# TAXONOMIC CONFIRMATION AND SPECIES COMPOSITION OF MUD CRAB *Scylla* spp. AVAILABLE IN BANGLADESH

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# Abstract

Bangladesh is riverine country located in South Asia along with a coastline about 710 km including 618,780 ha mangrove with tidal flats which are greatly suitable for distribution and good composition for mud crab population. In past many researchers worked on the mud crab for aquaculture purpose in the real field without knowing their proper species recognition including with their composition in the coastal regions of Bangladesh. Recently some researchers dealt with taxonomic work on crab for species clarification based on molecular techniques which required highly modern equipped laboratory that is known to be difficult for general people including illiterate fishermen. This research was conducted for measuring species composition of the mud crab (*Scylla* spp.), in the particular area of Bangladesh. The present study was conducted at Bagerhat, Cox's Bazar and Chittagong districts of Bangladesh for taxonomic confirmation and species composition of mud crab (*Scylla*). About 70-100 mud crab specimens were collected from each of those regions. From primary identification, 46%, 59% and 75% crabs were considered as *S. olivacea*, while 54%, 41%, and 25% crabs were *S. serrata* at Bagerhat, Cox's Bazar and Chittagong, respectively. For more clarification, all crabs were observed external morphology including with the description of first and second male gonopods and measured 24 morphological characters for morphologically distinct samples. From the measured characters were calculated into 27 morphometric ratio to recognise each single species. The present study confirmed the existence of two species of mud crabs namely *S. olivacea* and *S. serrata* where 59% was *S. olivacea* and 41% was *S. serrata* from the collected sample in Bangladesh. The study revealed that *S. olivacea* is dominant mud crab species among four *Scylla* spp. after that *S. serrata* also well distributed in the coastal regions of Bangladesh.



**Keywords:** *S. serrata*; species composition; taxonomy; morphology; morphometric ratios

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# List of Abbreviation

| Abbreviation | : | Elaboration |
|---|---|---|
| et al. | : | Associates |
| viz. | : | Videlicet |
| e.g | : | Example |
| Mm | : | Millimeter |
| *S.* | : | *Scylla* |
| etc. | : | Et cetera |
| % | : | Percentage |
| MS | : | Master of Science |
| CVASU | : | Chittagong Veterinary and Animal Sciences University |

# CHAPTER 1:
# INTRODUCTION

Mud crab of genus *Scylla* is most promising aquaculture species in marine fish industry after shrimp for its greater economic benefits (Fukunga and Fukomoto, 1960; Cowan, 1984; Oshiro, 1988).They are found in mangroves areas, intertidal swamps as well as coastal regions (MacNae, 1968; Marichamy & Rajapackiam, 2001; Hoq, 2008) in many countries of Indo-West Pacific regions (Imai et al., 2004) like Tahiti, Australia, Japan, Southern Africa (Chhagar, 1957; Hill, 1975; Sakai, 1976) India, Sri Lanka (Jones and Sujanisingani, 1952; Chandy, 1973), Indonesia, Philippines, Malaysia (Arriola, 1940; Ong, 1966) Thailand, China, Taiwan (Tamura, 1966) etc. Now a day mud crabs are important exportable commodity of marine fisheries resources in Asian countries through its farming due to high demand with good price. So the knowledge of taxonomic details and distribution of *Scylla* are useful for the better management of the wild fishery and aquaculture development (BOBP, 1992; Brown, 1994).

Mud crabs of genus *Scylla* has four species in the worldwide, namely *S. serrata* (Forskal, 1775), *S. tranquebarica* (Fabricius, 1798), *S. olivacea* (Herbst, 1796) and *S. paramamosain* (Estampador, 1949). But all of these are closely similar that each species specifically is rarely difficult to identify for their overlapping morphological and morphogenetic traits. The taxonomy classification of these *Scylla* crabs was controversial reported for long time by Estampador (1949). He worked on mud crabs which were collected from Philippines and also classified those specimens into three species and one sub-species based on their external morphology and gametogenesis, namely *S. serrata, S. tranquebarica, S. olivacea* and *S. paramamosain* (Estampador, 1949). Then the existence of four form of the crabs of *Scylla* in Vietnam were recognized by Serene (1952). From the revision of the taxonomy of *Scylla* of Keenan et al., (1998) employed twenty-four morphological parameters and twenty-seven ratios, to identify these four distinct species as *S. serrata, S. tranquebarica, S. olivacea* and *S. paramamosain.* Many researchers already worked with the taxonomy of mud crabs accordance to Keenan et al., (1998) with morphological characteristic of mud crabs (Jiranpupipat et al., 2008; Ogawa et al., 2012). Despite this the taxonomy of

the *Scylla* crabs has been already reported in worldwide, there is something misleading along with overlapping theory to identify the four species.

Recently some scientific paper reported that the existence of three species, *S. serrata*, *S. tranquebarica*, *S. olivacea* (Radhakrishana and Samuel, 1982, Joel and Raj, 1983; Padate et al., 2013) in our neighbouring countries. For worldwide consumer value of mud crab, a large number of researchers were dealing with mud crabs from Bangladesh on biology, distribution, culture, brood stock development, biochemical analysis due to its economic importance (Khan and Alam, 1992; Saha et al., 2000; Begum et al., 2009; Ferdoushi and Xlang-guo, 2010; Sarowar et al., 2012, 2013). But their taxonomical work was not done for long time for its complicacy with misidentification report. Recently some researchers worked on taxonomic clarification based on the molecular techniques in digital modern equipped laboratory for confirmation of occurrence of *Scylla* species in Bangladesh. They identified only *S. olivacea* as major mud crab species instead of *S. serrata* (Sarower et al., 2016) in Bangladesh.

The coastal regions of Bangladesh consists of canals, rivers and estuaries that provide muddy substrate along with significant habitat, shelter and nursery ground for mud crab diversity. The existence of mud crabs is seen most of the coastal regions like Cox's Bazar, Chittagong, Noakhali, Bhola, Patuakhali, Bagerhat, Khulna and Shatkhira (Khan and Alam, 1991). Mud crab farming is common economic source as livelihood for local people for its availability in this region. In the past, mud crab as seafood was not so much preferable to people as Muslim country of Bangladesh for the thought of religious misconception. From recent decades, people interested as seafood besides traditional prawn among the local community in Bangladesh. These crabs expanded everywhere for its economic benefits. So local fishermen are also encouraged to harvest mud crabs from wild. Mud crabs are known as "mangrove" crabs by fishermen on the basis of habitat (Begum et al., 2009). They don't know these mangrove crabs consists of varieties. If the present studies are developed based on the morphological identification of these varieties, then anyone can differ four mud crabs easily and caring them with better environmental management.

The taxonomical knowledge is important for the development of a more successful aquaculture industry and also for wild stock management in Bangladesh. There is an

urgent need to clearly identify the mud crab species in Bangladesh using morphological diagnostic characteristics of mud crabs. This research also plays dignified role for investigating the dominant species in coastal regions of Bangladesh.

### 1.1 Objectives of this study:

i. To know the mud crab species diversity in different coastal region of Bangladesh
ii. To measure mud crab species composition in different region of Bangladesh
iii. To update the identification process based on the morphological characters of mud crabs

# CHAPTER 2:

# REVIEW OF LITERATURE

## 2.1 Distribution of mud crab:

The highly valued mud crab *Scylla* is widely distributed in Indo-West-Pacific (IWP) regions and Indian Oceans along with the coast of Tahiti, Australia, Japan, Southern Africa, Philippines, Vietnam, Sri Lanka, Indonesia, Thailand, Taiwan, China, Bangladesh, India, Malaysia etc. (Chhapgar, 1957; Hill, 1975; Sakai, 1976; Dai and Yang, 1991 Keenan et al., 1998; MacNae, 1968; Marichamy & Rajapackiam, 2001; Hoq, 2008; Jones and Sujanisingani, 1952; Chandy, 1973; Arriola, 1940; Ong, 1966 ).

Adult mud crabs generally inhabit muddy estuaries and enclosures in mangrove ecosystems that are influenced by tidal waters (Arriola, 1940; Brown, 1993;). In Deception Bay, southeast Queensland, Hill et al., (1982) studied the use of different habitats by different life stages. Large adults were predominantly distributed in the subtidal with peak abundances in the summer season (January to April; Hill et al., 1982). Some were also found in intertidal areas where they occasionally inhabit burrows at low tide (Arriola, 1940; Le Reste et al., 1976; Brown, 1993). Female crabs rather bury in the mud than seeking shelter in burrows, so the majority of crabs found in burrows are males (Perrine, 1978; Ewel et al., 2009).

Smaller crabs ae hardly found in burrows and inhabit subtidal waters only at low tide and move into the intertidal zone at high tide with peak abundances from spring to autumn (September–March; Hill et al., 1982). The movement of mud crabs seems to be closely related to the kind of habitat they live in (Hyland et al., 1984).

In general, crabs that live in enclosed habitats such as narrow mangrove-fringed creeks, normally do not move more than 1 km (Hill, 1975; Perrine, 1978; Hyland et al., 1984; Bonine et al., 2008), whereas in southern Moreton Bay, Queensland, crabs that are found in open environments like intertidal flats in open bays show larger movement (average 3.7 km) (Hyland et al., 1984). It is suggested that these different distances of routine movement (daily movements, e.g., foraging activity) are dependent on the

availability of alternative feeding grounds at high tide. Most of the Southeast Asian countries harvest and farming them as small to moderate scale commercial fisheries.

**2.2 Mud crab in Bangladesh:**

Mud crabs are also known commonly as green crabs or mud crabs (Shafi and Quddus, 1982). It is locally known as "Shila Kankra", "Habba Kankra"or "Kankra" (Saha and Ahmed, 1999). The coastal region of Bangladesh including its canals, rivers and estuaries provides a muddy substrate, which play great roles as habitat, shelter and nursey ground for commercially important mud crab species (Acharya and Kamal, 1994). In Bangladesh, mud crab occur abundantly in the coastal rivers of Cox's Bazar, Chittagong, Barisal, Patuakhali, Sathkhira, Khulna, Noalkhali and in the inshore of island of Moheskhali, Kutubdia, Swanddwip, Hatia and Dubla i.e. all inshore island except St. Martin Island (Khan and Alam, 1992). The population density of mud crab in the intertidal zones of the estuary and coastal backwater swamps of Cox's Bazar, Chittagong, Khulna, Sathkhira and Bagerhat which have mangrove vegetation appears to be relatively higher than that of Noakhali, Bhola, Patuakhali and Barisal where deltaic muddy shores with vegetation is dominant (Ahmed, 1992).

Mud crab is one of the most potential exportable aqua-resources of Bangladesh (Ahmmed, 1992; Khan and Alam, 1992) where mud crab was considered as *Scylla serrata.* So continued increase in export of live mud crab plays an important role to the foreign exchange earning of Bangladesh (Azam et al., 1998). From that local communities were involved to culture mud crab. For that fattening of mud crab has become a new agro-business across the coastal zone of Bangladesh (Kamal, 2002; Kamal et al., 2003; Zafar, 2003, 2004).

In Bangladesh, crab fattening in ponds was started in the early 1990's (Kamal, 2002 ), while fattening and culture of mud crab in bamboo cages, pens and pots only experimental level and started 2000's (Obeyed, 1998; Kamal, 2002; Kamal and Uddin, 2004; Zafar, 2003, 2004; Khatun, 2007). Salam et al., (2003), using GIS tools, identified the lower South-Western region as the most suitable for mud crab culture in Bangladesh. Zafar (2003) conducted an experiment on the fattening of mud crab as *S. serrata* in cell (7 x 3x 1 inch in size) type and open type cage (7x3x2 inch in size) through the participation of poor coastal people in Bangladesh. Saha et al., (2000) studied the effect of stocking density on brood stock development of mud crab as

*S. serrata* in brackish water earthen ponds in Bangladesh with the stocking density of 0.6, 0.8, 1.0 and 1.2 crabs / $m^2$. In past, *S. serrata* was annually reported as single species by Department of Forest in Bangladesh (DoF, 2011). From that many researcher used the name in their studies like stock assessment (Chantarasri, 1994), growth, recruitment and economic performance (Zafar et al., 2006), different fattening technology (Kamal et al., 2007; Begum et al., 2009), harvesting technique (Hossain and Ahmed, 2006), culture and bio-economics (Ferdoushi and Xiang-Guo, 2010), feasibility of mud crab (Mahmud and Mamun, 2012). Keenan et al., (1998) revised the genus *Scylla* and described four species based on morphological with molecular analysis work. These type of related work didn't perform for a long period in Bangladesh. So researcher worked their research with misconception findings. Recently three species of *Scylla* except *S. paramamosain* were recorded based on taxonomic work in India (Trivedi and Vachhrajani, 2013). After knowing this information, some Bangladeshi researcher worked on taxonomic clarification on mud crabs on the basis molecular analysis which revealed as major species is *S. olivacea* (Sarower et al., 2016).

**2.3 Taxonomic identification of mud crab genus *Scylla* spp.:**

The occurrence of various species of the crabs belonging to genus *Scylla,* their taxonomic status under considerable ambiguity in view of the localized variations in morphology of these crabs (BOBP, 1992; Joel and Raj, 1980; Marichamy and Rajapackiam, 2001). There general taxonomic classification defined that the mud crab belongs to the family Portunidae (Rafineesque, 1815) which known as swimming crab. There Portunidae is under order and infraorder as Decapoda and Brachyura (Latreille, 1802) respectively. The portunidae consists of 27 genera and the mud crabs belongs to the genus *Scylla* (De Haan, 1833). The classification of mud crabs *Scylla* is controversial reported from beginning research studies. Stephenson and Campbell, (1960) argued the genus *Scylla* has only one species *Scylla serrata.* Then Keenan et al., (1998) revised the genus *Scylla* and identified the four non-hybridizing species as *S. serrata* (Forskal, 1775), *S. olivacea* (Herbst, 1796), *S. tranquebarica* (Fabricus, 1798) and *S. paramamosain* (Estampador, 1949*).* The differences of four species are given following which described by Keenan et al., (1998).

- *Key indicator:*
    i. Carpus of chelipeds with two obvious spines on distal half of outer margin… (1); (2)
    ii. Carpus of chelipeds without two obvious spines on distal half of outer margin…(3); (4)

1. *S. serrata:* Frontal lobe spines high (mean height c. 0.06 times frontal width measured between medial orbital sutures), bluntly pointed with tendency to concave margins and rounded interspaces. Anterolateral carapaces spines narrow with outer margin straight slightly concave. Chelipeds and legs all with polygonal patterning for both sexes and abdomen female only.

**Figure 1: Dorsal and frontal view of *S. serrata***

2. *S. tranquebarica*: Frontal lobe spines of moderate height (mean height c. 0.04 times frontal width measured between medial orbital sutures) blunted with rounded interspaces. Anterolateral carapaces spines broad with outer margin convex. Polygonal pattering weak on chelipeds and first two pairs of legs; last two pairs of legs with stronger patterning for both sexes; pattering variable on abdomen of female, absent on male.

**Figure 2: Dorsal and frontal view of *S. tranquebarica***

3. *S. paramamosain*: frontal lobe spines high (mean height c. 0.06 times frontal width measured between medial orbital sutures), typically triangular with straight margins and angular interspaces. Palm of cheliped with a pair of distinct spines on dorsal margin behind insertion of the dactyl, followed by ridges running posteriorly. Cheliped and legs with weak polygonal pattering for both sexes.

**Figure 3: Dorsal and frontal view of *S. paramamosain***

4. *S. olivacea*: Frontal lobe spines low (mean height c. 0.03 times frontal width measured between orbital sutures), rounded with shallow interspaces. Palm of cheliped usually with a pair of blunt prominences on dorsal margin behind insertion of the dactyl, inner larger than outer; may be spinous in juveniles and young adults. Cheliped legs and abdomen all without obvious polygonal patterning for both sexes.

**Figure 4: Dorsal and frontal view of *S. olivacea***

**2.4 Diversity of the mud crab:**

From the beginning of the research on mud crabs recorded as *Cancer serratus* by Forskal, (1775). Then several carcinologists from different parts of the Indo-Pacific region concentrated on this species (Herbst, 1796; Fabricius, 1798; De Haan, 1833; Milne Edwards, 1834; Dana 1852 a,b,c; Stimpson, 1907). After that in India, Fabricius, (1798) firstly reported and described the mud crabs specimens from Tranquebar (Tharagambady of Tamil Nadu coast) and designated them as *Portunas tranquebaricus*. Following this, many authors viz., Alcock (1899), De Man (1909), Kemp (1915), Gravely (1927), Pearse (1932), Chopra and Das (1937), Panikker and Aiyyer (1937), Pillai (1951), Naidu (1953), Chhapgar (1957, 1962), Balasubramanian (1966), Rekha (1968), Premkumar and Daniel (1971) have mentioned the existence of mud crabs,

which was designated as *Scylla*, while dealing with various aspects such as fishery, biology etc.

Estampador (1949) gave outline about three species and a new sub species of genus *Scylla* from Philippines while Serene (1952) reported the four forms of *Scylla* in Vietnam. These species are inconspicuously overlapped for distinguishing them. So these work subsequently reviewed by Stephenson and Campbell, (1960) and Holthius, (1978). Fushimi (1983) and Oshiro (1988) reported the presence of three forms of mud crabs in Japan. Fushimi and Watanabe, (1996) describes the major problems to identifying them. At the same time Keenan et al., (1998) worked on mud crabs from collecting specimens from Red Sea and throughout the Indo-Pacific regions and classified them into four species, *S. serrata*, *S. tranquebarica*, *S. olivacea* and *S. paramamosain* , based on their morphological, morphometric and molecular analysis. Later three species as *S. serrata*, *S. olivacea* and *S. paramamosain* are distributed in Japan by Oshiro and Imai, (2003). However, among the four known *Scylla* spp., *S. serrata* and *S. olivacea* were reported from the neighbouring countries like India (Mandal et al., 2014) and Thailand (Jirapunpipat et al., 2008). Another two species *S. tranquebarica* are conspicuously available in India (Trivedi and Vachhrajani, 2013; Mandal et al., 2014) and *S. paramamosain* were rarely available in Thailand (Jirapunpipat et al., 2008). Three species of genus *Scylla* namely *Scylla serrata*, *Scylla tranquebarica, Scylla olivacea* are present in the Malaysia (Keenan et al. 1995). Mud crab of the genus *Scylla* known as green or mangrove crab (Shafi and Quddus 1982) which inconspicuously reported as *Scylla serrata* for culture purpose due to increase demand among the local community in Khulna and Chittagong (Azam et al., 1998). There had great gap for working on taxonomical confirmation about the genus *Scylla* in Bangladesh. Recently reported *Scylla olivacea* as a major species in Bangladesh coastal areas based on molecular data by Sarower et al., (2016).

# CHAPTER 3:

# MATERIALS AND METHODS

## 3.1 Study areas:

The research studies carried out from three different coastal regions of Bangladesh such as Chittagong, Cox's Bazar and Bagerhat.

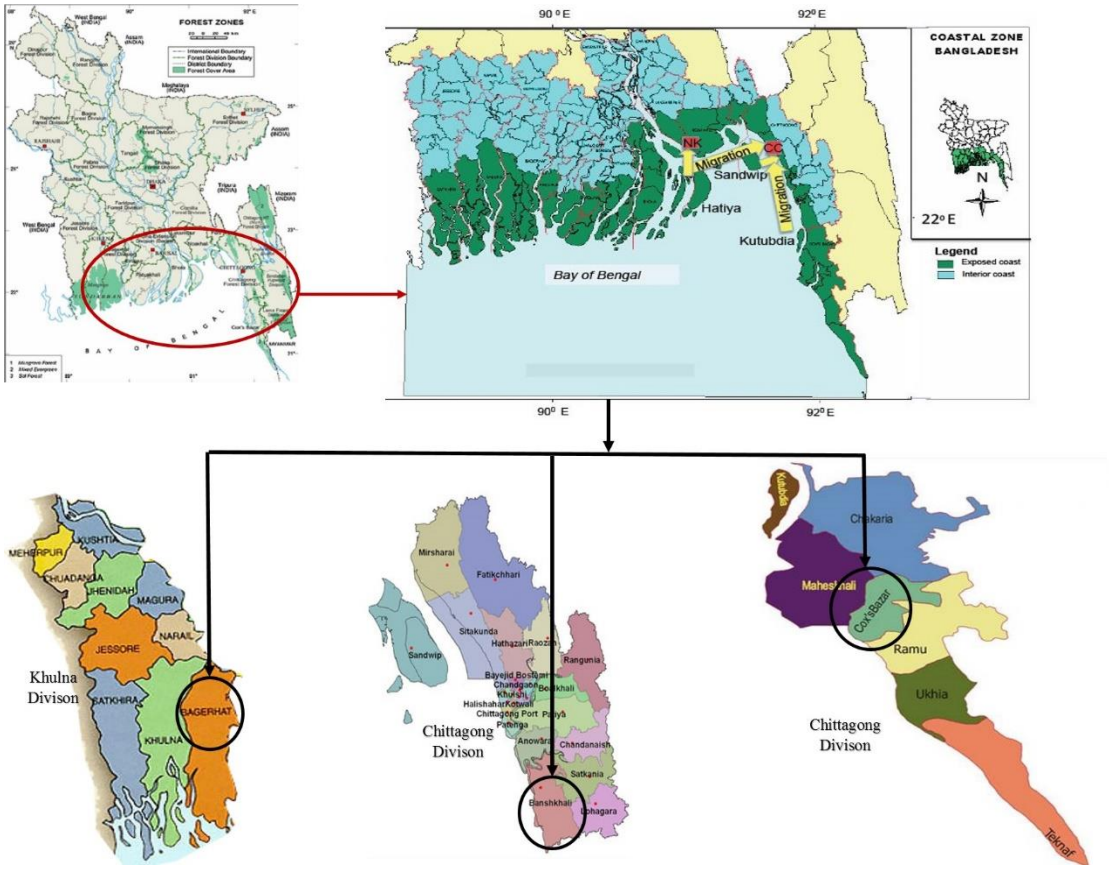


**Figure 5: Map of the study areas of three coastal zones of Bangladesh indicating sampling site**

These three coastal zones are located beside inter-tidal mudflats along with mangrove habitat which considered as nursery ground for mud crabs that provide food and shelter for adult mud crabs.

## 3.2 Sample collection and Study period:

Two hundred eight specimens were collected from mentioned three different coastal regions by the help of local fishermen using traditional trap for crabs and brought to the Marine Bioresource Science laboratory in the Chittagong Veterinary and Animal

Sciences University. All biological specimens were temporarily preserved in ice and primary identification was carried out to the laboratory. These crab were obtained and examined from August 2017 to March 2018. Mud crabs of colour, carapace width, carapace length and the morphological features like shape of the carapace, markings on the body, feature of frontal lobe, spination on the chelae and other legs etc. were noted as primary identification key to differ them for further final clarification using standard keys by Keenan et al., (1998). These identification key by Keenan et al., (1998) is widely accepted by the carcinologists world-wide as well as by the FAO.

**3.3 Species identification of genus *Scylla:***

i. *Morphological study:*

The obtained specimens were examined looked on the presence of polygonal pattern on the chelipeds, legs; shape and height of the frontal lobe spines; carpus and propodus spines of chelipeds; present or absent, conspicuous or inconspicuous of the setae of the 1$^{st}$ male gonopod; Structure of the bilobed tips of the 2$^{nd}$ male gonopod. All specimens were identified using the identification key provided by Keenan et al., (1998). For detail taxonomic studies of crabs, usually the first male gonopod and second male gonopod were examined by using stereo microscope. These parts were removed carefully using clean forceps, needle and scissors and then studied under stereo microscope to observe their structure. It is observed that the shape of the only male abdomen too varies with different species. In that case, crabs can be identified and distinguished without causing any harm to the crab.

ii. *Morphometric study:*

Twenty four characters (Figure 2) were noted for 208 mud crabs with a range of 64-110.5 mm carapace width (85.63± 10.77), measured using Vernier callipers. These characters were given as diagrams of the position of that measurement point in Figure 2 as well as 27 ratios were calculated to check the value provided by the table Keenan et al., 1998. The default specimens as missing appendages or broken any parts of the crabs that were avoided to obtain a reliable data. But major nine ratios of 9$^{th}$ lateral spine height (LSH)/Internal carapace width (ICW), Carapace frontal width (FW)/Internal carapace width (ICW), Posterior width of carapace (PWC)/ Frontal width(FW), Frontal median spine height (FMSH)/Frontal width(FW), Frontal median spine height (FMSH)/Distance between frontal median spine (DFMS), Distance

between frontal median spine (DFMS)/Frontal width(FW), Abdomen width (AW)/Sternum width (SW), Inner Carpus spine (ICS)/ Outer Carpus spine (OCS), Merus length (ML)/ Propodus length (PL) were emphasised to differentiate each species. Details of these 24 measurements were provided in Table 1 and 27 morphometric ratios were provided in Table 2 which were tabulated for statistical analysis.

**Table 1: List of morphometric parameters (N=24) used in morphometric analysis of mud crabs during the present study**

| SL No. | Types of analysis (mm) |
|---|---|
| **A.** | **Carapace** |
| i. | Carapace width (CW) |
| ii. | Internal Carapace width (ICW) |
| iii. | Carapace width at spine 8 (8CW) |
| iv. | Carapace length (CL) |
| v. | Posterior width of Carapace (PWC) |
| vi. | $9^{th}$ lateral spine height (LSH) |
| vii. | Frontal width (FW) |
| viii. | Frontal median spine height (FMSH) |
| ix. | Distance between frontal median spines (DFMS) |
| x. | Distance between frontal lateral spines (DFLS) |
| xi. | Sternum width (SW) |
| xii. | Abdomen width (AW) |
| **B.** | **Cheliped** |
| xiii. | Dactylus length (DL) |
| xiv. | Propodus length (PL) |
| xv. | Propodus width (PW) |
| xvi. | Propodus depth (PD) |
| xvii. | Inner Propodus spine (ICS) |
| xviii. | Outer Propodus spine (IPS) |
| xix. | Inner carpus spine (ICS) |
| xx. | Outer carpus spine (OCS) |
| xxi. | Merus length (ML) |

| C. | Pereiopods (Walking legs) |
|---|---|
| xxii. | 5th pereiopod dactyl length (5PL) |
| xxiii. | 5th pereiopod dactyl width (5PW) |
| xxiv. | 3rd pereiopod merus length (3PML) |

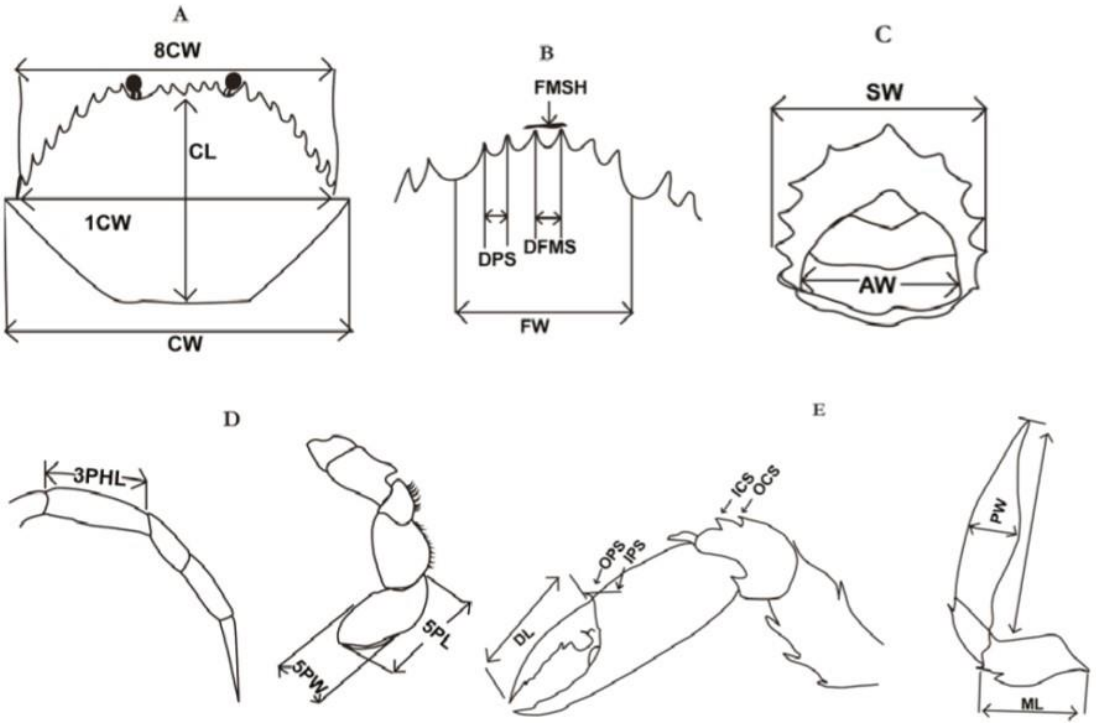


**Figure 6: Details of the morphological character considers for morphometric analysis; (A) Carapace, (B) Frontal Lobe, (C) Abdomen, (D) Periopods, and (E) Chelipeds that provided by Devi et al., 2017.**

**Table 2: Size standardized mud crab morphometric data used for this study**

| **A.** | **Carapace data** |
|---|---|
| 1. | 9th lateral spine height (LSH)/Internal carapace width (ICW) |
| 2. | Carapace width(CW)/ carapace width at spnie 8 (8CW) |
| 3. | Carapace length (CL)/ Internal carapace width (ICW) |
| 4. | Posterior width of carapace (PWC)/ Internal carapace width (ICW) |
| 5. | Carapace frontal width(FW)/Internal carapace width (ICW) |
| 6. | Posterior width of carapace (PWC)/ Frontal width (FW) |
| 7. | Frontal median spine height (FMSH)/Frontal width (FW) |
| 8. | Frontal median spine height (FMSH)/Distance between frontal median spine (DFMS) |
| 9. | Distance between frontal median spine (DFMS)/Frontal width (FW) |
| 10. | Distance between frontal lateral spine (DFLS)/Frontal width (FW) |
| 11. | Distance between frontal median spine (DFMS)/ Distance between frontal lateral spine (DFLS) |
| 12. | Sternum width (SW)/Internal carapace width (ICW) |
| 13. | Abdomen width (AW)/Sternum width (SW) |
| **B.** | **Cheliped data** |
| 14. | Propodus length (PL) /Internal carapace width (ICW) |
| 15. | Dactyle length (DL) / Propodus length (PL) |
| 16. | Propodus width (PW) / Propodus length (PL) |
| 17. | Propodus depth (PD)/ Propodus length (PL) |
| 18. | Propodus width * Propodus depth(PW*PD*0.7854)/Propodus length (PL) |
| 19. | Inner Propodus spine (IPS)/Propodus length (PL) |
| 20. | Outer Propodus spine (OPS)/ Propodus length (PL) |
| 21. | Inner Propodus spine (IPS)/ Outer Propodus spine (OPS) |
| 22. | Inner Propodus spine (IPS)/ Propodus length (PL) |
| 23. | Outer Propodus spine (OPS)/Propodus length (PL) |
| 24. | Inner Carpus spine (ICS)/ Outer Carpus spine (OCS) |
| 25. | Merus length (ML)/ Propodus length (PL) |
| **C.** | **Periopod data** |
| 26. | 5th periopod dactyl width (5PW)/ 5th periopod dactyl length (5PL) |
| 27. | 3rd periopod merus length (3PML)/Internal carapace width (ICW) |

After tabulating the 27 ratios for the obtained specimens and calculating their mean and standard deviation specially based on nine major ratio has been compared with the value that provided as key ratio of Keenan et al., 1988 (Table: 3).

**Table 3: Mean and standard deviations of the nine most useful morphometric ratio for differencing between *Scylla serrata* and *Scylla olivacea* by Keenan et al., 1988.**

| Morphometric Ratio | *Scylla serrata* | *Scylla olivacea* |
|---|---|---|
| **LSH/ICW** | 0.031 ± 0.006 | 0.022 ± 0.005 |
| **FW/ICW** | 0.371 ± 0.016 | 0.415 ± 0.017 |
| **PWC/FW** | 0.892 ± 0.075 | 0.762 ± 0.059 |
| **FMSH/FW** | 0.061 ± 0.010 | 0.029 ± 0.005 |
| **FMSH/DFMS** | 0.418 ± 0.059 | 0.221 ± 0.036 |
| **DFMS/FW** | 0.145 ± 0.009 | 0.130 ± 0.012 |
| **AW/SW** | 0.705 ± 0.176 | 0.576 ± 0.158 |
| **ICS/OCS** | 0.940 ± 0.233 | 0.006 ± 0.005 |
| **ML/PL** | 0.456 ± 0.064 | 0.459 ± 0.061 |

### 3.4 Statistical analysis:

The obtained information was imported, stored and coded accordingly using Microsoft Excel-2013 and observed data were conducted using the 27 ratios to determine the characters that was helpful for the morphologically recognized species (Keenan et al., 1998).

# CHAPTER 4:

# RESULTS

Two hundred eight crabs were examined to differentiate the species of the genus *Scylla* in the laboratory of the Chittagong Veterinary and Animal Sciences University, Chittagong. These were analysed with their morphological characters and measured their morphometric parameters for actual identifying each species from obtaining specimens.

## 4.1. Identification of the collected specimens:

These specimens were identified through the use of morphological traits using Keenan et al., 1988 as shown in Table: 3. Morphological traits such as frontal lobe spine, number and types of carpus spine, propodus spine chelae confirmation, presence of polygonal patterns on the body and walking legs were examined and differentiating each types of the specimens to recognise them which species they belong. From the primary identification, two species of *Scylla* spp. were recognised as *Scylla serrata* and *Scylla olivacea.* However these two species were examined on the based on morphological ratios where many ratios were overlapped ranges except two ratios as ICS/OCS and FMSH/FW (Table: 3) but also looked over the ratio FW/ICW. Another some major nine morphometric ratios were also measured to get more accuracy result for identifying the genus of *Scylla* spp. There was provided as key of value from the table of Keenan et al., 1988 (Table: 3). They were discussed following:

## 4.2 Examined Material with morphological analysis:

a) *Scylla olivacea* (Herbst, 1796)

About 30 crabs were recognized as *Scylla olivacea* among 40 collected specimens from Chittagong (22 March, 2017) which covers 75%, while 68 crabs were identified as same species among 115 obtained specimens from Cox's Bazar (17 June, 2017) which covers 59% and 25 crabs were found as same specimens among 54 collected crabs from Bagerhat (26 October, 2017) which covers 46% of the total species composition.

Carapace surface smooth with oval shape and H-shaped grooved prominently carved in the centre of the carapace (Fig. 8.A). Front of carapace four sub equal and equally

spaced teeth as lower blunted with rounded interspaces (Fig. 8.1). Dactylus structure were observed as slightly curved with wide shaped propodus (Fig. 8.2). Propodus of chelipeds had two spine where inner spines were bluntly pointed and outer spines were reduced (Fig. 8.3). Carpus of chelipeds had only outer margin which slightly blunted and no spine in inner margin (Fig. 8.4). There absolutely absences of polygonal patterns on the chelipeds, legs, carapace body and abdomen.


**Figure 7: A) Body shape of *Scylla olivacea* , 1) blunted frontal lobe, 2) thick and slightly carved dactylus, 3) blunted outer and inner propodus spine, 4) blunted outer and absent inner carpus spine**

First and second male gonopod also observed under digital microscope where first male gonopod mouth tips were narrow, Fig. 9(5.1) and thin shaped and one strongly conspicuous setae presence on the lower part, Fig. 9(5a). Second male gonopod were observed on bilobed shaped of mouth tips, Fig. 9(5.2).

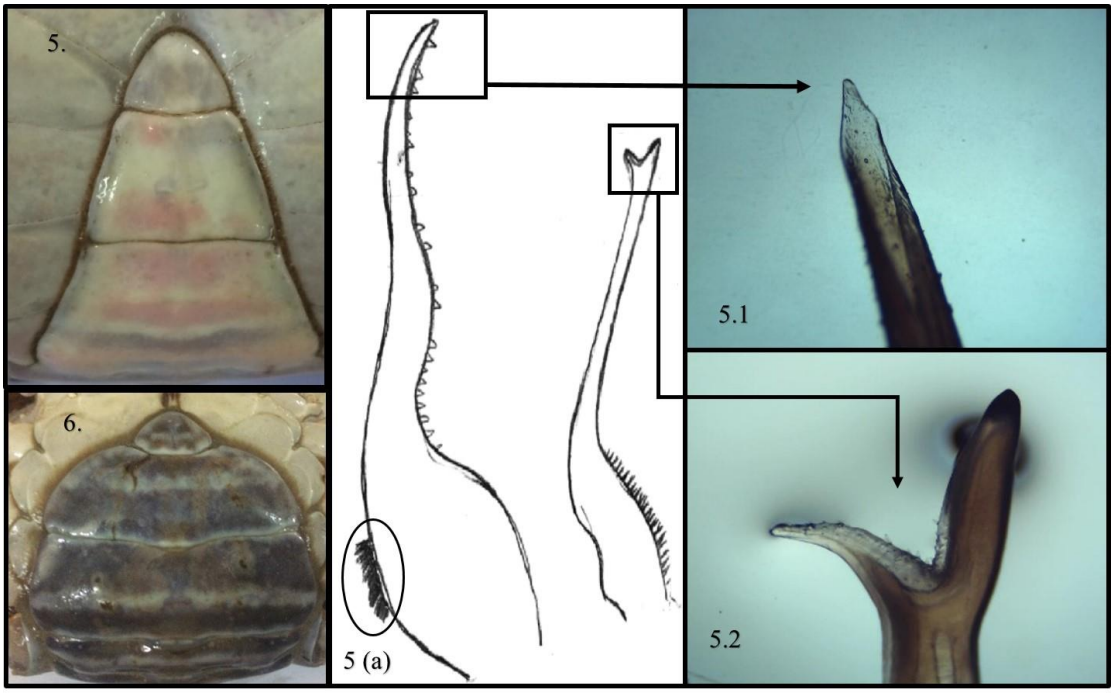


**Figure 8: 5) Male abdomen, 5(a) structure of gonopod and 1st gonopod with one conspicuous setae, 5.1) narrow mouth tip of 1st male gonopod, 5.2) biloped structure of 2nd male gonopod and 6) female abdomen of *Scylla olivacea***

Mean and standard deviation of the most important morphological ratios for species confirmation were presented in table.

**Table 4: Details of morphological measurement of *Scylla olivacea* from three different regions**

| Morphometric Ratio | Bagerhat | Cox's Bazar | Chittagong |
|---|---|---|---|
| **LSH/ICW** | 0.027 ± 0.007 | 0.019 ± 0.004 | 0.029 ± 0.004 |
| **FW/ICW** | 0.466 ± 0.015 | 0.438 ± 0.014 | 0.457 ± 0.007 |
| **PWC/FW** | 0.766 ± 0.025 | 0.762 ± 0.031 | 0.751 ± 0.033 |
| **FMSH/FW** | 0.032 ± 0.001 | 0.027 ± 0.005 | 0.040 ± 0.012 |
| **FMSH/DFMS** | 0.241 ± 0.025 | 0.200 ± 0.040 | 0.331 ± 0.103 |
| **DFMS/FW** | 0.136 ± 0.013 | 0.138 ± 0.013 | 0.131 ± 0.017 |
| **AW/SW** | 0.576 ± 0.053 | 0.493 ± 0.017 | 0.532 ± 0.057 |
| **ICS/OCS** | 0.000 ± 0.005 | 0.000 ± 0.001 | 0.048 ± 0.094 |
| **ML/PL** | 0.598 ± 0.017 | 0.587 ± 0.039 | 0.605 ± 0.022 |

b) *Scylla serrata* (Forskal, 1775)

There 10 crabs were recognized as *Scylla serrata* among 40 collected specimens from Chittagong (22 March, 2017) which covers 25%, while 47 crabs were identified as same species among 115 obtained specimens from Cox's Bazar (17 June, 2017) which covers 41% and 29 crabs were found as same specimens among 54 collected crabs from Bagerhat (26 October, 2017) which covers 54% of the total species composition.

Carapace surface smooth with oval shape (Fig. 10.B), front of carapace have 4 subequal and equally spaced teeth tips of the front teeth high with blunty pointed (Fig. 10.1). Dactylus structure were found as thin and elongated shaped (Fig. 10.2). Propodus spines also prominent in inner margin and another outer margin were smaller than the inner margin as bluntly pointed (Fig. 10.3). Carpus of chelipeds with two obvious spines on distal half of outer margin where strongly prominent spine in outer margin and slightly prominent or little reduced form of spine in inner margin (Fig. 10.4). Polygonal patterning on carapace, chelipeds and legs.


**Figure 9: B) Body shape of *Scylla serrata*, 1) bluntly pointed frontal lobe, 2) elongated dactylus, 3) prominent outer and inner propodus spine, 4) prominent outer and blunted inner carpus spine,**

First and second male gonopod also observed under digital microscope where first male gonopod mouth tips were widely shaped as thich, Fig. 11(5.1) and two conspicuous setae presence on the lower part, Fig. 11.5(a). Second male gonopod were observed on bilobed shaped of mouth tips, Fig. 11(5.2).

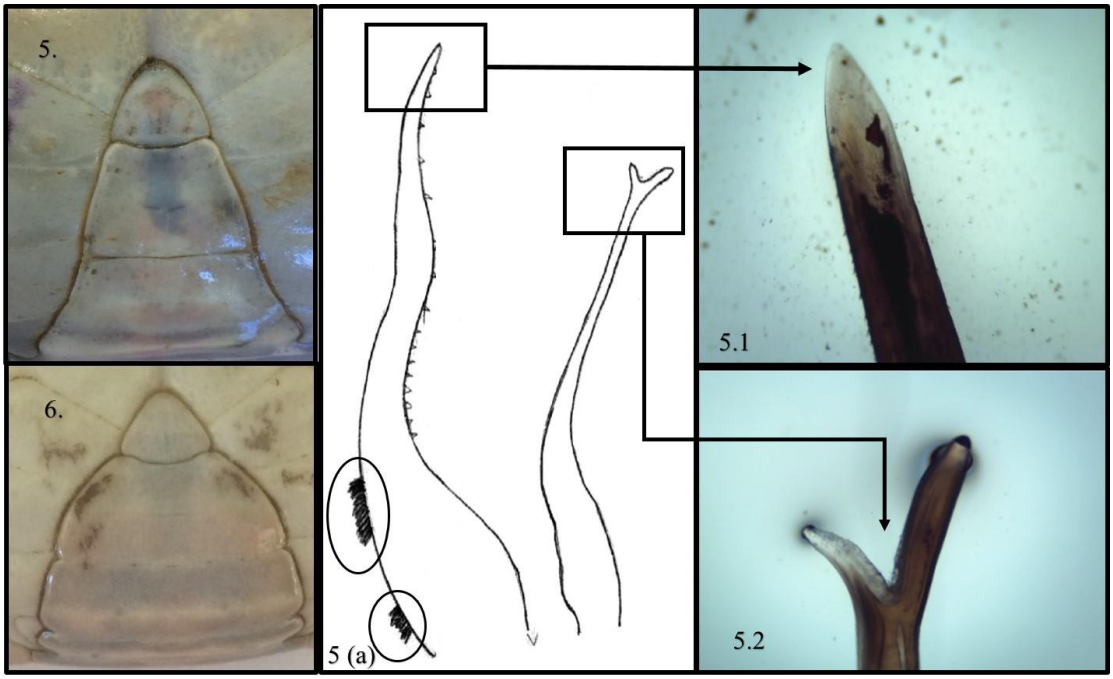


**Figure 10: 5) Male abdomen, 5(a) structure of gonopod and 1st gonopod with two conspicuous setae, 5.1) wide mouth tip of 1st male gonopod, 5.2) bilpoed structure of 2nd male gonopod and 6) female abdomen of *Scylla tranquebarica***

**Table 5: Details of morphological measurement of *Scylla serrata* from three different regions**

| Morphometric Ratio | Bagerhat | Cox's Bazar | Chittagong |
|---|---|---|---|
| **LSH/ICW** | 0.027 ± 0.018 | 0.029 ± 0.004 | 0.027 ± 0.005 |
| **FW/ICW** | 0.437 ± 0.022 | 0.467 ± 0.010 | 0.443 ± 0.022 |
| **PWC/FW** | 0.773 ± 0.029 | 0.778 ± 0.036 | 0.777 ± 0.061 |
| **FMSH/FW** | 0.050 ± 0.017 | 0.051 ± 0.005 | 0.047 ± 0.001 |
| **FMSH/DFMS** | 0.385 ± 0.105 | 0.352 ± 0.049 | 0.356 ± 0.043 |
| **DFMS/FW** | 0.132 ± 0.026 | 0.146 ± 0.017 | 0.134 ± 0.015 |
| **AW/SW** | 0.488 ± 0.014 | 0.589 ± 0.048 | 0.638 ± 0.140 |
| **ICS/OCS** | 0.664 ± 0.124 | 0.647 ± 0.124 | 0.479 ± 0.037 |
| **ML/PL** | 0.592 ± 0.042 | 0.594 ± 0.018 | 0.598 ± 0.023 |

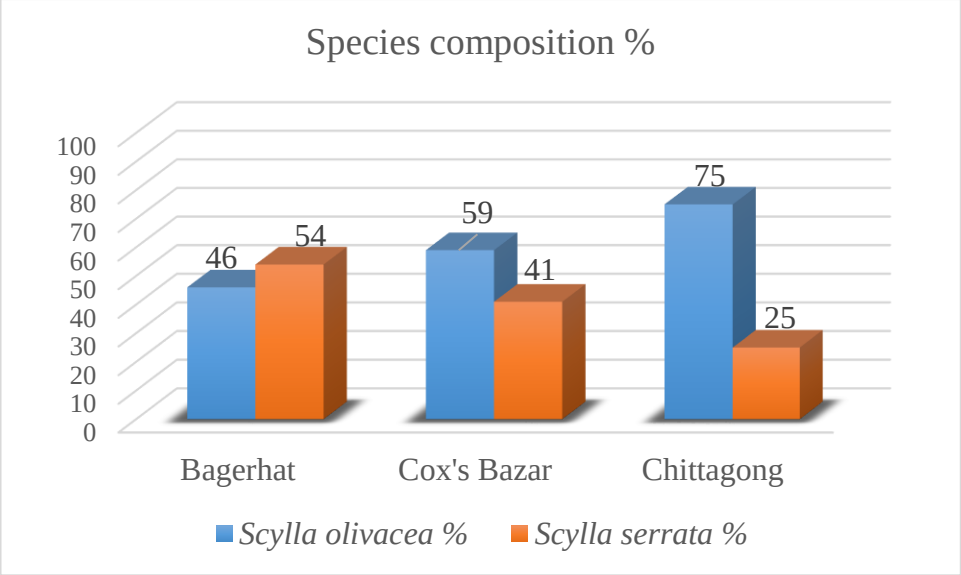


**Figure 11: Species composition of mud crabs *Scylla* spp. in three different regions**

### 4.3 Morphological analysis:

From the above description of the two crabs as *Scylla serrata* and *Scylla olivacea* were differentiated some features with morphological based like structure of frontal lobe, dactylus of chelipeds, presence and nature of the spine of both propodus and carpus of the chelipeds, presence of polygonal patterns on last two legs and carapace body which were shown as combined in following Figure 12 and Table 6**.** Also male abdomen of the mud crabs were combined under microscopic view which were shown in Figure 13.

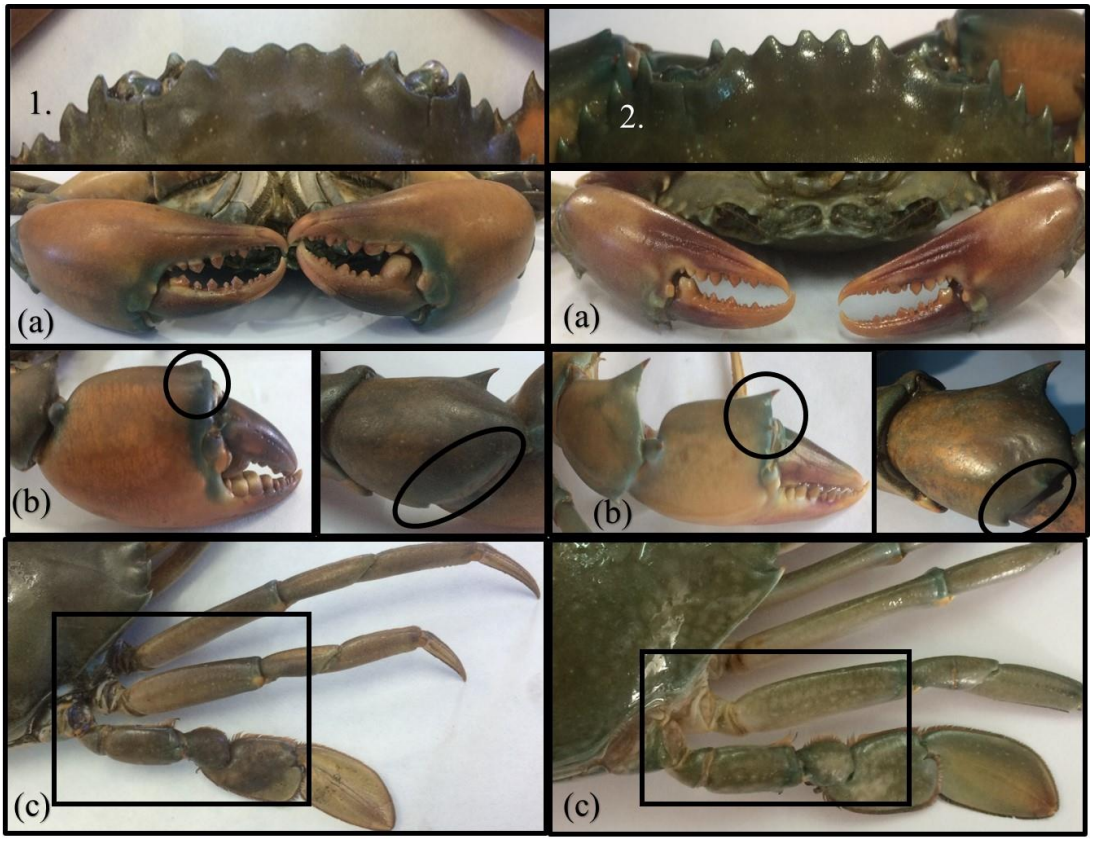


**Figure 12: Frontal lobe of 1) *S. olivacea* and 2) *S. serrata,* a) structure of dactylus, b) number and shape of the spination of propodus, carpus of chelipeds, c) polygonal patterns on body and legs**

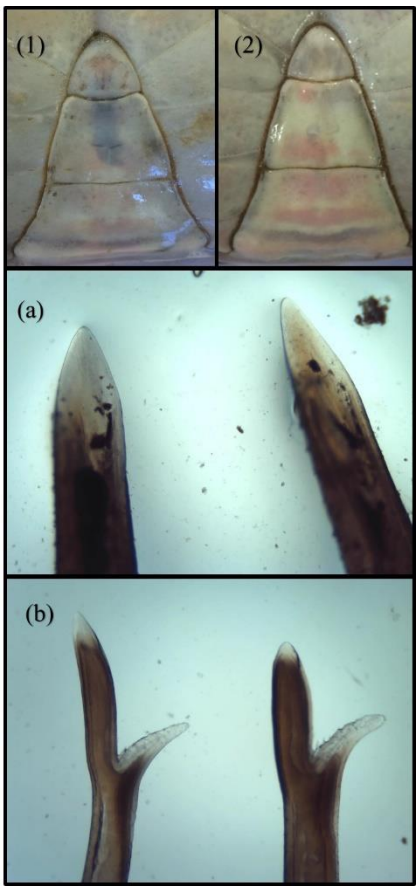


**Figure 13: Shape of male abdomen of 1) *S. serrata* and 2) *S. olivacea,* structure of a) 1st gonopod mouth tips and b) 2nd gonopod mouth tips**

**Table 6: Morphological character useful in determining species identify of mud crabs from three different regions**

| Species | ***Scylla olivacea*** | ***Scylla serrata*** |
|---|---|---|
| Sample No. | 59 | 41 |
| Frontal Lobe Spine Shape | Blunted | Bluntly pointed |
| Inner Carpus Spine | Absent | Present |
| Outer Spine | Bluntly pointed | Prominent |
| Inner Propodus Spine | Blunted | Prominent |
| Outer Propodus Spine | Reduced | Present |
| Dactyl | Slightly carved & unequal size | Thin & elongated |
| Polygonal patters on Legs | Absent | Present on the carapace and Legs |

### 4.4 Morphometric analysis:

After completing morphological observation, morphometric ratios were calculated to differentiate the S*cylla* spp. from total obtained specimens of three coastal regions.

**Table 7: The value of the 27 morphometric ratios that differentiating the two mud crab species**

| **Morphometric Ratio** | ***Scylla olivacea*** | | ***Scylla serrata*** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| LSH/ICW | 0.025 ± 0.005 | (0.013-0.037) | 0.026 ± 0.001 | (0.015-0.035) |
| CW/8CW | 1.005 ± 0.009 | (0.986-1.030) | 1.006 ± 0.005 | (0.988-1.027) |
| CL/ICW | 0.701 ± 0.002 | (0.681-0.747) | 0.700 ± 0.006 | (0.666-0.800) |
| PWC/ICW | 0.344 ± 0.011 | (0.304-0.371) | 0.347 ± 0.013 | (0.311-0.384) |
| FW/ICW | 0.453 ± 0.014 | (0.431-0.484) | 0.448 ± 0.015 | (0.401-0.500) |
| PWC/FW | 0.759 ± 0.008 | (0.710-0.833) | 0.776 ± 0.002 | (0.707-0.871) |
| FMSH/FW | 0.034 ± 0.007 | (0.020-0.071) | 0.049 ± 0.002 | (0.029-0.083) |
| FMSH/DFMS | 0.257 ± 0.066 | (0.150-0.625) | 0.364 ± 0.017 | (0.207-0.600) |
| DFMS/FW | 0.134 ± 0.003 | (0.101-0.171) | 0.137 ± 0.007 | (0.079-0.177) |
| DFLS/FW | 0.164 ± 0.010 | (0.116-0.205) | 0.164 ± 0.013 | (0.123-0.200) |
| DFMS/DFLS | 0.831 ± 0.068 | (0.571-1.111) | 0.838 ± 0.053 | (0.600-1.275) |
| SW/ICW | 0.561 ± 0.004 | (0.528-0.585) | 0.565 ± 0.008 | (0.522-0.700) |
| AW/SW | 0.533 ± 0.041 | (0.458-0.695) | 0.571 ± 0.076 | (0.458-0.862) |
| PL/ICW | 0.766 ± 0.045 | (0.638-0.875) | 0.748 ± 0.051 | (0.652-0.915) |
| DL/PL | 0.484 ± 0.011 | (0.448-0.542) | 0.484 ± 0.012 | (0.372-0.539) |
| PW/PL | 0.283 ± 0.012 | (0.238-0.317) | 0.285 ± 0.007 | (0.242-0.377) |
| PD/PL | 0.407 ± 0.027 | (0.345-0.474) | 0.410 ± 0.022 | (0.339-0.491) |
| PW*PD/PL | 7.216 ± 2.023 | (4.702-11.097) | 6.951 ± 1.627 | (4.363-12.03) |
| IPS/PL | 0.069 ± 0.022 | (0.025-0.132) | 0.082 ± 0.019 | (0.028-0.136) |
| OPS/PL | 0.017 ± 0.004 | (0.006-0.040) | 0.034 ± 0.015 | (0.002-0.075) |
| IPS/OPS | 4.034 ± 0.699 | (2.400-6.000) | 2.852 ± 1.136 | (1.511-6.00) |
| ICS/PL | 0.000 ± 0.008 | (0.000-0.014) | 0.025 ± 0.013 | 0.005-0.056) |
| OCS/PL | 0.017 ± 0.004 | (0.006-0.040) | 0.034 ± 0.014 | (0.002-0.075) |
| ICS/OCS | 0.016 ± 0.027 | (0.000-0.500) | 0.596 ± 0.102 | (0.330-0.900) |
| ML/PL | 0.596 ± 0.009 | (0.426-0.650) | 0.594 ± 0.003 | (0.455-0.655) |
| 5PW/5PL | 0.541 ± 0.027 | (0.482-0.636) | 0.538 ± 0.008 | (0.440-0.680) |
| 3PML/ICW | 0.386 ± 0.030 | (0.325-0.454) | 0.369 ± 0.035 | (0.313-0.439) |

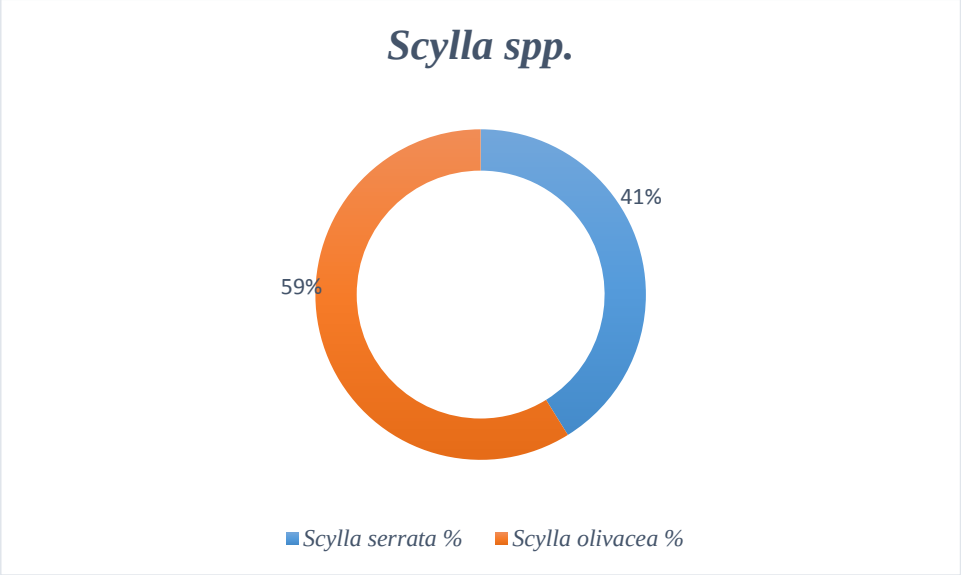


**Figure 14: Total species composition of *Scylla* spp. in three different regions of Bangladesh**

# CHAPTER 5:

# DISCUSSION

Many researchers studied about the genus *Scylla* to identify its several species with varieties (Estampador 1949; Serene 1952; Stephenson and Campbell 1960; Fushimi 1983; Joel and Raj 1983; Oshrio 1988; Kathirval and Srinivasagam 1992; Fuseya and Watanabe 1995, 1996 Fuseya 1998). Through the morphological plasticity of the genus *Scylla*, most of the biologist were studied to clear identification of the *Scylla* spp. in the nature. According to Keenan et al., (1998) four species were existed in the indo specific region. From these four species as *Scylla serrata* and *Scylla olivacea* were found in our neighbouring countries like India (Trivedi and Vachhrajani 2013; Mandal 2014) and Thailand while at same time other two species *Scylla tranquebarica* and *Scylla paramamosain* were found in Thailand (Jirapunpipat et al., 2008).

The present study revealed that two species of mud crabs *Scylla* spp. as *Scylla olivacea* and *Scylla serrata* were existed in the three coastal regions of Bangladesh. Previous study reported that the *Scylla olivacea* (Sarower et al., 2016) was major species in Bangladesh instead of *Scylla serrata* (Keenan et al., 1998; Jirapunpipat et al., 2008). In our study, we observed some variation in the morphometric character such as colour difference, slightly different shape frontal lobe that mentioned as Keenan et al., (1998) which may be occurred due to interbreed between *S olivacea* and *S. tranquebarica* or *S. olivacea* and *S. serrata*. Although many researchers worked on taxonomical study to find the genus *Scylla* spp. composition, they faced these kind of morphological plasticity which were not cleared after year around year.

Identification process of *Scylla* species have led to much confusion because of the fine morphological differences between two species. So initially, examined mud crabs were assigned as *S. serrata* or *S. olivacea*, based on their only external morphology which was recommended as an easy identification process for the local people.

According to Keenan et al., (1998), *S. serrata* was recognised by the presence of polygonal pattern on carapace and other legs, frontal lobe found as bluntly pointed and the presence of two carpus spine including with prominent outer margin, also

presence of prominent inner and slightly prominent outer propodus spine of chelae while *S. olivacea* was recognised as lacking of polygonal pattern on the any parts of the body of mud crabs and found as heavily lower blunted frontal lobe, absence of inner carpus spine with blunted outer carpus spine and both blunted outer and inner propodus spine of the chelae.

The identification process of Keenan et al., (1998) is generally accepted by crab taxonomists as well as by FAO (Ng, 1998), since he has given more concrete evidences on the basis morphological, morphometric and molecular analysis. Therefore, in the present study, two morphotypes of genus *Scylla*, viz. *S. serrata* and *S. olivacea*, has been recorded in three different coastal regions of Bangladesh. The first and second pairs of male gonopods have been recognised as of taxonomical value by several carcinologists (Stephson and Campbell, 1960; Joel and Sanjeevaraj, 1983; Fuseya, 1998; Keenan et al., 1998). Fuseya (1998) examined the first and second male gonopods of *S. serrta, S. tranquebarica* and *S. oceanica* and found these clearly distinguishable. Keenan et al., (1998) stated that the shapes of first male gonopods were similar in the *Scylla* spp. examined, however there exist some slight variations which were not so clear enough to characterise between the species easily. According to his observations, the first male gonopods showed variations in the apex region and the pattern of the setation. The first male gonopods of *S. olivacea* developed long and slender shaped mouth tips, while it is more sinuous in the other three species. From the identification key by Keenan et al., (1998) that the first male gonopod of *S. serrata* and *S. tranquebarica* shown double setation pattern, while *S. olivacea* and *S. paramamosain* shown single setae on the inner margin. So that, for precise identifying the obtained mud crabs, the first and second male gonopods were observed under digital microscope.

In this study, the first male gonopods of *S. serrata* shown wide mouth tips including with two conspicuous setae while *S. olivacea* shown long and narrow mouth tips including a single tuft of thick setae on the inner margin of the first male gonopod. The second male gonopod were observed on their bilopded structure for more accuracy which differ them easily that were designed in Figure 14**.**

Morphometric analysis were done to clarify the differences between *S. olivacea* and *S. serrata*. In this study, 27 morphometric ratios formed from 24 morphometric

characters were studied to difference between the *Scylla* spp. The study reveals that out of the 27 ratios, 9 ratios contribute to difference between the species. The ratios include LSH/ICW, FW/ICW, PWC/FW, FMSH/FW, FMSH/DFMS, DFMS/FW, AW/SW, ICS/OCS and ML/PL (Table:4 and Table: 5). Keenan et al., (1998) observed seven useful characters to distinguish between the *Scylla* species viz., FW/ICW, FMSH/FW, AW/SW, ICS/OCS, ML/PL, PL/ICW and IPS/PL. Mandal et al., (2014a) claimed that three ratios viz., ICS/OCS, FMSH/FW and FW/ICW can be considered to confirm the species as *S. serrata* and *S. olivacea.* But there were so much overlapped morphometric data to differ them. Therefore, only 9 ratios were considered to better understand and differentiate them among 27 morphometric ratios. From the morphometric study, it is observed that two morphotypes assigned to be *S. serrata* and *S. olivacea* are closely related to each other and at the same time, those are slightly different from the morphological characters like presence of polygonal pattern on legs and carapace, number of the spination on carpus spine, structure of frontal lobe.

Keenan et al., (1998) described the genus *Scylla* spp. in four species as *S. serrata, S. tranquebarica, S. olivacea* and *S. paramamosain* based on their morphometry and morphological characters, molecular methods that was useful indication key for this research to differentiate them as *S. serrata* and *S.olivacea*.

The present study clearly indicates the presence of two species of mud crab namely *S. serrata* and *S. olivacea* in the coastal regions of Bangladesh. Sarower et al. (2016), claimed that *S. olivacea* was the major mud crab species in Bangladesh, based on morphological characters and molecular studies. But now it can be concluded that the existence of the two species in our country.

Moreover, the present work would be the updated report of the existence of the mud crab with their composition in particular coastal regions in Bangladesh where *S. olivacea* already reported and *S. serrata* also recorded among four *Scylla* spp. However, the existence of *S. serrata* from Bangladesh has not been reported with strong scientific evidence before. Hence the present work can be counted as the first scientific report of the existence of *S. serrata* from Bangladesh.

# CHAPTER 6:

# CONCLUSION

Generally four species of *Scylla* are present in the world. Recently reported that *S. olivacea* was only major species of mud crab in Bangladesh. But the present experiment is shown that another species *S. serrata* is exist in coast of Bangladesh. There two species *S. serrata* and *S. olivacea* were found in my study areas. The research focused on the abundance, species composition and distribution of the mud crabs in the coastal area of nearby Bay of Bengal. Mud crab is facing as higher risk of extinction day-by-day. Scientists should be emphasised their research on mud crab population and their environmental health management. If they will, the another two endangered species (*S. tranquebarica* and *S. paramamosain*) may be populated by themselves. Because *S. tranquebarica* was found in our adjacent countries so there is a great chance of availability in Bangladesh. The current situation of crab fishery in the coastal zone will develop the blue economy and helps us to achieve the sustainable development goal. If we will develop the mud crab aquaculture that can be a great platform to the local fishermen for their livelihood. For their morphological differences between the species, it is very difficult to manage and culture. It is hardly enough to identify the species for their morphological similarity and interbreeding. Identify *Scylla* spp. have led to much confusion which cause difficulties to culture the mud crab in commercial purpose in hatchery. This research will be very helpful for the local fishermen to identify the mud crab without any expensive equipment which is very important for successful crab production in hatchery. This research also designed by simple identification process for all types of people who belong nearby coastal areas. However we have to more conscious about our surrounding coast areas for mud crabs better health management before declining existence of mud crab population.

# CHAPTER 7:

# RECOMMENDATIONS AND FUTURE PERSPECTIVES

Mud crabs are important decapod crustaceans in marine fishery after traditional shrimp production for better foreign currency in both national and international countries. Besides the wild catch of mud crab *Scylla* contributes significantly to the coastal fisheries of many developing countries like Bangladesh for their commercial value and high consumer demand. The local fishermen who belong nearby coastal areas are depended on them as livelihood. As result crab stock are facing risk for over harvesting practice in the wild. So many researcher were involved with mud crabs for better production of wild catch. Mud crab genus *Scylla* consists of four species which all are available in our neighbouring countries. In Bangladesh two species namely *S. olivacea* and *S. serrata* were found in three coastal regions through this present study. But this study does not confirm the existence of other species as *S. tranquebarica* and *S. paramamosain*. Because present study was conducted only three coastal region due to lacking of financial limitation and facilities of advanced molecular laboratory by the institution. However, the four species of *Scylla* are closely similar with each other that creating lot of confusion to recognise them especially it occurs between *S. tranquebarica* and *S. serrata.* The present study was just only conducted by collecting crab which carapace width between 64-110.5 mm that one of the confusing factor to identify as *S. tranquebarica.* On the other hand, interbreeding of mud crab is considered as problem for identifying process in nature which may be occurred between *S. olivacea* and *S. serrata* that creates another one. So there is healthy environment condition considered as prime factor for mud crab distribution which will contribute for natural breeding process and also sustainable fisheries management. However, we have to emphasis on environmental management that might be helpful for mud crab population which resulting that another two species namely *S. tranquebarica* and *S. paramamosain* will become populated if they existed as endangered condition in past. Recently *S. tranquebarica* found in our neighbouring countries so that this crab has great chances to availability in Bangladesh more than *S. paramamosain.*

Mud crabs are now incredible export product for that carb farming are encouraged to develop crab production. Now a day most of the entrepreneurs are interested to establish soft-shell crab farms which totally depend on the natural seed supply. But success of the artificial propagation of mud crabs largely varies among species. Now the study revealed the occurrence of two species that helpful for better hatchery management for successful crab production.

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## Appendix-A

**Table 1: Twenty four morphological measurements of two species of genus *Scylla* from Bagerhat**

| **Morphological Measurements** | ***S. olivacea*** | | ***S. serrata*** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| CW | 94.69 ± 6.03 | (82.0- 105.5) | 92.2 ± 8.60 | (80.0 -110.5) |
| 8CW | 95.20 ± 6.15 | (81.8- 106.0) | 92.2 ± 8.29 | (80.5 - 111.0) |
| ICW | 91.12 ± 5.74 | (78.5- 101.5) | 88.04 ± 8.46 | (75.0 -106.5) |
| LSH=(CW-ICW)/2 | 1.78 ± 0.38 | (1.25- 3.00) | 2.07 ± 0.61 | (0.00 - 2.90) |
| CL | 63.92 ± 4.24 | (54.0– 70.0) | 61.74 ± 5.43 | (54.0 - 74.0) |
| PWC | 30.37 ± 2.00 | (26.0- 35.0) | 29.54 ± 2.75 | (25.0 - 35.0) |
| FW | 39.87 ± 2.24 | (34.5- 43.5) | 38.16 ± 2.91 | (33.0 - 45.0) |
| FMSH | 1.095 ± 0.23 | (0.70- 1.60) | 1.93 ± 0.67 | (1.10 - 3.00) |
| DFMS | 5.48 ± 0.58 | (4.0- 6.50) | 5.07 ± 1.17 | (3.00 - 7.00) |
| DFLS | 6.35 ± 1.09 | (4.5- 8.0) | 5.69 ± 0.78 | (4.80 - 7.00) |
| AW | 25.04 ± 1.78 | (21.0- 28.0) | 23.72 ± 2.26 | (20.0 - 28.5) |
| SW | 50.75 ± 3.00 | (45.0- 55.5) | 48.57 ± 4.33 | (41.5 - 59.0) |
| ICS | 0.00 ± 0.00 | (0.0- 0.0) | 1.06 ± 0.39 | (0.40 - 1.80) |
| OCS | 1.40 ± 0.48 | (0.8- 2.5) | 1.58 ± 0.47 | (0.90 - 2.50) |
| PD | 32.77 ± 3.22 | (21.0- 37.0) | 30.82 ± 3.63 | (22.0 - 38.5) |
| IPS | 3.72 ± 0.68 | (2.0- 4.80) | 4.29 ± 0.93 | (2.00 - 5.70) |
| OPS | 0.90 ± 0.24 | (0.5- 1.50) | 1.18 ± 0.41 | (0.20 - 2.00) |
| DL | 35.35 ± 3.44 | (30.0- 41.0) | 33.77 ± 3.10 | (30.0 - 41.5) |
| PL | 74.66 ± 6.15 | (60.0- 84.0) | 70.46 ± 6.11 | (61.0 - 84.0) |
| PW | 21.68 ± 2.02 | (18.5- 26.0) | 20.07 ± 2.44 | (15.0 - 25.0) |
| ML | 43.76 ± 4.15 | (32.0- 49.0) | 41.70 ± 4.56 | (30.5 - 52.0) |
| 5PL | 28.97 ± 2.24 | (24.5- 34.0) | 27.52 ± 3.15 | (23.0 - 35.0) |
| 5PW | 14.84 ± 1.40 | (13.0- 18.5) | 14.70 ± 1.60 | (11.0 - 18.0) |
| 3PML | 33.14 ± 2.55 | (27.0- 37.0) | 31.48 ± 2.73 | (27.0 - 38.0) |

**Table 2: Twenty four morphological measurements of two species of genus *Scylla* from Cox's Bazar**

| **Morphological measurements** | ***S. olivacea*** | | ***S. serrata*** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| CW | 71.85 ± 4.52 | (66.0 - 80.0) | 71.00 ± 3.04 | (64.0 - 74.5) |
| 8CW | 71.00 ± 4.53 | (66.0 - 79.5) | 70.29 ± 3.18 | (63.0 - 74.5) |
| ICW | 68.10 ± 4.12 | (64.0 - 76.0) | 67.15 ± 3.01 | (60.0 -70.0) |
| LSH=(CW-ICW)/2 | 1.875 ± 0.48 | (1.00 - 2.50) | 1.925 ± 0.25 | (1.50 - 2.25) |
| CL | 47.55 ± 2.25 | (46.0 - 52.0) | 47.20 ± 2.24 | (42.0 - 51.0) |
| PWC | 24.30 ± 1.39 | (22.5 - 27.0) | 24.35 ± 1.19 | (22.0 - 26.0) |
| FW | 31.70 ± 1.03 | (31.0 - 34.0) | 31.32 ± 1.37 | (29.0 - 33.0) |
| FMSH | 1.03 ± 0.06 | (1.00 - 1.20) | 1.59 ± 0.14 | (1.50 - 2.00) |
| DFMS | 4.30 ± 0.42 | (3.50 - 5.00) | 4.56 ± 0.51 | (4.00 - 5.50) |
| DFLS | 5.00 ± 0.33 | (4.50 - 5.50) | 5.41 ± 0.46 | (4.50 - 6.20) |
| AW | 22.25 ± 2.80 | (19.0 - 28.0) | 22.6 ± 2.18 | (20.0 - 29.0) |
| SW | 38.55 ± 1.95 | (36.0 - 42.0) | 38.32 ± 1.79 | (35.0 - 41.0) |
| ICS | 0.00 ± 0.00 | (0.00 - 0.00) | 1.96 ± 0.39 | (1.00 - 2.50) |
| OCS | 2.64 ± 0.40 | (2.00 - 3.00) | 3.05 ± 0.39 | (2.50 - 4.00) |
| PD | 19.65 ± 1.71 | (17.0 - 21.5) | 19.37 ± 1.74 | (16.0 - 22.0) |
| IPS | 4.70 ± 0.78 | (4.00 - 6.50) | 4.85 ± 0.76 | (3.00 - 6.00) |
| OPS | 1.03 ± 0.06 | (1.00 - 1.20) | 2.02 ± 0.23 | (1.80 - 3.00) |
| DL | 24.05 ± 1.01 | (23.0 - 25.5) | 23.02 ± 1.74 | (19.0 - 26.0) |
| PL | 49.7 ± 1.43 | (47.0 - 52.0) | 48.47 ± 3.12 | (43.0 - 53.0) |
| PW | 14.4 ± 0.73 | (13.0 - 15.0) | 14.17 ± 1.48 | (12.0 - 18.5) |
| ML | 29.70 ± 0.78 | (28.5 - 31.0) | 28.75 ± 1.48 | (26.0 - 31.0) |
| 5PL | 21.75 ± 1.51 | (19.0 - 24.0) | 21.22 ± 1.41 | (18.5 - 23.5) |
| 5PW | 11.85 ± 0.91 | (10.5 - 13.5) | 11.45 ± 0.64 | (10.0 - 12.5) |
| 3PML | 28.60 ± 0.96 | (27.0 - 30.0) | 27.57 ± 1.76 | (24.0 - 30.0) |

**Table 3: Twenty four morphological measurements of two species of genus *Scylla* from Chittagong**

| **Morphological measurements** | ***S. olivacea*** | | ***S. serrata*** | |
|---|---|---|---|---|
| | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** |
| CW | 86.25 ± 4.66 | (76.0 - 93.0) | 85.95 ± 9.56 | (74.0 - 101.0) |
| 8CW | 85.58 ± 4.67 | (75.5 - 92.5) | 85.15 ± 9.23 | (73.0 - 100.0) |
| ICW | 81.60 ± 4.58 | (72.0 - 88.0) | 81.55 ± 8.73 | (70.0 - 95.00) |
| LSH=(CW-ICW)/2 | 2.325 ± 0.31 | (1.75 - 3.00) | 2.20 ± 0.53 | (1.00 - 3.00) |
| CL | 57.5 ± 3.80 | (50.0 - 65.0) | 56.55 ± 5.53 | (50.0 - 65.0) |
| PWC | 27.96 ± 1.83 | (25.0 - 32.0) | 28.00 ± 3.58 | (24.5 - 34.0) |
| FW | 37.26 ± 1.92 | (32.5 - 39.5) | 35.95 ± 2.31 | (32.0 - 39.0) |
| FMSH | 1.60 ± 0.45 | (1.00 - 2.50) | 1.69 ± 0.11 | (1.50 - 1.90) |
| DFMS | 4.90 ± 0.71 | (4.00 - 6.50) | 4.80 ± 0.63 | (4.00 - 6.00) |
| DFLS | 6.56 ± 0.63 | (5.00 - 7.50) | 6.15 ± 0.41 | (5.50 - 6.50) |
| AW | 24.27 ± 2.49 | (21.0 - 32.0) | 29.85 ± 8.65 | (20.5 - 44.0) |
| SW | 45.68 ± 2.27 | (41.0 - 49.0) | 46.30 ± 4.05 | (40.0 - 51.0) |
| ICS | 0.084 ± 0.16 | (0.00 - 0.90) | 1.22 ± 0.32 | (0.90 - 2.00) |
| OCS | 1.83 ± 0.84 | (1.00 - 4.00) | 2.55 ± 0.64 | (2.00 - 4.00) |
| PD | 23.85 ± 2.89 | (19.0 - 31.5) | 23.05 ± 3.14 | (19.0 - 27.5) |
| IPS | 3.85 ± 1.16 | (2.50 - 6.00) | 4.93 ± 0.87 | (4.00 - 6.80) |
| OPS | 1.21 ± 0.41 | (0.56 - 2.50) | 2.55 ± 0.76 | (2.00 - 4.50) |
| DL | 30.31 ± 2.29 | (25.0 - 34.5) | 29.00 ± 2.58 | (24.5 - 31.0) |
| PL | 61.22 ± 4.63 | (53.0 - 72.0) | 58.00 ± 3.68 | (52.0 - 62.0) |
| PW | 16.46 ± 1.76 | (14.0 - 22.5) | 16.15 ± 1.70 | (14.0 - 19.0) |
| ML | 37.01 ± 2.69 | (32.0 - 42.0) | 34.65 ± 1.61 | (32.0 - 36.5) |
| 5PL | 24.6 ± 2.29 | (21.0 - 29.0) | 26.00 ± 3.88 | (21.0 - 32.0) |
| 5PW | 13.88 ± 0.96 | (12.0 - 16.0) | 14.15 ± 2.18 | (12.0 - 17.0) |
| 3PML | 30.61 ± 3.53 | (26.0 - 39.0) | 28.25 ± 3.25 | (24.0 - 34.0) |

# Appendix-B

## Research Activities:

### Materials needed

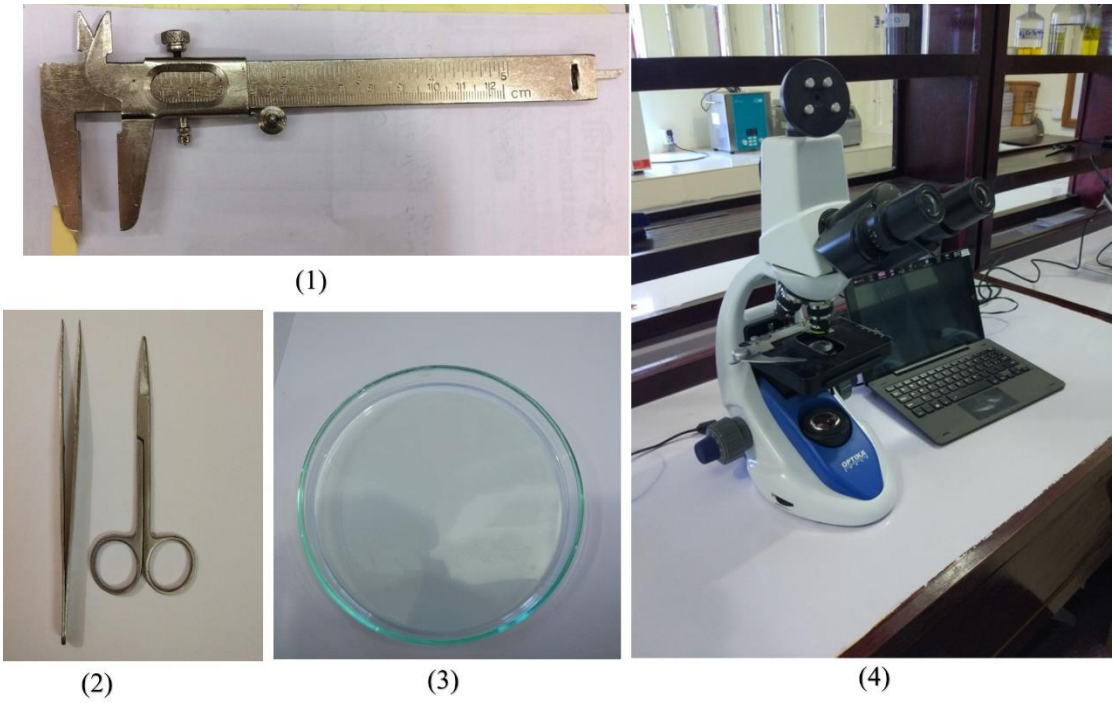


Figure 1: (1) Vernier calliper, (2) scissors and forceps, (3) Petridis and (4) digital Microscope

## Laboratory Work

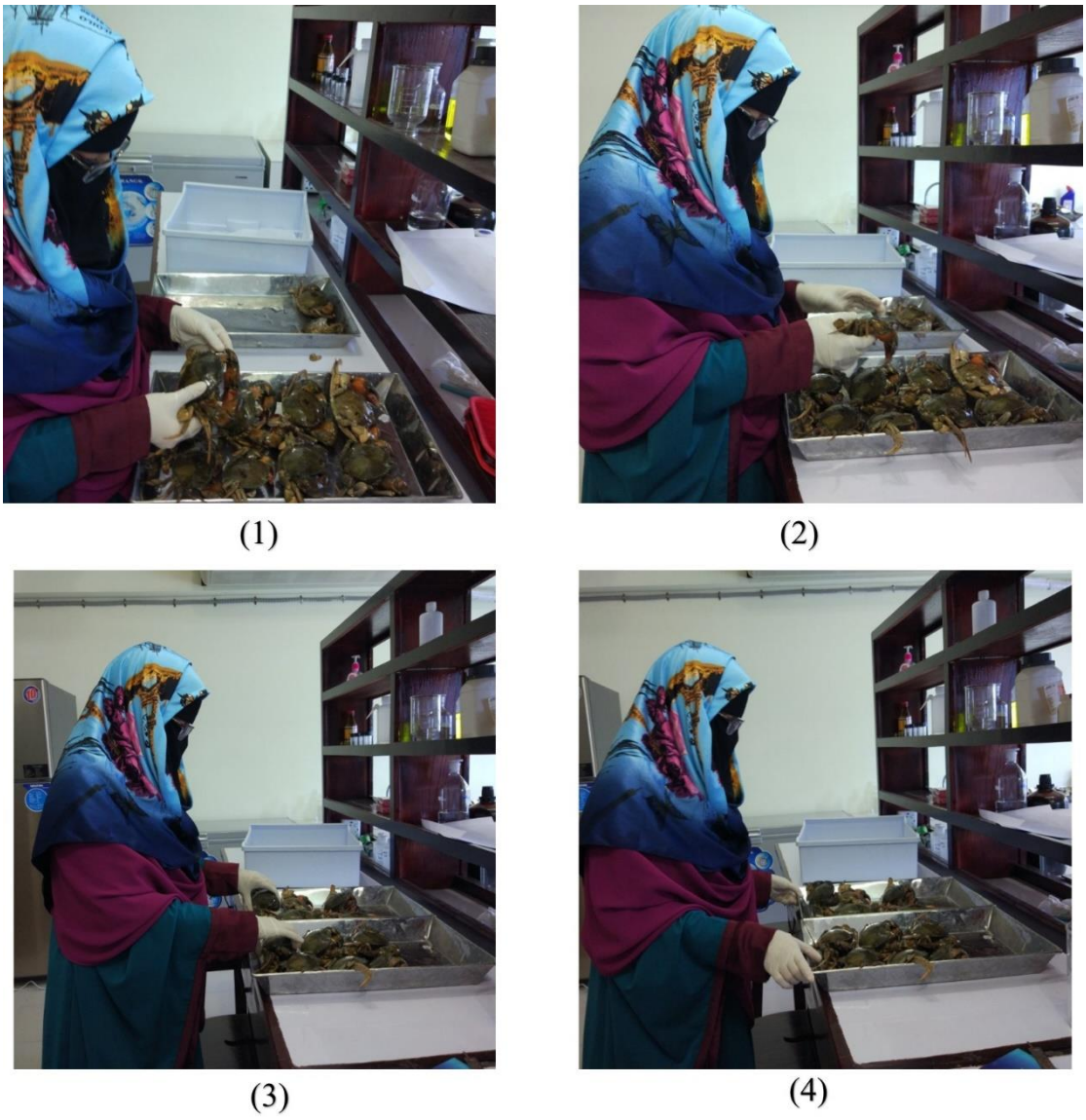


Figure 2: (1) Morphological observation, (2) primary identification, (3) placing two species in two different trey and (4) Keeping them for further gonopod examination

## Laboratory Work (Continued)

Figure 3: Measuring twenty four morphological characters by using callipers

## Laboratory Work (Continued)

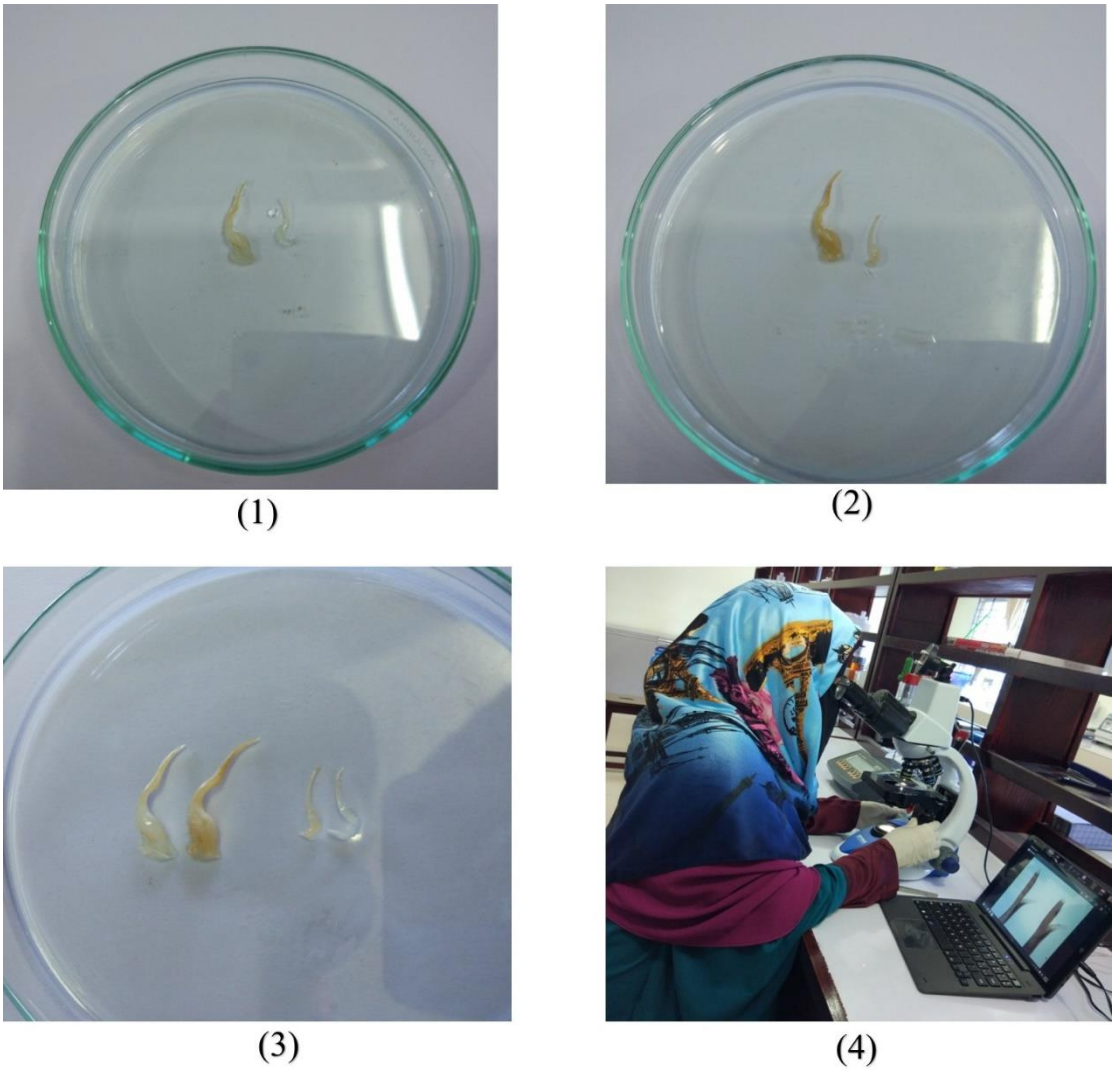


Figure 4: (1) Gonopods of *S. olivacea*, (2) gonopods of *S. tranquebarica*, (3)gonopods of both species and (4) gonopods observation under digital microscope

## Research Findings:

(1) (2)

Figure 5: The present study confirms the two species

(1) *S. serrata* and

(2) *S. olivacea*

## Brief biography of the author

Ismat Jahan; Daughter of Saber Ahmed and Jainab Begum from Banshkhali Upazila under Chittagong District of Bangladesh. Now she is the candidate for the degree of MS in Marine Bioresource Science under the Department of the Marine Bioresource Science, Faculty of Fisheries, CVASU, Chittagong, Bangladesh. She completed her graduation degree on B.Sc. Fisheries (hons.) in 2016 from Chittagong Veterinary and Animal Sciences University (CVASU), Chittagong, Bangladesh. She passed her Higher Secondary Certificate Examination in 2011 and Secondary School Certificate Examination in 2009 from Kapashgola City Corporation Girls' High School and College, Chittagong, Bangladesh. She has great interest on scientific research on Marine Science.