Hatchery-based Mud Crab Production at BFRI Paikgacha Station, Bangladesh

Experiences, lessons learnt and way forward

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1. Introduction

Mud crab farming in the southwest of Bangladesh, as an income generating activity, has seen a sharp rise, as it is becoming more lucrative to farmers. Mud crab fetches relatively high prices and is less prone to disease related losses than shrimp farming. Additionally, mud crab farming is regarded as less vulnerable to the local effects of climate change and deterioration of water quality (World Bank 2014). The increase in mud crab farming can therefore also be interpreted as an adaptive response to deteriorating climatological and environmental conditions.

As the industry develops and the production area expands (mainly through a shift from shrimp farming to crab fattening), the demand for seed stock increases. In Bangladesh all the seed stock needed for mud crab farming is collected from the wild, with the estuaries and mangroves of the Sundarbans being the main source of seed stock for the coastal areas in the southwest. Although there are no reliable figures with regard to off take and population trends, there is serious concern that the current level of seed stock harvesting is not sustainable and might lead to a depletion of the resource.

Besides putting the integrity of the Sundarbans' eco-system and biodiversity under pressure, a crash in the wild population, from overharvesting, would also lead to a situation where the existing industry can no longer be sustained, which in turn would threaten the livelihood of a large number of people. In Bangladesh, crab cultivation supports the livelihood of more than 50,000 fishers, traders, brokers, transporters, and exporters. Hatchery production of crablets is practiced successfully in a number of Asian countries but requires considerable technical skills and knowledge, which was until recently not available in Bangladesh. Successful hatchery production at a commercial scale would reduce the pressure on wild stock from the Sundarbans and increase the availability of seed stock to serve a growing demand. This would in turn lead to higher and uninterrupted production and improved livelihoods for those involved in the value chain, especially producers (Molla et al. 2009).

Recognizing the importance of mud crab farming, the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) has been supporting the Bangladesh Fisheries Research Institute (BFRI) in further developing their mud crab hatchery technology and capacities. Support has been provided under two consecutive projects funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and jointly implemented by the Bangladesh Forest Department (BFD) and the GIZ: i) the 'Sustainable Development and Biodiversity Conservation in Coastal Protection Forests' Project (SDBC) and ii) the 'Management of the Sundarbans Mangrove Forests for Biodiversity Conservation and Increased Adaptation to Climate Change' Project (SMP).

Under the two projects, two trials for hatching of mud crabs were conducted at BFRI Paikgacha Station with technical support of consultants from the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC), Philippines. Under SMP, a considerable a number of crablets was produced in hatchery for the first time in Bangladesh.

In order to share the experiences collected during the trials and to engage other actors in the field of mud crab hatcheries in Bangladesh in an active exchange, SMP organized a one-day 'Knowledge Sharing Workshop on Mud Crab Hatcheries in Bangladesh'. During the workshop, current major challenges and proposed solutions were discussed, and a roadmap towards feasible mud crab hatchery operation in Bangladesh was developed. A broad range of stakeholders from governmental and non-governmental agencies, the private sector, and the academia participated in the workshop.

This report describes the experiences of the cooperation between the BFD and BFRI with the support of GIZ, focussing on mud crab hatchery procedures and conditions specifically in context of Bangladesh as

compared to other countries in the region. It combines the knowledge gained during the two trials at BFRI and the multi-stakeholder knowledge sharing workshop on mud crab hatchery development in Bangladesh.

First, the experiences including institutional and operational aspects will be described. Secondly, challenges encountered and recommendations on how to overcome these challenges are discussed.

The reader should see this report as complimentary to already existing information on mud crab hatcheries. While acknowledging that readily available information has been compiled in a number of publications, this document focuses on new insights considering the practical experiences and specific considerations in the Bangladesh setting. In order to place this report in the overall context, an annotated literature list is given in chapter 6 of this report, where the reader may be guided to further publications on mud crab hatcheries as desired.

Practitioners, researchers and policy makers who are interested to know about the current situation of mud crab hatcheries in Bangladesh as well as those, who want to establish a mud crab hatchery, are expected to benefit from this report.

2. Institutional Aspects

Appropriate institutional settings are a major prerequisite for any growing industry. Suitable site, infrastructural facilities, funding and other institutional arrangements are key for long term and sustainable development of any sector - including the mud crab industry. In this chapter, existing institutional facilities of BFRI, the host institution of two consecutive hatchery trials, and other institutional aspects will be discussed.

2.1. Feasibility of Facilities at BFRI Paikgacha Station

In March 2014, with the technical support from SEAFDEC, a viability assessment of available sites at BFRI's brackish water station in Paikgacha was conducted and recommendations for potential operation of a crab hatchery were formulated. The assessment focused on existing shrimp hatcheries and their potential to satisfy the needs for crab hatcheries. It is to be mentioned that not all shrimp hatcheries can be converted to crab hatcheries. Some shrimp hatcheries have big and deep tanks which are not suitable for mud crab larval culture. Repurposing of such facilities may be more expensive. If tanks used for shrimp cultivation are rather small these can be converted for crab. In the case of BFRI, the assessment by SEAFDEC was the prerequisite before starting the trials. A summary of the observations of the feasibility assessment and recommended measures taken is given in Table 1.

Table 1: Summary of findings of the feasibility assessment of BFRI's brackish water station in Paikgacha

Item assessed	Findings and measures taken
Phycology Laboratory	The facility was designed appropriately.
Maturation Tanks	Two units of concrete tanks were used to hold the broodstock. Half of the tank bottom was provided with sand. Each tank was filled with 30 ppt seawater at 0.5 m depth and provided with aeration. One tank had 4 ablated broodstock and the other tank had 6 un-ablated brood stocks.
Larval Rearing Area	The area was enclosed with blue plastic sheet. Six white fiberglass tanks 350-li were used for crab larval rearing. Two black fiberglass tanks were used for incubation and hatching of larvae. Another white fiberglass tank was used to culture rotifer.
Artemia Hatching Tank	Recycled five liter water containers were used for hatching *Artemia* cysts.
Natural Food Culture Area	Four white FGT for outdoor natural food culture were utilized. The culture tanks were fully exposed to morning and afternoon sunlight, which was beneficial for algal growth.
Reservoir	There were separate reservoirs for algae and larvae culture. Seawater was hauled from Cox's Bazar or purchased brine water from another hatchery.

While it was concluded that the facilities at Paikgacha Station are adequate to run a mud crab hatchery operation as initial trial, it would be sub-optimal for further research on improved survival rate. Therefore, the trials were initially conducted at the station while construction of a new hatchery was proposed as an essential step towards scaling up the technology (see section 2.2.).

2.2. Proposed New Hatchery Lay-out

Since the existing hatchery facilities were not specifically designed for mud crabs, a new multi-species hatchery was proposed to be constructed inside the compound of BFRI. The number and size of all types of tanks indicates the size of the hatchery. In turn, the size of the hatchery depends on the target production and the financial capability of the investor. The newly developed sample lay-out of a crab hatchery proposes a total rearing tank capacity of 50 tons resulting in a production capacity of about 120,000 crablets (stages crab instar C1 and C2) per run. The ratio of rearing tanks to natural food tanks is 1:2 to 1:2.5. With this setting, up to four runs can be conducted per year considering the framework conditions (climate etc.) of Bangladesh: Hatchery operation can be done whole year round while in context of Bangladesh, it is recommended to avoid winter and rainy season. In winter (Nov-Jan), it will be difficult and expensive to maintain suitable temperature (28-32°C) for the larvae for the whole cycle period. On the other hand, sudden temperature drops and lack of sunlight in rainy season can also increase mortality of larvae.

A mud crab hatchery design was developed for BFRI Paikgacha station by SEAFDEC under SMP (see Figure 1 and Figure 2). In the proposed new hatchery, the old fiberglass tanks are integrated, while the shapes of larval rearing tanks are different. A detailed description of the technical assumptions and required assets is given in Annex A and B.

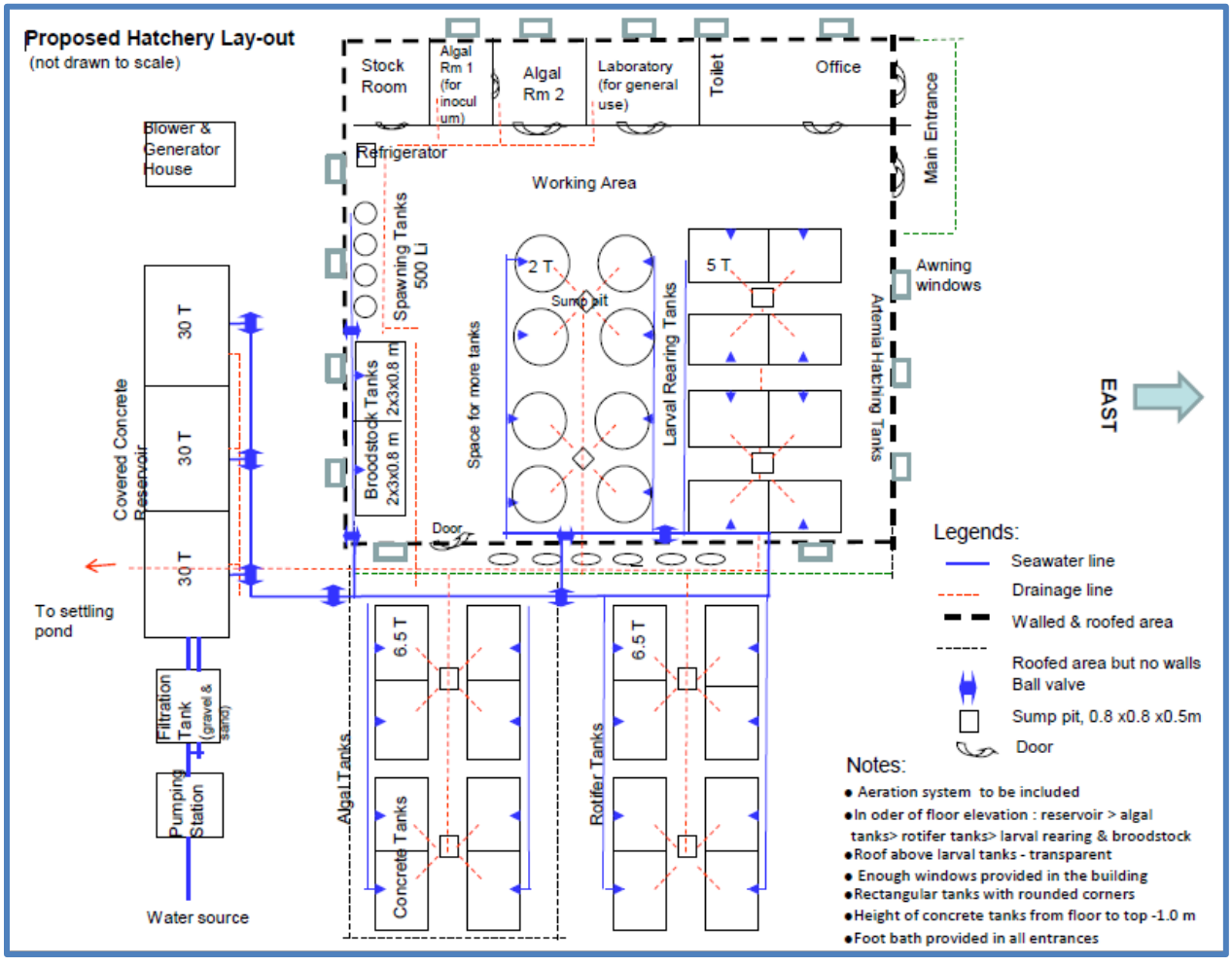

Figure 1: Mud crab hatchery lay-out newly developed by SEAFDEC under SMP (Part A: interior)

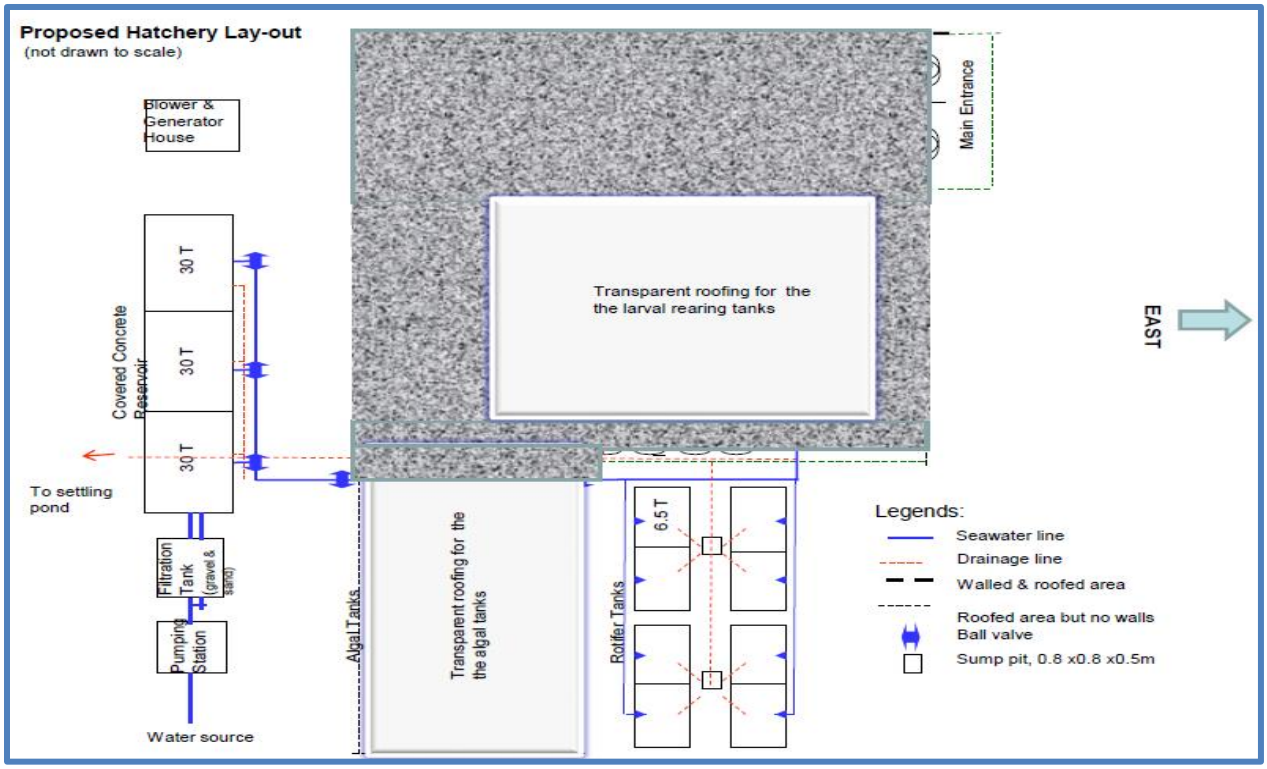

Figure 2: Mud crab hatchery lay-out newly developed by SEAFDEC under SMP (Part B: roofing)

2.3. Institutions and their Roles in the Mud Crab Sector

As a research institute, BFRI has a leading role for developing emerging fisheries technologies such as mud crab hatchery production. At the same time, there are other institutions such as government agencies, universities, NGOs and the private sector that play important roles in the mud carb hatchery development. While first steps to build up mud crab hatchery technology in Bangladesh have been taken, e.g. initial hatchery trials have been conducted, further work is needed towards economically viable mud crab hatchery operation(for more information refer to roadmap developed during the knowledge sharing workshop on mud crab hatchery development that was organized by SMP in November, 2017). For example, a strong role of the government in funding, decision making, increased coordination and collaboration among government organizations (e.g. BFD and the Department of Fisheries (DoF) under the Ministry of Fisheries and Livestock) and with other sectors (e.g. universities, NGOs, and the private sector) is indispensable for the further development of the mud crab sector in Bangladesh. While an early involvement of all relevant actors is fundamental, each sector may especially contribute in their area of expertise: The private sector should be included in a wide range of activities including investment, marketing and overall value chain development, while the NGO sector has valuable experience that can be tapped to engage with and train producers as the technology is rolled out in the field. Universities may focus on various research activities including biodiversity conservation and stock assessments as well as collaboration with international experts on mud crab hatchery development in the region.

Mud crab hatcheries cannot be successfully established and operated without applying a value chain approach, as the different segments are mutually dependent on each other. This means that other

activities beyond hatchery development need to be strengthened simultaneously so that there is a market for the output of the hatchery (crablets). For example, an intact transportation system is essential for transferring crablets to fatteners in order to avoid high mortality. It also includes nurseries, fattening, sales and others. Hence, aligning activities and interests of other actors early in this process can reduce bottlenecks and create synergies in the operationalization.

Since mud crab hatcheries are a considerably new concept in Bangladesh, the rollout of the technology and linkage to the next value chain segment, nurseries and fatteners, needs to be well prepared. This includes information and trust building, demonstration sites as well as facilities or incentives to adopt the new technology and its product. Only when investors and mud crab fatteners are convinced that the new technology is economically viable, they will take it up in their business. Addressing conservation related issues has been identified as an activity that needs to accompany the development of the sector in order to protect wild crab stocks once the sector is growing as well as alternative income generation for community members that currently depend on crablet collection from the wild. Keeping in mind the need to look at the entire value chain, Table 2 shows a list of activities that different sectors could contribute towards economically feasible mud crab hatcheries in Bangladesh (assessed during the knowledge sharing workshop on mud crab hatchery development that was organized by SMP in November, 2017).

Table 2: Mud crab activities need to be done by different institutions

Sector	Activities
Govern-ment sector	• Define clearly the institutional arrangement of FD and DoF as to their respective roles in the context of the mud crab industry in Bangladesh • Develop and establish a knowledge sharing platform • Ensure more collaboration between FD and DoF on mud crab conservation • Coordinate all activities on mud crab hatchery • Develop standard policy guidelines for the sustainable growth of the mud crab industry • Prepare clear guidelines for the issuance of certification pertaining to the mud crab industry • Subsidize the establishment of mud crab hatchery facilities adopting viable technology • Establish protocols for crab hatchery operations • Train professionals on mud crab hatchery techniques • Provide funds to support research on nutrition, diseases, live food culture, etc. • Explore the export market and work on the expansion of the domestic market
Academic sector	• Conduct research on the following topics: - Establishment of criteria for the selection of mud crab hatchery sites - Availability of good quality broodstock; development of disease-free broodstock and crablets - Improvement of survival rate from *zoea* to *megalopae* and from megalopa to crablet stage - Nutritional requirements (including protein level, P-E ratio) of larvae and crablets - Evaluation of water filtration/ treatment methods (ozonation, UV, chlorination) - Elimination/ reduction of antibiotic use; alternative to antibiotics - Determination of the breeding season of *S. olivacea*, life cycle, stock assessment - Identification of suitable sites for establishing crab sanctuaries in the wild - Validation of technology through several trials and treatments • Ensure support from experts abroad • Establish fully funded mud crab hatchery for the refinement of the technology through research and development • Train staff • Determine economic analysis of hatchery operation
Private Sector	• Investment in mud crab hatchery technology • Establish efficient and viable transport system for crablets • Develop efficient marketing including means to tap the export market • Establish suitable nursery operation • Establish grow-out technology • Engage with feed companies to produce formulated diets for crabs of various stages • Develop mud crab value chain both nationally and internationally

Table 2: Mud crab activities need to be done by different institutions *(continued)*

Sector	Activities
NGOs	• Develop nursery phase: capacity building of nursery operators and potential operators • Provide training for hatchery operators • Provide trainings and information sessions for mud crab fatteners • Establish an efficient transport system for *megalopae* and crablets to reduce mortality • Develop alternative livelihood for mud crab collectors • Engage community in mud crab conservation campaigns

Major activities concerning all sectors include improved hatchery technology, coordination, capacity building, investment, market and value chain development. In the Bangladesh context, the government holds the mandate to improve the existing technology, coordinate activities, formulate policies, etc. As an overarching topic, training of qualified staff at different segments of the value chain including hatcheries, nurseries and fattening emerged as an important topic mentioned by and for all sectors.

3. Operational Aspects

This chapter mostly includes reflections on the steps in the operation of a mud crab hatchery at different levels (see Figure 3). Detailed information concerning the technical protocol practiced at BFRI during the hatchery trials can be found in the technical reports submitted to GIZ by SEAFDEC consultants (see chapter 5: Further information on mud crab hatcheries - reading list).

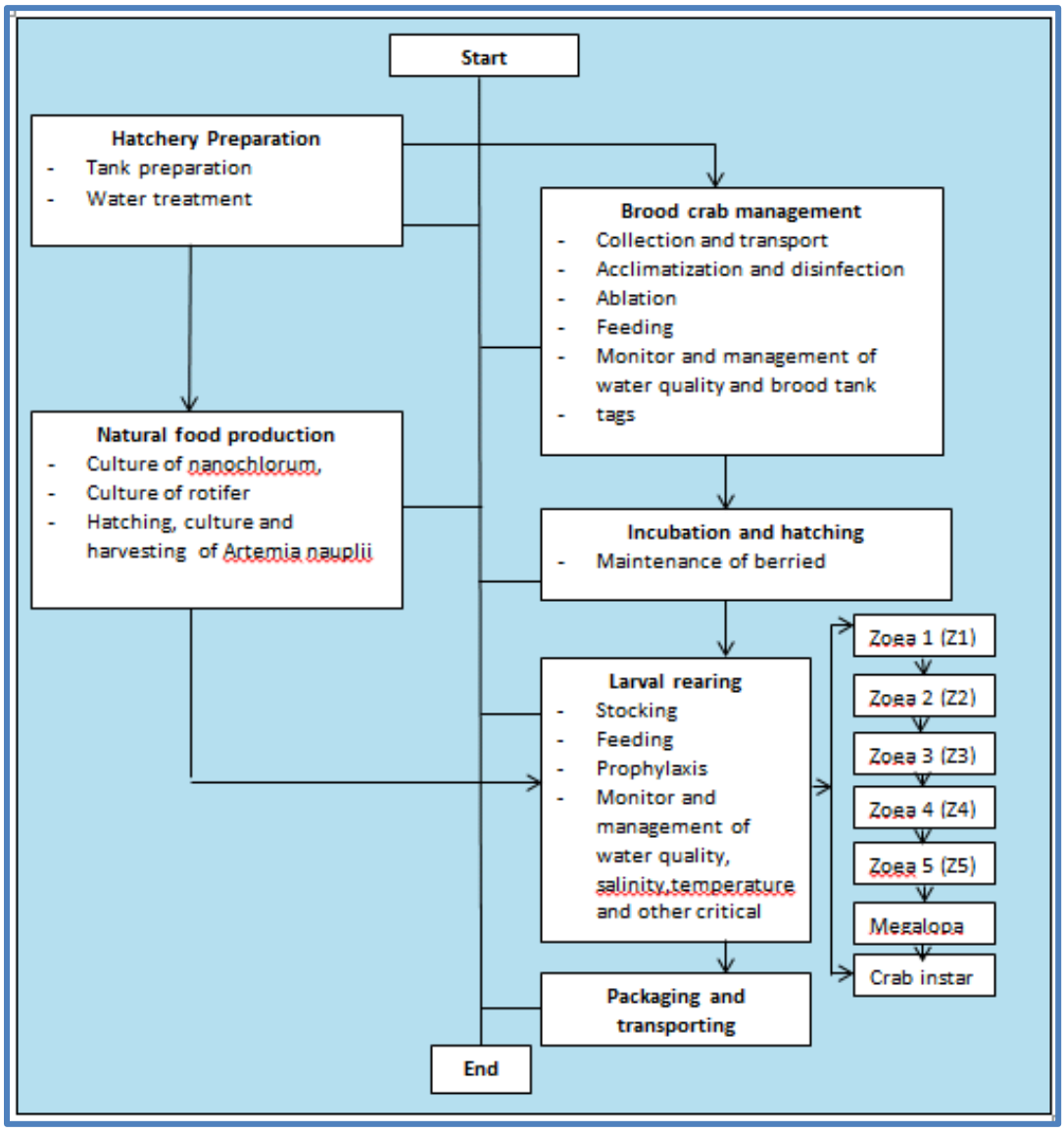

Figure 3: Flow chart of mud crab hatchery operation

3.1. Natural Food Culture

When SEAFDEC consultants arrived at BFRI to initiate the trial, all *Nannochloropsis* sp. cultured in flasks and 20-litre containers maintained in BFRI's Phycology Laboratory were contaminated with blue green algae. Only 10% of the culture was maintained (uncontaminated) and the rest was fed to rotifers. Algal starters of *Nannochlorum* sp. and *Tetraselmis* sp. supplied by SEAFDEC were used to scale up the culture. Boiled seawater to avoid biologic contamination was used for the algal cultures. Likewise, chlorinated seawater was used for 20-liter container. Unchlorinated seawater was utilized for the mass production of algae in bigger tanks. Live food production took 30 days from small bottles to mass production in bigger tanks for rotifer feeding (see Figure 4).

Figure 4: Indoor algal culture Outdoor algal culture Harvesting of rotifers

3.2. Broodstock Collection

When the SEAFDEC consultants arrived at BFRI to initiate the hatchery process, no berried crabs were available, e.g. from the concrete maturation tanks that were present at BFRI's Paikgacha Station. Hence, the collection of mature crabs as broodstock from BFRI ponds and nearby areas was done. Broodstock sampling and eyestalk ablation were performed on different dates (see Figure 5 and Table 3).

Figure 5: Ablation of mud crab broodstock

Table 3: Data on broodstock sampling

No.	Number of crab individuals	Weight range (g)	Date ablated	Source
1	4	-	-	Existing stock
2	6	120-150	April 18	Existing stock
3	3	150-180	April 24	Sourced from BFRI Pond
4	3	150-200	April 25	Sourced from Kopilmoni
5	3	100-150	May 9	Sourced from BFRI pond

From April 17 to May 31, 2016, 21 mud crab individuals were collected as broodstock. Before placing them in hatching tanks, acclimatization and disinfection was done as sudden changes in temperature and salinity can weaken broodstock, which may negatively affect larval health. In addition to that, disinfection is crucial to mitigate the risk of transferring exogenous pathogens (disease and infections) into the hatchery. According to FAO (2011), the most common treatment is application of formalin (40 percent formaldehyde) at 150–200 ppm for 30–60 minutes. Other chemicals such as potassium permanganate, malachite green and methylene blue can also be used. A regular treatment every 2–3 days for 15 minutes is recommended. Where fungal infection of eggs in brood stock facilities occurs, treatment of 0.1 ppm treflan (44 percent trifuralin) every 2–3 days can be used prophylactically. However, in the trials at BFRI a solution of 150 ppm formalin was applied for 30 minutes to disinfect berried crabs following the below steps for acclimatization and disinfection (Saracin, 2016):

- Put crabs in the empty basin and pour seawater over them slowly every 5 minutes for about 30 minutes. For berried crabs, acclimatize them until salinity and temperature are similar to the water in the hatching tank.
- Transfer crabs to a basin containing 150 ppm formalin for 30 minutes to disinfect.
- Untie crabs and stock in brood stock tanks. For berried crabs, put them in hatching tanks (one crab per tank) with adjusted seawater. Aerate moderately.

After placing brood crabs in the hatching tanks, however, not a single crab released eggs or spawned. Subsequently, all broodstock from two maturation tanks were assessed for ovarian maturity and health. Crabs have been maintained for more than two months in Tank 1. Hence, all crab individuals including those stocked in the previous month (Tank 2) were reassessed on May 13 as to their condition in terms of maturity and health. Healthy crabs were restocked in the maturation tanks, while those either damaged, small in size or with regressed ovaries were not maintained.

In Tank 1, eight out of the 15 females were restocked in the same tank after positive evaluation. Of these eight females two were unablated so that these were ablated prior to restocking.

In Tank 2, three of the six females were retained after positive evaluation. Of these three, only one was unablated. Ablation was done in this female (240 g BW and 10.2 cm CW) prior to restocking.

A detailed overview of the assessment data for fife selected brood crabs is given in Table 4.

Table 4: Assessment data for fife selected berried brood crabs

No	Date collected	Salinity (ppt)	Body weight (g)	Remarks
1	April 21	10	120	Sourced from Kopilmoni (lacks 1 claw and 4 walking legs) Multi-cell of embryonic development; Egg mass infested with protozoans; Egg mass started to be detach on the 2nd day after collection.
2	April 24	11	130	Sourced from Kopelmoni; Multi stage of embryonic development; slightly infested with protozoans; Eggs gradually detached.
3	April 24	11	110	Sourced from Kopilmoni; Naupliar stage of embryonic development; Eggs heavily infested with protozoans; subjected to Treflan bath at 0.05 ppm for 3 hours and transferred to hatching tank with new seawater. Hatching occurred on the 7th day; 455,000 larvae produced.
4	May 4	-	120	Berried crabs transported without water for 2h. Thoracico stage of embryonic development. Hatching occurred 3 days after; Larvae weak.
5	May 10	16	150	Sourced from BFRI pond with 16 ppt; Eye formation stage of embryonic development. Crab acclimatized gradually to 30 ppt for 2 days; Disinfected with 150 ppm formalin; Hatching occurred May 15, 2016; 680,000 larvae produced.

3.3. Larval Rearing

Two batches of crab larvae were produced and treated separately.

1st Batch:

Hatching of the first batch occurred on May 1, 2016. The total number of larvae produced was 455,531. About 180,000 larvae were stocked in 6 white fiber glass tanks at a culture density of 100 individuals / liter.

During the first three days, crab larvae were fed with rotifers (culture density: 10 individuals / milliliter) in the first three days. Since the quantity of rotifers was not sufficient to meet the requirement culture density of 15 individuals / milliliter, umbrella size Artemia were added at a culture density of 0.3 individuals / milliliter. Starting on day three, an artificial diet at 2 g/ton/day (divided into 4 rations) was introduced. Sediments in the tank bottom were siphoned out regularly. About 30% of the water volume was changed every five days. Prophylaxis application was done on the day of stocking and every other day until *megalopa* stage. Water temperature was recorded twice (morning and afternoon) daily.

Delayed molting of larvae from stages *zoea* 1 to *zoea* 5 and incomplete molting in the *megalopa* stage was observed. Eventually, no crab instar was produced from this batch.

2nd Batch:

Hatching of the second batch occurred on May 15, 2016. A total of 680,000 larvae were produced. About 80,000 larvae were stocked in two gray fiber glass tanks (capacity: 400-litler) and about 60,000 larvae in two white fiber glass tanks (capacity: 300-liter) positioned indoors. This was done to monitor the growth and molting of larvae in natural light intensity compared with exposure to continuous artificial (electric) light.

Larvae were fed immediately with rotifers (culture density: 15 individuals / milliliter) from *zoea* 1 to late *zoea* 2. From late *zoea* 2to *zoae* 5 crab larvae were fed with newly hatched *Artemia* at 0.5 to 1 individuals / milliliter. *Nannochlorum* sp. or *Tetraselmis* sp. were added daily at 5-10 liter / ton. Artificial feed was provided to *zoea* stages in three rations. Sediments in the tank bottom were siphoned out regularly. About 30% of the water volume was changed on day five. Prophylaxis application was done on the day of stocking and every other day until *zoea* 5 and every 3 days at the *megalopa* stage.

The growth of larvae in both outside and indoor tanks was normal from *zoea* 1 to early *zoea* 3 stages. However, the growth slowed down starting late *zoea* 3 stage, where the growth of larvae in indoor tanks was slower than that in outdoor tanks. As a consequence, the *zoea* 4 cultured indoors were transferred to the outdoor tanks where light conditions were better. Due to limited seawater availability, all larvae were transferred in one tank (capacity: two tons). Recycled seawater was used for larval rearing. Larvae in the indoor tank that had delayed molting were discarded due to high mortality.

Zoea 4 and 5 were observed to be actively swimming and consumed a lot of *Artemia*. On May 29, some *zoea* 5 started to molt to *megalopa* stage. Water change of only about 10% was done on the same day. To avoid cannibalism, bigger *Artemia* were introduced. *Zoae* 5 and *megalopa* were still active on the succeeding days. However, some larvae were found dead on day 17. On day 18, minced fish was added as food for *megalopa*. On day 19, seven newly molted crab instars were observed in the tanks. The same monitoring procedure was followed as for the first batch.

4. Challenges Identified During Trials at BFRI

During the trials of mud crab hatchery technology at BFRI's Paikgacha station, some challenges were identified as described below.

Hatchery facilities and infrastructure:
When the trial of mud crab hatchery technology started in Bangladesh, there was no hatchery constructed specifically for mud crab. In the framework of the cooperation with BFRI, a hatchery for shrimp and fish production was used for the trial of mud crab hatchery technology. As a consequence of this re-purposing of the hatchery facilities, certain difficulties emerged concerning larval rearing, because the present facility was not specifically designed for this. In particular, inappropriate infrastructure posed challenges related to a lack of seawater supply, natural light, proper aeration, seawater and drainage systems and biosecurity. Such measures can be addressed by establishing a hatchery specifically designed for mud crab (see chapter 1.2 Proposed New Hatchery Lay-out).

Figure 6: BFRI Paikgacha hatchery view from outside

Seawater supply:
Because of the distance from BFRI's Paikgacha hatchery to the sea, seawater supply for the broodstock, larvae and natural food cultures (for scale up) throughout the operation was limited. Brine water was sourced from Cox's Bazar and can be expensive due to transport cost, etc. There might also be a problem of insufficient seawater supply for the hatchery during rainy season because the salinity of the water source near Paikgacha station will decrease even more.. Because of the limited water supply, regular water change could not be undertaken for broodstock and larval cultures. For the same reason, water was reused after treatment at the later stage of larval rearing, which could have affected the broodstock and larval performance, respectively. Availability of clean seawater with a sufficiently high salinity has been identfied as one of the cricial factors determining the succes of mud crab hatchery production.

Power supply:
Interrupted power supply is a frequent problem not only in Paikgacha but also other rural areas in Bangladesh. Continuous power supply is crucial for maintaining an adequate temperature on the hatchery ground and the live feed laboratory. Continuous aeration, which depends on power supply also, is likewise vital for larval rearing. Alternative power supply by a generator can reduce the problem on a temporary basis.

Availability of berried Crab:
There were no berried crabs at BFRI Paikgacha station when the trial was started. The large distance to the sea made it difficult to collect any berried crabs from nature. Since there were no berried *S. olivacea* females to be obtained from BFRI concrete maturation tanks neither, berried females were sourced from the nearby area such as ponds. In total, 21 individuals were collected as broodstock and maintained in maturation tanks (first batch). However, not a single of these crabs released eggs or spawned. In a second batch, berried females were collected from a local fattening farm, with relative low salinity. The low salinity at the brood stock source, negatively affected the production and survival of crablets as compared to broodstock sourced from a high salinity environment.

Live feed culture technology:

Figure 7: *Nannochloropsis* sp used as live feed contaminated by blue green algae

Live feed culture is a crucial part of hatchery-based production of mud crab. The microalgae used as live feed can be easily contaminated through improper handling related to a lack of technical knowledge. During the hatchery trials at BFRI, all *Nannochloropsis* spp. cultured in flasks and 20-liter containers maintained in the Phycology Laboratory were contaminated with blue green algae (see Figure 7). Only 10% of the culture was left uncontaminated. The problem was solved by scaling-up the culture again by external algal starters of *Nannochlorum* sp. and *Tetraselmis* sp. supplied by SEAFDEC.

Lack of expertise:
In Bangladesh, the mud crab hatchery technology is comparatively new. The market has only recently emerged and is still relatively unexplored (niche market). Consequently, technical expertise in mud crab hatchery operation is not widely spread and skilled personnel are hard to find. While this was one of the reasons for this trial at BFRI to be supported by SEAFDEC, an internationally renowned institution with many years of experience in the mud crab sector (e.g. Philippines), lack of expertise remains a common yet vital problem in Bangladesh. Further training to stimulate knowledge transfer through hiring international mud crab hatchery experts can be considered to address this bottleneck.

Nursing technology:
Since the mud crab sector is an emerging market in Bangladesh, other elements of and linkages with the entire value chain are not yet in place. Nursing technology, for instance, is yet to be developed. This is a crucial aspect as nurseries build the next sequence after a hatchery in the value chain. In the absence of a hatchery as potential customer of crablets, it was challenging to identify which development stage and size of crablets will be suitable for farmers to adopt for grow up. In order to make mud crab hatcheries economically viable, a value chain approach beyond the hatchery operation has to be applied.

5. Recommendations

The trials at BFRI constituted a valuable learning process for all stakeholders involved. This learning process will be continued beyond the trials on the way toward economically feasible mud crab hatcheries in Bangladesh. Below, the most important recommendations that came up from both the trials at BFRI supported by SEAFDEC consultants and the multi-stakeholder knowledge sharing workshop on mud crab hatchery development organized by SMP are listed.

5.1. Technical Recommendations

Hatchery facilities:

- Sufficient seawater supply for regular water change is important. In the case of insufficient seawater supply, such as it was the case for BFRI's Paikgacha station, enough brine water has to be stored in a reservoir before starting the trial to guarantee continuous supply to the hatchery. Recycled water is not advisable to be used for larval rearing.
- It is advised that rotifers and natural food cultures are maintained under natural light intensity as compared to artificial light.
- Continuous aeration for larval rearing and algal cultures needs to be in place.
- Hatchery technical layout including natural light, proper aeration, seawater and drainage systems should be appropriate for mud crab production. This can be addressed through the proposed construction of a multi-species hatchery as designed under the cooperation between SMP and BFRI (see Proposed New Hatchery Lay-out). Newly proposed government-funded interventions in this sector open a window of opportunity to establish adequate infrastructure and increase ownership by government operators of the hatchery.
- The basic mud crab hatchery technology has been developed, but necessary modifications have to be done based on the conditions in a particular country. In the context of Bangladesh, sites should be carefully selected considering all criteria before establishing mud crab hatcheries.
- It is worthwhile to compare the economics of putting up a mud crab hatchery (multi-species hatchery) in Paikgacha compared to Cox's Bazar / other sites. In the latter case, seawater is abundant, but transport costs of crablets to the southwest, where most of the farms are situated, are comparatively higher. In the case of the hatchery operations at Paikgacha, seawater is purchased from Cox's Bazar which constitutes a significant cost factor. However, reduced transport cost and stress (reduced mortality) to the crablets could well offset the cost of seawater transport.

Broodstock sourcing:

- It is important that berried females for hatchery operation originate from a higher salinity environment with a salinity of around 30 ppt. In relation to that, timely supply of broodstock to the hatchery is another logistic consideration to be taken into account when planning mud crab hatchery establishment and operation (see above).

Broodstock management:

- For broodstock management, regular water change of 30-50% is recommended to be done twice a week.
- Sufficient supply of hypochlorite for disinfection purposes and biosecurity measures for the whole hatchery area should be in place.

Live feed:

- The quality of the natural food (microalgae) has to be examined regularly to avoid scaling-up of contaminated cultures. This may lead to cultivation of undesired species and collapse of the culture.
- Supplementation of diets, rotifers and *Artemia* enriched with Docosahexaenoic acid and Eicosapentaenoic acid, can be used to reduce incomplete molting of larvae.
- Brood stock maturation can be further improved by feeding squid, marine worms, and other food items high in highly unsaturated fatty acids, carotenoids, protein (5-10%) and other nutrients required for maturation.

5.2. Institutional Recommendations

Coordination and knowledge sharing:

- Different actors and initiatives have been active in further developing the mud crab hatcheries and the further value chain. Effective coordination and collaboration of activities and different sectors is fundamental to avoid duplications and benefit from synergies. . Therefore, a joint strategy needs to be developed and agreed upon by all sectors. Under this umbrella, each sector's contributions may focus on the area of their respective expertise in a coordinated way.
- Knowledge sharing among the different actors can be achieved through establishment of an institutionalized platform for knowledge exchange i.e. technical working group.. Government agencies (including the BFD, DoF and BFRI) should take the lead in establishing such a platform and create an enabling environment for cross-sectoral coordination and collaboration. The knowledge sharing workshop organized by BFD with support of SMP constituted a first attempt to bring together relevant actors for further development and commercialization of hatchery technology.

Manpower:

- Sufficient manpower including skilled laboratory technicians is required for proper operation of a mud crab hatchery. Since any changes in water temperature and quality, feed requirements, morphological features and behavior, appearance of biological contamination, etc. require an immediately management response in order to minimize mortality of larvae permanent monitoring needs to be ensured. Commitment of the institution needs to be high in order to fulfill the requirements of the demanding operating procedures in the hatchery and laboratory.
- In the case of BFRI (and any other institution that wishes to engage in mud crab hatchery development), it is recommended to permanently designate one staff as focal person to undergo training on all aspects of culturing mud crab (hatchery, nursery and grow-out) i.e. at SEAFDEC.

Scale-up and outlook:

- A harmonized approach across all sectors is essential for establishing economically viable mud crab hatcheries in Bangladesh. This especially concerns early involvement of the private sector join in developing the hatchery technology and build-up of nurseries / fattening installations to receive hatchery-produced crablets. Other value chain segments like transportation and feed production also need to be built up at the same time. However, the readiness of the private sector to take over currently government-led efforts is not yet in place and needs to be further stimulated for a roll-out. Roles of the BFD, DoF and other government agencies include information sessions, trainings and demonstrations to investors and fatteners, creation of an enabling environment and incentives to engage in the new technology, support to better coordination and policy formation.
- On the long term, areas that require further support include: continuous improvement of hatchery technology; capacity building for hatchery and nursery operators as well as fatteners; value chain and market development; networking and exchange with other countries in the region that have successfully developed mud crab hatcheries; research and investment in appropriate infrastructure.

6. Further Information on Mud Crab Hatcheries - Reading List

Table 5 list the most important publications related to mud crab hatcheries for further reading. A distinction is made between i) technical documents including manuals and guidelines, ii) scientific articles and assessments, and iii) other formats including videos. Complementary to this report, this list is intended to point the reader towards information that is readily available and has in many cases been compiled by a plentitude of experiences and research. This literature compilation may be useful for practitioners, researchers and policy makers who are interested to know about the state of the art of mud crab hatchery technology and further considerations concerning the mud crab sector.

Table 5: List of publications related to mud crab hatcheries including their online source, where available

Title	Author	Short description	Web-link
Technical documents (manuals, guidelines etc.)			
Report on the consultancy and supervision of mud crab hatchery operation and mud crab instar production at the Bangladesh Fisheries Research Institute Paikgacha, Khulna, Bangladesh		Consultant's report in the framework of the first trial under GIZ describing the protocol, observations and recommendations at the Bangladesh Fisheries Research Institute, Paikgacha	Please contact GIZ -SMP through: oemar.idoe@giz.de
Report on the development of mud crab hatchery and nursery techniques in Bangladesh Fisheries Research Institute, Paikgacha (1st visit)	GIZ – SMP	Consultant's report in the framework of the second trial under GIZ describing the protocol, observations and recommendations during the first visit to the mud crab hatchery trial at the Bangladesh Fisheries Research Institute, Paikgacha, as of May 2016	Please contact GIZ- SMP through: oemar.idoe@giz.de
Report on the development of mud crab hatchery and	GIZ – SMP	Consultant's report in the framework of the second trial under GIZ describing the protocol, observations and recommendations during the second visit to the mud crab	Please contact GIZ -SMP through: oemar.idoe@giz.de

nursery techniques in Bangladesh Fisheries Research Institute, Paikgacha (2nd visit)		hatchery trial at the Bangladesh Fisheries Research Institute, Paikgacha, as of June 2016	
Technical report on the supervision of mud crab hatchery operation at Bangladesh Fisheries Research Institute	GIZ – SMP	Consultant's report in the framework of the second trial under GIZ describing the protocol, observations and recommendations during the entire mud crab hatchery trial at Bangladesh Fisheries Research Institute, Paikgacha	Please contact GIZ -SMP through: oemar.idoe@giz.de
Detailed Protocol on the Hatchery Operation	Southeast Asian Fisheries Development Center/Aquaculture Department (SEAFDEC/AQD), Emilia T. Quinitio and Sharon A. Saracin	Detailed technical protocol of the methods applied during the mud crab hatchery trial at the Bangladesh Fisheries Research Institute, Paikgacha,	Please contact SEAFDEC http://www.seafdec.org.ph
Hatchery & nursery of mud crab	Southeast Asian Fisheries Development Center/Aquaculture Department (SEAFDEC/AQD)	Description of the hatchery and nursery technology of mud crab.	http://www.seafdec.org.ph/2011/hatchery-nursery-of-mud-crab/
Seed production of mud crab *Scylla* spp.	Emilia T. Quinitio, Fe Dolores Parado-Estepa and Eduard Rodriguez	This article briefly described crab farming, breeding, nursery, larval rearing, and grow out techniques.	http://library.enaca.org/AquacultureAsia/Articles/July-Sept-2002/Seed_production_mudcrab.pdf
Training Manual on Mud Crab Breeding and Culture	Indian council of agricultural research	A training manual on mud crab breeding and culture in India that includes topics like biology, hatchery, live feed culture, nursery, grow out, diseases, mud crab marketing and economics.	http://www.ciba.res.in/Books/ciba0186.pdf

Starting a mud crab hatchery	Junelyn S. de la Rosa	This article briefly describes crab species, breeding, feeding, nursery, larval rearing, and growout techniques in the Philippines.	http://www.bar.gov.ph/digest-home/digest-archives/83-2004-1st-quarter/3183-jan-mar04-starting-a-mud-crab-hatchery
Mud crab aquaculture: Breeding and Farming	Queensland Government, 2014	This guide provides an overview of mud crab aquaculture in Queensland.	http://www.business.qld.gov.au/industry/fisheries/aquaculture/aquaculture-species/mud-crab-aquaculture/breeding-mud-crabs
Seedling Production Of Mud Crab Scylla Serrata	UK Essays, web publications	This web publication treats the current status of mud crab production in Malaysia as well as existing broodstock and larval rearing practices.	http://www.ukessays.com/essays/biology/seedling-production-of-mud-crab-scylla-serrata-biology-essay.php
Scoping study for mud crab farming in Bangladesh – Part 1	Shelley, YH & CC Shelley Pty Ltd	The report gives an overall picture of the status of the mud crab industry, challenges and its scope.	
Scoping study for mud crab farming in Bangladesh – Part 2	Shelley, YH & CC Shelley Pty Ltd	The report gives an overall picture of the status of the mud crab industry, challenges and its scope.	http://www.worldfishcenter.org/resource_centre/Final-Report-Mud-Crab-Bangladesh-March-2013.pdf
Mud crab aquaculture: A practical manual	Colin Shelley, FAO Consultant, Australia and Alessandro Lovatelli, Aquaculture Officer, Aquaculture Service, FAO Fisheries and Aquaculture	This manual attempts to showcase the current wisdom on mud crab farming from key nations in the Asia-Pacific region where research and development, significant industry development and extension of technology have occurred in recent years.	http://www.fao.org/docrep/015/ba0110e/ba0110e.pdf

	Department Rome, Italy.		
Experiments on larval rearing and seed production of the mud crab *Scylla serrata* (Forskal)	R Marichamy and S Rajapackiam of the Central Marine Fisheries Research Institute, Cochin, India	Describes *Syclla serrata* metamorphosis into the crab stage, hatching, incubation period of berried female, embryo development, the effect of temperature and salinity on survival and development of the crab larvae is well described in this document. This also includes improved feeding strategies and water quality management.	ftp://ftp.fao.org/docrep/fao/007/ad840e/ad840e06.pdf
Transport and handling of live crabs	Dr. Burke Hill, CSIRO marine laboratories, Australia	Discusses the transport method and proper handling of live crab.	
Diseases in Farmed Mud Crabs *Scylla* spp.: Diagnosis, Prevention, and Control.	Celia R. Lavilla-Pitogo, Leobert D. de la Pena Aquaculture Department Southeast Asian Fisheries Development Center (SEAFDEC)	Described about diseases on eggs, larvae, juvenile and adult stage of mud crab and their diagnosis methods.	http://www.seafdec.org.ph/wp-content/uploads/2012/11/Diseases-in-Farmed-Mud-Crabs_complete1.pdf
Mud crab farming	Roysfarm	The publication includes culture method of mud crab on small scale basis	http://www.roysfarm.com/mud-crab-farming/
Culture of Mud Crab, *Scylla serrata* in Bangladesh	Bdfish	The publication includes culture method of mud crab in Bangladesh on small scale basis	http://en.bdfish.org/2011/02/culture-mud-crab-scylla-serrata/

Seed Production of Mud Crab *Scylla serrata* Juveniles	Emilia.T. Quinitio, F.D. Parado-estepa, O.M. Millamenia, E. Rodriguez and E. Borlongan. Aquaculture Department Southeast Asian Fisheries Development Center Tigbauan, Iloilo, Philippines	A protocol for the large-scale rearing of the mud crab *Scylla serrata* juveniles based on the results of small-scale experiments on feeding and water management. This paper also reports the success in producing the second generation (F2) crabs.	http://www.asianfisheriessociety.org/publication/pdf/0938266001355880924.pdf
Evaluation of the seed production and grow out culture of blue swimming crab in India	G Maheswarudu, JosileenJose, K. R. Manmadhan Nair, M. R. Arputharaj, A Ramakrishna, A Vairamani and N. Ramamoorthy. Crustacean Fisheries Devision, Mandapam regional centre of Central Marine Fisheries Research Institute, Tamil Nadu, India	A protocol for seed production, nursery rearing and grow-out culture of blue swimming crab, based on experiments conducted with different larval density.	http://nopr.niscair.res.in/bitstream/123456789/2054/1/IJMS%2037(3)%20313-321.pdf
Larval rearing and seed production of mud crab *Scylla tranquebarica*	Thirunavukkarasu. N, Sheeba Anitha Nesakumari. C, A. Shanmugam. A	Detailed seed production technology and larval rearing practice of mud crab *Scylla tranquebarica.*	http://fisheriesjournal.com/vol2issue2/Pdf/65.1.pdf

Scientific articles and assessment studies			
Investigations into the Reproductive and Larval Culture Biology of the Mud Crab, *Scylla paramamosain*: A Research Overview	Shaojing Li, Chaoshu Zeng, Hong Tang, Guizhong Wang and Qiongwu Lin	Reviews a series of studies on reproductive biology and larval cultural biology, as well as mass rearing of mud crab seeds, *Scylla paramamosain*, that have been carried out by the mud crab research group in the Department of Oceanography, Xiamen University, China, since 1985 up to date.	http://researchonline.jcu.edu.au/28595/
Improved hatchery-rearing techniques for juvenile production of blue swimming crab, *Portunus pelagicus* (Linnaeus, 1758)	Mhd Ikhwanuddin, Juariah Hafsya Mansor, Abol-Munafi Ambok Bolong & Shabdin Mohd Long from Institute of Tropical Aquaculture, Universiti Malaysia Terengganu, Kuala Terengganu, Terengganu, Malaysia and Faculty of Science and Resource Technology, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia	Hatchery-rearing techniques of blue swimming crab (*Portunus pelagicus*) is described in a scientific article.	http://www.google.com.bd/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CCAQFjAA&url=http%3A%2F%2Fwww.researchgate.net%2Fpublication%2F234017337_Improved_hatchery-rearing_techniques_for_juvenile_production_of_blue_swimming_crab_Portunus_pelagicus_%2528Linnaeus_1758%2529%2Flinks%2F02bfe50e4d5898ec83000000&ei=ZL9yVN2SMo_JuATmuICYCw&usg=AFQjCNFe-xJv_DcToKgIrG37Q1EImatg5w

Investigation of an Artemia-based Diet for Larvae of the Mud Crab *Scylla serrata*	D.L. MANN, T. ASAKAWA, M. PIZZUTTO, C.P. KEENAN and I.J. BROCK from QDPI, Bribie Island Aquaculture Research Centre, Australia	Techniques for the mass propagation of the mud crab *Scylla* spp. in hatcheries utilizing a Artemia-based diet. A series of experiments was designed to test the performance of the nauplii of different commercially available Artemia cyst products, sourced from various geographic regions, and nauplii enriched with a commercial lipid emulsion.	http://www.vliz.be/en/imis?module=ref&refid=53843&printversion=1&dropIMIStitle=1
Effects of temperature and salinity on the survival and development of mud crab, *Scylla serrata* (Forsska°l), larvae	Rahmi Nurdiani & Chaoshu Zeng Tropical Crustacean Aquaculture Research Group, School of Marine and Tropical Biology, James Cook University,Townsville, Qld 4811, Australia	The combined effects of temperature and salinity on larval survival and development of the mud crab, *Scylla serrata*, were investigated in the laboratory and the result described in the article.	http://www.researchgate.net/publication/229484802_Effects_of_temperature_and_salinity_on_the_survival_and_development_of_mud_crab_Scylla_serrata_%28Forsskl%29_larvae
Optimal Water Temperature and Salinity for Production of Blue Swimming Crab, *Portunus pelagicus* 1st Day Juvenile Crab	Mhd Ikhwanuddin, Mohamad N. Azra, Mir A.D. Talpur, Ambok B. Abol-Munafi, Mohammad L. Shabdin	The study recommended the optimal water temperature and salinity for the larvae rearing of blue swimming crab, *P. pelagicus*.	http://www.bioflux.com.ro/docs/AACL_5.1.2.pdf
Dietary cholesterol requirement of juvenile mud crab *Scylla serrata*	Shyn-Shin Sheen. Department of Aquaculture, National Taiwan Ocean University, Keelung 202, Taiwan	The effect of dietary cholesterol on growth, molting frequency and survival of juvenile mud crab, *Scylla serrata* was investigated using semi-purified diets.	http://www.researchgate.net/publication/222700108_Dietary_cholesterol_requirement_of_juvenile_mud_crab_Scylla_serrata

Evaluation of four dietary protein sources for use in microbound diets fed to megalopae of the blue swimmer crab, *Portunus pelagicus*	Sarah Castine, Paul C. Southgate, Chaoshu Zeng Tropical Crustacean Aquaculture Research Group, School of Marine and Tropical Biology, James Cook University, Townsville, Queensland, Australia	Microbound diets (MBD) with four different dietary protein sources (fish meal, squid meal, krill meal and soybean meal) were fed to newly molted *megalopae* of blue swimmer crab until they metamorphosed to the first crab stage. The result of the study shows interesting findings.	http://www.sciencedirect.com/science/article/pii/S0044848608004079
Nutritional significance of n-3 highly unsaturated fatty acids for larval survival and development in mass seed production of brachyuran crabs	Shigeki Dan, Katsuyuki Hamasaki, Takayuki Kogane, Tadao Jinbo, Takashi Ichikawa Fisheries Research Agency, Tokyo University of Marine Science and Technology	The presentation includes research outcome that combined effects of environmental factors (salinity) and dietary n-3HUFA on survival and development of larvae of the mud crab.	http://www.lib.noaa.gov/retiredsites/japan/aquaculture/presentation_slides/36th/Dan.pdf
A review of recent progress toward development of a formulated microbound diet for mud crab, *Scylla serrata*, larvae and their nutritional requirements	May-Helen Holme, Chaoshu Zeng , Paul C. Southgate	This article presents an overview of recent progress on the nutrition of *Scylla serrata* larva and its implications in feed formulation.	http://www.sciencedirect.com/science/article/pii/S0044848608006947
Hatchery feeds for the mud crab *Scylla serrata*: towards a nutritionally complete diet	David Mann, Tom Asakawa, Morris Pizzutto, Clive Keenan and Ian Brock	The experiments compare the survival and growth of mud crab larvae fed with nine types of Artemia nauplii hatched from cysts.	

Impacts of mud crab hatchery technology in Vietnam	Bob Lindner Economic Research Associates and School of Agricultural and Resource Economics University of Western Australia. ACIAR projects FIS/1992/017 and FIS/1999/076	This report describes the benefit–cost analysis carried out to quantify the economic impacts in Vietnam from two projects. In addition, their potential impact on poverty in Vietnam is assessed qualitatively.	http://ageconsearch.umn.edu/bitstream/113214/2/IAS36.pdf
Feasibility study on the culture of mud crab *Scylla serrata* in the mid coastal region of Bangladesh	A. I. Mahmub and Abdullah al Mamun; Department of Fisheries and Marine Science, Noakhali Science and Technology University, Bangladesh	A feasibility study of mud crab culture in Bangladesh. The study was conducted at Hatia and Nijhum island, Noakhali.	http://scialert.net/qredirect.php?doi=pjbs.2012.1191.1195&linkid=pdf
Capture-based aquaculture of mud crabs (*Scylla spp*.)	Colin Shelley YH & CC Shelley Pty. Ltd Brisbane, Australia	This paper provides an overview of the issues, needs, opportunities and risks in trying to maintain sustainable mud crab fisheries, whilst supporting the ecologically sustainable development of mud crab aquaculture.	http://www.fao.org/3/a-i0254e/i0254e13.pdf
Genetic and morphological relationships of mud crabs, genus *Scylla*, from throughout the Indo-Pacific	C.P. Keenan, D. Mann, S. Lavery and P. Davie. Project final report.	Includes genetic and morphological relationships of mud crabs, genus Scylla, from throughout the Indo-Pacific.	http://aciar.gov.au/files/node/9672/Final%20report%20FIS-1992-017.pdf
Mud Crab Culture as an Adaptive Measure for the Climatically Stressed Coastal Fisher- Folks of Bangladesh	Khandaker Anisul Huq, S. M. Bazlur Rahaman, and A. F. M. Hasanuzzaman, Fisheries and Marine Resource Technology	Treats on-farm adaptive research on crab fattening/culture in Barguna and Patuakhali districts as a livelihood option for the fisher folks including females. The study was conducted from September 2010 to August 2012.	http://link.springer.com/chapter/10.1007%2F978-3-319-06305-8_7#page-1

	Discipline, Khulna University ,Bangladesh		
Mud Crab Aquaculture and Biology	C.P Keenan and A. Blackshaw. Proceedings of an international scientific forum held in Darwin, Australia. Australian Centre for International Agricultural Research.	The article includes several scientific papers covering different fields of mud crab including genetics and ecology, growout in ponds and mangroves, broodstock, diet, larval rearing, larval ecology and rearing of mud crab.	http://aciar.gov.au/files/node/586/pr78-part1.pdf
Mud crab aquaculture in Australia and Southeast Asia	Geoff Allan and Don Fielder (edited by). Proceedings of the ACIAR Crab Aquaculture Scoping Study and Workshop 28–29 April 2003, Joondooburri Conference Centre, Bribie Island	The publication includes several scientific papers covering different topics including commercial production, seed production, feeding practice, nutritional and grow-out status of mud crab in different countries.	http://aciar.gov.au/files/node/531/wp54web.pdf
Effects of temperature on the egg incubation period, survival and developmental period of larvae of the mud crab *Scylla serrata* (Forskål) (*Brachyura: Portunidae*) reared in the laboratory	Katsuyuki Hamasak, Aquaculture journal	This study examined effects of temperature on the egg incubation period, survival and developmental period of larvae of the mud crab *Scylla serrata* reared in the laboratory.	http://www.sciencedirect.com/science/article/pii/S0044848602006622

Diet particle size preference and optimal ration for mud crab, *Scylla serrata,* larvae fed microbound diets	Jerome Genodepa, Paul C. Southgate, Chaoshu Zeng, Aquaculture Journal	This paper reports on experiments to determine particle size preference and optimal ration for the various larval stages of the mud crab, *Scylla serrata*, fed microbound diets.	http://www.sciencedirect.com/science/article/pii/S0044848603006136
Ingestion of *Brachionus plicatilis* and *Artemia salina* nauplii by mud crab*Scylla serrata* larvae	Juliana C Baylon, Ma Eugenie A Bravo and Nancy C Maningo, Aquaculture Journal	In this study, two feeding experiments were conducted to determine the food intake by crab larvae. The experiment was done by using *Brachionus plicatilis* and *Artemia salina* nauplii.	http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2109.2004.00987.x/abstract;jsessionid=6FCB63C536B6AFA44769C78C648DD6AF.f04t01?deniedAccessCustomisedMessage=&userIsAuthenticated=false
Effects of tank colour on larval survival and development of mud crab *Scylla serrata* (Forska˚l)	Abed Golam Rabbani & Chaoshu Zeng. Tropical Crustacean Aquaculture Research Group, School of Marine Biology and Aquaculture, James Cook University, Queensland, Australia	An experiment was carried out to test whether the background colour of the culture vessel in hatchery affected mud crab larval culture success.	http://www.researchgate.net/publication/227607173_Effects_of_tank_colour_on_larval_survival_and_development_of_mud_crab_Scylla_serrata_(Forskl)
Induced out-of-season spawning of the mud crab, *Scylla paramamosain* (Estampador) and effects of temperature on embryo development	Chaoshu Zeng. Tropical Crustacean Aquaculture Research Group, School of Marine andTropical Biology, James Cook University,Townsville, Queensland, Australia	The study includes the effect of temperature on embryo development of *S. paramamosain* in subtropical southern China.	http://www.researchgate.net/publication/229732522_Induced_outofseason_spawning_of_the_mud_crab_Scylla_paramamosain_%28Estampador%29_and_effects_of_temperature_on_embryo_development

Limiting the use of rotifers to the first zoeal stage in mud crab (*Scylla serrata* Forskål) larval rearing	Ian M Ruscoe, Graham R Williams and Colin C Shelley Darwin Aquaculture Centre, Fisheries Group, Department of Business, Industry and Resource Development, GPO Box 3000, Darwin, NT 0801, Australia	Two experiments were conducted to assess the requirement for rotifers in the larval feeding regime for *S. serrata* to figure out a commercially viable larval rearing protocol for *Scylla serrata.*	http://www.researchgate.net/publication/238371247_Limiting_the_use_of_rotifers_to_the_first_zoeal_stage_in_mud_crab_%28_Scylla_serrata_Forskl%29_larval_rearing
Use of microbound diets for larval culture of the mud crab, *Scylla serrata*	May-Helen Holme , Chaoshu Zeng, Paul C. Southgate. Tropical Crustacean Aquaculture Research Group, School of Marine Biology and Aquaculture, James Cook University, Townsville, Queensland 4811, Australia	This study investigated the use of microbound diet (MBD) particles as a food source for *megalopa* and *zoea* III stage larvae of *Scylla serrata*.	http://www.researchgate.net/publication/229259423_Use_of_microbound_diets_for_larval_culture_of_the_mud_crab_Scylla_serrata
Towards development of a formulated diets for mud crab (*Scylla serrata*) larvae, with emphasis on lipid nutrition.	May-Helen Holme. PhD thesis, James Cook University, Townsville, Queensland 4811, Australia	The study described the lipid requirement of mud crab larvae for growth promotion.	http://researchonline.jcu.edu.au/2150/2/02whole.pdf
Towards development of a formulated diet for mud crab larvae and a better understanding of their nutritional	May-Helen Holme , Chaoshu Zeng, Paul C. Southgate. Tropical Crustacean Aquaculture Research	Treats the effects of a formulated diet on female gonad development, fecundity, hatching rates as well as larval survival.	http://researchonline.jcu.edu.au/28580/1/mud_crab_larvae_feed.pdf

requirements.	Group, School of Marine Biology and Aquaculture, James Cook University, Townsville, Queensland, Australia		
Crab culture potential in southwestern Bangladesh: alternative to shrimp culture for climate change adaption	Salam M. A., S. M. M. Islam, Jianbang Gan and L. G. Ross. Department of Aquaculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. Department of Ecosystem Science and Management, University of Texas A&M, TX 77843, USA. Institute of Aquaculture, University of Stirling	The paper discusses the imminent capabilities of satellite imaging technology and a multi criteria evaluation (MCE) module in GIS for the development of sustainable crab aquaculture. It covers physical, environmental and socioeconomic data to evaluate coastal land-based criteria for mud carb farming based on water quality, water availability, salinity, risks of flooding, soil types, topography, land use/land cover, infrastructure, inputs, seed sources, market and support services.	http://www.researchgate.net/publication/259495394_Crab_culture_potential_in_southwestern_Bangladesh_Alternative_to_shrimp_culture_for_climate_change_adaption
Comparative study of mud crab (*Scylla serrata*) fattening practices between two different systems in Bangladesh	M. Begum, M. M. R. Shah, Abdullah-Al Mamun and M. J. Alam. Bangladesh Fisheries Research Institute, Brackishwater Station, Paikgacha, Khulna-9280, Bangladesh	Study conducted to compare the survival, production and economics of mud crab fattening in cages with fattening in encircled earthen brackish water ponds.	https://www.google.com.bd/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0CCkQFjAC&url=http%3A%2F%2Fwww.banglajol.info%2Findex.php%2FJBAU%2Farticle%2Fdownload%2F4978%2F3985&ei=opdMVIbxLMeF8gXApIAw&usg=AFQjCNGsPFWucKdSLsoJPV8IL8

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Handling, Transport and Storage of Live Crabs and Lobsters	Nia Whiteley and Ted Taylor. Seafood training academy.	Discusses in detail the biology, storage facilities and transport of crustaceans and crab.	http://www.seafoodacademy.org/Library/Seafish/Crabs%20and%20Lobsters.pdf
Larval rearing of mud crab, Scylla tranquebarica (Fabricius, 1798) and feeding requirements of its zoea	G. Maheswarudu , Josileen Jose, K.R. Manmadhan Nair, M.R. Arputharaj, A. Ramakrishnan, A.Vairamani, S.Mohan and S.Palinichamy. Visakhapatnam Regional Centre of CMFRI,Oceanview Layout, Pandurangapuram, Visakhapatnam -530 003, India	Narrating the feeding behaviour of *zoea* 1 of mud crab.	http://eprints.cmfri.org.in/2112/1/Maheswarudu_41-46.pdf
Reproductive Biology of Mud Crab *Scylla serrata* in Lawele Bay, Southeast Sulawesi, Indonesia.	La Sara, Jose A. Ingles, Rodolfo B. Baldevarona, Riza O. Aguilar, Liberato V. Laureta and Seiichi Watanabe	A study on reproductive biology (growth patterns, size at maturity of female, fecundity and sex ratio) of mud crab *Scylla serrata* in Lawele Bay, Southeast Sulawesi to provide basic data for its population management as well as its habitat management.	https://www.academia.edu/5520283/Reproductive_Biology_of_Mud_Crab_Scylla_serrata_in_Lawele_Bay_Southeast_Sulawesi_Indonesia
Mud crab hatchery technology	V.N. Pillai and N.G. Menon (Editors). Central Marine Fisheries Research Institute (Indian Council of Agricultural Research) Tatapuram P.O., Cochin-682 014 Kerala, India.	Results of experiments on brood stock management, incubation, seed production through larval rearing, live feed production for larval stages, water quality management, crab culture and fattening conducted in tanks are presented in this paper.	http://eprints.cmfri.org.in/4324/1/49.pdf

Marketing and Value Chain Analysis of Mud Crab (*Scylla sp.*) in the Coastal Communities of Bangladesh	Prof. Dr Mohammed Zafar, Dr M. Nazmul Ahsan. Institute of Marine Sciences, Chittagong University Chittagong-4331, Bangladesh Fisheries and Marine Resource Technology Discipline Khulna University, Khulna-9208, Bangladesh	The study focuses on the socio economic conditions of fishers involved in the collection and trading of mud crab with particular attention to marketing channel and value chain analysis and a wide range of data was collected to that effect in greater Khulna region, Bangladesh.	http://www.bfrf.org/value-chain-mudcrab.pdf
Internship Experiment in the Bang la hatchery of Fisheries Do Son – Hai Phong, Vietnam	Bui Van Dien. Research Institute for Aquaculture. Vietnam	Includes the current state of technology in production facilities like private hatcheries, Vietnam.	http://aarm-asialink.info/internship/RIA1/Batch3/buivandien.pdf
The Novel Hatchery Facilities Based on Main Effect Factors of Seedling Rearing of Mud Crab (*Scylla* spp.) in China	Zhenguo Qiao, Jiangang Wang, Zhongli Yu, Keji Jiang, Lingbo Ma. Key Laboratory of Marine and Estuarine Fisheries Resources and Ecology, Ministry of Agriculture of China, East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai, China.	This article reviews and discusses major factors affecting seedling rearing of mud crabs, and presented novel hatchery facilities for improvement of seedling rearing.	http://www.davidpublishing.com/davidpublishing/Upfile/4/8/2012/2012040882300561.pdf

Marketing of Mud Crab *Scylla serrata* (Forksal) from Khulna District to International Markets	Anisul Islam Mahmud, Abdullah-Al-Mamun. Dept. of Fisheries and Marine Science, Noakhali Science and Technology University, Bangladesh	Study evaluating the marketing channel of mud crab (*Scylla serrata*) from Khulna region to international destinations as well as assessing the livelihoods of people related to this industry.	http://www.researchgate.net/publication/259079829_Marketing_of_Mud_Crab_Scylla_serrata_(Froksal)_from_Khulna_district_to_International_markets
Studies on the present status and future potential of molluscs, dry fish and crab in Bangladesh coast: A GIS methodological perspective	Dr M. A. Salam, M. Shahadat Hossain and A. M. Hasnein Bin Tareque. Department of Aquaculture Bangladesh Agricultural University Mymensingh, Bangladesh; Institutes of Marine Science, University of Chittagong, Bangladesh; Fisheries and Marine Resource Technology Discipline Khulna University, Bangladesh	The study identified different land use types in the coastal region, present production and harvest level of mollusks, crab and fish drying and their sites and presented in GIS platform.	http://www.researchgate.net/publication/234907473_Studies_on_the_present_status_and_future_potential_of_molluscs_dry_fish_and_crab_in_Bangladesh_coast_A_GIS_methodological_perspective

Socio-economic status of crab collectors and fatteners in the southwest region of Bangladesh	M. A. G. Molla, Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh M. R. Islam, Department of Fisheries Biology and Genetics, BAU, Mymensingh, Bangladesh S. Islam, Department of Aquaculture, BAU, Mymensingh, Bangladesh M. A. Salam, Department of Aquaculture, BAU, Mymensingh, Bangladesh	This study assesses the socio-economic conditions of mud crab (*Scylla serrata*) collectors and fatteners in Khulna and Satkhira districts and found that 45% of crab collectors collects crabs from the Sundarbans and fattening of mud crabs was generally done in bamboo cages and in ponds. It also revealed that most of the crab collectors and fatteners are Hindus, and about half of crab collectors and fatteners are from the age group of 31-40 years and most of them above 6-10 members in their family. They have also identified varied amount of land holding and income by the carb collector and fattener households. The study identified natural disasters and other constraints affected the livelihood of crab collectors and fatteners in the region and suggested crab collection and fattening among alternative sources of income and sustainable livelihood for the disadvantaged people in the region.	http://www.banglajol.info/index.php/JBAU/article/viewFile/4754/3788
Economic analysis of traditional mud crab (*scylla* sp.) fattening in Bangladesh	Zannatul Ferdoushi, Department of Fisheries Management, Faculty of Fisheries, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh Zhang. Xiang-Guo, College of Economics	This study assesses the current crab fattening practice with its profitability analysis in two upazillas of Khulna. It showed a great potentiality of mud crab fattening in the south west part of Bangladesh. However, study also identified the highest seed cost (constitutes 74.18% of total cost) and lack of proper knowledge about mud crab fattening amongst challenges to this industry.	http://cidsbd.org/wp-content/uploads/2014/04/5-13.pdf

	and Management, Shanghai Ocean University, Shanghai, China		
Approaches to Stock Enhancement in Mangrove-Associated Crab Fisheries	Lewis le Vay et al.	Discusses the relation of habitat availability with recruitment success and subsequent stock abundance in more open mangrove systems. It claims lost or degraded mangrove area restoration is effective in promoting stock recovery through natural recruitment as well as replanted mangroves could support fisheries of equivalent economic value to that of natural mangroves, although it may take some years to reach these levels. It suggests, a balanced approach to stock management integrating both hatchery-release and habitat restoration programs, depending on local conditions and over different time scales, with parallel co-management to support for achieving good results.	http://www.vliz.be/imisdocs/publications/132813.pdf
Safe Usage of Antibiotic (Oxytetracycline) in Larval Rearing of Mud Crab, *Scylla serrata* (Forsskål, 1775) in Fiji	K. Azam, School of Marine Studies, The University of the South Pacific, Laucala Campus, Suva, Fiji P. Narayan, School of Marine Studies, The University of the South Pacific, Laucala Campus, Suva, Fiji	This paper presents the findings of the research conducted to assess the optimal concentration and duration of the use of oxytetracycline (OTC) in mud crab larvae rearing process in Fiji.	http://idosi.org/wjfms/wjfms5(2)13/16.pdf
Mud crab (*Scylla serrata*) fattening in Bangladesh-present status and future prospects	Zannatul Ferdoushi, Department of Fisheries Management, Faculty of Fisheries, Hajee Mohammad Danesh Science and Technology University,	The paper reviews different aspects of the mud crab farming and marketing system in the southwest region of Bangladesh as well as problems associated with farming and marketing through surveys and provides suggestions and recommendations for the overall development of this resource.	

	Dinajpur 5200, Bangladesh Zhang. Xiang-Guo, College of Economics and Management, Shanghai Ocean University, Shanghai, China		
An assessment on the barriers in mud crab (*Scylla* sp.) fattening and marketing in Bangladesh	Zannatul Ferdoushi, Department of Fisheries Management, Faculty of Fisheries, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh Zhang. Xiang-Guo, College of Economics and Management, Shanghai Ocean University, Shanghai, China	The paper presented the findings of the study conducted to know the barriers of mud crab fattening practice and marketing in Bangladesh particularly in Khulna, Bagrhat and Satkhira districts. Insufficient credit and lack of proper knowledge of farmers about crab farming, price influenced by the marketing operators, lack of market information were amongst the most important barriers as identified.	http://jsthstu.org/JST_PDF/JST2013(1)/26_JST_10_01%20Ferdoushil.pdf

Other publications (factsheets, videos, presentations, comprehensive books etc.)			
Mud crab Industry Profile and Trends	Frank F. Santos	Includes taxonomy, species distribution, production and technology, research and development of mud crab in the Philippines.	http://www.bfar.da.gov.ph/services?id=4
RGCA Mud Crab Farming Demonstration, Karaikal	nn.	Short video.	http://www.youtube.com/watch?v=qUr6ZdlBfW0
Crab Farming in Navua, Fiji	nn.	Short video.	http://www.youtube.com/watch?v=gEEb65OIz3c
How to tie a mud crab	nn.	Short video.	http://www.youtube.com/watch?v=KGcBcop6qB8
Mud Crab Farming in Asia	Shrimpnews	Comprehensive book beginning with chapters on the general aspects of aquaculture like water quality, genetics, disease, nutrition, feeds, disease, harvesting, processing and marketing and ending with chapters on all the economically important aquaculture species including crab.	http://www.shrimpnews.com/FreeReportsFolder/CrabFolder/MudCrabFarminginAsia.html
Polyculture of Tilapia and Seaweeds in Soft-Shell Mud Crab Ponds in Indonesia and Thailand	May Myat Noe Lwin, CNN Aquaculture for ISTA 9, Shanghai, China	This presentation (ppt format) outlines the potentials and process of Tilapia and Seaweeds polyculture in soft-shell mud crab ponds in Indonesia and Thailand with challenges associated to production, marketing and processing.	http://ag.arizona.edu/azaqua/ista/ISTA9/PDF's/NoeNoeMudCrabs.pdf

References

Quinitio, E. T. (2016). *Report on the consultancy on the development of mud crab hatchery and nursery techniques at Bangladesh Fisheries Research Institute, Paikgacha, Khulna, Bangladesh.* Bangladesh Forest Department, GIZ, SEAFDEC/AQD.

Saracin, S. A. (2016). *Technical report on the supervision of mud crab hatchery operation at Bangladesh Fisheries Research institute, Paikgacha, Khulna, Bangladesh.* Bangladesh Forest Department, GIZ, SEAFDEC/AQD

Bangladesh Forest Department, GIZ. (2016). *Documentation report on knowledge sharing workshop on mud crab hatcheries in Bangladesh*.

FAO (2011). Mud crab aquaculture: A practical manual. Colin Shelley, and Alessandro Lovatelli, Italy. http://www.fao.org/docrep/015/ba0110e/ba0110e.pdf

Molla, M. A. G., M. R. Islam, S. Islam and M. A. Salam, (2009). Socio-economic status of crab collectors and fatteners in the southwest region of Bangladesh. J. Bangladesh Agril. Univ. 7(2): 411–419

World Bank, (2014). www.worldbank.org

Annex A: Technical Assumptions of Mud Crab Hatchery Operation for the Newly Proposed Mud Crab Hatchery

Total larval rearing capacity (tons)	50
Broodstock	
% broodstock that will survive and mature	45%
Ave zoeae/female	1,200,000
Ave BW of broodstock (g)	230
Number of successful spawners needed	3.33 or 3.0
Total number of broodstock to be purchased	8.41 or 9
Kg broodstock to be purchased	1.9 or 2.0
% of body weight used for feeding rate	3-5
Hatchery	
Stocking density of larvae/liter	80
Total no. of zoea to be stocked at max cap	3.6 -4.0 million
% survival from zoea to C1C2 (conservative estimate)	3.0
No. of crablets (C1C2) produced	108,000-120,000
Number of runs/year (successful runs)	4
Nursery	
% survival from C1C2 to 1.5 cm juveniles	70
No. of 1.5 cm juveniles produced (3-4 weeks, Phase 1)	84,000

Annex B: Capital Assets of Mud Crab Hatchery

CAPITAL ASSETS HATCHERY

	Volume/ unit	No. of units	Total	Cost/Unit	Total Cost (BDT)	Life (Yrs)	Cost of Dep/Yr
Larval tanks, concrete rectangular	5 t	8	40 t			10	
round fiberglass, 4 units	8 t	2	16 t	available		10	
Rotifer tanks, concrete rectangular	6.5 t	8	52 t			10	
Chlorella tanks, concrete	6.5 t	8	52 t			10	
Natural food tank starters, 70-li x 8 plastic containers				available			
Broodstock tank, concrete 2x3x0.8m		2				10	
Spawning tanks, fiberglass, 500-li FGT with stand x 4	500 li	4	2,000 li	available		10	
Reservoir	30 t	3	90 t			10	
Filtration tank, gravel and sand, concrete						10	
Water pump	1					5	
Air blower		1				8	
Generator (4 cyl)		1	pc			8	
UV water sterilizer or ozonizer		1				6	
Microscope for counting algae, rotifers and monitoring of larvae, etc		1				8	
Weighing balance for weighing artificial feeds, chemicals, etc; 0.00 g up to 300g capacity		1	unit			6	
Weighing balance, up to 2 kg capacity		1	unit			3	
Refractometer, Atago		1	unit			4	
Refrigerator, 2-door, 8 cu ft		1	unit			6	
Air-conditioner for algal culture rooms & lab (0.5 and 1.0 HP)	1-0.5HP 2-1.0HP	3	units			8	
Structure to house the larval tanks, lab including algal lab & stock room		1				20	
Artemia hatching tanks & natural food starters (water jugs)							
Wooden stand for *Artemia* hatching tanks (see above for *Artemia* hatching containers)							
Solar panel		1	set				
Drainage system							
Plumbing							
Electrical							

CAPITAL ASSETS NURSERY

Net cages (15 sq.m); other C1C2 direct stocking in nursery pond	50
Shed and catwalk	2

Annex C: Documentation Report of Knowledge Sharing Workshop on Mud Crab Hatcheries in Bangladesh

DOCUMENTATION REPORT

on

Knowledge Sharing Workshop on Mud Crab Hatcheries in Bangladesh

7 November 2016

Christian Service Society Ava Center, 82 Rupsha Strand Road, Nutan Bazar, Khulna

Report published in December, 2016

Contents

List of Abbreviations

BFD	Bangladesh Forest Department
BFRI	Bangladesh Fisheries Research Institute
DoF	Department of Fisheries
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit* GmbH
IFAD	International Fund for Agricultural Development
NGF	Nawabenki Ganamukhi Foundation
NGO	Non-Governmental Organization
PACE	Promoting Agricultural Commercialization and Enterprises (Project)
PKSF	Palli Karma Sahayak Foundation
SDBC	Sustainable Development and Biodiversity Conservation in Coastal Protection Forests (Project - Sundarbans Component)
SEAFDEC	Southeast Asian Fisheries Development Center (Philippines)
SMP	Management of the Sundarbans Mangrove Forests for Biodiversity Conservation and Increased Adaptation to Climate Change Project

Introduction

Mud crab farming in the southwest of Bangladesh as an income generating activity has seen a sharp rise as it is becoming more lucrative to farmers. According to the Bangladesh Export Promotion Bureau, from fiscal year 2002-03 to 2006-07 the total export value of mud crabs increased by 65%, and in 2013-14 Bangladesh exported crabs worth BDT 3.5 billion (ca. EUR 40 million). As the industry develops and the production area expands, the demand for crablets as seed stock increases.

In Bangladesh, all the seed stock needed for mud crab farming is collected from the wild, with the estuaries and mangroves of the Sundarbans being the main source of seed stock for the coastal areas in the southwest. The current potentially unsustainable harvest rate of seed stock not only puts the integrity of the Sundarbans' ecosystem and biodiversity under pressure; but also a collapse in the wild population from overharvesting in turn will threaten the existing industry can no longer be sustained, which in turn would threaten the livelihood of a large number of people.

Successful hatchery production at a commercial scale will reduce the pressure on wild stock from the Sundarbans and increase the availability of seed stock to serve a growing demand. This will consequently lead to higher and uninterrupted production and to improved livelihoods for those involved in the value chain, especially producers.

Hatchery production of crablets is practiced successfully in a number of Asian countries, but requires considerable technical skills and knowledge, which have until recently not been available in Bangladesh. In order to strengthen local capacity to take up commercial hatchery-based production of crablets, the Bangladesh Forest Department (BFD) has been cooperating with the *Gesellschaft für Internationale Zusammenarbeit* (GIZ) since 2014 during two consecutive projects: "Sustainable Development and Biodiversity Conservation in Coastal Protection Forests" (SDBC) Project and "Management of the Sundarbans Mangrove Forests for Biodiversity Conservation and Increased Adaptation to Climate Change (SMP)" Project. In an alliance with the Bangladesh Fisheries Research Institute (BFRI) and with continuous technical support of the Southeast Asian Fisheries Development Center (SEAFDEC), Philippines, two trials for hatchery based crablet production were undertaken in the BFRI Paikgacha Station.

With increasing environmental concerns and economic importance putting the mud crab sector in Bangladesh more and more into the spotlight, the Government has recently launched a second initiative for mud crab hatchery development in Callbari, Burigoalini, Shyamnagar, Satkhira. Under the Crab Value Chain Development Project, the Nowabenki Gonomukhi Foundation (NGF) has implemented a trial for hatchery-based crablet production and accompanying activities with the aim of eventually facilitating the scaling-up of the technology. The initiative is part of a larger project on Promoting Agricultural Commercialization and Enterprises (PACE) funded by the International Fund for Agricultural Development (IFAD) to the Palli Karma-Sahayak Foundation (PKSF). While initial results were produced, little official information is available as of now. Secondary information that reached the workshop participants indicates that differences in the setting as well as the methodology used may give new insights concerning challenges and lessons learnt. In the absence of PKSF and NGF at the workshop,

albeit being invited, there is a need for exchanging more concrete experiences. Hence, future effort needs to further stimulate a pro-active exchange among actors engaged in the mud crab hatchery sector. This would give the opportunity to mutually profit from the experiences gained and to speed up development.

Experiences in Bangladesh and elsewhere have shown that the successful development and subsequent scaling-up of hatchery-based mud crab production involves a variety of actors including the government, non-governmental organizations (NGOs), the academia, and the private sector, each playing an important role. Effective coordination and harmonization of approaches among all these actors towards an economically viable concept is therefore essential.

In order to share the extensive experiences of two successful trials at BFRI as well as to facilitate an exchange among relevant stakeholders the BFD- and GIZ-led SMP organized a one-day ''Knowledge Sharing Workshop on Mud Crab Hatcheries in Bangladesh'' on 7 November, 2016 at the Christian Service Society Ava Center, Khulna.

The overall objectives of the workshop were:

- To bring together relevant actors in the sector of mud crab hatcheries in Bangladesh to stimulate active exchange of experiences (lessons learnt and challenges) as well as to plan activities.
- To identify synergies and possible areas for collaboration.
- To identify essential milestones on the way forward towards economically feasible mud crab hatcheries in Bangladesh.

The workshop was attended by a total of 21 participants consisting of staff of government agencies such as the Department of Fisheries (DoF), BFD and BFRI; non-governmental organizations (NGOs); researchers from Khulna University (KU); representatives of the private sector; and technical staff of GIZ. Dr. Emilia T. Quinitio, SEAFDEC Philippines, likewise joined the workshop as a resource person.

Opening of the Workshop

The workshop started with brief opening remarks by Mr. Oemar Idoe, Principal Adviser of SMP. As a facilitator for the day, he explained the rationale, mechanism and expected outputs of the workshop.

Expert Presentation Session

Presentation 1: Initial Efforts on the Mud Crab Hatchery Operations at BFRI, Paikgacha

Presenter: Dr. Emilia T. Quinitio; SEAFDEC, Philippines

Dr. Quinitio has more than 20 years of experience in hatchery-based mud crab production in the Philippines and other countries in the region. As a consultant engaged by GIZ, she accompanied the entire process of mud crab hatchery trials with BFRI in Bangladesh.

In her presentation, Dr. Quinitio gave an overview of her experiences with the hatchery operation at BFRI in Paikgacha based on two trials (June –July 2015 and April-June 2016). The capacity building measures that she supported included lectures to BFRI staff and practical sessions in the station. Based on the trials, the main problems she identified related to a insufficient seawater supply for the hatchery, poor quality broodstock that was sourced from low salinity areas, a lack of rotifers as food source, unstable electric supply leading to fluctuating water temperatures unsuitable for the organisms as well as the fact that Paikgacha station was not designed for hatchery operation and hence facilities were not ideal for mud crab rearing. To address these challenges, Dr. Quinitio shared some recommendations not only relevant for BFRI but also for existing and potential actors in mud crab hatchery development: A suitable site location for any hatchery that would be newly established as well as a suitable design ensuring facilities customised to the needs of mud crab hatching were regarded as essential to address structural challenges. In addition, the need to select healthy and resistant broodstock from high salinity areas was emphasised, which is one of the most important factors determining survival of crablets during the initial life cycle stages.

During her presentation, Dr. Quinitio made reference to practices in hatchery and nursery operations in the Philippines.

Presentation 2: Hatchery Based Seed Production of Mud Crab at BFRI, Paikgacha, Khulna: Challenges, Experiences, Progress and Future Research Development

Presenter: Dr. Latiful Islam; Senior Scientific Officer of BFRI, Paikgacha Station

Dr. Latiful Islam had the overall responsibility from BFRI side over the trials conducted with the joint support of FD and GIZ including knowledge transfer from SEAFDEC to local staff, hatchery operation management, and ensuring required input supply (e.g. brine, brood).

Looking back at the two trials at Paikgacha Station, Dr. Latiful Islam talked about BFRI's experience on mud crab seed production, problems encountered and recommendations. One of the findings he shared was that broodstock originating from a 30 ppt salinity environment showed the highest spawning success rate. Similar to Dr. Quinitio's presentation, he also identified the main problems as being low quality broodstock taken from a low salinity water source, insufficient seawater supply, and unreliable electric power. Considering these challenges, an outlook into future envisioned engagement of BFRI was given. Here, key areas of interventions include different measures to increase the survival of larvae and crablets, to enhance nursery management of crablets as well as to promote collaboration with other government agencies, NGOs and the private sector for research and development. As recommendation, he emphasised that BFRI is aware of the need to improve infrastructure and facilities adequate for mud crab hatcheries, and that further capacity building of staffs by national and international trainings was desirable.

Presentation 3: Overview of the Mud Crab Culture in India and Vietnam

Presenter: Dr. Emilia T. Quinitio (SEAFDEC/Aquaculture Department, Iloilo, Philippines)

Taking India and Vietnam as examples, Dr. Quintitio presented her experiences from other countries concerning the development of mud crab hatcheries as well as the wider connection with the mud crab value chain. Some highlights relevant for the future mud crab (hatchery) development in Bangladesh are described below.

It was discussed how India initiated mud crab hatchery operation through government funding and with technical assistance from SEAFDEC starting in 2004. The Rajiv Gandhi Centre for Aquaculture (RGCA), the Research and Development arm of the Marine Products Exports development Authority (MPEDA), simultaneously developed the nursery and grow-out facilities with the establishment of a pilot scale hatchery. RGCA collaborated with farmers by providing hatchery-reared crablets and training until some farmers adopted the technology (Farmer Field School approach). Farmers have gradually utilized hatchery-reared crablets to boost their mud crab industry. To date, hatchery-reared crablets are used for aquasilviculture in India.

Secondly, the experiences of mud crab culture in Bac Lieu and Cau Mau, Vietnam were presented. The major species in Vietnam is *S. paramamosain*. In the larval rearing, umbrella stage *Artemia* are used as feed at the early larval stage instead of rotifers. This system reduces the use of tanks for the culture of

natural feed (rotifers and green microalgae). In Bangladesh, this method was applied during the trial conducted by NGF with support from PKSF. Although little official information has been shared so far, the organisations stated to have achieved a satisfactory survival rate yielding “a few thousand crablets”. Future trials comparing different methods of feed production and administration can be a valuable source of information in order to confirm these results. If indeed feasible in the context of Bangladesh, this finding could catalyse the scaling-up to the private sector as this method is comparatively easier for hatchery operation.

In Vietnam, one of the major expenses in the hatchery is the hauling of seawater. Most of the hatcheries are situated near rivers and mangroves where clean seawater is not available.

Vietnam practices value chain segmentation (dividing the overall value chain into smaller sub-sets or segments) for mud crab culture. This strategy involves focusing only on one particular segment of the entire business. For the crab industry, some entrepreneurs deal only with the production of broodstock, while the hatchery operator only deals with larval rearing and production of megalopae. The hatchery operators sell the megalopae or crab instar to nursery operators who grow them to a size suitable for direct stocking in grow-out ponds. These crablets are purchased by farmers for fattening them to market size in grow-out ponds.

Question and Answer Session

Building on the input by Dr. Quinitio, a number of questions relating to the cultivation practices, market access, and challenges of the mud crab sector in other countries in the region were posed by the participants. One of the crucial points of discussion among participants concerned the success factors of other countries that have been able to develop the sector at an economically feasible scale, e.g. achieving a viable survival rate of hatchery-based crablets as an important milestone. This was compared to the situation in Bangladesh where progress has not reached economically feasible levels yet. While it was acknowledged that many factors are influencing the success of building up the mud crab sector, participants stressed that strong commitment by all actors is vital. In this regard, participants agreed that in Bangladesh there is scope to make an even larger effort and create stronger national ownership.

Below, a summary of specific questions by participants and corresponding important technical information as a response by Dr. Quinitio is given.

- **How many production cycles per year are possible for a mud crab hatchery? Does it differ country-wise? What is the scenario in Bangladesh?**

In a normal hatchery operation, an average of seven successful runs can be conducted per year with one cycle at a time. In Bangladesh, hatchery operation may not be possible in Paikgacha during the rainy season due to the drop in water temperature and salinity. In Cox’s Bazar, where the salinity is suitable for mud crab culture, six to seven runs can be conducted all year round.

In the Philippines, pond-reared broodstock showed better performance than wild ones. However, the situation in Bangladesh still has to be investigated in this regard. Adult crabs can be collected from the wild and then reared in the pond with suitable salinity for broodstock development.

- **Is there any medicine or chemical which can be used to prevent incomplete molting during larval stage of mud crab?**

Incomplete molting (from stage zoea 5 to megalopae) is one of the major problems in larval rearing. Possible causes are inadequate nutrition, application of too high a dose of chemicals, and low water temperature. Supplementation of diets, rotifers and Artemia enriched with Docosahexaenoic acid and Eicosapentaenoic acid, can reduce incomplete molting of larvae.

- **Is there any major difference in production practices between different countries?**

The protocol of seed production of mud crab differs slightly among countries. The basic technology is the same with minor modifications based on the local conditions and available facilities. For instance, some hatchery operators use concentrated algae to feed the rotifers in order to reduce labor and required facilities for the production of green microalgae.

- **Can the shrimp hatcheries in Bangladesh be converted into crab hatcheries?**

Not all shrimp hatcheries can be converted to crab hatcheries. Some shrimp hatcheries have big and deep tanks which are not suitable for mud crab larval culture. Rehabilitation of such facilities may be more expensive. If tanks used for shrimp cultivation are rather small these can be converted for crab.

- **How does the market value for *S. olivacea* and *S. serrata* differ?**

The price comparison between *S. olivacea* and *S. serrata* depends on its size and the specific market. In Bangladesh, the market price of *S. olivacea* is almost the same as *S. serrate*, but internationally, giant *S. serrata* have very good prices because of size. *S. olivacea* cannot grow as big as *S. serrata.*

- **In Vietnam, artificial light has been used to cultivate crablets successfully in indoor facilities. Is there any major difference of the larval survival rate between exposure to natural light and artificial light? Why has the trial at BFRI shown improved survival rate for larvae exposed to sunlight as opposed to the experiences in Vietnam?**

Although artificial light can be used for larval rearing, natural light intensity is more suitable. At BFRI, larvae exposed to sufficient natural light are more active and healthy than those cultured indoors and provided with artificial light only.

- **What are the larval survival rate for India, Vietnam and Philippines?**

Survival rate of crablets in different countries are as follows: India - up to 17%; Vietnam - more than 10%; Philippines - up to 22%. Since the survival rate in Bangladesh is considerably lower, much effort remains to achieve commercially viable production rates.

- **What types of crab do the Philippines and Thailand export?**

The Philippines export mostly live crabs. Thailand exports live and soft-shell crabs.

- **What is the scenario of mud crab hatcheries in Myanmar?**

Hatchery trials in Myanmar have been initiated but so far success has been limited, mainly due to unreliable sources of electric power (continuous operation of generator is a major cost factor). No further effort was put into continuing the trials so that a commercially viable larval survival rate is yet to be achieved.

Video presentation

In the framework of the SMP project, a short video was produced that documents the hatchery operation process at BFRI Paikgacha Station. The video was presented to the participants during the workshop. It is freely available on the GIZ channel here.

Group Work Session

Group Work 1

Task: Requirements and actors of the mud crab hatchery sector in Bangladesh

Participants were divided into four groups depending on the sector they are affiliated with: (1) government, (2) academia, (3) private sector, and (4) NGOs. Within their groups, participants were asked to brainstorm on steps towards successful mud crab hatchery operation in Bangladesh, distinguishing between what is already in place and what is still required to be done in the future. In a second step, participants allocated each of the collected ideas to the corresponding sector that could be leading the execution (government, academia, NGOs or private sector). For the purpose of better visualising the results, a matrix was prepared (see Figure 8). After completing the matrix, each group presented their results in plenary where an active discussion and complementation of ideas took place among the participants.

Results

Below, all points mentioned by the four groups are summarised. A distinction is made between (A) what is already in place and (B) what still needs to be done.

(A) Items already in place in the mud crab hatchery sector in Bangladesh

From the group work, it became evident that the majority of activities and framework conditions already in place were mostly categorized in a shared manner, in other words involving more than one sector (see Table 1). In addition, similar points were repeatedly identified independently by the different groups.

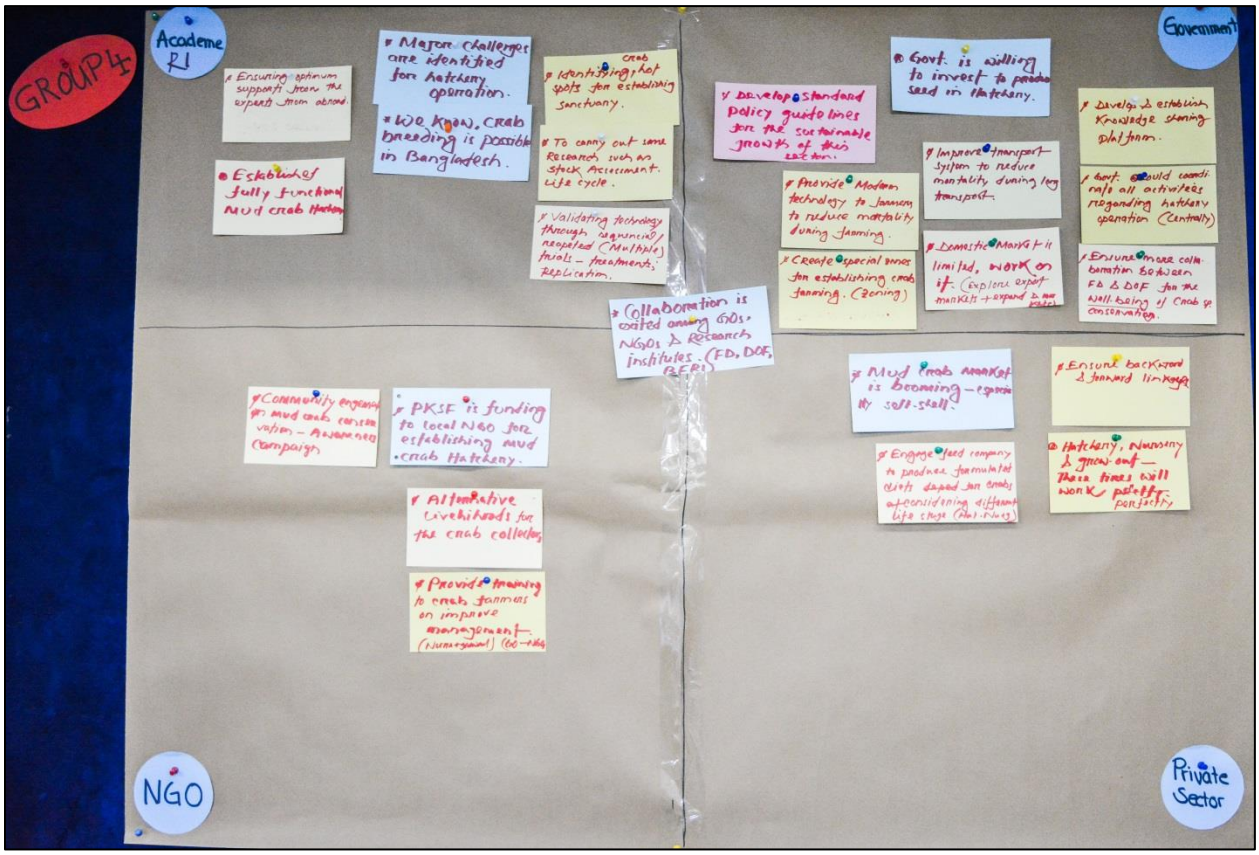

Figure 8: Results of group work 1 by group 4 (NGO sector) showing ideas of what is already in place and what still needs to be done towards successful mud crab hatchery operation

Table 6: Items already in place in the mud crab hatchery sector in Bangladesh

Item	Sector
Hatchery operation trials initiated at Cox's Bazar by World Fish, at Paikgacha by BFRI-SMP, and more recently at Munshiganj by Nowabenki Gonomukhi Foundation (NGF) - Palli Karma Sahayak Foundation (PKSF)	Government, NGO
Mud crab hatchery established in Mushiganj by NGF. Their first trial was announced to have successfully produced crablets	Government, NGO
Funding of mud crab hatcheries approved by the government	Government
Capacity building of BFRI staff for mud crab hatchery operation by international experts (SEAFDEC) at BFRI	Government, NGO
Capacity building of NGO staff for mud crab larval rearing through an exposure visit to Vietnam (e.g. NGF-PKSF)	Government, NGO
The understanding was created that hatchery-based crablet production is a viable option in Bangladesh	Academia
Criteria for good quality broodstock and larvae to improve performance identified	Private sector
Major challenges for hatchery operation identified	Academia, Government, NGO
Initial research identifying biological constraints initiated by government and academia	Government, Academia
Research on seed production technology on-going at BFRI	Government
NGOs interested in supporting crab grow-out operation	NGO
Mud crab market booming (e.g. soft shell)	Private sector
Experience on successful hatchery operation, research and development shared	Government, NGO
Sharing of experiences initiated by GIZ (in this workshop)	Government, NGO
International linkages on technical support established	Government, NGO, Academia

(B) Items that still need to be done in the mud crab hatchery sector in Bangladesh

Major items to be addressed in the future identified by the participants focused on improved hatchery technology, coordination, capacity building, investment and market / value chain development engaging the government, universities, NGOs and the private sector one after the other (see Table 2). An interesting observation was that the group consisting of representatives from the government focused more on activities related to funding, decision making and increased coordination and collaboration among government organizations (e.g. FD and DoF) and with other sectors (e.g. academia, NGOs, and the private sectors). In contrast, the group with representatives from the academia rather focused on biodiversity conservation, stock assessment and collaborating with international experts along with research.

The private sector group included a wide range of activities highlighted by investment, marketing and overall value chain development. While at first glance not many activities were associated with the NGO sector, it was acknowledged during the subsequent discussion that this sector plays a vital role especially as the technology is rolled out in the field. The engagement of community members and the support for scaling-up from trials was regarded as an area of expertise where NGOs could contribute to.

As an overarching topic, training emerged as an important topic mentioned by and for all sectors. In addition, coordination as a cross cutting issue was agreed on by all as being highly relevant but lacking.

Table 7: Items that still need to be done in the mud crab hatchery sector in Bangladesh

Government sector
• Define clearly the institutional arrangement of FD and DoF as to their respective roles in the context of the mud crab industry in Bangladesh • Develop and establish a knowledge sharing platform • Ensure more collaboration between FD and DoF on mud crab conservation • Coordinate all activities on mud crab hatchery • Develop standard policy guidelines for the sustainable growth of the mud crab industry • Prepare clear guidelines for the issuance of certification pertaining to the mud crab industry • Subsidize the establishment of mud crab hatchery facilities adopting viable technology • Establish protocols for crab hatchery operations • Train professionals on mud crab hatchery so that they can quickly solve hatchery problems • Provide support to undergo training on mud crab hatchery operation in other countries • Provide funds to support research on nutrition, diseases, live food culture, etc. • Provide modern technology to farmers to improve survival during farming • Create special zones (zoning) for establishing mud crab farms • Improve/develop transport system to reduce mud crab mortality during long transport • Explore the export market and work on the expansion of the domestic market

Academia

- Conduct research on the following topics:
  - Establishment of criteria for the selection of mud crab hatchery sites
  - Availability of good quality broodstock; development of disease-free broodstock and crablets
  - Improvement of survival from zoea to megalopa and from megalopa to crablet stage
  - Nutritional requirements (including protein level, P-E ratio) of larvae and crablets
  - Evaluation of water filtration/ treatment method (ozonation, UV, chlorination), protein fractionation
  - Elimination/ reduction of antibiotic use; alternative to antibiotics
  - Determination of the breeding season of *S. olivacea*, life cycle, stock assessment
  - Identification of suitable site for establishing crab sanctuary
  - Validation of technology through several trials and treatments
- Ensure support from experts abroad
- Establish fully funded mud crab hatchery for the refinement of the technology through research and development
- Train staff
- Determine economic analysis of hatchery operation

Private sector

- Tap willing to invest in economically viable mud crab hatchery technology, which may include*:*
  - Hatchery infrastructure
  - Skilled hatchery technicians
  - Disease free crablets
  - Disease free broodstock
- Establish efficient and viable transport system for crablets
- Develop efficient marketing channel to include vibrant export market exploration, and develop forward and backward linkages for hatchery operation
- Establish suitable nursery operation
- Establish grow-out technology
- Develop hatchery, nursery and grow-out- integrated system
- Invest in the establishment of hatchery through the bank sector
- Economic analysis of a commercial hatchery
- Engage with feed companies to produce formulated diets for crabs of various stages
- Develop mud crab value chain both nationally and internationally
- Undergo training in other countries with established technology

NGOs
• Develop nursery phase: capacity building of nursery operators and potential operators • Provide training for hatchery operators and farmers • Establish an efficient transport system for megalopae and crablets to reduce mortality • Develop alternative livelihood for mud crab collectors • Provide suitable mud crab supply chain guideline • Engage community in the mud crab conservation campaign

In conclusion of group work 1, the achievements so far include a clear concept developed by the trials that hatchery-based crablet production is possible in Bangladesh. At the same time, the interest and hence the commitment by the government, NGOs and the private sector are growing so that expectations towards the advancement of the sector are promising. While initial trials conducted by government agencies and NGOs have already shown first satisfactory results for future hatchery-based crablet production, more research trials, corresponding funding and efforts are required to fine-tune the technology. With the further development of the technology towards scaling-up, the role of the private sector becomes increasingly important. In this regard, the group work indicated that the private sector has already stepped in and is willing to contribute to a quick market expansion at national and international level.

Group Work 2

In this segment, the participants were divided into three heterogeneous (cross-sectoral) groups. Each group had one facilitator. Participants were asked to work on two different tasks namely, A: Challenges, probable solutions and lessons learnt (two groups were working on this topic); and B: development of a roadmap (one group was working on this topic). The output of each group was captured and later on presented in plenary. As a last step, priorities were jointly identified by votes of participants. Below, details of the tasks and results of the group work are summarised.

Task A: Challenges, probable solutions and lessons learnt

The group was asked to discuss about challenges relating to mud crab hatcheries both expected in future or experienced in the past. If possible, participants should identify corresponding solutions addressing the challenges. As a third point, lessons learnt were collected among group members.

Results

Table 8: Results of group work 2, task A pecifying challenges, probable solutions and lessons learnt relating to the mud crab hatchery sector in Bangladesh

Challenge	Probable solution
Lack of reliable source of power supply	Development of renewable energy sources (e.g. solar energy)
Difficulty in sourcing good quality food (natural and artificial) for broodstock	Development of broodstock diet; sourcing of other natural food to improve broodstock quality
Slow uptake of hatchery technology by the private sectors	• Demonstration / capacity building on the viability of technology • Involvement of community on hatchery, nursery and grow out phases • Development of criteria for government certification to support private sector in establishing hatchery
Lack of dedicated manpower	
Lack of reliable supply of good quality broodstock	Development of brood rearing community
Lack of skilled manpower	Training technology
High cost and lack of available hatchery inputs	Initiative from the government (e.g. taxes, incentives)
Lack of knowledge on hatchery water management (salinity)	• Selection of suitable site and enough storage facility for seawater - important for successful hatchery operation • Knowledge on the proper water management practices; application of good aquaculture practices, biosecurity and hygiene, and responsible use of prophylaxis • Development of geo-zoning for hatchery water management
Lack of coordination between academia, government organizations, private sector and NGOs	• Knowledge sharing platform (web-based) for effective collaboration, coordination and capacity building • Initiation of institutional / sectoral coordination by the government; involvement of NGO to share this at the community level
Lack of fine-tuned technology ready for	• Institutional/sectoral coordination

Challenge	Probable solution
commercial hatchery operation	• Research on nutrition, disease and live feed. • Government and NGO initiative for coordination
Occurrence of disease in the hatchery	Water treatment, follow Good Agricultural Practice (GAP), biosecurity and hygiene, use of prophylaxis
Collapse of natural food due to contamination or bad weather condition	Development of artificial diet for larvae as supplementary feed.
Inadequate knowledge on live feed culture technology	Development of artificial diet for larvae as supplementary feed that can reduce nutritional deficiency
No available hatchery manual in the context of Bangladesh	
Lack of information on larval nutrition	Research on nutrition, disease and live feed
Effects of long term use of antibiotics	Reduction on the use of antibiotics; use of probiotics can reduce health threat
Reliable source of seawater	Suitable site selection, enough storage facility for seawater

Lessons learnt

- Selecting a suitable site for a hatchery is important for a successful operation
- Broodstock sourced from low salinity water can cause poor reproductive performance
- Unreliable source of ovigerous (berried) females causes major problems in the scheduling of hatchery operation
- Hatchery technology initiated at BFRI needs further refinement
- Research is important to address various problems which may differ among countries
- Sharing of knowledge is important for coordination and capacity building
- Strong collaboration among various sectors is important for synchronizing the activities
- Identification of *Scylla olivacea* found in Bangladesh has been confirmed

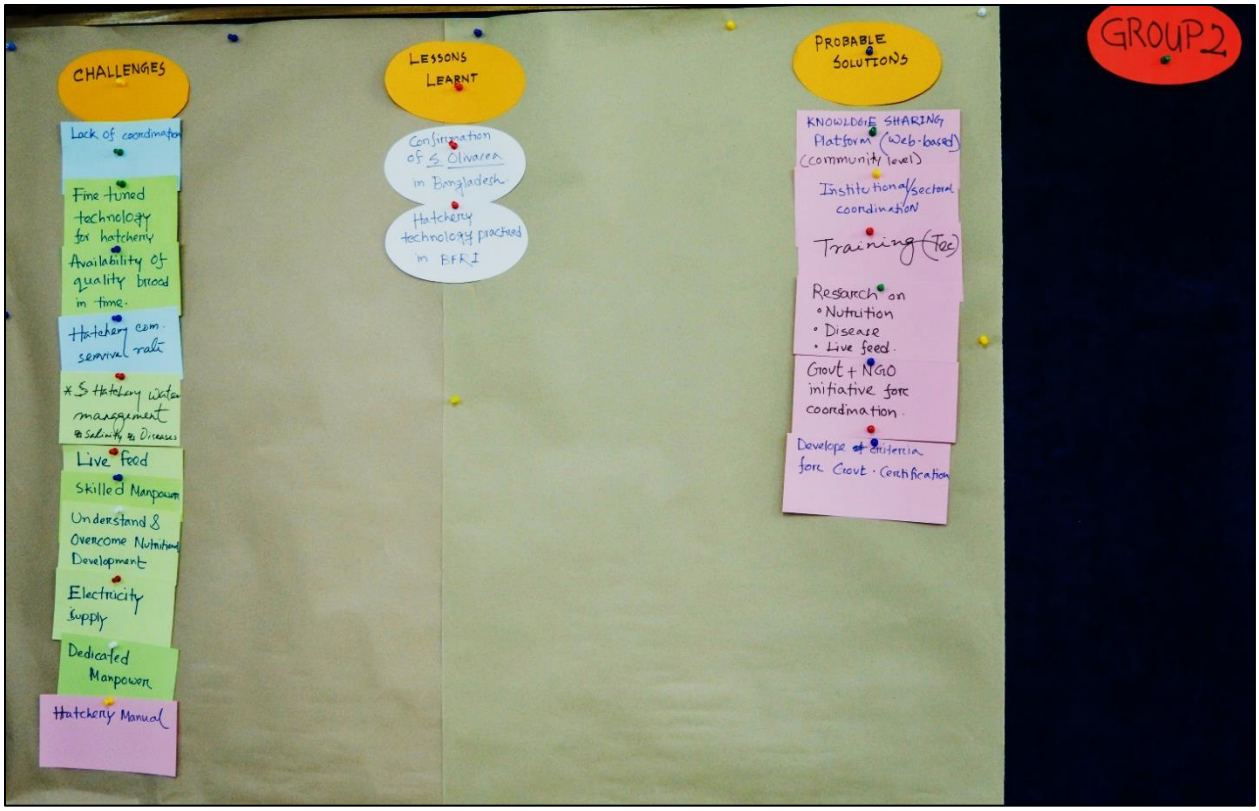

Figure 9: Results of group work on specifying challenges, probable solutions and lessons learnt relating to the mud crab hatchery sector in Bangladesh

Both groups working on this task identified similar challenges and corresponding probable solutions for successful hatchery-based mud crab production. A broad range of technical issues relating to hatchery management was mentioned including handling of brood, water management, brine water availability and power supply problems. At the same time, the importance of knowledge and experience with the technology as well as the need for further capacity were identified as key approaches to further develop the mud crab hatchery sector in Bangladesh. Lastly, a consensus existed among participants that better coordination among relevant actors in the sector could be achieved through establishment of an institutionalised platform for knowledge exchange.

Task B: Development of a Roadmap

This task aimed at identifying essential milestones on the way towards an overall vision of "successful hatchery operation in Bangladesh". During this exercise, participants were given the option to use the results of group work 1 and complement these with their own ideas. By arranging all activities in a logical sequence (roadmap) leading to the vision, a rough timeline was to be generated by the group.

Results

Vision: The group noted the following key aspects of a possible vision for the mud crab sector in Bangladesh:

- Sustainable livelihood for coastal communities
- Economically viable crab hatchery sector produces quality crablets
- Consistent production of healthy broodstock from ponds and crablets from hatcheries
- Conservation and management of natural resources

Roadmap: Essential milestones to achieve the vision were formulated as follows:

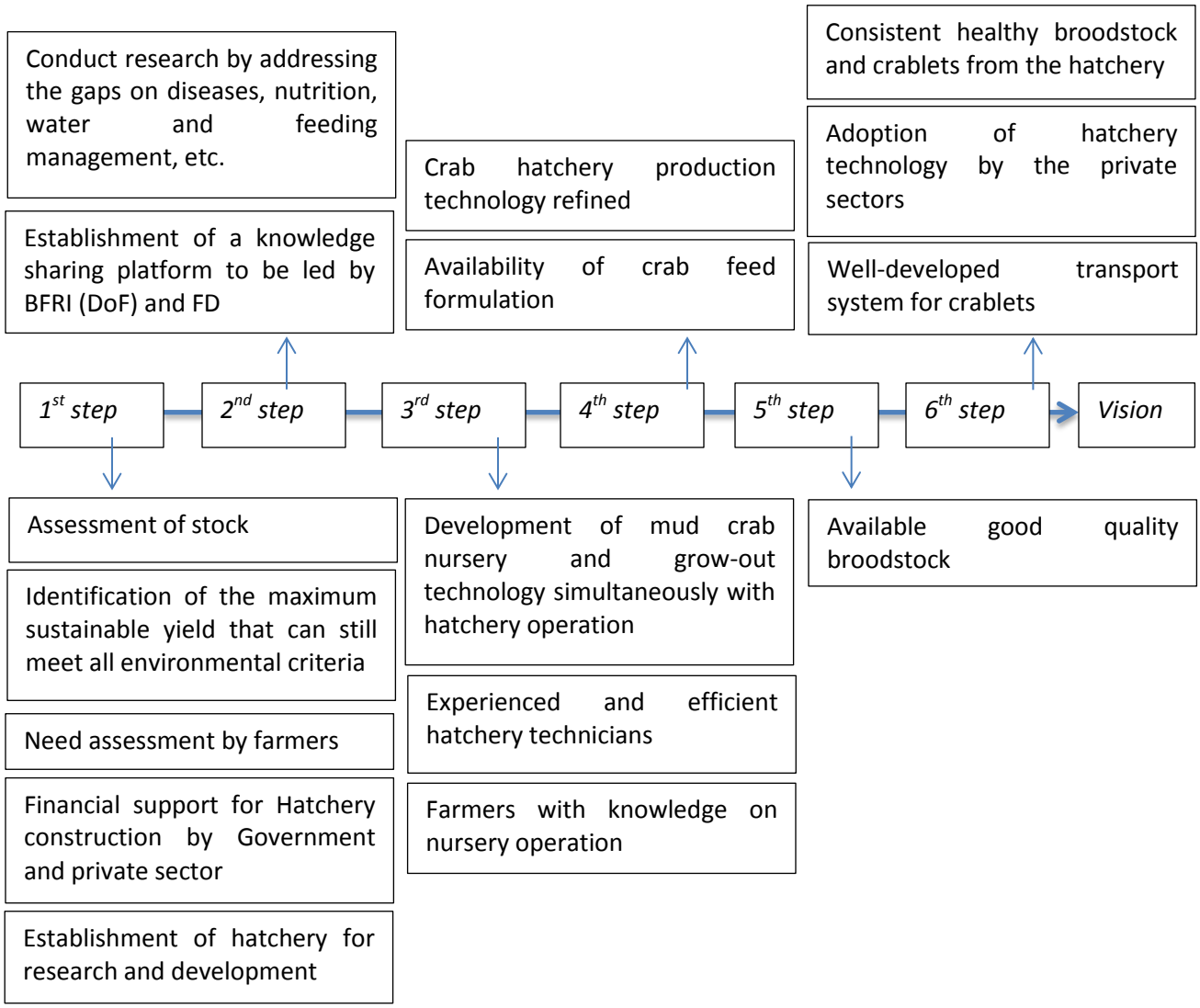

Figure 10: Summary of results of group work 2, task B, sketching a road map for the mud crab hatchery sector in Bangladesh

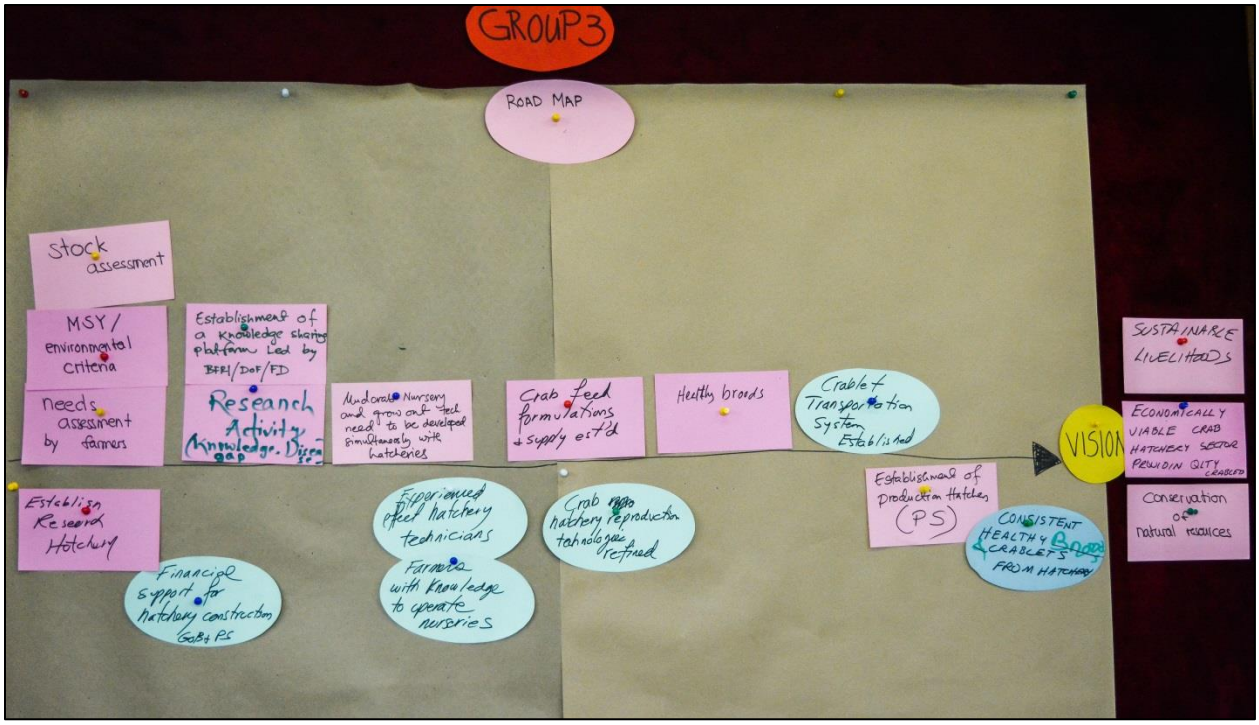

Figure 11: Results of group work on sketching a road map for the mud crab hatchery sector in Bangladesh

By drafting the roadmap it became evident to participants that a lot of activities would need to be initiated at the same time as they are mutually dependent on each other. At the same time it was acknowledged that the simple roadmap which was drafted as a first attempt to capture the sequence of milestones towards successful mud crab hatchery development does not adequately reflect the varying durations of certain activities. However, the key message here is that it is difficult to develop one of the segments of the value chain independently without considering the conditions beyond. For example, an intact transportation system is essential for transferring crablets to farmers without further losses associated with the mortality of the organisms. Hence, aligning activities and interests of other actors early in this process can reduce bottlenecks and create synergies in the operationalization.

In addition, the group pointed out that some considerations pertaining to the environmental sustainability defined as a key aspect in the vision will need more targeted interventions such as identifying the maximum sustainable yield for extraction of broodstock from the wild. Again, the need for leadership by the government especially concerning financial support during the initial developmental stage of the mud crab sector was emphasised as important factor triggering subsequent interventions to refine and up-scale the technology.

Looking at the results of both tasks in group work 2 it becomes evident that both groups identified similar essential elements, may they take the shape of challenges and probable solutions or the milestones of a roadmap, all participants seem to be clear and agree in principal on the way forward towards economically viable crablet production in Bangladesh's hatcheries.

Prioritization of challenges

The objective of the task was to find out the most important challenges based on the results of task A. Each person was given three votes in the form of "*tips*" to select their most important challenges. Giving more than one vote to an item was possible. In the end, the total number of tips was calculated for each challenge to give an overall impression about most important challenges needed to be solved for successful development of mud crab hatcheries in Bangladesh.

Results

The following points were regarded as most important by the participants:

Rank	Challenge	Votes
1	Lack of skilled manpower	13
2	Lack of reliable supply of good quality broodstock	10
3	Lack of fine-tuned technology ready for commercial hatchery operation	9
4	Lack of coordination between academia, government organizations, private sector and NGOs	3
4	Lack of knowledge on hatchery water management (salinity)	3
6	Slow uptake of hatchery technology by the private sectors	2
6	Difficulty in sourcing good quality food (natural and artificial) for broodstock	2
8	Lack of reliable source of power supply	1

Based on the prioritization exercise, workshop participants regarded the improvement of human capacity as most important issue to be addressed. Next to that, issues related to the input required for hatcheries such as good quality broodstock, reliable power supply and feed were selected. Thinking beyond hatchery operation, it was also acknowledged that the readiness of the private sector to take over currently government-led efforts are not yet in place and need to be further stimulated for a roll-out of the technology.

Outlook

- It was agreed that the basic mud crab hatchery technology has been developed but necessary modifications have to be done based on the conditions in a particular country. In the context of Bangladesh, sites should be carefully selected considering all criteria before establishing mud crab hatcheries.
- It was also recognized by all participants that conservation of the wild stock should be done along with the establishment of mud crab hatcheries. Provision of alternative livelihood to wild crab collectors needs to be considered when any conservation measure is done by the BFD.
- Participants acknowledged that sharing of knowledge is very important for better coordination and collaboration among different organizations. Government organizations e.g. FD, DoF or BFRI can take the initiative.
- Representatives from government organizations, academia, and NGOs have agreed that they all are responsible in propelling the mud crab industry. Likewise, the government has the responsibility to improve the existing technology, coordinate activities, formulate policies, etc.
- CCF of FD proposed DoF to organize the next mud crab knowledge sharing workshop.
- BRFI and DoF are going to construct mud crab hatcheries through a new Government project for mud crab and eel. Dr. Quinitio, through the SMP Project, supported BFRI by designing the layout for their new hatchery. BFRI will continue hatchery trials.
- Once the technology is transferrable with satisfactory survival rate (achieved from government projects through DoF, BFRI or FD), it will be transferred to the private sector for commercial production. FD will try to support any private company interested in establishing a hatchery.

Closing remarks

The wrap up and closing remarks were conducted by Dr. Quinitio and Mr. Zahid Uddin Ahmed, Conservator of Forest, Khulna Circle.

As a representative of the Forest Department, Mr. Jahir Uddin Ahmed mentioned that strong commitment and increased coordination among FD, DoF, and other sectors will be significant milestones for further developing mud crab hatcheries in Bangladesh, which was also well proved by the group work during the workshop. In this sense, Mr. Jahir Uddin thanked all participants for their valuable inputs emphasising the high value of such an exchange and the need to institutionalise a similar platform on a regular basis.

Dr. Quinitio likewise reflected on her involvement during the two trials she accompanied in Bangladesh, where she acknowledged that significant contributions have been made towards commercial hatchery-based crablet production in Bangladesh. Carrying on these trials will imply a continuous learning process where increased coordination among relevant stakeholders will be essential and allow for building synergies. With joint efforts, challenges such as the achievement of a commercial survival rate can be overcome with time. Accordingly, she ensured her further support to Bangladesh, if need be.