-1} $crop^{-1}$)	1383±67		815±22.6	
Average total cost (BDT ha^{-1} $crop^{-1}$)	316,654.00±37,042.00			
Average gross return (BDT ha^{-1} $crop^{-1}$)	514,748.00±32,056.00			
Average net profit (BDT ha^{-1} $crop^{-1}$)	198,094.00±8,387.00			
Benefit-cost ratio	1.63			
Average income increased (%)	94.11%			
Feeding schedule (no. day^{-1})	Single			
Perform acclimatization (%)	56%		44% stock directly	
Provide shelters in the pond (%)	0			
Turnover from shrimp to crab culture (%)	38%	62% of farms add crab in shrimp culture		

BDT: Bangladesh Taka.

Fattening techniques practiced. The average pond size used for crab fattening was 0.27±0.21 ha, which is in line with the previous reports by Chandra et al (2012) and Molla et al (2009). Joseph & Sathiadhas (2006) reported that the size of crab farms ranged from 0.04 to 0.8 ha in India. However, Ferdoushi & Xiang-Guo (2010) reported the average pond size as 0.07±0.04 ha in southwest Bangladesh. The largest pond (locally known as *gher*) reported in this study covered 0.91 ha area while the smallest one was 0.04 ha. It is often claimed that medium-sized water bodies are easier for the adoption of better management practices, especially for feeding, harvesting, maintenance of a sustainable environment, particularly on disease outbreak. There are varieties of pond sizes used in the coastal districts that are under use for shrimp farming. It is significantly important and wise of the farmers that the pond sizes appear to be suitable for mud crab farming for gradual transformation from shrimp to crab fattening. It is also practicable to use larger water bodies subdivided into smaller compartments using bamboo fencing for crab fattening.

Most of the crab fattening farms (~68%) included in this study were stocked during the wet season (June to November) and only 32% in the dry season (December to April (Table 2). Dana et al (2015) found that 83% of farmers preferred the November-February season as a suitable time for crab stocking. Further, the data revealed that 43% of the fattening farmers produce crabs on a year-round basis, whereas 57% practice alternate farming of 6 months' shrimp farming and six months' crab farming. This makes it an interesting case study with a glaring example for the rest of the world to follow. A possible reason for this could be that approximately 60% of crab fatteners carry out shrimp farming as a secondary occupation (Rahman et al 2015) to enhance their earnings. Further enrichment in the year-round crab culture practices may help increase in total crab production. However, to make it a success, an urgent need for an enough and steady supply of crab seeds, improved technology, and training of farmers.

The average duration of crab culture in days/crops required for fattening of both male and female crabs varied between 32 to 46 days. This investigation further revealed that the shortest period for crab fattening starts from 7 days in summer, and the most prolonged period might require up to 70 days in winter (Table 2). Some reports have calculated alternative fattening periods (e.g., 15 to 40 days by Dat (1999); 49 to 56 days by Marichamy & Rajapackiam (1999)) for improved revenue. A short crab fattening cycle is beneficial for the crab farmers as it has economically advantageous by requiring less investment for recycling/rotating capital (Rahman et al 2017). Almost 96% of crab farmers are fatteners, and the remaining are grow-out farmers. The leading reason for the growing popularity of crab fattening practice over the grow-out culture could be attributed to the higher turnover of production and lower economic risks (Keenan 1999; Shelley & Lovatelli 2011). Furthermore, lower investment requirements, easy culture techniques, less susceptibility to diseases, and tolerance of mud crabs to a wide range of environmental factors are the other obvious reasons (Khan & Alam 1992; Liong 1992; Mwaluma 2003).

A total of 94% of crab fattening farmers preferred polyculture by stocking crabs with other finfish species such as tilapia (*Oreochromis niloticus*), rui (*Labeo rohita*), catla (*Catla catla*), parshe (*Mugil cephalus*), tengra (*Mystus tengara*), bhangon (*Cirrhinus reba*), and khorsula (*Mugil corsula*), leaving only 6% of crab culture as monoculture. The polyculture of mud crab, in combination with fish, prawn, and algae, has been recommended as an alternative farming approach to avoid the production loss of shrimp farming (Shelley & Lovatelli 2011). Similarly, high profit and production, better economic returns, and advanced yield already established in polyculture experiments of mud crab with tiger shrimp, milkfish, and mullet (Marichamy & Rajapackiam 1999; Venugopal et al 2012; FAO 2015). Therefore, higher stocking density, selection of compatible species, feeding, and other management options in the polyculture of mud crab should be complemented by the recommendations of best management practices (BMP).

This study recorded an average stocking density of 1.0±0.5 crab per m^2 in the existing crab fattening systems, and the stocking ratio male to female that is consistently followed by fatteners is 1:3.35 crabs (Table 2). Such low stocking density is advantageous, having decreased investment cost, better returns, higher survival rate and

shortest payback period among commonly used fattening practices (Saha et al 2000; Venugopal et al 2012). Begum et al (2009) recommended one crab per m^2 stocking density in polyculture with shrimp. Mwaluma (2002) presented 2.12 crabs per m^2 in pen culture practices while Trino et al (1999a) suggested a stocking density of both male and female mud crabs at 0.5-1.5 crabs per m^2 with *Gracilaria*. However, Trino & Rodriguez (2001) observed the stocking density of 1.5 crabs per m^2 as an economically viable and profitable option. The higher stocking densities in crab culture usually result in low survival rates and vice versa (Baliao et al 1981).

The crab farmers stock different sizes of male and female crabs in the fattening ponds. Juvenile female crabs are stocked in sizes ranging from 60 to 110 g, and the size of male crabs ranged from 100 to 280 g in fattening ponds (Table 2). It is believed that improved production, touching 2,000-2,500 kg per ha, resulted because of the stocking of slightly large-sized juveniles for fattening (Marichamy & Rajapackiam 2001). Rahman et al (2017) displayed that most of the crab farmers purchase required juvenile crab seed from depots of local crab assembling markets, while fewer buy directly from collectors of wild stock. Since crab farmers depend on depots supplies of juveniles, therefore, depots are necessarily required to be mindful about handling and delivery of acceptable quality seeds. Having a 710 km long coastal belt with a utilized area of about 272717 ha for shrimp farming, Bangladesh harbours the immense potential for expansion of crab fattening and crab farming (DoF 2017). However, the absence of a reliable and sustainable supply of hatchery-raised seed is among the high barriers for improvement and sustainable growth of the mud crab industry in Bangladesh and other countries as well (Gaillard 2010; Marichamy & Rajapackiam 2001). Therefore, considerable efforts are essentially required in coastal aquaculture development by establishing hatchery seed technology of crab and shrimps. This will further strengthen the initiatives that take for the conservation of biodiversity and sustainability of crab farming in the marginalized coastal communities.

Survival, production, and economics. The crab fatteners reported the average survival rate from 64 to 68% of the stocked crabs overall (Table 2). The highest and lowest survival rates were recorded as 87% and 40%, respectively. Previously reported the highest survival was nearly 90% (Trino et al 1999b; Begum et al 2009; Hasanuzzaman et al 2014), although Saha et al (2000) observed the best survival rates at 93.33% in male crabs and 45% in females. However, Shelley & Lovatelli (2011) reported the crab survival rate from 27 to 40% for polyculture crops.

Our survey revealed that the high average production of crab fattening was 1,383±67 kg ha^{-1} $crop^{-1}$, whereas the average low production was estimated at 815±22.6 kg ha^{-1} $crop^{-1}$. The overall productivity of crab aquaculture in Bangladesh is reported to be 678 kg ha^{-1} (DoF 2017). In India, crab production in the polyculture system has been estimated to be 292±6.7 kg ha^{-1} $crop^{-1}$ (Venugopal et al 2012), which is much lower than in Bangladesh. Joseph & Sathiadhas (2006) presented crab production of 5,423 kg ha^{-1} for 8 crops in the fattening system. In crab fattening farms, Devaraj et al (1999), and Marichamy & Rajapackiam (2001) reported production equal to 1,870 kg ha^{-1} $crop^{-1}$. Sathiadhas & Najmudeen (2004) also noted a yield of 2,890 kg ha^{-1} $crop^{-1}$ crab production. However, it is essential to mention that the existing fattening systems displayed substantially lower production in farms than potential. Therefore, we stress on farmers training, best management practices (BMP) implementation, adoption of improved culture technologies would help boost farming productivity.

The average estimated cost of mud crab fattening was determined equal to 316,654±37,042 BDT per crop per hectare (Table 2). Types and estimates of costs incurred in crab culture are shown in Figure 2. Jahan & Islam (2016) stated the total cost of crab fattening as 729,619.00 BDT per hectare for a round of single culture crop from November to February. The lowest production cost reported for mud crab fattening is 3.14 US$ per kg (Hasanuzzaman et al 2014). A study by Joseph & Sathiadhas (2006) revealed that 99% of farmers incurred most of the production costs in fattening out of which the highest expense incurred on crab stocks purchase (about 71% of total cost) followed by feed (12%), fencing (8%), land lease (5%) and labour (4%) costs (Figure 2).

Ferdoushi & Xiang-Guo (2010) reported that seed input cost is about 74.18% for crab culture while Sathiadhas & Najmudeen (2004) reported a grand share of 87% going into the farming cost for crab fattening. In other studies, 58% reported feed cost as the 2nd highest expense (Amutha 2016). However, 42% responded fencing cost for ponds as the 2nd highest followed by labor cost and pond lease value. Improper management and insufficient feeding can promote intra-species cannibalism, resulting in reduced production (Mwaluma 2003). Hence, fatteners require improved training on acceptable farming techniques to enhance production and survival rates.

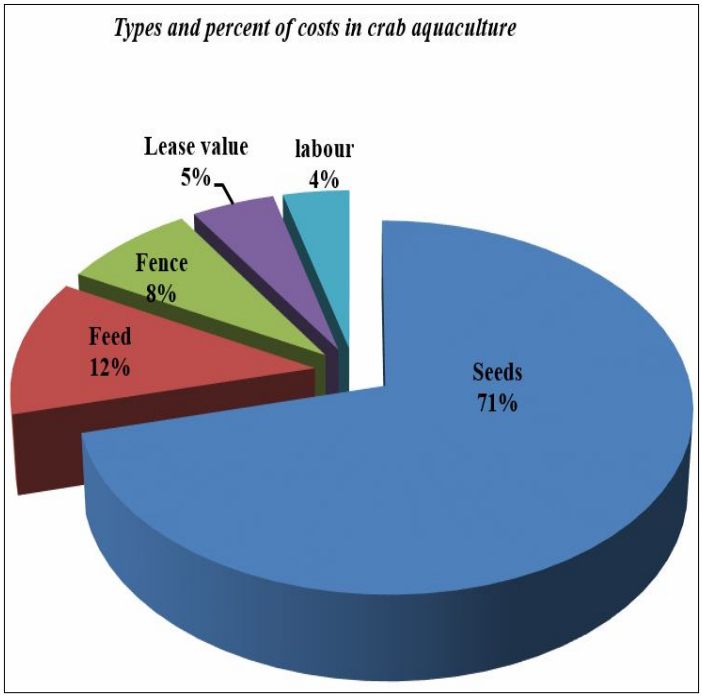

Figure 2. Results of various costs for crab culture in SW coastal Bangladesh.

The benefit-cost analysis showed the average gross return to be approximately 514,748.00±32056.00 BDT ha^{-1} $crop^{-1}$, while the average net benefit was calculated equal to 198,094.00±8387.00 BDT ha^{-1} $crop^{-1}$ (Table 2). The gross return and net profits previously recorded are 864,314 BDT $acre^{-1}$ and 13495 BDT $acre^{-1}$, respectively, in one culture period of fattening (Jahan & Islam 2016). The average gross return and net profit of crab fattening in Paikgacha and Koyra areas were assessed by nearly 1,128,602.73 BDT ha^{-1} $crop^{-1}$ and 545,164.45 BDT ha^{-1} $crop^{-1}$, respectively (Ferdoushi & Xiang-Guo 2010). However, Begum et al (2009) summarized the gross return and net profit gains of 1,110,000 BDT ha^{-1} $crop^{-1}$ and 194,687.5 BDT ha^{-1} $crop^{-1}$, respectively. Huq et al (2015) revealed that a net profit of 1,313.83 to 14,761.30 BDT $crop^{-1}$ could be earned from crab fattening in pen culture (100 m^2) for a period of 20-30 days. Additionally, mud crab fattening was found to achieve an annual profit of 30,820.80 US$ ha^{-1} $year^{-1}$, as reported by Sathiadhas & Najmudeen (2004). In our study, the benefit to cost ratio is equal to 1.63, whereas, the same was reported as 1.18 by Jahan & Islam (2016) and 1.21 by Begum et al (2009). However, Ferdoushi & Xiang-Guo (2010) documented an average benefit to cost ratio of 1.94 in mud crab fattening systems. We anticipate that the return could be enhanced in the existing fattening practices as mud crab culture offers comparatively higher returns in comparison with other coastal aquaculture systems (Rahman et al 2017).

Best management practices. Our study establishes only 56% crab growers performing acclimatization for juveniles by sprinkling with mixed saltwater and sometimes dipping into saltwater before releasing into ponds while remaining 44% stocked directly into ponds. The farmers collect crab juveniles from nearby depots that could have been collected a few days ago, that may result in substandard quality carb seed that further

decline during transportation, preservation, and handling. The seeds stocked without proper acclimatization could result in higher mortality rates. Owodeinde et al (2012) reported acclimatized fingerlings in a research experiment recovered from post-collection stress. Such preconditioning is expected to increase temperature tolerance and extend the range of passive tolerance (Beitinger & Bennett 2000; Hoffmann et al 2003; Portner 2010). None of the farmers provide any shelter facilities in the crab rearing ponds. Reportedly, the shelters could contribute to avoid or minimize the cannibalism during moulting. Crabs cultured with seaweeds have shown higher survival rates because of the protective role of seaweeds (Kathirvel et al 1997). The *Gracilaria* species may provide a safe shelter to mitigate cannibalism in crab farming systems. Shelter and size grading reportedly decrease mortality and cannibalism by 31 and 26%, respectively (Mirera & Moksnes 2015). Macrophytes are also recommended as shelter alternatives in crab farms (Mwaluma 2003).

Shift from shrimp to crab farming. Previously, mud crab was considered as a secondary crop in comparison with shrimp, prawn, and finfish farming in polyculture systems in coastal Bangladesh. Crabs were never stocked properly; instead, juvenile crabs would enter *gher* farming systems during water exchange (Baliao 2000) as undesired species. Gradually, mud crabs attracted attention as a potential candidate species in coastal aquaculture, due to soaring price and demand in local and international markets. On the other hand, shrimp farming started disease outbreaks repeatedly in the post-1995 era. Here crabs appeared as an alternative option with promising to earn via crab fattening (Khan & Alam 1992; Kar et al 2016). Our study revealed that approximately 38% of coastal shrimp farms had been wholly converted into crab fattening farms from penaeid shrimp culture. This reflects the growing popularity of crab fattening as a profiting alternative to shrimp culture (Overton & Macintosh 1997). Farmers often reported some of the desirable features of crab culture as; comparatively less susceptible to disease outbreaks, tolerant to adverse environmental conditions and abrupt changes, and most adaptable to impending climate change (Salam et al 2012). The remaining 62% of farmers routinely add crab as a supplementary crop with shrimp in their polyculture systems, as a hedge against drowning investments from repeated disease outbreaks (Marichamy & Rajapackiam 1999; Rahman et al 2015). The addition of mud crab in aquaculture is widely appreciated as profitable, with no detrimental effect on fish production or other species.

Crab harvesting and marketing. We asked the participants about possible methods of harvesting the stocked crabs. The mean percentages were recorded as DHP (direct hand picking), WDO (water drain out), HASN (hand angling with scoop net), LA (line angling), showing in Figure 3. The other types included the use of different traps (locally called *Charo, Atol*) called for the second-highest (28.70%) method of harvesting crabs. There is no percentage accounted for using cast net (CN) to catch crabs in fattening ponds. The harvesting by draining (WDO) was opted at the final stage of the crab culture crop, followed by drying out the pond for the next crop. Three additional harvest methods have also been reported as hook-and-line with a scoop net, digging out crabs burrowed in the dykes after pond drainage, and handpicking from the bottom mud (Christensen et al 2004). Shelley & Lovatelli (2011) have discussed two other methods of harvesting by using various designs of crab pot/trap with bait, and pond drainage.

Regarding the marketing, this survey indicated that 92% of fatteners sell their harvested crabs to preferred depots in nearby markets, while only 8% preferred the local middlemen (*Farias)* (Figure 4). Therefore, the depots offer a vital role in crab value chain and marketing. Previous studies do not report the marketing information, furtiveness and unfair pricing practices, grading differences from depot to depot, and from market to market among the supplier markets in the southwest coastal region (Ferdoushi & Xiang-Guo 2013; Rahman et al 2017). There are no standard storage facilities in these markets as well. Overloaded packaging systems and poor transportation lead to considerable losses by mortality. Therefore, taking special initiatives for value chain management and

improvement of marketing conditions would ensure generalized improvements and improved trade at local and international markets.

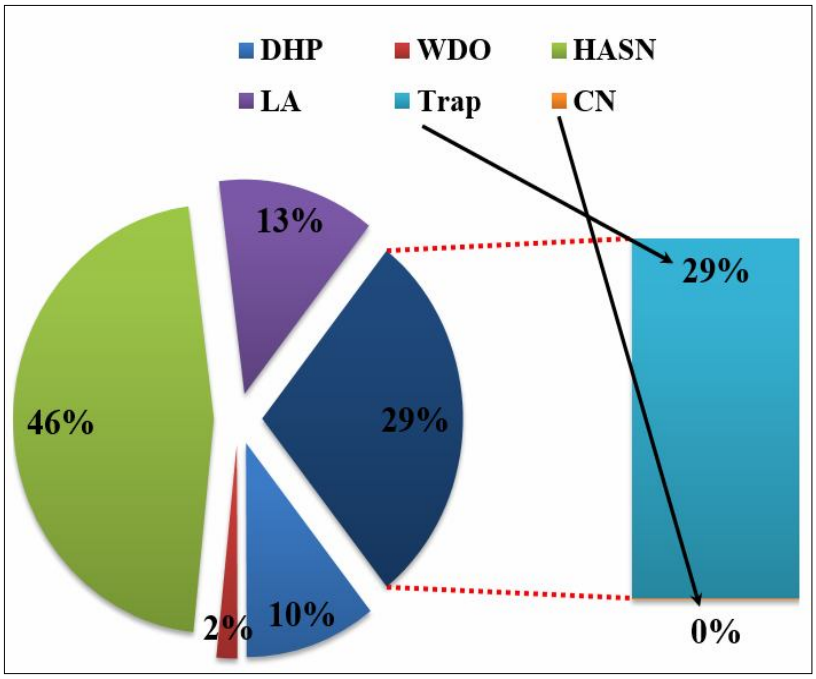

Figure 3. Percentages of various harvesting methods practice in crab aquaculture. DHP = direct handpicking, WDO = water drain out, HASN = hand angling with a scoop net, LA = line angling, CN = cast net.

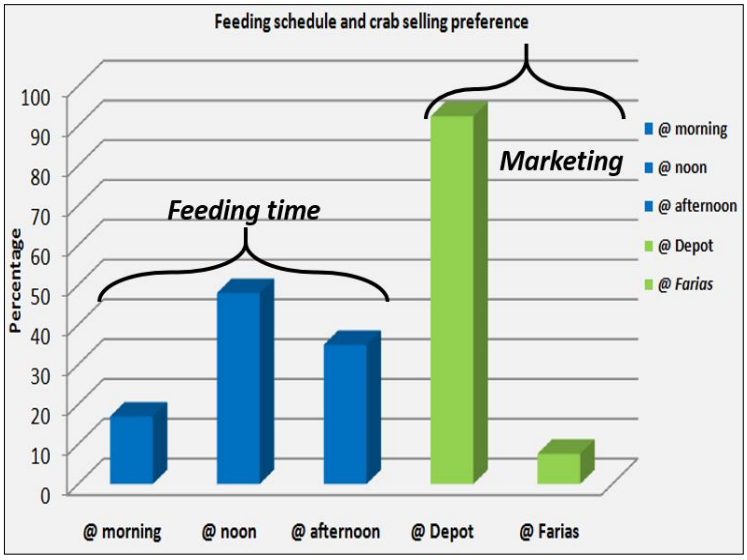

Figure 4. The figure shows the feed applying times and crab selling status.

Our survey revealed that crabs are cultured and fed on different feed types that are formulated according to the availability of ingredients at the local level. Almost 95% of farmers fed stocked crabs with fresh tilapia, being the most preferred source by farmers followed by snails and trash fish of marine and freshwater origin. Apart from these protein sources, boiled rice, poultry entrails, wheat, maize, shrimp/prawn heads, etc. were dispensed as well. Low-cost trash fishes played a vital role as major feed components of protein sources in mud crab aquaculture (Hasanuzzaman et al 2014; Huq et al 2015) and resulted in higher survival rates with better growth performance as compared to other feed types. All farmers follow a single feeding schedule for growing their stocked crabs (Mwaluma 2002). However, our findings recorded that 48% of the farmers dispensed feed to crabs at noon, 35% in the late afternoon, while only 17% in

the morning (Figure 4). Feedstuffs, their sources, and feeding strategies are critically important for aquaculture systems in general and mud crab fattening in particular. As Bangladesh is kicking off its development, precise feeding management recommendations (body weight percentage, diet, daily ration, feeding time, feeding method, and other BMP-type parameters) are particularly significant for the development and sustainable production.

Farmer satisfaction. In the end, we discuss the average income of crab fatteners that has shown an increase up to 104.1% through crab aquaculture compared to the same unit production of shrimp culture. It helps farmers in different ways such as economic uplift and resilience, improved socio-economic status, the better chances of child education, women empowerment, and their involvement in crab aquaculture. Crab fatteners generally expressed a high degree of satisfaction with crab aquaculture (Kar et al 2016) in comparison to the shrimp farming. Most of the farmers reported a higher satisfaction level with crab fattening with alternative sources of income (Ferdoushi & Xiang-Guo 2013). These findings suggest an overall preference for crab productions with feelings of satisfaction and the energetic potential of mud crab aquaculture in coastal Bangladesh.

Conclusions. This study characterized the existing cultural practices and technologies used in crab fattening in the southwest coastal region of Bangladesh by providing robust comparison and contrasts with the existing references from development perspectives. Most of the outcomes, including production, the net return, and farmer's satisfaction, reflected positivity on the prospects of further expansion of crab aquaculture. This study also identified potential areas that can be addressed to develop a sustainable crab industry in Bangladesh. Lack of professional knowledge of crab fatteners regarding improved crab aquaculture methods, sparse marketing networks, and inconsistent supply of crab seeds are some of the critical challenges that hinder the production and profitability of crab aquaculture. Our results identify the appropriate steps required by the government, private sectors, academicians, research institutions, NGOs, and most importantly, the stakeholders to further the growth potential of crab aquaculture as a viable and sustainable economic option for building resilience and well-being of disadvantaged people in the climate-vulnerable coastal regions. In conclusion, adequately developed crab aquaculture may serve as a prosperous and promising export-based trade for foreign currency earnings and supporting the livelihoods of the coastal communities.

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