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Ecology and reproductive biology of Mud Crab *Scylla spp:* A study of commercial mud crab in Bangladesh

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Abstract
Mud crab (*Scylla* spp.) are one of the most delicious seafood items and attaining high economic value around the world especially tropical and subtropical countries. Still the mud crab trade are subject to wild capture mostly from coastal mangrove and there is no absolute procedure for hatchery production. The current revision states the knowledge of crab biology, ecology and reproductive behaviors of the genus *Scylla* species in order to better adapting their ecology, population biology and the sustainable administration for artificial seed production in addition to the selection of species for aquaculture.

Keywords: mud crab, Scylla, coastal, seafood, aquaculture

1. Introduction
The mud crab or Mangrove crab of the genus *Scylla* is an important species and valued as a source of food [11, 13] and income for many tropical Indo-Pacific countries like Philippines, Indonesia, Vietnam, China, Taiwan, India, Sri Lanka, Bangladesh and Malaysia [2, 5, 9]. The growing demand for mud crab in Asia, Europe and America has stimulated an increase in mud crab production [11, 16]. It is a euryhaline species occurs in the coastal waters of 2-30 ppt salinity [1, 3, 19] and particularly dominates in the mangrove area. Biochemically mud crab is enriched with 15–25 % protein, 1 % fat and 2–3 % minerals [3, 11] that make crab as popular food items globally and also with high market prices [18, 23]. There are about 15 crab species found in Indo pacific region. The main species supporting the crab fisheries in Asia and Australian region are *Scylla serrata*, *Scylla tranquebarica*, *Portunus pelagicus*, *Portunus sanguinolentus*, *Charybdis feriata*, *Charybdis lucifera and Charybdis truncate* [18].
In historical aspect Crab farming is not so ancient one. Attention in the farming of *Scylla* species has existed in tropical Asia (China) since the 1970s [8]. At that time carb farming just developed with polyculture pond with fish and shrimp at very low density. In 1994-1995 shrimp production was decreased drastically due to repeated disease outbreaks in shrimp ponds [8, 13, 16]. For this reason crab farming has become increasingly popular in many Asian nations. At present there is an emergent demand for mud crab in Asia, Europe and America and it has been found an increasing trend in mud crab production (Figure 1). China is the largest producer of farmed Indo-Pacific mud crabs; again Philippines, Indonesia, India, Myanmar, Viet Nam and Bangladesh are also a good contributor of crab production.

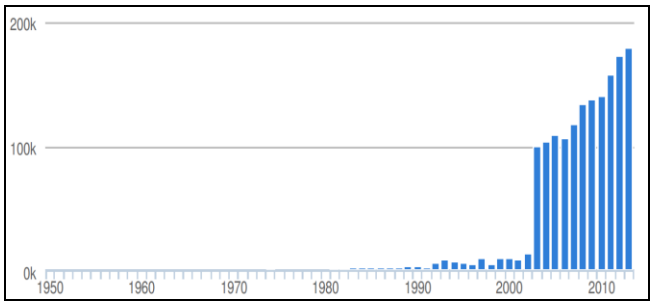

Fig 1: Global mud crab production trend from 1950 to 2014 (Photo adopted from Fisheries, F.A.O., 2010)

The *Scylla serrata* is the commercially important crabs in Bangladesh has a great demand for their esteemed seafood delicacy and also the value of fishery they support. More than 300000 fishermen are involved in its harvesting from the Sundarbans and its backwaters [13]. According to Export Promotion Bureau [4], Bangladesh exported *Scylla* crab at worth of Tk3.5 billion in 2013-14 fiscal year. However, the major part of the export is based on the harvest from the wild resources. About 80-85 per cent of crab exported from Bangladesh is caught from natural sources, especially Sundarban mangrove forest [16, 23]. Because of huge demand and good price the species is discriminately harvested from vast area of low lying tiger shrimp (*Penaeus monodon*) ponds along the whole coastal zone of Bangladesh. Thus the continued pressure on the species could result the declining its natural stock.
So it is necessity to develop artificial breeding techniques for the sustainability of this species. The high market value and its commercialization, most crab farmers ultimate target is to find seeds from any sources.

Availability of crab seed from a hatchery will reduce pressure on the natural crab sources as well as will increase availability of crab seed for commercial culture and fattening, leading to higher production. Hence in the present study an attempt to focus some aspects of biology, reproduction, artificial breeding and fattening technique of mud crab.

2. General Biological feature

Mud crab is a crustacean belongs to the phylum Arthropoda. It has flattened shaped body (Figure 2) with smooth carapace and strong transversal ridges [14, 20, 23]. Gastric zone on the carapace with a deep H-shaped groove and Cephalothorax is much enlarged and covered by a hard chitinous partly calcified carapace. Cephalothorax has five pairs of head appendages and eight pairs of thoracic appendages, last five pairs are legs. The last pair of legs is powerful and chelated (Figure 2) with well-developed spines on the outer surface [7]. The mud crab species *Scylla serrata* can grow up to 300 millimeters in shell width and 2.5 kilograms Carapace green to almost black with legs that may be marbled [7].

2.1 Systematic position

Phylum: Arthropoda
Class: Crustacea
Order: Decapoda
Sub order: Brachyura
Family: Portunidae
Sub family: Portuninae
Genus: *Scylla*
Species: *Scyalla serrate*

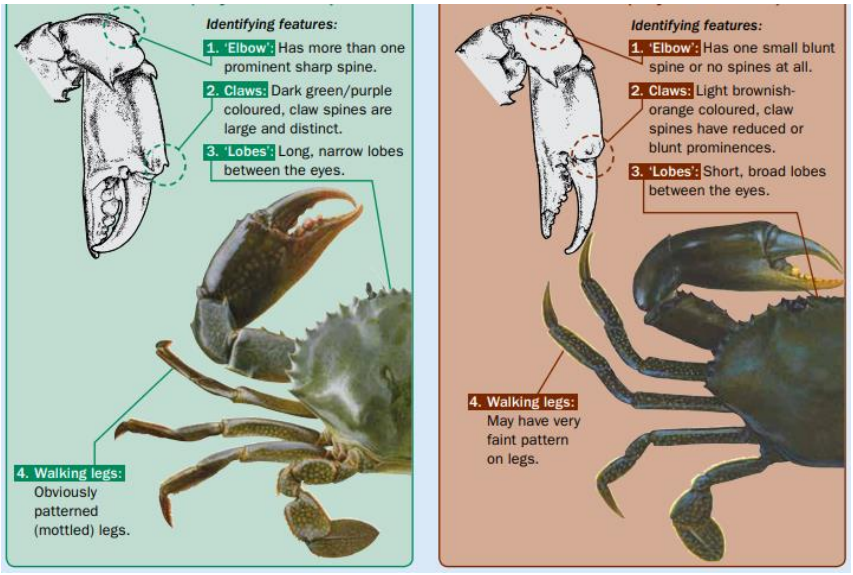

Fig 2: Identifying feature of appendages between two mostly available mud crab a. *Scylla serrata*, b. *Scylla olivacea*. (Australia W, 2013)

2.2 Habitat and Global Distribution

They prefer Mangrove area, intertidal flats, mangrove swamps of the estuaries and soft muddy bottom so that they can burrows bottom easily [7]. They are highly tolerant of variations in water salinity (2-30 ppt) and temperature [7, 11]. Also found in beel, gher, pond especially in muddy and sandy bottom[11]. These species are mostly found in estuarine and sheltered coastal habitats and, in general, large populations are usually associated with established mangroves, especially in estuaries [15]. Mud crabs are widely distributed in the Indo-West Pacific region from East and South Africa to southeast and east Asia, Japan and Northeast Australia [12, 21]. Also found in the eastern Pacific around the Marianas, Fiji, the Samoa Islands and the Hawaiian Archipelago. There are four predominant *Scylla* species (Table 1) available in tropical and subtropical mangrove area, among them *S. serrata* is the most widely distributed species among the genus *Scylla* [14, 15, 20, 23].

Table 1: Global distribution of *Scylla* species (Keenan *et al*., 1999; Vay, 2001)

Species	Global Distribution
Scylla serrata	Indo-West Pacific: South Africa, Red Sea, Australia, Philippines, Pacific Islands (Fiji, Solomon Islands, New Caledonia, Western Samoa), Taiwan, Japan
S. paramamosain	South China Sea: Cambodia, Vietnam, Singapore, China, Taiwan, Hong Kong, Singapore; Java Sea: Kalimantan, Central Java
S. olivacea	Indian Ocean: Pakistan to Western Australia; South China Sea: Thailand, Singapore, Vietnam, Sarawak to southern China; Pacific Ocean: Philippines, Timor, Gulf of Carpentaria, Bay of Bengal
S. tranquebarica	Indian Ocean: Pakistan to Malaysia; South China Sea: Sarawak, Singapore; Pacific Ocean: Philippines

Most of the Scylla species are capable to tolerate high level of salinity at their larval and juvenile stage [11, 14, 20]. They reported that *S. serrata*, is dominant in oceans with salinity more than 34 psu and in mangroves that are inundated with high salinity water for most of the year. The other species are more abundant in seas where salinity is normally below 33 psu and are able to colonize estuarine habitats in which periods of low salinity season [15, 19].

2.3 Food and Feeding

Mud crabs are Omnivorous and nocturnal feeders. Voraciously feed on crustaceans, mollusks, small fish,

detritus sand and plant matter and other dead crab. In pond they feed on natural food as algae, crustaceans and other animal matter. They also feed on trash fish and eel fish. Feeds are caught by chelate legs. The reproductive performance and larval productions of mud crab are mostly dependent on variation of maturation diets [10, 19]. The natural diets are also used for broodstock culture during the hatchery production, but sometime the use of natural feeds causes deterioration of water quality [2].

3. Reproduction

3.1 Identification of sex

Crabs have separate sexes. Morphologically sexes can be distinguished by the shape of abdominal flap. Although the shape of flap is more or like similar in both mature and immature male (Figure 3a) but in female flap has distinct separation in both stages [6]. In mature female the shape of abdominal flap is half–rounded (Figure 3b) while triangular in immature one (Figure 3c). Sometime externally sex can be identified by Chelipeds. Male cheliped is comparatively larger than female.

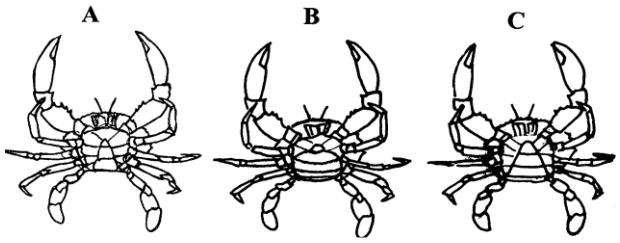

Fig 3: Shape of abdominal flap a. Immature/mature male; b. Mature female; c. Immature female (Photo modified from Srinivasagam, 2000)

3.1 Male Reproductive system

Male reproductive system internally consists of a pair of testes, vas deferentia and ejaculatory ducts and externally a pair of pleopods and accessory reproductive organs present in the inner side of abdomen (Figure 4 a). The ejaculatory ducts open into small genital papilla. The ejaculate consists of non-motile sperms and seminal plasma. Sperms are store into vas eferentia and pleopods helps to pass the sperms from ejaculatory ducts. Both male and female become sexually mature when Carapace width reaches above 90 mm[6]. Sexual maturity can be classified into three stages like (i) *Immature*-creamy/transparent colour and absence of prominent vas deferens (ii) *Maturing*-Creamy white occupy 1/4th of body cavity and (iii) *Mature*-milky white vas deferens occupying full body cavity (Figure 5).

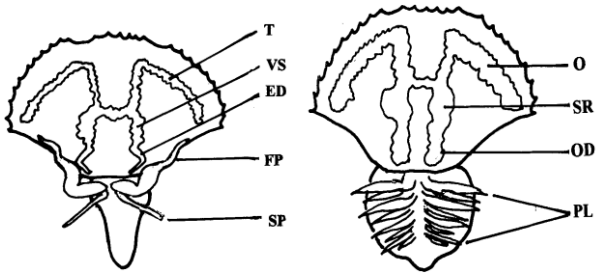

Fig 4: a. Male reproductive system; T-Testes; VS-Vas Deferens; ED-Ejaculatory duct; FP-First pleopods; SP- Second Pleopods; b. Female reproductive system; O-Ovary; OD-Oviducts; SR- Seminal Receptacle, PL-Pleopods (Photo adopted from Quinitio, 2010)

3.2 Female Reproductive systems

Female reproductive system consists of a pair of ovaries, seminal receptacles, a pair of oviduct and four pair of pleopods (externally) and some accessory organs (Figure 4b). The seminal receptacles are the large part of oviduct and oviducts open to the exterior through the female genital opening situated at sixth thoracic segments [17]. Ovarian development can be classified into three stages like (i) *Immature*-yellowish/transparent colour and absence of prominent seminal receptacle (ii) *Maturing*-Pink in colour occupy 1/3th of body cavity and (iii) *Mature*- Orange red colour with prominent seminal receptacle occupying full body cavity (Figure 5) [6, 17].

3.4 Life cycle of Mud Crab

Crab spawns in sea then the larval development occurs in estuary. Because of their inflexible exoskeletons, the copulatory partners (male) wait until the female moults. The male senses through pheromones released by the female that her moult is imminent. Then, to ensure that he will be the copulatory partner, he holds her in a close embrace known as amplexus until she moults. After copulation, which involves the male inserting spermatophores (sperm packets) into the vagina of the female. Life cycle of mud crab can be described into some stages (Figure 6) [7, 17, 22]. Eventually it was observed all Scylla species completed similar larval developmental stage (Figure 7)

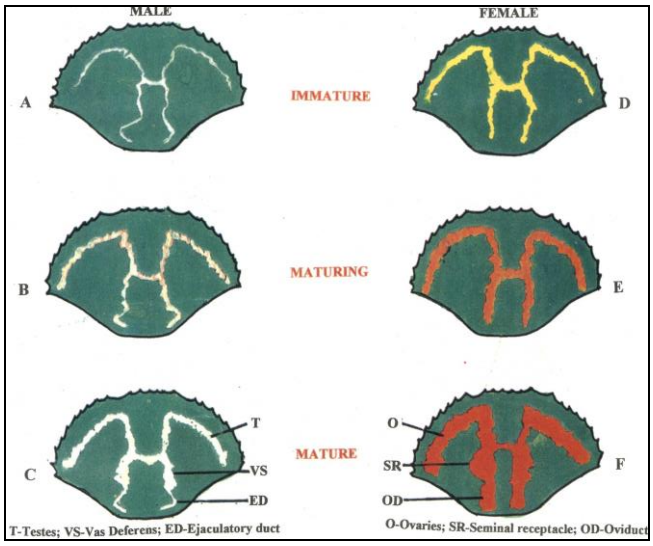

Fig 5: Development stage of testes and ovary (Modified from Srinivasagam, 2000)

1. **Zoea:** A mud crab begins life as a larva called a 'zoea', which hatches from an egg. It is about one millimetre long with undeveloped limbs and looks a little like a tadpole. The zoea floats in the water with plankton – microscopic organisms that drift in clusters [7, 17, 23].
2. **Megalopa:** A zoea grows by moulting four times during a period of 12 to 15 days. As it moults for the fifth time, it transforms into a megalopa, which has functional claws. After a week or so, it moves inshore and settles on the seabed. After a few days, it moults into a juvenile crab [7, 17, 23].
3. **Juvenile crab:** The juvenile crab is a miniature version of the adult, about four millimetres wide. About a month after hatching, when 10 – 20 millimetres wide, it moves to an estuary and settles in a sheltered area [7, 23].

4. **Young adult**: The crab reaches sexual maturity at 18 to 24 months. A green mud crab matures at about 110 millimetres (carapace width) [7, 18].
5. **Mating:** Mud crabs mate in warmer months. Mature females release a 'pheromone' (chemical attractant) into the water to attract males. Once paired, the successful male climbs on top of the female, clasps her with his hind legs, picks her up and carries her around for up to four days. The male deposits a capsule of sperm inside the female's reproductive opening, where it's stored for months until the developing 'ova' (eggs) are ready to be fertilized [7, 18].
6. **Spawning and hatching:** The female migrates offshore to spawn. Eggs are about 0.3 millimetres in diameter. The fertilised eggs are released in batches of two to five million. The eggs hatch in two to four weeks. During hatching, the female stands on the tips of her legs and moves her abdominal flap to help free the zoea. The lifecycle then begins again [7, 18, 23].

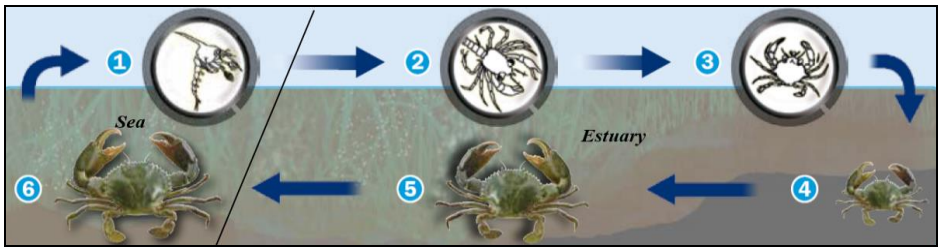

Fig 6: Reproductive cycle of Mud crab modified from Australia W, 2013

4. Artificial breeding technique

Aquaculture production of mud crabs relies on wild-caught seeds. However, good news that hatchery-produced seed stock has been started in the Philippines, Vietnam and China over the last 5-10 years. A basic technology for artificial breeding has been developed for the commercial seed production of crabs by Southeast Asian fisheries development centre [7, 17].

4.1 Collection of Broodstock

The success of breeding depends of broodstock. Live mature male and female *S serrata* obtained from the wild sources like inshore sea and brackish water region. Then the crab should be disinfected individually in 100 ppm formalin for 30 minutes before transferring them to the broodstock holding tank [17].

4.2 Acclimatisation of Broodstocks

Before transferring the crab into hatchery the adult mud crabs should be held in a tanks containing sea water (30 to 35ppt) for a week in order to acclimate them to the hatchery condition. After a week induced maturation and breeding program should be done [17].

Stadium	Specification	Period required by larvae in the rearing tank (days)
 Zoea-1	Total number of plumose setae 4 Sessile eyes, Abdomen 5 segmented	6
 Zoea-2	Total number of plumose setae 6 Sessile eyes, Abdomen 5 segmented	4
 Zoea-3	Total number of plumose setae 8, eyes stalked. Abdomen 6 segmented.	3
	Total number of plumose setae 10, Pleopod bud on abdomen segmen 2-6	4
 Zoea-5	Pleopod in abdominal segment well developed	5
 Megalop	First periopod modified into cheliped. Four pair of leg, where swimming leg stil undevelop	7
 Crablet	A pair of cheliped, three walking legs and a pair of swimming leg, 9 anterolateral spines	

Fig 7: Identifying feature of different larvae development and period required by each stage. (Photo modified from Gunarto and Parenrengi, 2016)

4.3 Hormonal control: Eye-stalk ablation

In crab most of the endocrine system regulated from eye stalk. The X-organ and sinus gland complex in mud crab plays an important role in the regulation of metabolism [14]. Eye-stalk contains Hyperglycemic Hormon (HGH) and moult inhibiting hormone (MIH) those are responsible for metabolic regulation and inhibition of Y-organ secretion. So eye-stalk ablation done to control the sources of HGH and MIH therefore increased food intake faster growth of ovary and also significantly increases weight and size of oocytes. Usually the eye-stalk of mature female should be removed in breeding purpose and for male it is not obligatory [17, 22].

4.4 Stocking in Spawning tank

After ablation the adult crab transferred to the spawning tank. Usually the circular or rectangular tanks of 5-10 tonne capacity are used as spawning tank. The stocking rate of brood should be 1-2 crabs per square metre. Male and female sex ratio should be 1:1 [11, 17].

4.5 Spawning and larval rearing

Spawning takes place within 10 days after eyestalk ablation. A combination of two or more natural food items, such as fish, marine worms (polychaetes), shellfish and squid is fed at 5-10 percent of biomass. Formulated diet is fed at 1-3 percent in combination with natural food. The hatchling called zoea and transferred to hatchling tank. The stocking density of zoea is 80–100/litre. Zoea are fed rotifers and Artemia nauplii, while early megalopae are offered processed food or ≥5-day old Artemia to provide larger-sized prey. Once the megalopae settle on the bottom, minced mussel meat and/or fish is given. Various feeding and water management schemes have been developed to suit the diverse conditions in different countries [17, 22].

4.6 Nursing of crab lets

The final step is to nurse crablets into nursing pond. The pond area ranges from 200 to 800 m^2. Sometime hatcheries include net cages in ponds. Crabs of less than 1.0 cm are grown to 1.5-2.0 cm CW in net cages at 20-50/m^2 (Phase 1). Some farmers prefer larger crabs, so they on grow them to 3.0-4.0 cm CW in ponds lined with nets or net fences lining the dikes at 5-10/m^2 (Phase 2) [11, 15]. The culture period is 3-4 weeks in each phase, depending on the desired size for stocking in ponds. Stocking density can be increased if the culture period is less than 4 weeks. At this time crabs are fed a combination of at least two food items such as minced low-value fish, shellfish, chicken trash, boiled corn, or formulated feeds at satiation once or twice daily.

5. Fattening Technique

Fattening involves in monoculture of crab for short time focusing in commercial aspects. There is some specific grading available for crab marketing. Sometime market sized but lean crabs (soft shell) from ponds or the wild get a low price in either local or export markets. Therefore lean crabs are fattened for 15-30 days in ponds [11], pens and cages set in ponds, protected coastal waters or shallow lagoons.

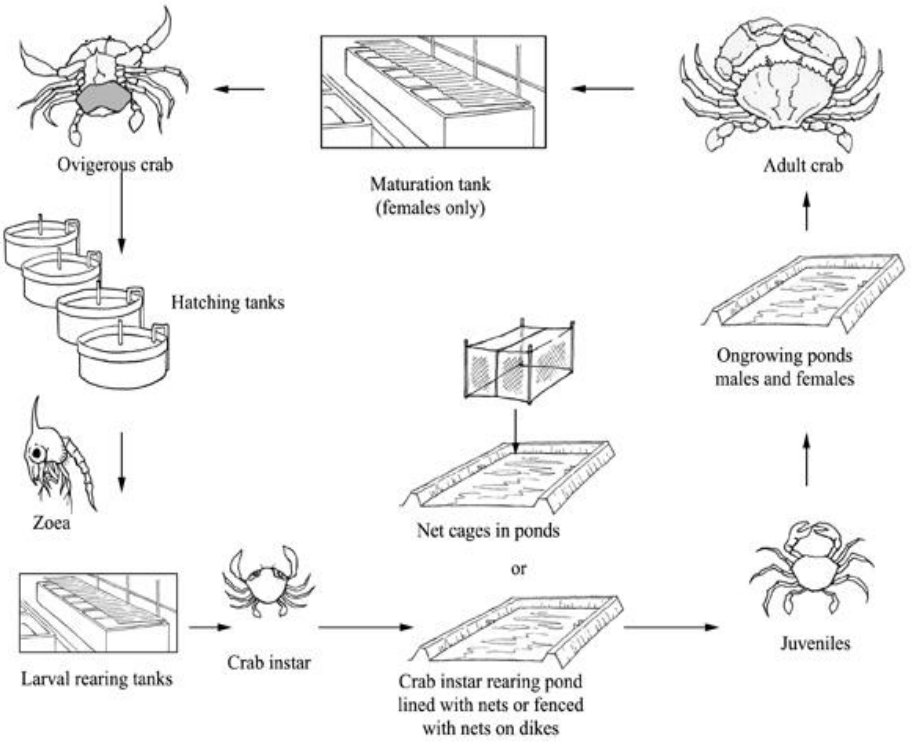

Fig 8: Induced breeding cycle of mud crab (Modified from the Protocol of Quinitio, 2010 and Fisheries, F.A.O., 2010)

5.1 Collection and stocking of lean crab in cage/pond

Pond size should be 0.5 to 1 ha with 1-1.5m depth. The water temperature, salinity DO, and pH should be 20-30 degree C, 5-25 ppt, 4-8mg/l and 7.5-8.5 respectively [3, 11]. In case of cage the size of each cage is 2 m×1 m× 0.3 m (length × width × height) comprising of 50 cells. The stocking density may be up to 1/cells in communal rearing since the culture period is short. The water Crabs are fed

With low-value fish, snails and chicken trash at 5-8 percent or to satiation.

5.2 Collection and grading

Generally the gonad will mature within 12-16 days. At that time the crab are harvested and separated the crab according to marketable grade (Table 2). Sometime if it fails to reach marketable size, stock again for another time.

Item	**Female**				
Name of grade	F1	KS-1[a]	F2	F3	F4
Weight (g)	>180	>180	150–<180	120–<150	<120
Price range (BDT)	250–1,000	100–350	200–500	150–400	100–300
Item	**Male**				
Name of grade	XXL	XL	L	M	SM
Weight (g)	>500	>400	>300	>200	>100
Price range (BDT)	250–800	200–650	150–450	100–350	50–200

Fig 2: Grading system of gonad matured/hard shell mud crab (Modified from Huq *et al*., 2015)

6. Conclusion

The mud crab industry is a rapid growing sector in the world especially in Asia and Australia. With the establishment of hatcheries and breeding technique in some countries, worldwide mud crabs production is increased from last few years. To improve further overall performance of mud crabs in captivity and to sustain the industry artificial seed production is very important. This seed not only increases the world production but also reduced the pressure on nature and also create involvement of millions people as their livelihood.

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