

# **Genetic Diversity, Phylogenetic Relationship and Status of Shrimps (Crustacea: Decapoda) of Bangladesh**

**A thesis submitted to the University of Dhaka in partial fulfillment of the requirements for the degree of Doctor of Philosophy**

**Submitted by**

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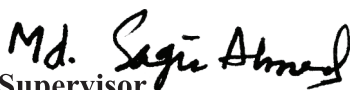


**Department of Zoology  
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**July, 2025**

## CERTIFICATION

The dissertation entitled “**Genetic Diversity, Phylogenetic Relationship and Status of Shrimps (Crustacea: Decapoda) of Bangladesh**” submitted to the Department of Zoology, Faculty of Biological Sciences, University of Dhaka, Bangladesh in partial fulfillment of the requirements for the degree of Doctor of Philosophy. I certified that the candidate, **Sujan Kumar Datta** (Registration No. **54/2020-2021**) has been completed his research under my supervision and suggestions. I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy. The work has not been and will not be presented for any other degree. It is further certified that to the best of our knowledge the thesis contains original research.

  
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## DECLARATION

I do hereby declare that the research work entitled “**Genetic Diversity, Phylogenetic Relationship and Status of Shrimps (Crustacea: Decapoda) of Bangladesh**” submitted to the Department of Zoology, Faculty of Biological Sciences, University of Dhaka, Dhaka, Bangladesh, for the degree of Doctor of Philosophy is the results of my own observations and analysis. The thesis or part of it has not been presented before for any other degree.



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## Abstract

Shrimp, a popular and delicious food item worldwide, holds significant commercial and food value, providing a vital source of protein and contributing to a multi-billion-dollar industry in both wild-caught and farmed varieties. Belonging to the order *Decapoda*, shrimp play a vital role in both marine and freshwater ecosystems. However, a comprehensive, systematic taxonomic study, especially in molecular taxonomy, has not been conducted for these species in Bangladesh. To address this gap, the present study aimed to explore the genetic diversity, phylogenetic relationships, and status of shrimp species found in Bangladesh. An integrative taxonomic approach was used, combining morphological examination, DNA barcoding, and molecular species delimitation to provide a broad understanding of the systematics of shrimps in the region. Specimens were initially identified morphologically, followed by molecular analysis using two genetic markers: the mitochondrial cytochrome c oxidase I (COI) gene and the 16S ribosomal RNA (16S rRNA) gene. 50 shrimp species, representing six families and 16 genera, were morphologically identified, and 38 species and two genera were further confirmed through molecular analysis. A total of 127 sequences were generated, comprising of 55 COI and 72 16S rRNA sequences. Sequence analysis revealed 136 conserved, 561 variable, and 321 parsimony-informative sites for the COI gene, and 101 conserved, 583 variable, and 372 parsimony-informative sites for the 16S rRNA gene. The average GC content was 40.87% for COI and 33.49% for 16S rRNA. Genetic divergence was assessed with mean distances of  $1.18 \pm 0.02\%$ ,  $23.53 \pm 0.08\%$ , and  $28.29 \pm 0.05\%$  within species, genus, and family for the COI gene. For the 16S rRNA gene, the corresponding values were  $2.94 \pm 0.09\%$ ,  $13.91 \pm 0.06\%$ , and  $25.26 \pm 0.04\%$ . Notably, the mean interspecific genetic distance for COI was 34 times greater than the intraspecific distance, while for 16S rRNA, it was 15 times greater, with barcode gaps of 38.54% and 40.91% for the two markers, respectively. Phylogenetic trees based on the Neighbor-Joining (NJ) method were generated for each gene marker to explore the phylogenetic relationships among the identified species. Additionally, 11 species were newly recorded from Bangladesh, marking their first geographic occurrence in the region. This is the first comprehensive study combining morpho-taxonomy, molecular analysis, and phylogenetic relationships of shrimps from Bangladesh. The study underscores the need for effective conservation strategies and sustainable management practices to preserve the rich shrimp diversity in Bangladesh, as revealed by the molecular and phylogenetic findings. The results not only enhance our understanding of shrimp biodiversity in Bangladesh but also lay a foundation for future research on the ecological and evolutionary dynamics of these crucial aquatic organisms.

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**March, 2025**

**The Author**

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## **1. General Introduction**

### **1.1 Background**

Bangladesh's unique combination of rivers, wetlands, and coastal ecosystems, along with its favorable climatic conditions, makes it one of the most ecologically rich regions for aquatic fauna in South Asia. Fish is the second most valuable agricultural product in Bangladesh that plays a vital role in the livelihoods and employment of millions of people. The production and consumption of fish have significant implications for the country's national income and food security. That why Bangladeshi people are popularly known as "*Machhe Bhate Bangali*" or "*Fish and Rice makes a Bengali*". In the fiscal year 2022-23, the fisheries sector in Bangladesh showed a growth rate of 2.43%, contributing 22.14% to the overall agricultural sector (DoF, 2023). Additionally, it accounted for 0.80% of the country's national export earnings. This sector plays a crucial role in the country's food security, providing 60% of all animal protein consumed. The importance of fisheries to both the economy and nutrition of Bangladesh cannot be overstated, making it a key driver of employment, export revenue, and sustainable livelihoods for millions.

Bangladesh's rich and diverse fisheries resources are broadly categorized into two main groups: Inland Fisheries and Marine Fisheries. Inland fisheries are further subdivided into Inland Capture Fisheries and Inland Culture Fisheries. Inland Capture Fisheries include natural water bodies such as rivers, estuaries, beels (wetlands), floodplains, the Sundarbans, and Kaptai Lake that constitutes about 3861261hectare water area (DoF, 2023). These areas are vital for capturing wild fish species. Inland Culture Fisheries involve the controlled farming of fish in man-made or modified water bodies, including ponds, seasonal water bodies, baors (oxbow lakes), shrimp and prawn farms, crab farming, as well as pen and cage culture systems that constitutes about 846341-hectare water area (DoF, 2023).

Marine fisheries, on the other hand, are divided into Industrial (Trawl) Fisheries and Artisanal Fisheries. Industrial fisheries involve large-scale commercial fishing, often using trawlers, while artisanal fisheries are small-scale, traditional fishing practices primarily carried out by local communities along the coast.

## **1.2 Crustacean resources of Bangladesh**

A crustacean is a member of the subphylum Crustacea within the phylum Arthropoda, which encompasses crayfish, crabs, lobsters, prawns and shrimps. Crustaceans are a successful and diverse group of arthropods and extremely crucial members of both planktonic and benthic communities in nearly all inland water ecosystems, such as wetlands, freshwater and saline lakes, caves, and rivers (Chandra, 2021). Members of this group have ten legs and are distinguished from other crustaceans by a well-developed carapace that covers the head and thorax. All crustaceans possess two pairs of antennae, a pair of mandibles, a pair of compound eyes (typically on stalks), and two pairs of maxillae on their head. Each body segment also bears a pair of appendages. These appendages are typically branched (biramous), and although this feature may be modified in various species, adult crustaceans always retain at least some biramous appendages. Crustaceans breathe through gills and, like other arthropods, have a rigid yet flexible exoskeleton. They are useful and suitable models for many areas of biological research, and are also important to many economies as highly-valued edible shellfish. Throughout the world, the shrimps, lobsters and Portunid crabs are caught extensively for human consumption.

The updated crustacean red list of Bangladesh recorded a total of 141 species, including 64 prawns and shrimps, six lobsters, 38 crabs, and four hermit crabs (IUCN, 2015). More than 10 million tons of crustaceans, mainly shrimps, prawns, and crabs, are produced annually for human consumption through fishing or farming. Ahmed et al. (2008) listed around 185 crustacean species, categorized under 89 genera and 45 families (Ahmed et al., 2008).

## **1.3 Shrimps of Bangladesh**

The terms "shrimp" and "prawn" are often used interchangeably, yet their definitions can vary depending on the region. Both can be found in saltwater and freshwater, typically near the sea floor. However, it's difficult to provide a clear-cut definition for each, as these terms are applied inconsistently across different areas and even within the same region (Holthuis, 1980). In North America, the term "prawn" is mostly outdated and has been replaced by "shrimp," even for species such as *Palaemonetes* (grass shrimp) and *Macrobrachium* (river shrimp), which are part of the Palaemonidae family. While "shrimp" is the more commonly used term in both Britain and North

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America, the term "prawn" refers to larger Palaemon-like species in Britain, while in the U.S., it typically refers to the smaller varieties (Holthuis, 1980).

Shrimps belongs to the order Decapoda under class Malacostraca. They inhabit in a variety of environments, from low-salinity areas to inland hill streams and artificial water bodies. Ahmed (1990) states that Bangladesh is home to 56 species of shrimp and prawn, found in both freshwater and marine habitats. Of these, four species are commercially exported worldwide, while 10 species are exploited for commercial purposes.

A total of 64 prawns and shrimps under 8 Families are documented in the country (IUCN 2015). The group is primarily led by two families: Palaemonidae, which includes 20 prawn species mainly from freshwater and estuarine environments, and Penaeidae, which consists of 24 shrimp species primarily from marine and coastal habitats. Among the 64 taxa assessed, 27 are classed as Least Concern and 37 as Data Deficient (IUCN 2015) indicating a huge gap of knowledge. Ahmed et al., (2008) described 55 shrimp species in Encyclopedia of Flora and Fauna of Bangladesh. From Teknaf about 10 species of shrimp has been recorded by Chowdhury et al. (2008)

### **1.4 Fresh water shrimps of Bangladesh**

Bangladesh is considered one of the most favorable countries for freshwater shrimp (golda chingri) farming due to its conducive climatic conditions. The two primary families, Atyidae and Palaemonidae, are predominantly freshwater species, although some also inhabit brackish and marine environments. Among the 64 species of shrimp found in Bangladesh, 24 are freshwater species, including 10 species of *Macrobrachium*. However, only *M. rosenbergii* has significant aquaculture potential and is commercially farmed. There is also considerable potential for farming *M. malcolmsonii* in Bangladesh, as its larval production and cultivation processes are similar to those of *M. rosenbergii*, which has been successfully farmed in India (Ahmed et al., 2008).

Genus *Macrobrachium* includes freshwater shrimps which inhabit most diverse habitats. They inhabit environments ranging from low-salinity areas to inland hill streams and impounded water bodies. These organisms play crucial roles in the food chain and serve as a vital food source for larger animals, from fish to whales.

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Freshwater shrimp or Golda farming started in the mid-1970s and during the late 1980s and 1990s attained steady growth (Islam et al., 2003). Such farming was subjected to less criticism than brackish water shrimp farming (Ahmed et al., 2008). In 2022-23, the country produced nearly 144,352 metric tons of shrimp from culture (DoF, 2023)

**1.5 Marine shrimps of Bangladesh**

Most marine shrimp species are penaeid shrimps, belonging to families such as Penaeidae, Alpheidae, Solenoceridae, and Sergestidae. The Penaeidae family includes most of commercially valuable shrimp species, with *Penaeus monodon* being the most significant species for Bangladesh. Other important species includes *Penaeus indicus*, *Penaeus semisulcatus*, and *Metapenaeus monoceros* etc. (IUCN, 2015). These shrimps are characterized by a well-developed, toothed rostrum that extends to or beyond the eye stalk, and their first three pairs of legs are chelate (clawed), with all five pairs being well-developed. Penaeids have a short lifespan of about 1–2 years. The larvae and post-larvae migrate to nursery areas in estuaries or wetlands, and as they mature, they move to offshore waters to reach sexual maturity. Female adults mature within six months and exhibit high fecundity (Esmaeili and Omar, 2003). With few exceptions, most marine shrimp are nocturnal, reclusive, and primarily scavengers. Artemia (Brine Shrimp) is the most crucial live feed for penaeid shrimp larvae (Banglapedia, 2014).

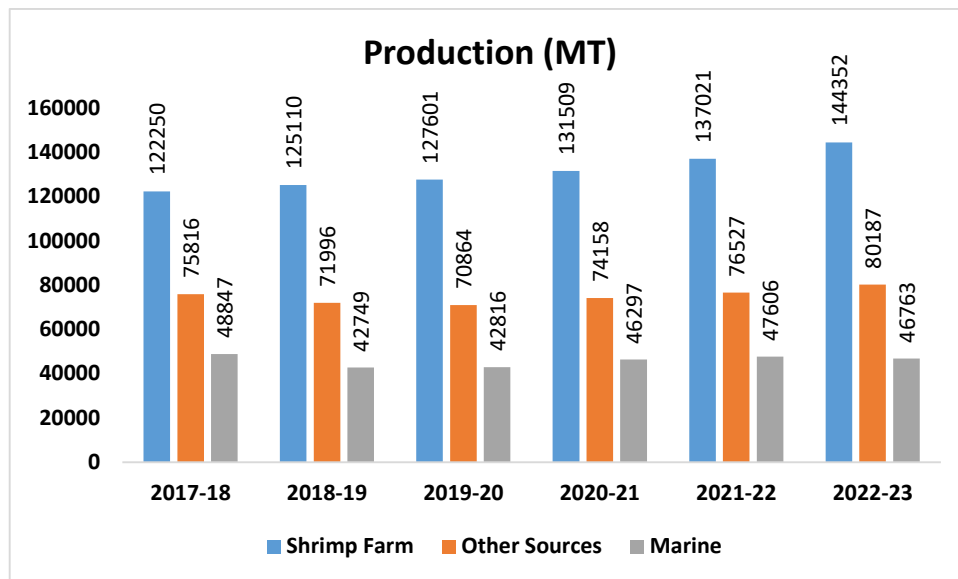
These shrimps are farmed globally, contributing significantly to foreign exchange for key shrimp-producing countries in Asia and the Americas. According to Lightner et al. (2009), over 2 million tons of marine penaeid shrimps were farmed in 2006, representing nearly half of the world's total shrimp supply. Additionally, a substantial number of wild fry are collected from the coastal waters of Cox's Bazar and Khulna. Out of about 9, 31,788 m tons of world production of penaeid shrimps, about 34,030 m tons were produced in Bangladesh in 1995 (Banglapedia, 2014)

**1.6 Current Status of Shrimp Production in Bangladesh**

Shrimp and prawn farming has been a traditional practice in the brackish, saltwater, and freshwater areas of the coastal districts of Khulna, Satkhira, Bagherhat, and Cox's Bazar in Bangladesh. The primary species cultivated are *Macrobrachium rosenbergii* (Giant freshwater prawn - Galda Chingri), *Macrobrachium malcolmsonii* (Monsoon river prawn - Chatka Chingri) and *Penaeus monodon* (Tiger shrimp - Bagda Chingri). Other cultivated shrimp species include *Metapenaeus monoceros* (Brown shrimp -

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Horina), *P. indicus* (Indian white shrimp - Chaka), *P. semisulcatus* (Green tiger shrimp), and *P. merguensis* (Banana shrimp).



**Figure 1.** Production of shrimp from 2017 to 2023 (DoF, 2018-23)

The total production of shrimp and prawn, including capture, has risen from 160,000 MT in 2002-03 to 271,000 MT in 2022-23, the corresponding contributions to total fish production is 5.52 percent and the corresponding growth rate is 3.89 percent. Various programs and development projects are being carried out to boost production and promote shrimp aquaculture (DoF, 2023).

### 1.7 Economic importance of shrimps

Shrimp is a key export item for Bangladesh. Total shrimp and prawn production including capture has been increased 1.40 lakh MT to 2.71 lakh MT in last 20 years from 2000-01 to 2022-23 (DOF, 2023). Bangladesh has exported 30036.18 MT frozen shrimp and earned about BDT 2948.94 crore (DOF, 2020). Prawn and shrimp sector as a whole contribute 74.05% of the total export earnings from fisheries products (DOF, 2020). The country exports these products to over 50 nations, including Belgium, the UK, the Netherlands, Germany, the USA, China, France, the Russian Federation, Japan, and Saudi Arabia (Ahmad, 2018). Around 1.2 million people are employed in prawn and shrimp production, with an additional 4.8 million household members linked to the industry (FRSS, 2015).

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These shrimps are a vital food source for fish, particularly during their juvenile stages. In addition to their role in food chains, larger shrimp species hold significant economic value and are becoming increasingly important in aquaculture. Shrimp and prawn farming has been a traditional practice in the brackish, saltwater, and freshwater areas of the coastal districts of Khulna, Satkhira, Bagherhat, and Cox's Bazar in Bangladesh.

Shrimp farming plays a crucial role in the national economy of Bangladesh. Shrimp is a vital export product for the country, with significant international demand and high market prices. Additionally, its production through aquaculture and trade creates valuable opportunities for employment and poverty reduction, making it the third-largest source of hard currency earnings for the country (Mazid, 2000).

**1.8 Rationale of the research work**

Morphological identification of shrimp is challenging due to their various larval stages, sexual dimorphism, and plasticity, which can be affected by rough handling (Nicolè et al., 2012). Additionally, penaeid shrimps have the ability to change color based on growth, background color, and time of day due to chromo-metaphors (CSIRO, 2013).

No comprehensive survey has been conducted on the shrimp fauna of Bangladesh, and while there are a few scattered publications providing information on local shrimp species, there has been no thorough, systematic taxonomic study, particularly in the area of molecular taxonomy for decapod species. This gap in research is concerning, as many of the commercially important shrimp stocks are either overexploited or at risk. Despite the heavy exploitation of these species, their precise taxonomy and stock status remain poorly understood. This lack of knowledge hampers effective management and conservation efforts. Furthermore, it is likely that numerous new species or records remain undiscovered in the coastal waters of Bangladesh, underscoring the need for more targeted research to explore and document the full extent of shrimp biodiversity in the region.

Accurate identification in species-rich or taxonomically complex groups often requires expert knowledge, which may not always be accessible. However, proper identification is essential for enforcing regulations and ensuring the future conservation of species. The identification process can be challenging, particularly when closely related species appear similar. For this, a potential method to meet these identification challenges is DNA barcoding is a method of species identification using a short, universal DNA

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sequence that contains enough variation to distinguish between species (Hebert et al., 2003).

A global DNA-based barcode system applicable to all animal species would offer a straightforward and universal tool for identifying species and their products. The barcode system relies on sequence variation in a single gene region, specifically a segment of the mitochondrial DNA cytochrome c oxidase I gene (COI). Once the reference sequence library is established, new specimens and products can be identified by comparing their DNA barcode sequences to this reference library. Many countries of the world (Australia, Brazil, Canada, China, Cuba, Germany, Indonesia and Indian) have already barcoded all species of their freshwater and marine fishes (Ward et al., 2005; Lakra et al., 2011; Hubert et al., 2008; Steinke et al., 2009; Knebelsberger et al., 2014).

Another mitochondrial marker, the 16S rRNA gene, being a conserved sequence, can accurately measure the genetic divergence between closely related organisms and can be easily amplified and sequenced across different animal species (Lakra et al., 2009; Ma et al., 2015; Ma et al., 2013). It has been successfully used to distinguish specific species in various organisms, including Zoantharia (Sinniger et al., 2008), hydrozoans (Zheng et al., 2013), and fishes (Lee et al., 2014; Chakraborty and Iwatsuki, 2006), and amphibians (Vences et al., 2005). The combination of conserved and variable regions within the same gene is probably one of the reasons why 16S rRNA has become one of the most popular genes for reconstructing animal phylogenies. If properly applied, it allows the study of the old phylogenetic relationship as well as fairly recent separation events. On the other hand, the popularity of this gene is probably also due to its successful use by previous workers and the limited number of alternative primers available for invertebrate molecular comparisons.

The Department of Zoology at the University of Dhaka established the first DNA Barcoding Laboratory in Bangladesh, beginning its work in 2013. Since then, the lab has successfully barcoded major marine and freshwater fishes including small indigenous species (SIS) (Ahmed et al., 2019). But DNA barcoding of shrimps of Bangladesh yet to be done. The present study aims to explore the use of the COI and 16S rRNA gene in DNA barcoding of shrimps of Bangladesh.

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The outcome of this research will be an inventory and data base of all known species of shrimps of Bangladesh waters with their current status and spatial distribution. Moreover, genetic diversity along with barcode data will be uploaded and preserved in GenBank with their assigned GB accession numbers accessible anytime for all researchers, managers and policymakers. These information and data will be a millstone for future biodiversity research, increase production, utilization and sustainable management of our invaluable aquatic resources.

Documenting genetic variation and diversity is crucial for developing effective conservation strategies with lasting effects. It is essential for the country to preserve both the genetic identity and integrity of species in their natural environments. Therefore, the proposed study focused on the genetic characterization of shrimp and prawn species in Bangladesh.

**1.9 Objectives of the research work**

- a. To know the genetic diversity of shrimps (Crustacea: Decapoda) of Bangladesh based on the mitochondrial Cytochrome C Oxidase Subunit I (COI) and 16S rRNA gene;
- b. To develop a standardized reference library of barcode database system to store the DNA barcode data for the use of researchers, students and policy makers;
- c. To established the phylogenetic relationships among shrimps;
- d. To know the distributional status of shrimps of Bangladesh and
- e. To explore the new species, new records or cryptic species and recommendation on conservation & management of shrimps of Bangladesh



# **Chapter 1**

## **Morpho-taxonomy**

## **1. Introduction**

### **1.1 Importance of taxonomy**

Taxonomy, in a broad sense the science of classification, but more strictly the classification of living and extinct organisms—i.e., biological classification. The importance of taxonomy in biology is immense for study, research, and is also quite fascinating. Taxonomy is the scientific method used to classify all living organisms on Earth. It is crucial because it reveals the relationships between organisms and their peers, as well as their interactions with ancestors. However, taxonomy has undergone numerous changes, deviations, and modifications over time due to the variations among living organisms.

Taxonomy helps catalog and describe the vast diversity of shrimp species. There are thousands of shrimp species, many of which are still being discovered. Proper taxonomy allows scientists to distinguish between them, understand their ecological roles, and track their distribution. It plays a critical role in assessing biodiversity, conserving species, managing fisheries and aquaculture, and monitoring ecological health. By providing a structured framework for identifying species, taxonomy supports the sustainable management of shrimp populations, helps track invasive species, and aids in the development of disease control strategies. Furthermore, it ensures global communication and standardization in research, conservation, and trade, making it a cornerstone for both scientific study and practical applications in shrimp-related industries.

### **1.2 Morphological identification**

Morphology can be defined as the study of the size, shape, structure of organisms and microorganisms and of the relationships of their fundamental parts. The term denotes to the overall features of biological form and arrangement of the parts of a plant or an animal (Claude, 1999). For the last 250 years, taxonomy has been primarily defined by morphological structures, focusing on the phenotypic traits of individual organisms (Hebert and Gregory, 2005). Morphological systematics developed from the field of comparative anatomy (Hillis, 1987). There are many advantages to using morphological systematics to identify and compare species.

A morphologist would use the size, shape, color and structure of one organism according to the morphological species concept and compare it with another to determine its species. In case of decapod crustaceans like shrimps, individuals are generally characterized by differences in colour, body, rostrum teeth, cheliped morphology etc.

Morphological identification of shrimp is particularly challenging due to their diverse larval stages, sexual dimorphism, and plasticity, all of which can be compromised by rough handling (Nicolè et al., 2012). Accurate identification of species within species-rich or taxonomically complex groups often necessitates expert knowledge, which may not always be readily available. However, correct identification is essential for enforcing regulations and ensuring the future conservation of the species.

## **2. Review of Literatures**

The literature on shrimp diversity in Bangladesh is scarce, with limited research available on the full extent of species distribution and biodiversity. While shrimp farming and production have been extensively studied, there has been little focus on documenting the various shrimp species found in the country. There are few thorough surveys on the total biodiversity of shrimps and prawns, and the majority of current research tends to concentrate on economic factors or particular shrimp species. This lack of detailed, countrywide studies hinders effective conservation efforts and the development of sustainable management practices for shrimp biodiversity in Bangladesh. This section discusses the most relevant and significant literature related to the topic in the context of Bangladesh.

**Hasan et al. (2021)** investigated and prepared a checklist of freshwater prawn, *Macrobrachium* found in Kurigram district of Bangladesh. The investigation identified eight *Macrobrachium* species. The study recommends DNA barcoding of freshwater Palaemonid prawn in the waterbodies of Bangladesh for more detail's information.

**Azadi and Arshad-Ul-Alam (2020)** documented the ichthyodiversity of five interconnected rivers in Chattogram, Bangladesh, namely the Karnaphuli, Halda, Sikalbaha, Chandkhali, and Sangu rivers. A total of 130 ichthyofaunal species were recorded, comprising 112 finfish species and 18 shellfish species (including 16 species of shrimps and prawns). Among these, 128 species (110 finfish and 18 shellfish) were identified from the Karnaphuli River, 85 species (74 finfish and 11 shellfish) from the Sikalbaha River, and 83 species (72 finfish and 11 shellfish) from the Chandkhali River. The 112 finfish species, including four exotic species, belonged to 20 orders, 47 families, and 90 genera, while the 18 shellfish species were classified into one order, 3 families, and 7 genera. The most diverse families for finfish were Cyprinidae (22 species), and for shellfish, Palaemonidae (9 species).

**Debnath et al. (2020)** assessed the availability of fish species in the Halir Haor of Sunamganj district in Bangladesh from May 2019 to January 2020. A total of 68 fish species, including 3 prawns, were documented, belonging to 11 orders and 25 families. The identified species were *Macrobrachium rosenbergii*, *Macrobrachium malcolmsonii* and *Macrobrachium sp.*

**Ray et al. (2020)** formulated a checklist of freshwater prawn species (Palaemonidae) from the northwest part of Bangladesh (Dinajpur, Rangpur, and Thakurgaon) based on the collection of sixty samples. The study identified six species: *Macrobrachium lanchesteri*, *M. palaemonides*, *M. lamarrei*, *M. idella*, *M. dollicodectylus*, and *M. latidactylus*. While *M. rosenbergii* was sometimes found during flooding, it was not a consistent presence. The study provides valuable insight into the freshwater prawn species in Bangladesh but recommends further research, including DNA barcoding, to better document these species in the region.

**IUCN Bangladesh (2015)** assessed a total of 64 shrimp species belonging to 8 families within the class Malacostraca, order Decapoda. The assemblage is primarily dominated by two families: Palaemonidae, which includes 20 prawn species mainly of freshwater and estuarine origin, and Penaeidae, with 24 shrimp species primarily of marine and coastal origin. Of these 64 species, 27 are classified as Least Concern (LC), while the remaining 37 are listed as Data Deficient (DD)

**Azadi and Arshad-Ul-Alam (2014)** recorded 9 shrimp species from the Palaemonidae family (*Macrobrachium rosenbergii*, *M. villosimanus*, *M. malcolmsonii*, *M. dollicodactylus*, *M. dayanus*, *M. rude*, *M. birmanicus*, *M. mirabilis*, *Palaemon styliferus*) and 7 species from the Penaeidae family (*Metapenaeus monoceros*, *M. brevicornis*, *M. dobsoni*, *M. lysianassa*, *Penaeus merguensis*, *P. monodon*, and *Parapenaeopsis sculptilis*) in the Sangu River. Overall species richness in the river was 127, comprising 109 finfish and 18 shellfish species.

**Hossain, M.A.R. (2013)** enlisted a total of documented 62 shrimp and prawn species found in Bangladesh, with the aim of raising awareness among relevant stakeholders about the urgent need for effective and sustainable conservation efforts to protect the nation's diverse shrimp and prawn biodiversity. Although shrimp and prawn culture are a significant issue in Bangladesh and has been extensively discussed and researched, their biodiversity has received little attention, with no nationwide survey conducted to assess the number of species, their abundance, and current biodiversity status. The study was attempted to address this gap.

**Rashed-Un-Nabi et al. (2011)** recorded 45 estuarine species (34 finfish and 11 shrimps) from Bakhkhali River estuary. The study looked at how different water quality characteristics related to the temporal and spatial distribution of fish and shrimp

assemblages in Bangladesh's Bakkhali River estuary. *Metapenaeus lysianassa* (17.07%), and *Macrobrachium villosimanus* (12.13%) were observed to be dominant.

**Chowdhury et al. (2011)** conducted a study on the diversity of fisheries using Estuarine Set Bag Net (ESBN) sampling, examining the relationship between fish populations and physicochemical variables across both spatial and temporal scales. A total of 162,755 individuals, representing 76 families and 161 species, were recorded in the study. This included 98 species of finfishes across 44 families, 23 species of shrimps and prawns from 5 families, 13 species of crabs from 8 families, 11 species of mollusks from 11 families, 3 species of echinoderms from 3 families, 4 species of other crustaceans, and 9 unidentified species. Shrimps and prawns comprised 38.85% of the total catch in terms of individual numbers in the ESBN.

**Azadi and Arshad-Ul-Alam (2011)** investigated the diversity of finfish and shellfish in the River Halda, observing a species richness of 92, comprising 83 finfish and 9 prawn species. These species belonged to 14 orders, 37 families, and 71 genera, including 3 exotic species. The recorded 9 prawn species were *Macrobrachium villosimanus*, *M. rosenbergii*, *M. malcolmsonii*, *M. doliodactylus*, *M. dayanus*, *M. rude*, *M. birmanicus*, *M. mirabilis*, and *Metapenaeus monoceros*. The study provided some suggestions for the protection, conservation, and sustainable yield of the fish population of Halda River.

**Arumugam, S. (2011)** documented a checklist of freshwater prawns in Tamil Nadu, India that concludes a total of 24 species. A detailed analysis reveals that freshwater prawns (*Macrobrachium* spp.) in Tamil Nadu are commonly found in various inland freshwater habitats, including lakes, rivers, swamps, irrigation channels, canals, ponds, and estuarine areas.

**Ahmed et al. (2008)** described a total of 55 shrimp species in Encyclopedia of Flora and Fauna of Bangladesh, Vol.18. Part II. Arthropoda: Crustacea including both marine and freshwater. The species were under 8 families and 18 genera.

**Hossain et al. (2007)** recorded and depicted 98 finfish species, 23 prawn species, and 13 crab species from the Naaf River.

**Paul S.K. (2001)** authored a book titled *Shrimp and Lobster: Biology*, which covers the systematics of shrimp species recorded in Bangladesh. The book details 65 different shrimp species, two of which do not have confirmed records in Bangladesh.

**Rahman, M.S. (1999)** conducted a master's thesis work on the abundance and distribution of Prawns from the Northeast (Sylhet, Maulavi Bazar and Sunamganj) and Northwest (Pabna, Sirajganj and Natore) regions of Bangladesh. The study reported a total of ten *Macrobrachium* species found in Bangladesh's extensive freshwater resources. The author also examined the seasonal abundance and distribution of seven prawn species.

### 3. Materials and Methods

#### 3.1 Study area

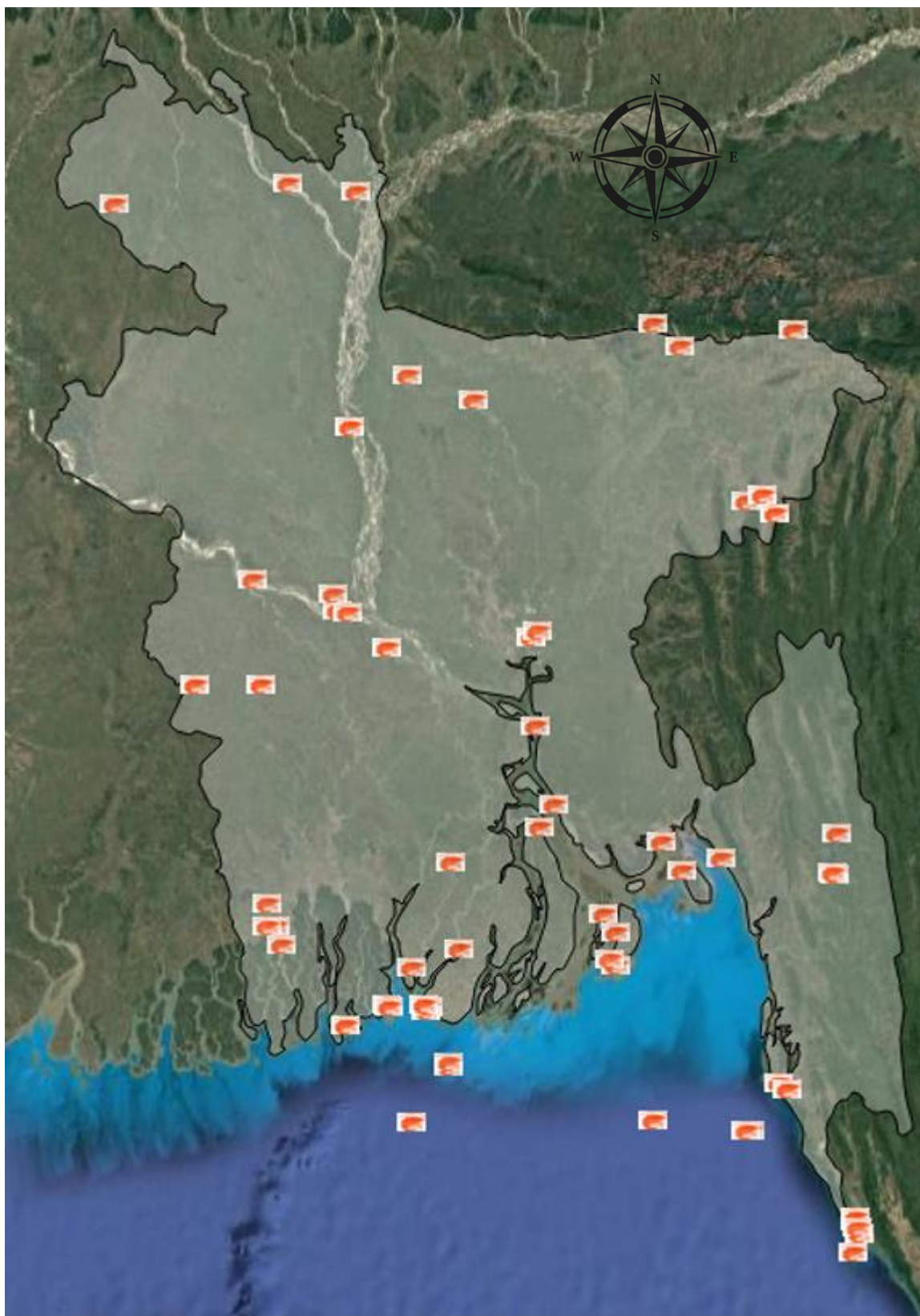
The study area encompasses a diverse range of freshwater sources, including hill streams, brackish water, and marine habitats, from different locations and regions across the country.

**Table 1.** Sampling Locations by District

| Division          | District     | Sampled |
|-------------------|--------------|---------|
| <b>Barisal</b>    | Barguna      | ✓       |
|                   | Barishal     | ✓       |
|                   | Bhola        | ✓       |
|                   | Jhalokati    | ✓       |
|                   | Patuakhali   | ✓       |
|                   | Pirojpur     | ✓       |
| <b>Chittagong</b> | Bandarban    | ✓       |
|                   | Brahmanbaria |         |
|                   | Chandpur     | ✓       |
|                   | Chittagong   | ✓       |
|                   | Comilla      | ✓       |
|                   | Cox's Bazar  | ✓       |
|                   | Feni         | ✓       |
|                   | Khagrachhari | ✓       |
|                   | Lakshmipur   | ✓       |
|                   | Noakhali     | ✓       |
|                   | Rangamati    | ✓       |
| <b>Dhaka</b>      | Dhaka        | ✓       |
|                   | Faridpur     | ✓       |
|                   | Gazipur      | ✓       |
|                   | Gopalganj    | ✓       |
|                   | Kishoreganj  | ✓       |
|                   | Madaripur    | ✓       |
|                   | Manikganj    | ✓       |
|                   | Munshiganj   | ✓       |
|                   | Narayanganj  | ✓       |
|                   | Narsingdi    | ✓       |
|                   | Rajbari      | ✓       |
|                   | Shariatpur   | ✓       |
|                   | Tangail      | ✓       |
| <b>Khulna</b>     | Bagerhat     | ✓       |
|                   | Chuadanga    | ✓       |

| Division          | District         | Sampled |
|-------------------|------------------|---------|
| <b>Khulna</b>     | Jashore          | ✓       |
|                   | Jhenaidah        | ✓       |
|                   | Khulna           | ✓       |
|                   | Kushtia          | ✓       |
|                   | Magura           | ✓       |
|                   | Meherpur         | ✓       |
|                   | Narail           | ✓       |
|                   | Satkhira         | ✓       |
| <b>Mymensingh</b> | Jamalpur         | ✓       |
|                   | Mymensingh       | ✓       |
|                   | Netrokona        | ✓       |
|                   | Sherpur          |         |
| <b>Rajshahi</b>   | Bogura           |         |
|                   | Joypurhat        |         |
|                   | Naogaon          | ✓       |
|                   | Natore           | ✓       |
|                   | Chapai Nawabganj |         |
|                   | Pabna            | ✓       |
|                   | Rajshahi         | ✓       |
|                   | Sirajganj        | ✓       |
| <b>Rangpur</b>    | Dinajpur         | ✓       |
|                   | Gaibandha        |         |
|                   | Kurigram         | ✓       |
|                   | Lalmonirhat      |         |
|                   | Nilphamari       |         |
|                   | Panchagarh       |         |
|                   | Rangpur          | ✓       |
|                   | Thakurgaon       | ✓       |
| <b>Sylhet</b>     | Habiganj         | ✓       |
|                   | Moulvibazar      | ✓       |
|                   | Sunamganj        | ✓       |
|                   | Sylhet           | ✓       |





**Figure 2.** Map of Bangladesh indicating the sampling areas

### 3. 2. Study period

The study was conducted from March 2021 to November 2024, during which multiple field visits were made to collect the targeted samples.

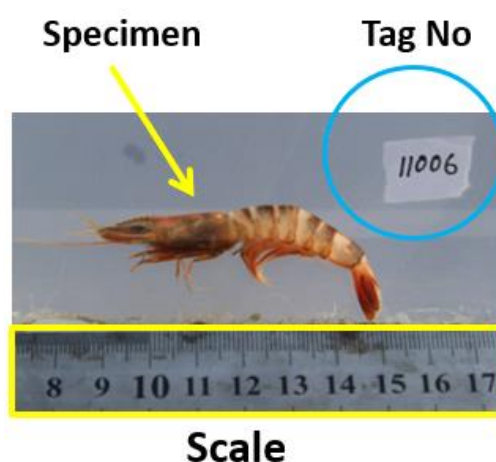
### 3. 3. Procedure of sampling

Samples were collected from a variety of sources, including common habitats (sea, river, beels, haor, baor etc.), landing centers, fish markets, and local fishermen. In addition, personal fishing efforts were undertaken to gather rare and non-commercial species when needed. Night survey was also conducted in the hill streams of the Moulvibazar, Hobiganj and Sylhet regions to collect samples.



**Figure 3.** Night survey and sample in natural habitat

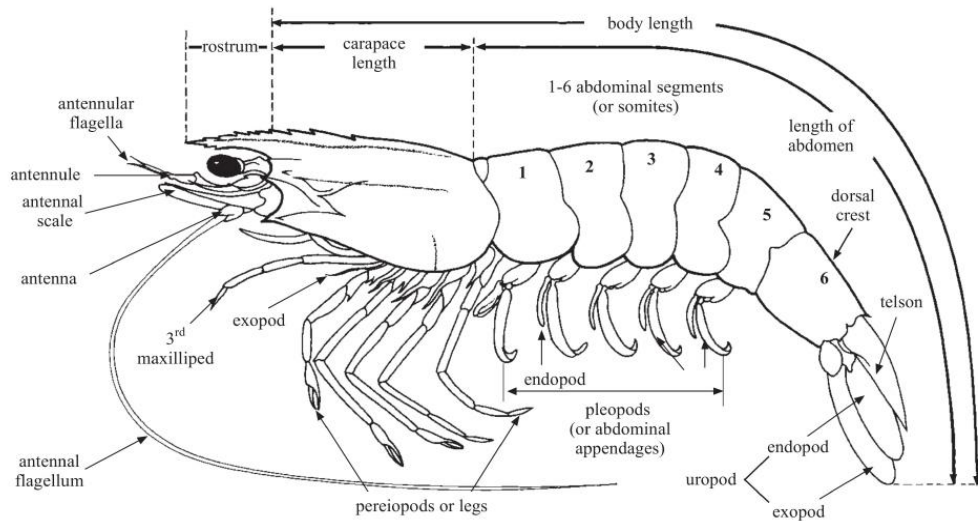
The shrimp specimens were placed in a cool box with ice immediately after collection and transported to the Advanced Fisheries and DNA Barcoding Laboratory, Department of Zoology, University of Dhaka, for further analysis. Digital photographs of all specimens were taken, and each was tagged with a unique voucher number corresponding to its museum ID for proper identification and documentation.



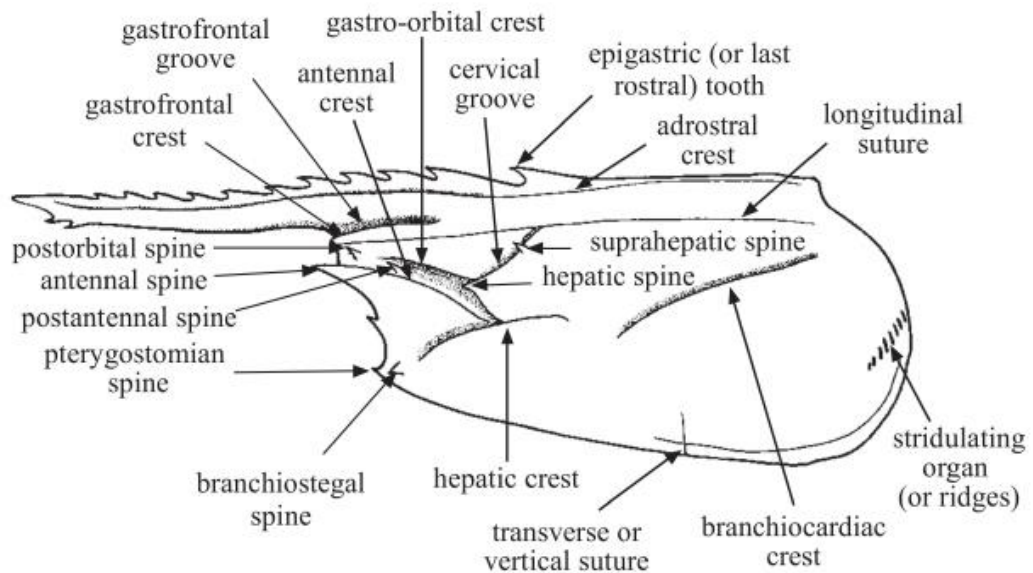
**Figure 4.** Procedure of taking digital photographs with lab tag number

### 3.4 Morphological study

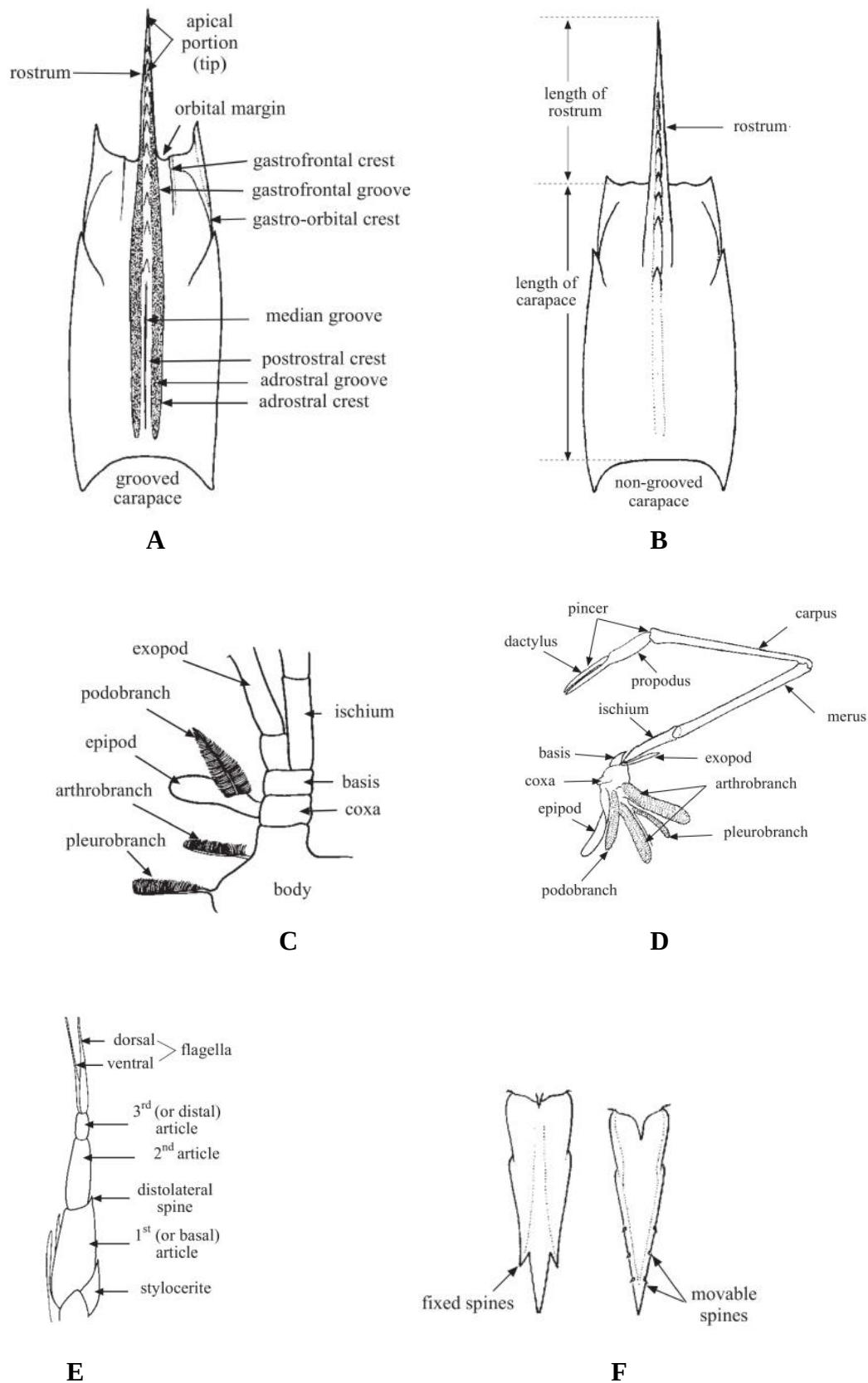
Over 1,000 individuals of different shrimp species were collected from the study areas, identified and classified based on their morphological characteristics. The collected shrimp specimens were taxonomically identified following Holthuis (1980), Fischer and Bianchi (1984), Chan (1998), Ahmed et al. (2008), Dore (2012), and IUCN (2015). A taxonomic key was developed by modifying these sources.



**Figure 5.** Lateral view of a typical shrimp



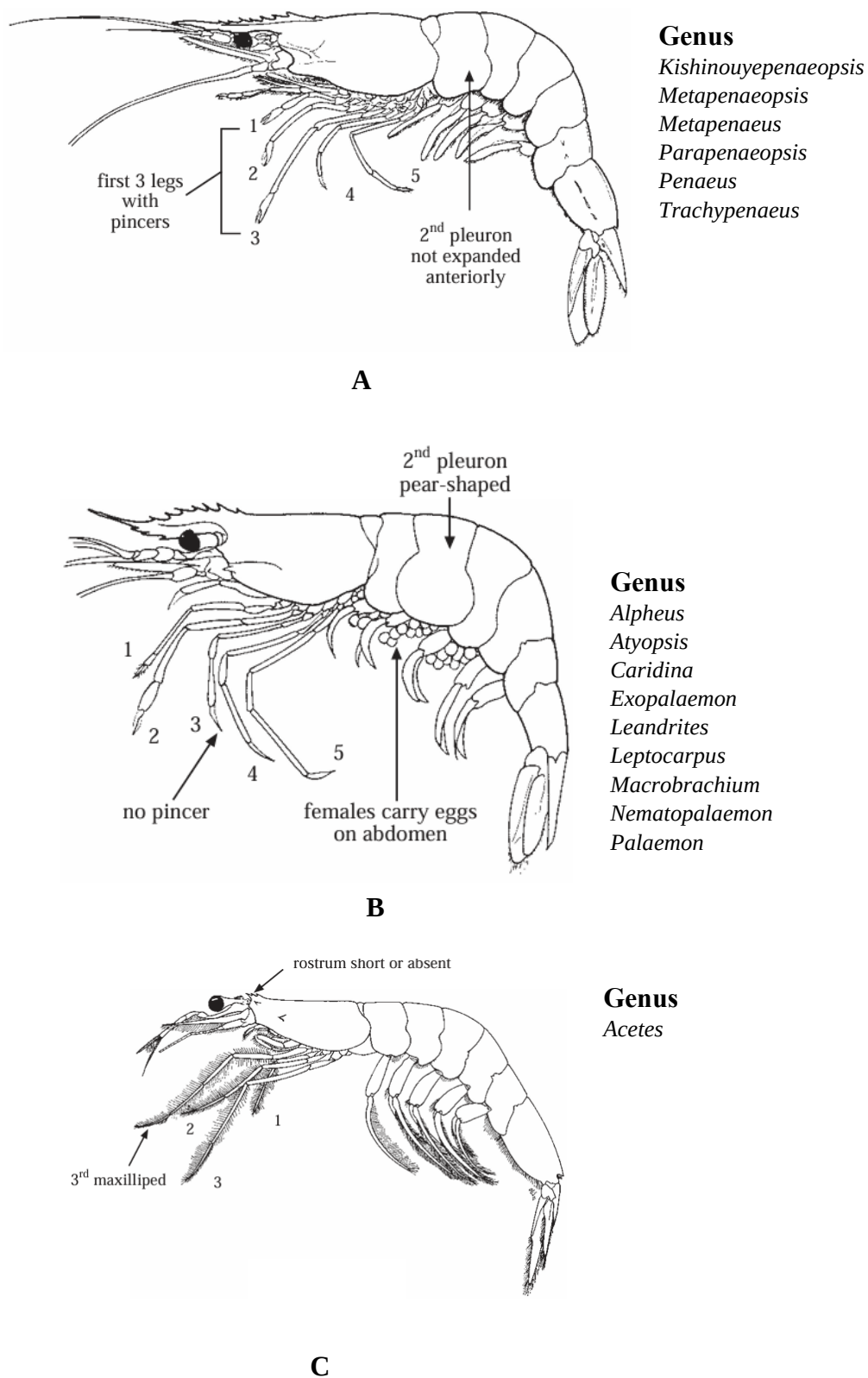
**Figure 6.** Carapace (lateral view)



**Figure 7.** A-B. Carapace (dorsal view); C. proximal part of pereopod; D. pereopod with branchiae; E. Antennule F. types of spined telsons



**3.4.1 Guide to the major groups of shrimps found in Bangladesh** (modified from Chan, 1998)

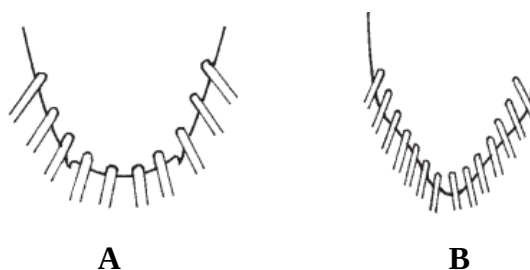


**Figure 8. A.** Penaeoid shrimps **B.** Caridean shrimps (Non Penaeoid shrimps), **C.** Sergestoid shrimps

### 3.4.2 Taxonomic Key for the identification shrimp found in Bangladesh

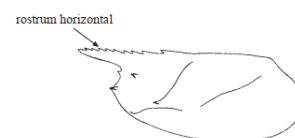
The fourth and fifth legs are completely absent (Figure 8C), reduced to a pair of protuberances (genital coxae) in males.....*Acetes*

- 1(a) Telson apex rounded/truncated (Figure 9A) .....2
- 1(b) Telson apex triangular (Figure 9B) .....3
- 2(a) Inner margin of the third leg's basis with a sharply pointed projection; third and fourth thoracic sternites deeply longitudinally channeled .....*A. indicus*

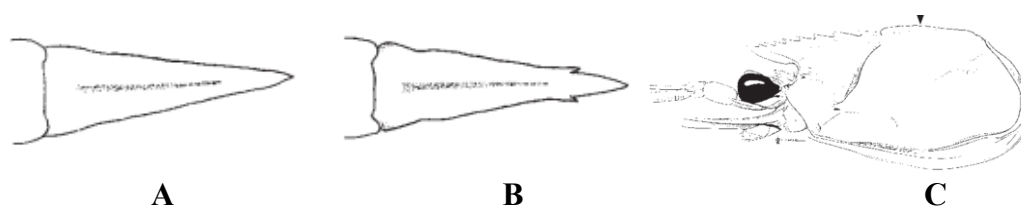


**Figure 9.** Telson **A.** rounded or truncated, **B.** triangular

Antennular flagella flattened and tube-like with rostrum nearly horizontal (Figure 2b); exopod of uropod without disto lateral spine.....*Solenocera*



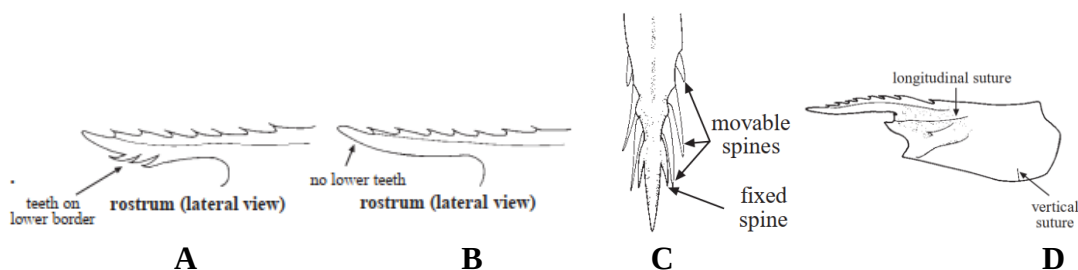
- 1(a) Telson without lateral spine (Figure 10A). .....*S. crassicornis*
- 1(b) Telson with lateral spines (Figure 10B) .....2
- 2(a) Postrostral crest elevated, Rostrum extending to 2/3 of eye .....*S. choprai*



**Figure 10.** Telson **A.** without lateral spine; **B.** with lateral spines **C.** carapace of *S. choprai*

### Identification Key to the genera of Penaeidae occurring in Bangladesh

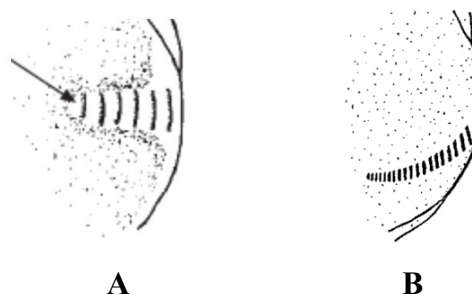
- |      |                                                                                                                      |                             |
|------|----------------------------------------------------------------------------------------------------------------------|-----------------------------|
| 1(a) | Rostrum with lower teeth (Figure 11A)                                                                                | .....2                      |
| 1(b) | Rostrum without lower teeth (Figure 11B)                                                                             | .....3                      |
| 2(a) | Abdomen with many deep pubescent grooves                                                                             | .....Others genus           |
| 2(b) | Abdomen glabrous and smooth                                                                                          | ..... <i>Penaeus</i>        |
| 3(a) | Telson with a pair of large subapical fixed lateral spines (Figure 11C)                                              | .....4                      |
| 3(b) | Telson without large subapical fixed lateral spines, third maxilliped without epipod                                 | .....5                      |
| 4(a) | Body covered by short hairs, grooves and crests on carapace unclear (Figure 11C)                                     | ..... <i>Metapenaeopsis</i> |
| 4(b) | Body almost naked, grooves and crests on carapace distinct (Figure 7a)                                               | .....Others genus           |
| 5(a) | Fifth leg lacking exopod (longitudinal or vertical sutures absent on carapace, Figure 11B).                          | ..... <i>Metapenaeus</i>    |
| 5(b) | Fifth leg with exopod                                                                                                | .....6                      |
| 6(a) | Body naked; grooves and crests on carapace distinct; long longitudinal suture (Figure 11D); third leg lacking epipod | ..... <i>Parapenaeopsis</i> |



**Figure 11.** Rostrum of **A.** *Penaeus* **B.** *Metapenaeus* **C.** telson of *Metapenaeopsis* **D.** carapace of *Parapenaeopsis*

### Identification Key for *Metapenaeopsis* Species found in Bangladesh

- |      |                                                                    |                            |
|------|--------------------------------------------------------------------|----------------------------|
| 1(a) | Stridulating organs present on posterolateral carapace (Figure 12) | .....2                     |
| 1(b) | Stridulating organs absent on posterolateral carapace              | .....Not found in BD       |
| 2(a) | 4-6 Stridulating ridges (Figure 12A).                              | ..... <i>M. stridulans</i> |
| 2(b) | More than 7 Stridulating ridges (Figure 12B)                       | ..... <i>M. toloensis</i>  |



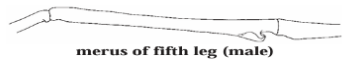
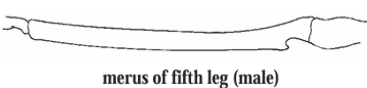
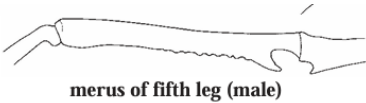
**Figure 12.** Stridulating ridges of **A.** *M. stridulans*; **B.** *M. toloensis*

**Identification Key to the species of *Metapenaeus***

- 1(a) Distomedian petasmas projection with fully developed or vestigial apical filament .....2
- 1(b) Distomedian petasmas projection without apical filament .....4
- 2(a) Rostrum very short and high, not extending beyond eye .....*M. lysianassa*
- 2(b) Rostrum extending beyond eye .....3
- 3(a) Posterior part of rostrum with distinctly elevated crest (Figure 13A) .....*M. brevicornis*
- 3(b) Posterior part of rostrum with distinct high basal crest (Figure 13A) .....*M. tenuipes*
- 4(a) Branchiocardiac sulcus distinct in at least posterior 1/3 carapace .....5
- 4(b) Branchiocardiac sulcus completely absent .....Other species
- 5(a) Ischial spine on 1st pereopod distinct .....6
- 5(b) Ischial spine on 1st pereopod small/absent .....8
- 6(a) Ischial spine sub equal to basial spine .....Other species
- 6(b) Ischial spine much smaller than basial spine .....7
- 7(a) Distomedian petasmas projections directed anteriorly .....*M. ensis*
- 7(b) Distomedian petasmas projections directed anterolaterally .....Other species
- 8(a) Branchiocardiac carina distinct, extending from posterior margin of carapace almost to hepatic spine .....*M. affinis*

**A****B****Figure 13.** Rostrum of **A.** *M. brevicornis* **B.** *M. tenuipes*

Beside this taxonomic keys, the species under *Metapenaeus* genera found in Bangladesh can be identified by the merus of fifth pereopod (only for male). In adult males, merus of fifth pereopod bears

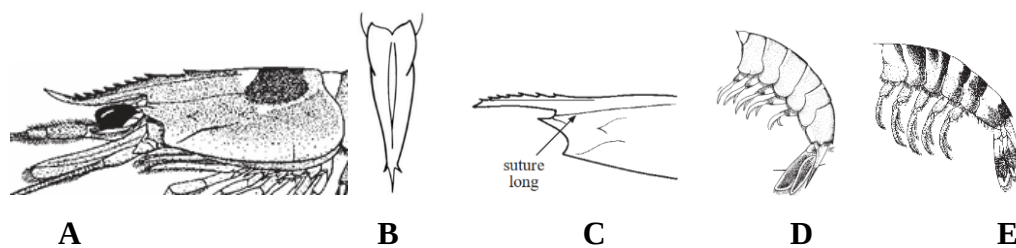
|                       |                                                                                                   |                                                                                       |
|-----------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <i>M. affinis</i>     | a proximal indentation, followed by a twisted, ridge-like projection                              |  |
| <i>M. brevicornis</i> | a proximal notch, followed by a keel-like projection                                              |  |
| <i>M. tenuipes</i>    | a proximal notch, succeeded by a keel-shaped tubercle                                             |  |
| <i>M. ensis</i>       | a basal notch, followed by a long, inwardly curved spine-like structure and a series of tubercles |   |
| <i>M. lysianassa</i>  | a proximal notch, followed by a large, slightly curved triangular tooth                           |  |



**Key to the species of *Parapenaeopsis* occurring in the area**

- |      |                                                                                                                                                   |                               |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| 1(a) | First and second legs with epipods, in first leg basal spine present                                                                              | .....2                        |
| 1(b) | First and second legs without epipods                                                                                                             | ..... <i>Other sp</i>         |
| 2(a) | Second leg lacks a basal spine or a very small one; the carapace features a prominent dark brown patch on the dorsoposterior region (Figure 14A). | ..... <i>P. uncta</i> *       |
| 2(b) | Second leg typically with a noticeable basal spine; the carapace lacks distinct dark patches on the dorsal surface.                               | .....3                        |
| 3(a) | Telson armed one or two pairs of fixed lateral spines (Figure 14B)                                                                                | ..... <i>P. coromandelica</i> |
| 3(b) | Telson without fixed lateral spines; long longitudinal suture, extending near to posterior of carapace (Figure 14C)                               | .....4                        |
| 4(a) | body not strikingly cross-banded (Figure 14C,D)                                                                                                   | ..... <i>P. hardwickii</i>    |
| 4(b) | body strikingly cross-banded (Figure 14E)                                                                                                         | ..... <i>P. sculptilis</i>    |

\* Sakai and Shinomiya (2011) revised the petasma morphology of this species and placed it in a new proposed genus, *Ganjampenaeopsis*. The species is now recognized as *Ganjampenaeopsis uncta*.

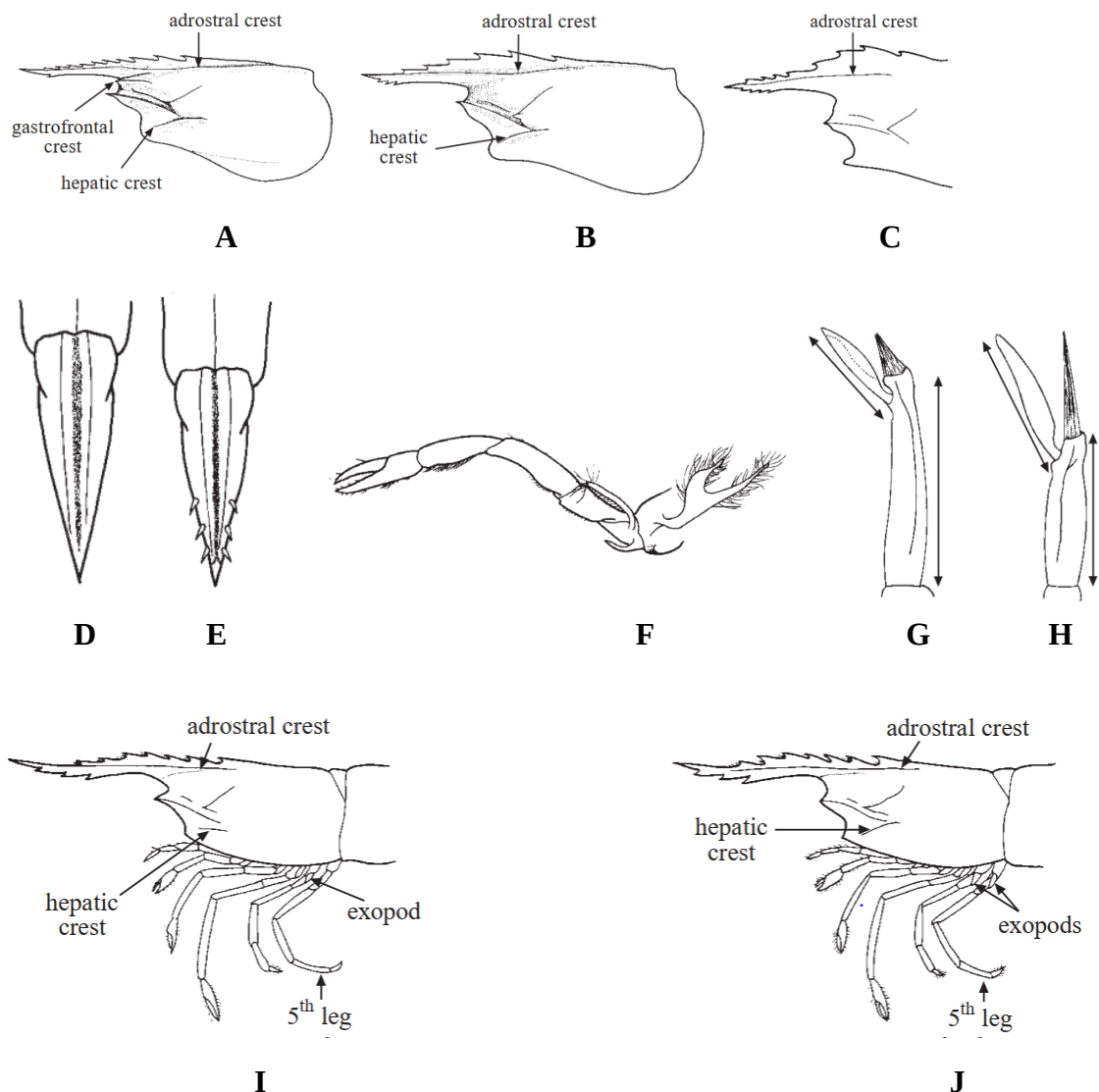


**Figure 14.** A. Carapace of *Ganjampenaeopsis uncta*; B. fixed spine of telson; C. Suture D. no cross-band (*P. hardwickii*) E. strikingly cross-banded (*P. sculptilis*)

**Key to the species of *Penaeus* occurring in the area**

- |      |                                                                                                                                         |                               |
|------|-----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| 1(a) | Adrostral crest reached to posterior border of carapace; gastrofrontal crest present; generally 1 to 2 lower rostral teeth (Figure 15a) | .....2                        |
| 1(b) | Adrostral crest not reached to midcarapace; gastrofrontal crest absent; generally 3 to 6 lower rostral teeth (Figure 15b, c)            | .....7                        |
| 2(a) | Postrostral crest without median groove; usually 2 lower rostral teeth                                                                  | ... .. <i>Other sp.</i>       |
| 2(b) | Postrostral crest with median groove (Figs 15a); usually 1 lower rostral tooth                                                          | .....3                        |
| 3(a) | Telson spineless (Figure 15D) and body covered with cross bands                                                                         | ..... <i>P. canaliculatus</i> |
| 3(b) | Movable lateral spines present on Telson (Figure 15e)                                                                                   | .....4                        |
| 4(a) | First leg with distinct ischial spine                                                                                                   | ..... <i>Other sp.</i>        |
| 4(b) | First leg with ischial spine minute/absent (Figure 15f)                                                                                 | .....5                        |
| 5(a) | Rostrum with accessory ridges                                                                                                           | ..... <i>Other Sp.</i>        |
| 5(b) | Rostrum without distinct accessory ridges                                                                                               | .....6                        |
| 6(a) | Dark brown transverse bands reach to the lower half of the carapace                                                                     | ..... <i>P. japonicus</i>     |
| 6(b) | Dark brown transverse bands do not reach to the lower half of the carapace                                                              | .. <i>P. pulchricaudatus</i>  |
| 7(a) | Hepatic crest present; body covered with cross bands; generally, 3 lower rostral teeth (Figure 15b)                                     | .....8                        |
| 7(b) | Hepatic crest lacking; generally, 4-6 lower rostral teeth (Figure 15c)                                                                  | .....10                       |
| 8(a) | Fifth leg do not bear exopod; antennal flagella not banded (Fig 15I)                                                                    | ..... <i>P. monodon</i>       |
| 8(b) | Fifth leg bearing a small exopod; antennal flagella banded (Fig 15J)                                                                    | .....9                        |

- 9(a) Adrostral crest extends beyond the last postrostral tooth; postrostral crest clearly grooved; hepatic crest extends well past the antennal crest *P. semisulcatus*
- 10(a) Male third maxilliped with the distal segment about half the length of the second segment, which has a tuft of hairs at the tip (Figure 15C,G) ....*P. merguiensis*
- 10(b) Male third maxilliped with the distal segment as long as or longer than the second segment .....11
- 11(a) Male third maxilliped with the second segment equal in length to the distal segment and bearing a tuft of long hairs at the tip (Figure 15H) .....*P. indicus*

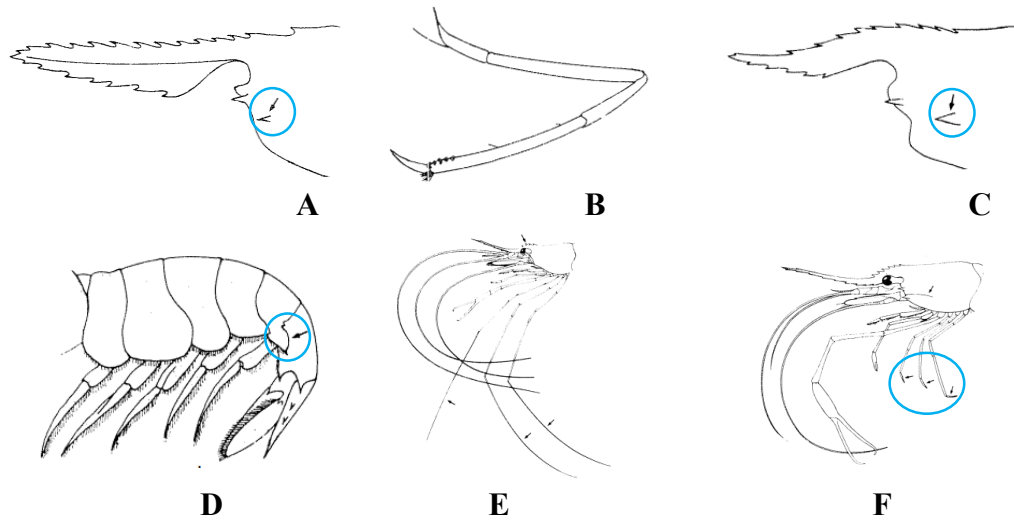


**Figure 15.** Carapace of **A.** *P. japonicus* **B.** *P. semisulcatus*; **C.** *P. merguiensis*; Telson of **D.** *P. canaliculatus* **E.** *P. japonicus* **F.** first leg of *P. japonicus*; distal part of third maxilliped in adult males of **G.** *P. merguiensis*, **H.** *P. indicus*; Fifth leg of **I.** *P. monodon* **J.** *P. semisulcatus*

**Taxonomic key for the family Palaemonidae**

|       |                                                                                                             |                               |
|-------|-------------------------------------------------------------------------------------------------------------|-------------------------------|
| 1(a)  | Branchiostegal spine present (Figure 16A)                                                                   | .....2                        |
| 1(b)  | Branchiostegal spine absent                                                                                 | .....8                        |
| 2(a)  | Fifth pair of pereopods lacks transverse rows of hairs on distal part of propodus                           | .....other                    |
| 2(b)  | Fifth pair of pereopods with transverse rows of hairs on distal part of posterior margin (Figure 16B)       | .....3                        |
| 3(a)  | Rostrum with an elevated basal dorsal crest of teeth                                                        | .....4                        |
| 3(b)  | Rostrum without an elevated basal dorsal crest of teeth                                                     | .....6                        |
| 4(a)  | Dactyls of last 3 pairs of pereopods very strongly lengthened (Figure 16E)                                  | <i>Nematopalaemon</i> (5)     |
| 4(b)  | Dactyls of last 3 pairs of pereopods short (Figure 16F)                                                     | ..... <i>Exopalaemon</i>      |
| 5(a)  | Ventral margin with 2-6 teeth                                                                               | ..... <i>N. tenuipes</i>      |
| 6(a)  | Mandibular palp present, pleura of the fifth abdominal segment terminating in a tooth (Figure 16D)          | ..... <i>Palaemon</i> ...(7)  |
| 6(b)  | Mandibular palp present                                                                                     | .....Other genera             |
| 7(a)  | Ventral margin with 6-10 teeth                                                                              | ..... <i>P. styliferus</i>    |
| 7(b)  | Ventral margin with 3 teeth, inferior half of rostrum with dark red spots                                   | ..... <i>P. adspersus</i>     |
| 8(a)  | Both hepatic and branchiostegal spines absent                                                               | ..... <i>Leptocarpus</i>      |
| 8(b)  | Hepatic spine present, branchiostegal spine absent (Figure 16C)                                             | .....10                       |
| 9(a)  | Lower margin armed with 6-10 equidistant teeth                                                              | ..... <i>L. potamiscus</i>    |
| 10(a) | Dactyls of last 3 pairs of pereopods simple                                                                 | <i>Macrobrachium</i> (11)     |
| 11(a) | Merus of the 2 <sup>nd</sup> pereopod smaller than carpus; rostrum with 1-4 ventral teeth                   | .....12                       |
| 11(b) | Merus of the 2 <sup>nd</sup> pereopod smaller than carpus; rostrum with more than 4 ventral teeth           | .....13                       |
| 12(a) | Rostrum short and high dorsal crest                                                                         | ..... <i>M. mirabile</i>      |
| 12(b) | Rostrum straight and long                                                                                   | ..... <i>M. rude</i>          |
| 13(a) | High basal crest above the eye                                                                              | .....14                       |
| 13(b) | No clear basal crest present                                                                                | .....18                       |
| 14(a) | Tip of telson exceeding posterolateral spines                                                               | .....15                       |
| 14(b) | Tip of telson do not exceed posterolateral spines and generally straight                                    | .....17                       |
| 15(a) | In male 2 <sup>nd</sup> leg very large and robust                                                           | ..... <i>M. rosenbergii</i>   |
| 15(b) | In male 2 <sup>nd</sup> leg feeble                                                                          | .....16                       |
| 16(a) | Carpus of 2 <sup>nd</sup> pereopod in adult male as long as, slightly longer or slightly shorter than chela | ..... <i>M. villosimanus</i>  |
| 16(b) | Carpus smaller than chela                                                                                   | ..... <i>M. birmanicum</i>    |
| 17(a) | Basal crest is moderately elevated, palm of 2 <sup>nd</sup> leg thick and cylindrical                       | ..... <i>M. malcolmsonii</i>  |
| 17(b) | Basal crest not so elevated, palm of 2 <sup>nd</sup> leg not thick                                          | ..... <i>M. lamarrei</i>      |
| 18(a) | Rostrum with 2 ventral teeth and reached to antennular peduncle or extend little                            | ... <i>M. dolichodactylus</i> |
| 18(b) | Rostrum with more than 2 ventral teeth and extend beyond antennular peduncle                                | ..... <i>M. dayanum</i>       |

Other species within the genus *Macrobrachium* exhibit distinct characteristics that complicate their inclusion in the taxonomic key. These traits, along with their unique features, are discussed in the Results section (species description).



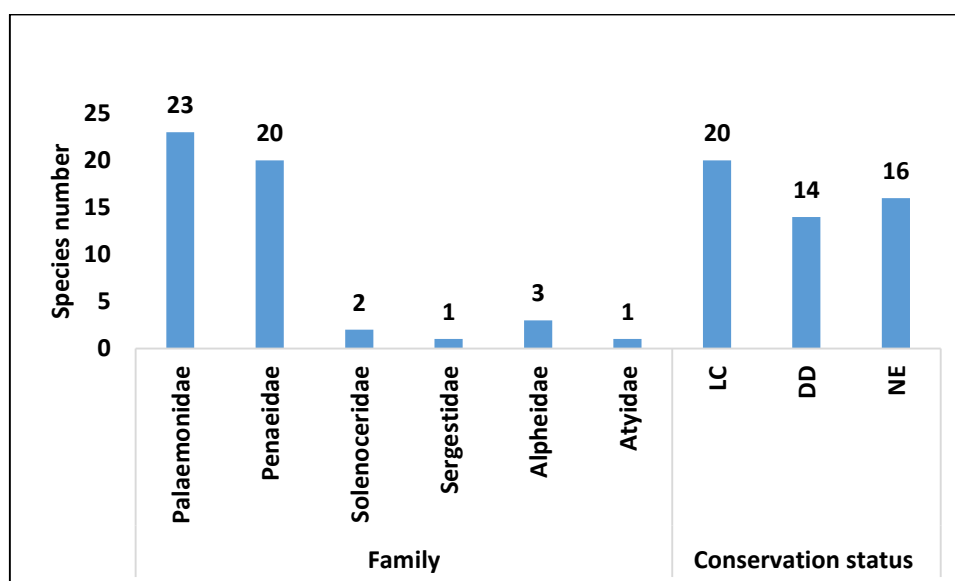
**Figure 16.** **A.** Branchiostegal spine **B.** Fifth pereopod; **C.** Hepatic spine **D.** Abdomen of the genus *Palaemon* **E.** Large pereopods (last 3 pairs) **F.** Short pereopods (last 3 pairs) (Modified from Fischer and Bianchi, 1984)

## 4. Results

### 4.1 General Inference

A total of 50 shrimp species were identified, belonging to 16 genera and 6 families (Table 2). The Palaemonidae family was the most dominant, comprising 23 species, with the genus *Macrobrachium* alone contributing 17 species. Following Palaemonidae, the Penaeidae family was the second most abundant, with 20 species, followed by Alpheidae (3 species), Solenoceridae (2 species), and Sergestidae and Atyidae, each with one species (Table 2 and Figure 17). A total of 11 species were newly recorded from Bangladesh, marking their first geographic occurrence in the region. These species include *Macrobrachium lantau*, *M. neglectum*, *M. scabriculum*, *M. grandimanus*, *M. assamense*, *Palaemon adspersus*, *Kishinouyepenaeopsis incisa*, *Penaeus pulchricaudatus*, *Metapenaeopsis toloensis*, *Solenocera choprai*, and *Alpheus microrhynchus*.

Among the identified species, 40% (n=20) were classified as Least Concern (LC), and 28% (n=14) were categorized as Data Deficient (DD) according to the IUCN Red List of Bangladesh, 2015. The remaining 32% (n=16) were not evaluated.



**Figure 17.** Family wise species number and conservation status.

For the morphological identification of shrimp species, a taxonomic key was developed based on critical diagnostic features such as rostrum structure, rostrum tooth and the arrangement of spines on the carapace and telson. The taxonomic key, detailed in the Materials and Methods section, includes these morphological traits and serves as a practical tool for future identifications of shrimp species in the region.

To complement the morphological approach, molecular analysis was also employed to confirm species identification. DNA barcoding, particularly the use of mitochondrial COI gene sequencing, provided an additional layer of validation by comparing genetic sequences with those available in global reference databases. This molecular data allowed for the accurate identification of species that were difficult to differentiate morphologically, ensuring a higher level of confidence in the species identification process.

**Table 2.** List of identified shrimp species with their conservation status

| SL No | Family       | Species                                       | English Name                           | Local Name                                | IUCN status Bangladesh 2015 | IUCN Global status | Figure No |
|-------|--------------|-----------------------------------------------|----------------------------------------|-------------------------------------------|-----------------------------|--------------------|-----------|
| 1     | Palaemonidae | <i>Macrobrachium equidens</i>                 | Rough River Prawn                      | Goda Ichha.                               | DD                          | LC                 | 44        |
| 2     | Palaemonidae | <i>Macrobrachium rosenbergii</i>              | Giant River Prawn, Freshwater Lobster. | Gholda Chingri, Boro Icha                 | LC                          | LC                 | 45        |
| 3     | Palaemonidae | <i>Macrobrachium lamarrei</i>                 | Kuncho River Prawn.                    | Kuncho Chingri, Gura Ichha.               | LC                          | LC                 | 46        |
| 4     | Palaemonidae | <i>Macrobrachium rude</i>                     | Hairy river prwan                      | Ghoda Chingri, Paitta Icha                | LC                          | LC                 | 47        |
| 5     | Palaemonidae | <i>Macrobrachium assamense</i> <sup>a</sup>   |                                        |                                           | NE                          | NE                 | 48        |
| 6     | Palaemonidae | <i>Macrobrachium birmanicum</i>               | Birma River Prawn                      | Shul Icha, Najari Icha, Thangua Chingri.  | LC                          | LC                 | 49        |
| 7     | Palaemonidae | <i>Macrobrachium dayanum</i>                  | Kaira River Prawn.                     | Ghoda Chingri, Kaira Icha, Daiya Chingri. | NE                          | NE                 | 50        |
| 8     | Palaemonidae | <i>Macrobrachium grandimanus</i> <sup>a</sup> | Hawaiian river shrimp                  |                                           | NE                          | NE                 | 51        |
| 9     | Palaemonidae | <i>Macrobrachium scabriculum</i> <sup>a</sup> | Goda river prawn                       |                                           | NE                          | NE                 | 52        |
| 10    | Palaemonidae | <i>Macrobrachium nipponense</i>               | Oriental river prawn                   |                                           | NE                          | NE                 | 54        |
| 11    | Palaemonidae | <i>Macrobrachium neglectum</i> <sup>a</sup>   |                                        |                                           | NE                          | NE                 | 55        |
| 12    | Palaemonidae | <i>Macrobrachium lantau</i> <sup>a</sup>      |                                        |                                           | NE                          | NE                 | 56        |
| 13    | Palaemonidae | <i>Macrobrachium lar</i>                      | Monkey River Prawn, Hill Stream Prawn  | Chara Chingri.                            | DD                          | LC                 | 57        |
| 14    | Palaemonidae | <i>Macrobrachium malcomsonii</i> .            | Monsoon River Prawn.                   | Chatka Chinghri, Thangua Icha             | LC                          | LC                 | 58        |
| 15    | Palaemonidae | <i>Macrobrachium kistnense</i>                |                                        |                                           | NE                          | NE                 | 59        |
| 16    | Palaemonidae | <i>Macrobrachium dolichodactylus</i>          | River Prawn.                           | Goda Chingri.                             | LC                          | NE                 | 60        |
| 17    | Palaemonidae | <i>Macrobrachium villosimanus</i>             | Dimua River Prawn.                     | Dimua Icha, Dimoala Icha.                 | LC                          | LC                 | 61        |
| 18    | Palaemonidae | <i>Arachnochium mirabile</i>                  | Short Leg River Prawn                  | Lotia Icha                                | LC                          | NE                 | 53        |
| 19    | Palaemonidae | <i>Leptocarpus potamiscus</i>                 | Bombay Prawn.                          | Gura Icha, Kunco Chingri, Lona Chingri.   | LC                          | LC                 | 62        |
| 20    | Palaemonidae | <i>Palaemon styliferus</i>                    | Roshma Prawn.                          | Gara Icha, Gura Chingri                   | DD                          | NE                 | 63        |

| SL No | Family       | Species                                      | English Name                          | Local Name                                 | IUCN status Bangladesh 2015 | IUCN Global status | Figure No |
|-------|--------------|----------------------------------------------|---------------------------------------|--------------------------------------------|-----------------------------|--------------------|-----------|
| 21    | Palaemonidae | <i>Palaemon carinicauda</i>                  | Oriental prawn                        |                                            | NE                          | NE                 | 64        |
| 22    | Palaemonidae | <i>Palaemon adspersus</i> <sup>a</sup>       | Baltic prawn                          |                                            | NE                          | NE                 | 65        |
| 23    | Palaemonidae | <i>Nematopalaemon tenuipes</i>               | Spider Prawn.                         | Shada Chingri, Gura Chingri/Icha.          | DD                          | NE                 | 66        |
| 24    | Penaeidae    | <i>Penaeus merguensis</i>                    | Banana prawn                          | Bagha Chama, Bara Chingri, Chama Chingri   | LC                          | NE                 | 20        |
| 25    | Penaeidae    | <i>Penaeus pulchricaudatus</i> <sup>a</sup>  |                                       |                                            | NE                          | NE                 | 18        |
| 26    | Penaeidae    | <i>Penaeus japonicus</i>                     | Kuruma prawn                          | Changa Chingri                             | LC                          | NE                 | 21        |
| 27    | Penaeidae    | <i>Penaeus monodon</i>                       | Black Tiger Shrimp, Giant Tiger Prawn | Bagda Chingri, Bara Icha.                  | LC                          | NE                 | 23        |
| 28    | Penaeidae    | <i>Penaeus semisulcatus</i>                  | Green Tiger Prawn, Bamboo Node Prawn  | Baghtara Chingri.                          | LC                          | NE                 | 24        |
| 29    | Penaeidae    | <i>Penaeus indicus</i>                       | Indian white prawn                    | Chaka chingri, Sada Chingri                | LC                          | NE                 | 25        |
| 30    | Penaeidae    | <i>Penaeus canaliculatus</i>                 | Witch prawn                           | Dorakata Chingri                           | DD                          | NE                 | 22        |
| 31    | Penaeidae    | <i>Metapenaeus brevicornis</i>               | Yellow Shrimp                         | Nona Chingri, Loilla                       | LC                          | NE                 | 27        |
| 32    | Penaeidae    | <i>Metapenaeus affinis</i>                   | Jinga shrimp                          | Honye Chingri, Kharkhia                    | DD                          | NE                 | 26        |
| 33    | Penaeidae    | <i>Metapenaeus tenuipes</i>                  | Strok Shrimp.                         | Chamma, Loilla Chingri.                    | DD                          | NE                 | 28        |
| 34    | Penaeidae    | <i>Metapenaeus ensis</i>                     | Greasyback Shrimp                     | Gura Icha.                                 | DD                          | NE                 | 29        |
| 35    | Penaeidae    | <i>Metapenaeus lysianassa</i>                | Bird Shrimp.                          | Kucho, Loilla, Gusha Chingri.              | LC                          | NE                 | 30        |
| 36    | Penaeidae    | <i>Metapenaeopsis stridulans</i>             | Fiddler Shrimp                        | Nona Chingri                               | DD                          | NE                 | 31        |
| 37    | Penaeidae    | <i>Metapenaeopsis toloensis</i> <sup>a</sup> | Tolo velvet shrimp                    |                                            | NE                          | NE                 | 32        |
| 38    | Penaeidae    | <i>Mierspenaeopsis sculptilis</i>            | Rainbow Shrimp.                       | Tiga Chingri, Baga Tara Ichha, Ruda Ichha. | LC                          | NE                 | 37        |
| 39    | Penaeidae    | <i>Mierspenaeopsis hardwickii</i>            | Spear Shrimp.                         | Gusha, Godda Chingri                       | DD                          | NE                 | 36        |
| 40    | Penaeidae    | <i>Parapenaeopsis styliifera</i>             | Kiddi Shrimp.                         | Ruda Chingri, Godda Chingri.               | LC                          | NE                 | 33        |
| 41    | Penaeidae    | <i>Parapenaeopsis coromandelica</i>          | Coromandel Shrimp                     | Baga Chingri, Godda.                       | DD                          | NE                 | 34        |
| 42    | Penaeidae    | <i>Ganjampenaeopsis uncta</i>                | Uncta shrimp                          | Tiga Chingri                               | DD                          | NE                 | 35        |



| SL No | Family        | Species                                         | English Name                            | Local Name                               | IUCN status Bangladesh 2015 | IUCN Global status | Figure No |
|-------|---------------|-------------------------------------------------|-----------------------------------------|------------------------------------------|-----------------------------|--------------------|-----------|
| 43    | Penaeidae     | <i>Kishinouyepenaeopsis incisa</i> <sup>a</sup> |                                         |                                          | NE                          | NE                 | 19        |
| 44    | Sergestidae   | <i>Acetes indicus</i>                           | Jawla Paste Shrimp                      | Lailla Icha, Gura Icha, Banguri Chingri. | LC                          | NE                 | 38        |
| 45    | Solenoceridae | <i>Solenocera crassicornis</i>                  | Coastal Mud Shrimp                      | Ghora Chingri.                           | LC                          | NE                 | 39        |
| 46    | Solenoceridae | <i>Solenocera choprai</i> <sup>a</sup>          | Ridgeback Shrimp                        |                                          | NE                          | NE                 | 40        |
| 47    | Alpheidae     | <i>Alpheus microrhynchus</i> <sup>a</sup>       | Giant mangrove snapping shrimp          |                                          | NE                          | NE                 | 41        |
| 48    | Alpheidae     | <i>Alpheus malleator</i>                        | Hammerclaw snapping shrimp              |                                          | NE                          | NE                 | 42        |
| 49    | Alpheidae     | <i>Alpheus euprosyne</i>                        | Nymph Snapping Shrimp                   | Bhati Chingri                            | DD                          | NE                 | 43        |
| 50    | Atyidae       | <i>Caridina propinqua</i>                       | Hairy-handed Prawn/<br>Bengal Caridina. | Chuianni Icha,<br>Chuanicha Chingri.     | DD                          | LC                 | 67        |

<sup>a</sup> New geographical records from Bangladesh

DD: Data Deficient; LC: Least Concern and NE: Not Evaluated

## 4.2 Morphological description of identified shrimp species

### *Penaeus pulchricaudatus* Stebbing, 1914

#### Family-Penaeidae

**Synonyms:** Misidentified as *Penaeus japonicus* Spence Bate, 1888

**Description:** Carapace characterized by well-developed ridges and grooves, without any longitudinal or transverse sutures. The rostrum features 9 dorsal teeth, including 3 on the carapace and 1 ventral tooth. The integument is smooth. The postrostral carina extends nearly to the posterior end of the carapace, with a deep median groove along its length. The adrostral groove, matching the postrostral carina in width, also extends close to the posterior carapace. There is no postocular sulcus. The gastrofrontal groove is well-defined, branching into two at its posterior end. The cervical carina is sharp, accompanied by a distinct groove. The hepatic spine is highly prominent, and the hepatic carina is well-defined, curved, and slopes ventrally at the anterior. The ischial spine on the first pereiopod is either absent or barely visible. The sixth abdominal somite lacks a dorsolateral groove but contains three cicatrices. The thelycum is double-tubed, pouch-like, and opens anteriorly, receiving the spermatophore through a large, subtriangular, wing-like structure. The telson has three sets of movable lateral spines.



**Figure 18.** *Penaeus pulchricaudatus*

**Color:** The body is pale yellowish, marked by dark brown transverse bands extending from the top to approximately the middle of the carapace. The eyes appear blackish-brown. The scaphocerite exhibits a greenish tint with white tips, while the antennal flagella transition in color from reddish-brown to yellowish-brown. The pereiopods are whitish to yellowish, and the pleopods display a range from yellowish to reddish, with brown and white spots near their bases.

**Habits:** It is nocturnal and omnivorous. Its food consists of polychaetes, small and large crustaceans, parts of fish and vegetable matter.

**Habitat:** Marine; resides in shelf regions ranging from the coastline to depths of approximately 90 meters, typically favoring sandy or sandy-mud bottoms at depths of less than 50 meters.

**Distribution:** It is found in the South China Sea, Australia, and the western Indian Ocean. Its presence in Bangladesh was first documented in Teknaf (Datta et al. 2024).

**Economic importance:** *P. pulchricaudatus* marketed mostly fresh and frozen, consumed locally mixed with *P. japonicus*.

**Fishing Gear Used:** Trawls and shrimp drift nets, fish corrals, pocket netting, set gill nets, beach seining.

**Key characteristics:** *P. pulchricaudatus* closely resembles *P. japonicus* but can be distinguished by the ventrolateral carapace coloration. In *P. pulchricaudatus*, the dark brown transverse bands are confined to the upper half of the carapace, whereas in *P. japonicus*, they extend to the lower half.

***Penaeus merguensis* De Man, 1888****Family-Penaeidae**

**Synonyms:** *Fenneropenaeus merguensis* (De Man, 1888)

**English names:** Banana prawn

**Local names:** Bagha Chama, Bara Chingri, Chama Chingri

**Description:** The carapace is relatively smooth, lacking gastrofrontal and hepatic crests. The adrostral crest extends to, or just before, the epigastric tooth. The tip of the rostrum is horizontally straight, and the rostral crest becomes notably high and broadly triangular in larger specimens (especially in females). The rostrum generally bears 6 to 9 upper teeth (including those on the carapace) and typically 3 to 5 lower teeth. The postrostral ridge extends close to the posterior margin of the carapace. In adult males, the third maxilliped has a distal segment that is approximately half the length of the second segment, which is tipped with a tuft of dense, short hairs slightly shorter than the distal segment.



**Figure 19.** *Penaeus merguensis*

**Color:** The body is semi-translucent, exhibiting a slightly yellowish to greenish hue in larger specimens, and is densely covered with numerous tiny dark brown dots. The distal portion of the uropods is yellowish-green with red margins. Younger specimens often display multiple broken black longitudinal lines along the abdomen.

**Habits:** Nocturnal and omnivorous. It prefers small crustaceans, vegetable matters, polychaetes, molluscs, fish, insects, debris and sand particles.

**Habitat:** Inhabits on mud or sandy-mud bottoms; prefers turbid waters.

**Distribution:** Indo- Pacific region (Philippines, Malaysia, Indonesia, Mergui Archipelago, India to New Guinea and Australia). In Bangladesh throughout the coastal areas of the country.

**Economic importance:** Found fresh and frozen condition in the market; also canned and fried, consumed locally and exported.

**Fishing Gear Used:** Trawls and shrimp drift nets, fish corrals, pocket netting, set gill nets, beach seining, scoop nets, drag nets, push nets and cast nets.

***Penaeus japonicus* Spence Bate, 1888****Family-Penaeidae**

**Synonyms:** *Marsupenaeus japonicus* (Spence Bate, 1888); *Penaeus canaliculatus* var. *japonicus* Spence Bate, 1888

**English names:** Kuruma prawn

**Local names:** Changa Chingri

**Description:** The carapace with well-defined grooves and crests, including both gastrofrontal and hepatic crests. The rostrum is typically armed with 9 or 10 upper teeth (including those on the carapace) and a single lower tooth. The postrostral crest is prominent, featuring a deep median groove along its entire length. The adrostral groove extends near the posterior margin of the carapace and is nearly as wide as the postrostral crest. The telson is equipped with three pairs of movable lateral spines.



**Figure 20.** *Penaeus japonicus*

**Color:** The body is pale yellowish with dark brown transverse bands; those on the carapace generally extend to the lower half, while the last abdominal band is interrupted.

**Habits:** It is nocturnal and omnivorous. Its food consists of polychaetes, small and large crustaceans, parts of fish and vegetable matter.

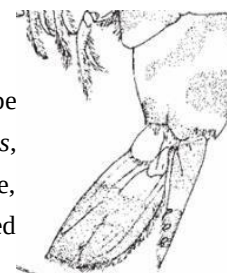
**Habitat:** Marine; Inhabits sandy or sandy-mud bottoms.

**Distribution:** Africa to the Red Sea, Japan, Australia and Fiji. In Bangladesh, often found throughout the coastal areas.

**Economic importance:** Marketed mostly fresh and frozen, consumed locally and probably also exported to some extent.

**Fishing Gear Used:** drift nets and set gill nets

**Key characteristics:** *P. japonicus* closely resembles *P. pulchricaudatus*, but can be distinguished by the coloration of the ventrolateral carapace. In *P. pulchricaudatus*, the dark brown transverse bands do not extend to the lower half of the carapace, whereas in *P. japonicus*, they do. Additionally, *P. japonicus* can be differentiated from *P. canaliculatus* by the presence of movable spines on the telson.



***Penaeus canaliculatus* (Olivier, 1811)****Family-Penaeidae**

**Synonyms:** *Melicertus canaliculatus* (Olivier, 1811); *Palaemon canaliculatus* Olivier, 1811

**English names:** Witch prawn

**Local names:** Dorakata Chingri

**Description:** The carapace features distinct grooves and crests, including both gastrofrontal and hepatic crests. The rostrum is equipped with 10 or 11 upper teeth (including those on the carapace) and 1 lower tooth. The postrostral crest is well-developed, with a deep median groove running its entire length. The adrostral groove extends nearly to the posterior margin of the carapace and is slightly wider than the postrostral crest. The first leg lacks an ischial spine, and the telson is devoid of lateral spines.



**Figure 21.** *Penaeus canaliculatus*

**Color:** The body is pale yellowish with distinct dark brown transverse bands. The bands on the carapace do not extend over the lower half, whereas those on the last abdominal segment are typically continuous to the ventral margin.

**Habits:** Mainly carnivorous. Food consists of polychaetes, small and large crustaceans, parts of fish and vegetable matter.

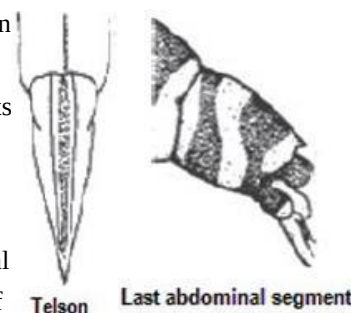
**Habitat:** Marine; Found on sandy bottoms.

**Distribution:** India, Southeast Africa, Taiwan, Polynesia, Japan and Australia and South Africa. In Bangladesh, found in Cox's Bazar region.

**Economic importance:** Marketed fresh, dried, frozen and canned, often mixed with other species of *Penaeus*, and locally consumed.

**Fishing Gear Used:** Stake nets and bag nets; sometimes shrimp gill nets and otter trawls.

**Key characteristics:** Can be easily confused with *Penaeus japonicus* in colour, and *Penaeus latisulcatus* when without colour. *P. canaliculatus* can be differentiated from *P. japonicus* by the absence of movable lateral in telson (present in *P. japonicus*) from *P. latisulcatus* by the presence of cross bands in body (no cross bands in *P. latisulcatus*)





## *Penaeus monodon* Fabricius, 1798

### Family-Penaeidae

**Synonyms:** *Penaeus bubulus* Kubo, 1949; *P. carinatus* Dana, 1852; *P. semisulcatus exsulcatus* Hilgendorf, 1879

**English names:** Black Tiger Shrimp, Giant Tiger Prawn, Jumbo Tiger Prawn.

**Local names:** Bagda Chingri, Bara Icha.

**Description:** The carapace features distinct grooves and crests, with the rostrum typically having 6 to 8 upper teeth (including those on the carapace) and 3 lower teeth. The postrostral crest is well-developed, extending nearly to the posterior margin of the carapace, sometimes with a faint median groove. The adrostral crest reaches just before the last postrostral tooth. The gastrofrontal crest is absent, and the hepatic crest is almost horizontal, extending well beyond the antennal crest. The fifth leg lacks an exopod. In males, the petasma has distomedian projections that slightly overhang the distal margin of the costae. The female thelycum consists of two suboval lateral plates with swollen lips; the anterior process is concave with a rounded distal end, while the posterior process is subtriangular and partially inserted between the lateral plates. The telson lacks lateral spines.



**Figure 22.** *Penaeus monodon*

**Color:** The body is typically greyish-green or dark greenish-blue, becoming reddish-brown in large adults. The carapace is adorned with mud-yellow transverse bands, and the abdomen features dark brown and mud-yellow crossbands. The distal half of the uropods is dark blue or dark brown, with a red or mud-yellow median transverse band.

**Habits:** Mainly nocturnal and omnivorous. It prefers crustaceans, vegetable matters, polychaetes, molluscs, fish, insects, debris and sand.

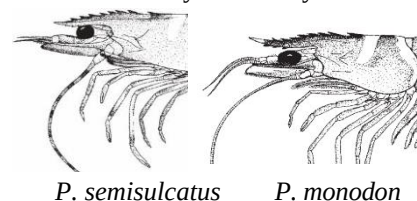
**Habitat:** Bottoms of sand, mud, or silt. Juveniles usually inhabit seagrass beds, mangrove swamps and estuaries, adults are usually found in deeper waters in the sea.

**Distribution:** Indo-Pacific region, (Japan, Taiwan, Australia, and Africa). In Bangladesh *P. monodon* occurs throughout the coastal belt of the country like Khulna, Bagerhat, Satkhira, Patuakhali and Cox's Bazar, in sea and tidal rivers.

**Economic importance:** Marketed mostly fresh and frozen, consumed locally and exported. Export of frozen shrimp has become the second largest foreign exchange earner of the country in recent years.

**Fishing Gear Used:** Stake nets and bag nets; sometimes shrimp gill nets and otter trawls.

**Key characteristics:** The species can be differentiated from *P. semisulcatus* by the absence of white and black cross bands in antennal flagella.



*P. semisulcatus*

*P. monodon*

***Penaeus semisulcatus* De Haan, 1844****Family-Penaeidae**

**Synonyms:** *Penaeus ashiaka* Kishinouye, 1900; *P. monodon manillensis* Villaluz and Arriola, 1938; *P. semisulcatus paucidentatus* Parisi, 1919

**English names:** Green Tiger Prawn, Bamboo Node Prawn or Grooved Tiger.

**Local names:** Baghtara Chingri.

**Description:** Smooth carapace with distinct grooves and crests. Rostrum armed with 5 to 8 teeth on dorsal and 2 to 3 teeth on ventral margin; well-developed postrostral crest reaching nearly to posterior margin of carapace, with a distinct median groove; groove and adrostral crest extending beyond last postrostral/epigastric tooth; gastrofrontral crest absent; hepatic crest long, straight but distinctly sloping anteroventrally and extending behind antennal crest. Exopod on fifth leg. Petasma of males with distomedian projections reaching as far as costae. Thelycum of females formed by 2 suboval lateral plates with tumid lips; subtriangular anterior process with raised edges, posterior process convex, partly inserted between lateral plates. Lateral spines absent on telson.



**Figure 23.** *Penaeus semisulcatus*

**Color:** Body pale brown or dark green to reddish brown, carapace often with 2 yellow-cream dorsal transverse bands; abdomen with greyish brown and pale yellow dorsal transverse bands; dull red on antennal scales, eye stalks, pleopods and uropods; pereopods with reddish bands

**Habits:** Reported to form small shoal sand to be predominantly nocturnal, buried in the substrate during the day time.

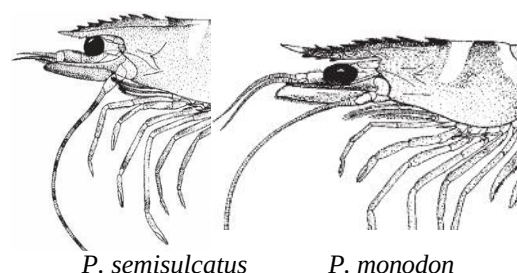
**Habitat:** Bottoms of sand, mud, or sandy-mud. Can tolerate water with a high salinity.

**Distribution:** Indo-West Pacific; Africa, Japan, Australia, and Fiji. In Bangladesh, occurs throughout the coastal belt of the country like Khulna, Bagerhat, Satkhira, Patuakhali and Cox's Bazar, in sea and tidal rivers.

**Economic importance:** Marketed mostly fresh and frozen, consumed locally and exported.

**Fishing Gear Used:** Stake nets and bag nets; sometimes shrimp gill nets and otter trawls.

**Key characteristics:** The species can be differentiated from *P. monodon* by the white and black cross bands in antennal flagella



***Penaeus indicus* H. Milne Edwards, 1837****Family-Penaeidae**

**Synonyms:** *Penaeus merguensis* De Man, 1888; *P. penicillatus* Alcock, 1905; *P. silasi* Muthu and Motoh, 1979.

**English names:** Indian white prawn

**Local names:** Chaka chingri, Sada Chingri, Chapda Chingri, Chapra Chingri, Changa Chingri.

**Description:** The carapace is relatively smooth, without gastrofrontal or hepatic crests. The adrostral crest extends to or just before the epigastric tooth. The rostrum is slightly curved at the tip and sigmoidal in shape, typically bearing 7 to 9 upper teeth (including those on the carapace) and 3 to 6 lower teeth. The postrostral crest extends close to the posterior margin of the carapace. The gastro-orbital crest is distinct, stretching from the hepatic spine to the orbital margin, covering approximately the posterior 3/5 to 2/3 of the distance between them. In adult males, the third maxilliped's distal segment is about the same length as the second segment, which has a tuft of dense, long hairs at its tip, matching the length of the distal segment. The petasma of males has strongly curved distomedian projections that overhang the distal margin of the costae. The female thelycum is formed by two semi-circular lateral plates, with their median margins creating swollen lips. The anterior process is slightly rounded and convex, while the posterior process is elongated and inserted between the anterior part of the lateral plates, with both processes being quite distinct. The telson lacks lateral spines.



**Figure 24.** *Penaeus indicus*

**Color:** The body is semi-translucent, either yellowish-white in small specimens or greyish-green, and is covered with numerous small dark brown dots. The eyes are light brown with dark brown mesh-like stripes. The antennular flagella match the body color and are covered with many dark spots. The legs are translucent and somewhat whitish, while the pleopods are yellowish to pinkish. The distal part of the uropods is yellowish with red margins.

**Habits:** Mainly nocturnal and omnivorous. It prefers crustaceans, vegetable matter, polychaetes, molluscs, fish, insects, debris and sand.

**Habitat:** Sandy and muddy bottoms.

**Distribution:** Widely distributed in Africa to the Red Sea, Japan, and Australia. In Bangladesh, found entire coastal region.

**Economic importance:** Marketed mostly fresh and frozen, consumed locally and also exported.

**Fishing Gear Used:** Stake nets and bag nets; sometimes shrimp gill nets and otter trawls.

**Key characteristics:** *P. indicus* is often confused with *P. silasi*. *P. indicus* can be differ by the third maxilliped of males with second segment as long as distal segment with a tuft of long hairs at tip in *p. indicus* where only a rudimentary tuft of hairs at tip in the latter species.



***Metapenaeus affinis* (H. Milne Edwards, 1837)****Family-Penaeidae**

**Synonyms:** *Penaeus affinis* H. Milne Edwards, 1837; *Penaeus mutatus* Lanchester, 1901; *Parapenaeus affinis* M.J. Rathbun, 1902; *Metapenaeus mutatus* Nobili, 1903; *Metapeneus affinis* Alcock, 1906; *Penaeopsis affinis* De Man, 1911; *Penaeopsis affinis* Kemp, 1915; *Metapenaeus necopinans* Hall, 1956;

**English names:** Jinga shrimp

**Local names:** Honye Chingri, Karaney Chingri, Kharkhia

**Description:** Rostrum straight; nearly whole body pubescent, seldom partially or totally bald; The fifth pereopod's merus in mature males has a proximal notch that is followed by a twisted, keeled tubercle; the petasma's distomedian projection is crescent-shaped; the lycum's anterior plate is long and deeply grooved; and the lateral plates have highly elevated lateral borders that form two longitudinal crests.



**Figure 25.** *Metapenaeus affinis*

**Color:** Body pale greenish to pale pinkish or pink-brownish with green or red-brown specks.

**Habits:** It is a nocturnal and omnivorous animal. feeds on small zooplanktons, Mainly phytoplanktons and debris.

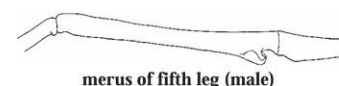
**Habitat:** Found on mud or sandy-mud bottoms, from the coastline to depths of about 90 m, usually less than 55 m.

**Distribution:** Widespread over the Indo-West Pacific, extending from the Persian Gulf to the Philippines, Papua New Guinea, and Taiwan Province, China. In Bangladesh, it is mostly caught in coastal areas and tidal rivers.

**Economic importance:** Both frozen and canned versions of this shrimp are exported from Bangladesh. They are peeled, cooked, or fried and used to make paste and shrimp meal for local consumption.

**Fishing Gear Used:** Traps, seine nets and artisanal gears.

**Key characteristics:** The fifth pereopod's merus in mature males has a proximal notch that is followed by a twisted, keeled tubercle



merus of fifth leg (male)

***Metapenaeus brevicornis* (H. Milne Edwards, 1837)****Family-Penaeidae**

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**Synonyms:** *Penaeus avirostris* Dana, 1852; *Penaeus brevicornis* H. Milne Edwards, 1837

**English names:** Yellow Shrimp

**Local names:** Nona Chingri, Loilla, Kucho Chingri, Karaney, Saga Chingri, Changa.

**Description:** The rostral crest is high. In adult males, the merus of the fifth pereiopod features a proximal notch followed by a keel-shaped tubercle. The disto-median projection of the petasma has a long, slender apical filament. The anterior plate of the thelycum is large, square, and grooved, while the lateral plates are boomerang-shaped, often continuous with the posterior sternite, enclosing two pear-shaped plates.



**Figure 26.** *Metapenaeus brevicornis*

**Color:** The body varies from yellow to white, sometimes appearing greyish, with distinct dark green to bluish-brown specks. The pleopods range from yellowish to pinkish. The distal part of the uropods is brown to rusty red, though sometimes only the tips are colored.

**Habits:** This species is nocturnal and omnivorous, feeding primarily on small zooplankton, phytoplankton, and debris.

**Habitat:** A marine to almost fresh-water species, found on sand or mud. Reared in the ghers with *Penaeus monodon*.

**Distribution:** Indo-Pacific, from the Arabian Sea off Pakistan to Malaysia, Indonesia, and Thailand. In Bangladesh, it is mostly caught in coastal areas and tidal rivers.

**Economic importance:** Marketed fresh or frozen, mainly for local consumption.

**Fishing Gear Used:** Commonly caught using set nets, traps, cast nets, scoop nets, drag nets, and various artisanal fishing methods.

**Key characteristics:** The fifth pereiopod's merus in mature males has a proximal notch that is followed by keel-shaped tubercle.



merus of fifth leg (male)

***Metapenaeus tenuipes* Kubo, 1949****Family-Penaeidae**

**Synonyms:** *Metapenaeus spinulatus* Kubo, 1949

**English names:** Strok Shrimp.

**Local names:** Chamma Chingri. Loilla Chingri.

**Description:** Body hairless; rostral crest high; adrostral crest and groove extending to second rostral tooth; telson armed exclusively with spinules, 1 or 2 distal pairs bigger; ischial spine on first pereopod; rostrum armed with 5 to 8 dorsal teeth, toothles on little less than its distal half. Adult males have a keel-shaped tubercle on merus of the fifth pereopod, which has a proximal notch.



**Figure 27.** *Metapenaeus tenuipes*

**Color:** Body flesh or white coloured with light grey dots; thoracic legs, swimmerets and antennal scales flesh coloured with ash dots. Size: maximum body length of females about 100 mm and males 80 mm.

**Habits:** It is a nocturnal and omnivorous animal. Mainly feeds on small zooplanktons, phytoplanktons and debris.

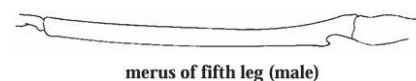
**Habitat:** Occurs in the coastline and brackish waters to a depth of 30 m.

**Distribution:** Indo-Pacific: India, Thailand. Malaysia, Singapore and Indonesia. In Bangladesh, most of the coastal areas.

**Economic importance:** Marketed fresh or frozen, mainly consumed locally.

**Fishing Gear Used:** Trawls, set nets, traps, seines and artisanal gear.

**Key characteristics:** Adult males have a keel-shaped tubercle on merus of the fifth pereopod, which has a proximal notch.



merus of fifth leg (male)



## ***Metapenaeus ensis* (De Haan, 1844)**

### **Family-Penaeidae**

**Synonyms:** *Metapenaeus mastersii* aswel, 1879; *Metapenaeus incisipes* Bate, 1888; *Metapenaeus incisipes* Alcock, 1905; *Metapenaeus mastersii* Alcock, 1905; *Penaeopsis mastersi* De Man, 1911; *Penaeopsis incisipes* De Man, 1911; *Penaeopsis ensis* De Man, 1911

**English names:** Greasyback Shrimp.

**Local names:** Gura Icha.

**Description:** The body is covered in fine pubescence. Armed with eight to eleven teeth along the entire dorsal margin, the rostrum is almost straight and extends to about the tip of the antennular peduncle. It features a low postrostral crest. Typically, the branchiocardiac crest is prominent, curved, and nearly extends to the hepatic spine. There is a little ischial spine in the first leg. A row of tubercles and a long, inwardly curved spine-like process follow the basal notch on the merus of the fifth leg in adult males. In ventral view, the male petasma's distolateral projection is almost entirely covered by a very massive, triangular distomedian process. Female thelycums have a lengthy anterior plate and lateral plates with posterolateral borders that are substantially elevated and curve inward to form two triangular projections.



**Figure 28.** *Metapenaeus ensis*

**Color:** Large adults may have a slightly pinkish appearance, while the body is greyish-green to dark green and heavily speckled with dark brown. The antennal flagella are reddish, and the eyes are black-brown. In larger adults, the basal segments have red stripes, while the legs are usually white. The uropods' distal portion bears reddish-brown edges and a bluish tinge.

**Habits:** This species is nocturnal and omnivorous, feeding primarily on small zooplankton, phytoplankton, and debris.

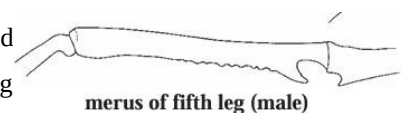
**Habitat:** It mostly lives on silty, sandy-mud, or muddy bottoms in turbid waters that reach a depth of 95 meters. Seagrass beds, mangrove banks, backwaters, and estuaries are all home to juveniles.

**Distribution:** Found in the Indo-West Pacific, ranging from the eastern coast of India and Sri Lanka to Japan and Australia. Found abundantly in the mangrove region (Sundarban) of Bangladesh.

**Economic importance:** This species is primarily marketed fresh or frozen but is also cooked, salted, or used as bait. It is consumed locally and exported.

**Fishing Gear Used:** Commonly caught using set nets, scoop nets, traps, and various artisanal fishing methods.

**Key characteristics:** A row of tubercles and a long, inwardly curved spine-like process follow the basal notch on the merus of the fifth leg in adult males



merus of fifth leg (male)

***Metapenaeus lysianassa* (De Man, 1888)****Family-Penaeidae**

**Synonyms:** *Metapenaeus lysianassa* var. *malaccaensis* Hall, 1962; *Penaeus lysianassa* De Man, 1888

**English names:** Bird Shrimp.

**Local names:** Kucho, Karaney, Loilla, Gusha Chingri.

**Description:** Rostrum wide and short not reaching to distal end of basal antennular segment (Reddy, 1995). The dorsal margin is fully armed with 6 or 7 teeth. The rostral crest is prominent, while the postrostral ridge extends close to the posterior margin of the carapace. The adrostral crest and groove reach up to the third rostral tooth. The branchiocardiac groove does not extend to the middle of the carapace. The telson is equipped only with spinules. The ischial spine on the first pereiopod is either absent or extremely small. In adult males, merus of fifth pereiopod with a proximal notch followed by a large, slightly arcuate triangular tooth; distolateral projections of petasma bifurcate distally (Miquel, 1984); distomedian projection with vestigial apical filament represented by a pair of rounded bosses. In females, the anterior and lateral plates of thelycum ovoid in shape and subequal in size; conjoined pads usually set obliquely (Reddy, 1995).



**Figure 29.** *Metapenaeus lysianassa*

**Color:** Body flesh coloured with grey dots; the thoracic legs, swimmerets and antennal scales flesh coloured with ash coloured dots; the anterior part of the tail fin and the lower flagellae deep grey.

**Habits:** It is a nocturnal and omnivorous animal. Mainly feeds on small zooplanktons, phytoplanktons and debris.

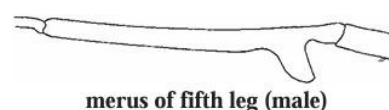
**Habitat:** It is found on muddy bottom in inshore waters, to depths of about 28 m.

**Distribution:** Indo-West Pacific from Bangladesh, India to Viet Nam, Malaysia, and Indonesia. Mostly caught in our country throughout the coastal areas.

**Economic importance:** Mainly sold for local consumption and marketed as fresh, frozen, or dried.

**Fishing Gear Used:** Nets, traps, set nets, push nets, seines, and trawls.

**Key characteristics:** The fifth pereiopod's merus with a proximal notch which is broad, somewhat arcuate triangular tooth.



**merus of fifth leg (male)**





## *Metapenaeopsis stridulans* (Alcock, 1905)

### Family-Penaeidae

**Synonyms:** *Metapenaeopsis tchekunovae* Starobogatov, 1972; *Metapenaeus stridulans* Alcock, 1905

**English names:** Fiddler Shrimp

**Local names:** Nona Chingri.

**Description:** The body is densely pubescent. The rostrum extends to or almost reaches the tip of the antennular peduncle and is straight, pointing forward or slightly upward. It is armed with seven to eight dorsal teeth, with the penultimate tooth usually situated in front of the carapace's orbital border. Four to six powerful stridulating ridges are grouped in a broad, straight band on the back of the carapace. The third abdominal segment's mid-dorsal crest features a wide groove. The petasma's left lobe is triangular and strongly pointed. Compared to *M. barbata*, the thelycum's intermediate plate has more noticeable lateral elevations and a deeper, more distinct posterior transverse groove. There are two sub-apical fixed lateral spines on the telson.



**Figure 30.** *Metapenaeopsis stridulans*

**Color:** The carapace, abdomen, and telson display red to dark brown mottling. The pereopods range from pinkish to dark red, with white coloration except on their proximal portions.

**Habits:** Nocturnal species. Mainly feeds on small zooplankton, phytoplankton and debris.

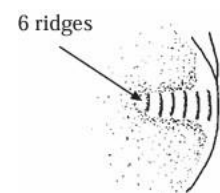
**Habitat:** Sandy and muddy bottoms at depths from 9 to 90 m.

**Distribution:** It is widely distributed in Indo- Pacific region from the Persian Gulf to the South China Sea and New Caledonia including- Bangladesh, India, Malaysia and Sri Lanka. Collected from Cox's Bazar and Chattogram.

**Economic importance:** This species has limited commercial significance and appears to be relatively scarce. It is primarily sold fresh for local consumption.

**Fishing Gear Used:** Stake nets and bag nets; sometimes shrimp gill nets and otter trawls.

**Key characteristics:** On the posterior of the carapace, the species has a broad, straight band of 4 to 6 (usually 6) strong stridulating ridges.



***Metapenaeopsis toloensis* Hall, 1962****Family-Penaeidae**

**English names:** Tolo velvet shrimp

**Local names:** Not known

**Description:** The rostrum is moderately upcurved, extending to the end of the second antennular segment or slightly beyond. The stridulating ridges consist of 14–22 small ridges arranged in a curved band. The dorsal crest of the third abdominal segment features a deep median groove. The right disto-ventral projection of the petasma is short, while the left disto-ventral projection is broadly swollen. The thelycal plate is subquadrate with rounded corners.



**Figure 31.** *Metapenaeopsis toloensis*

**Color:** The body is brownish with dark red to dark brown mottling. The pereopods range from pinkish to reddish-brown. The uropods are dark red to brown, except for their proximal portions, which are lighter.

**Habits:** Nocturnal species. Mainly feeds on small zooplankton, phytoplankton and debris.

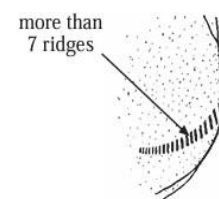
**Habitat:** Sandy and muddy bottoms at depths from 9 to 90 m.

**Distribution:** Indo-West Pacific from the Maldives to Japan and New Caledonia. Collected from Cox's Bazar.

**Economic importance:** It appears to be uncommon and offers little commercial value. Sometimes marketed with other shrimp.

**Fishing Gear Used:** Stake nets and bag nets; sometimes shrimp gill nets and otter trawls.

**Key characteristics:** More than 7 stridulating ridges present on the posterior part of carapace



***Parapenaeopsis incisa* (Wang & Liu in Liu & Wang, 1987)****Family-Penaeidae**

**Synonyms:** *Kishinouyepenaeopsis incisa* Wang & Liu in Liu & Wang, 1987; *Parapenaeopsis incisa* Liu & Wang, 1986

**English names:** Not known

**Local names:** Not known

**Description:** Body slender and covered in setae. Rostrum mostly straight, with a slight upward curve at the tip, bearing 7-8 dorsal teeth, except for a short, toothless distal section (Fig. 2). It does not extend past the third antennular segment of the peduncle. The antennular flagella are equal in length and shorter than the carapace, while the antennal flagellum is larger and surpasses the total body length. The distolateral projections of the petasma are longer than the distomedian projections, slender, horn-like, and diverge at the base before curving inward at the tips. The anterior plate of the thelycum is rectangular with rounded corners and is fused to the posterior plate by a broad posteromedian process. The posterior plate has a pair of lateral depressed areas and a tuft of long hairs behind the thelycum. The legs are well-developed, with pincers on the first three pairs.



**Figure 32.** *Parapenaeopsis incisa*

**Color:** The body is pale greenish, adorned with numerous small dark spots. Eyes are black-brown. The scaphocerite exhibits a greenish hue with white tips, while the antennal flagella range from reddish-brown to black-brown. Pereiopods are whitish to yellowish, and the pleopods are yellowish to reddish, with brown and greenish spots near the bases.

**Habits:** It is nocturnal and omnivorous. Its food consists of polychaetes, small and large crustaceans, parts of fish and vegetable matter.

**Habitat:** Marine; Inhabits in shelf areas, sandy or sandy-mud bottoms.

**Distribution:** South China Sea, the Straits of Malacca, Malaysia. Its presence in Bangladesh was first documented from Kuakata (Datta et al., 2024, present study).

**Economic importance:** Marketed fresh and frozen mixed with the species of genus *Parapenaeopsis*.

**Fishing Gear Used:** Trawls and shrimp drift nets, fish corrals, pocket netting, set gill nets, beach seining.

**Key characteristics:** This species is often confused with *P. cornuta*, but can be differentiated by the distinct shape of its petasma and thelycum, as well as the unique pubescence pattern on its carapace. Furthermore, *P. incisa* differs from *P. cornuta* in that its posterior plate of the thelycum lacks a median boss (Hurzaid et al., 2020).





### ***Parapeneopsis stylifera* (H. Milne Edwards, 1837)**

#### **Family-Penaeidae**

**Synonyms:** *Penaeus styliferus* H. Milne Edwards, 1837; *Parapeneopsis stylifera* (H. Milne Edwards, 1837); *Parapeneopsis stylifera* Alcock, 1906; *Parapeneopsis stylifera* George, 1969.

**English names:** Kiddi Shrimp.

**Local names:** Ruda Chingri, Godda Chingri.

**Description:** The sigmoid-shaped rostrum, strongly upcurved, and significantly overreaching tip of the antennular peduncle with seven to nine dorsal teeth, but the distal half or more is toothless; there is an epigastric tooth; the postrostral crest is distinct and nearly reaches the posterior border of the carapace; the longitudinal suture is long and reaches two thirds of the length of the carapace; Hepatic sulcus very clear and horizontal in its anterior 1/4; hepatic crest distinct for lower 1/2 sulcus from below hepatic the sharp pterygostomian angle spine to (Reddy, 1995); telson armed with 4 pairs of lateral fixed spines; orbital spine small, post-ocular sulcus moderately deep at an angle of 45° to rostrum; cervical sulcus shallow and short, not quite reaching longitudinal suture; hepatic crest/carina ending below hepatic spine; flagella on the antenna as long as the carapace: epipod and basal spine on first two pereopods. basis of third pereopod unarmed.



**Figure 33.** *Parapeneopsis stylifera*

**Color:** The body is pale brownish or pinkish-white, sometimes appearing greyish, with the rostrum and abdominal crest being darker. The pereopods and pleopods range from yellowish-pink to reddish-pink. The distal portion of the uropods is dark grey, with distinctly white tips.

**Habits:** A nocturnal and omnivorous species, primarily consuming small zooplankton, phytoplankton, and organic debris.

**Habitat:** Found from coastal areas to depths of approximately 90 meters, though it is more commonly observed at depths of less than 50 meters, inhabiting muddy or sandy-mud substrates.

**Distribution:** Widely dispersed throughout the Indo-West Pacific, from Malaysia to Indonesia to Kuwait. Available in Teknaf, Cox's Bazar, Kuakata.

**Economic importance:** Primarily sold fresh or frozen for local consumption.

**Fishing Gear Used:** Stake nets, seines, and trawls

***Parapenaeopsis coromandelica* Alcock, 1906****Family-Penaeidae**

**Synonyms:** *Parapenaeopsis stylifera coromandelica* Alcock, 1906; *Parapeneopsis stylifera* var. *coromandelica* Alcock, 1906

**English names:** Coromandel Shrimp

**Local names:** Baga Chingri, Godda.

**Description:** The rostrum is sigmoidal, with at least the distal half (often more) lacking teeth. It is strongly upcurved and extends well beyond the tip of the antennular peduncle, though in some males it is slightly shorter. It is armed at the base with 6 to 8 dorsal teeth. An epigastric tooth is present. The postrostral crest extends almost to the posterior margin of the carapace. A longitudinal suture reaches about two-thirds of the carapace length. The telson is armed with 1 or 2 pairs of fixed subapical spines. The first and second pereopods possess both an epipod and a basal spine, while the third pereopod lacks armature on its basis.



**Figure 34.** *Parapenaeopsis coromandelica*

**Color:** The body is typically grey, though some individuals may appear grey-reddish or brownish. The rostrum and abdominal crest are darker in contrast. The pereopods and pleopods range from pale brown to red or greyish. The uropods are generally grey or brownish, occasionally showing a brown-red hue.

**Habits:** A nocturnal and omnivorous species, primarily feeding on small zooplankton, phytoplankton, and organic debris.

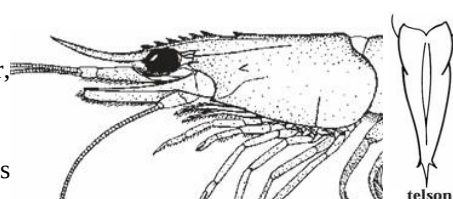
**Habitat:** Commonly found in shallow waters at depths of around 11 meters, predominantly over muddy substrates. It is abundant at sea but does not inhabit lagoons or ghers.

**Distribution:** Borneo to the Indonesian Archipelago, the Gulf of Thailand, and southern India. Found in the coastal region of Bangladesh, especially Cox's Bazar, Teknaf, Maheshkhali.

**Economic Importance:** Marketed in various forms, including fresh, frozen, canned, and processed into prawn meal.

**Fishing Gear Used:** Typically caught using artisanal gear, particularly seine nets, as well as shrimp gill nets and push nets.

**Key characteristics:** The telson is distinctly armed with 1 or 2 pairs of fixed subapical spines.





## *Ganjampenaeopsis uncta* (Alcock, 1905)

### Family-Penaeidae

**Synonyms:** *Parapenaeopsis probata* Hall, 1961; *Parapenaeopsis uncta* Alcock, 1905

**English names:** Uncta shrimp

**Local names:** Tiga Chingri

**Description:** Rostrum equipped with 0 to 11 dorsal teeth; in females and young males, sigmoid-shaped, toothless on the distal 1/4 to 1/3, and styliform, usually reaching the third antennular article or beyond; in large males, straight, not reaching beyond the second antennular article. Epigastric tooth present, although tiny in males. The postrostral crest is grooved and almost reaches the carapace's posterior border. A longitudinal suture that extends 3/4 of the length of the carapace. Telson is unarmed. The first pereopod has an epipod and a basal spine, which are also present on the second pereopod in females. In men, the basal spine is either missing or extremely tiny. Males have distolateral projections of petasma that taper to the end and have a lengthy dorsomedian spine-like structure; distomedian projections are modest. In females, anterior plate of thelycum wide and short, with curved anterior margin and 2 longitudinal ridges, medially fused with the quadrate posterior plate.



**Figure 35.** *Ganjampenaeopsis uncta*

**Color:** Flesh coloured with ash-coloured wide cross bands on the rostrum and abdominal segments; anterior part of rostrum flesh coloured; telson and tail fin red under sides including the thoracic legs and swimmerets red.

**Habits:** It is nocturnal and omnivorous. Feeds on small zooplanktons, phytoplanktons and debris.

**Habitat:** Found on clean sand, sometimes mixed with shell fragments.

**Distribution:** Indo-West Pacific from Kuwait to India, Malaysia, and Indonesia. Available throughout the coastal region of Bangladesh.

**Economic importance:** Marketed fresh or frozen for local consumption.

**Fishing Gear Used:** Trawls, cast nets, set bag nets, seine nets, moi jals, chai and pushnets.

**Key characteristics:** Dark blotch present on the carapace.



***Mierspenaeopsis hardwickii* (Miers, 1878)****Family-Penaeidae**

**Synonyms:** *Parapenaeopsis hardwickii* (Miers, 1878); *Penaeus hardwickii* Miers, 1878

**English names:** Spear Shrimp.

**Local names:** Gussha, Godda Chingri

**Description:** The body is smooth and lacks any external ornamentation. The rostrum is armed with 9 to 11 dorsal teeth. In females, it is exceptionally long, sigmoidal in shape, with the distal one-third to one-half unarmed, extending well beyond the antennular peduncle. In adult males, the rostrum is completely armed, slightly curved downward, and only reaches the middle of the second antennular segment. A longitudinal suture extends over approximately three-quarters or more of the carapace length. The first and second legs possess an epipod and a basal spine, while the basis of the third leg is unarmed. The anterolateral angles of the posterior plate are prominently extended forward. The telson has only 3 to 5 pairs of small, movable lateral spinules.



**Figure 36.** *Mierspenaeopsis hardwickii*

**Color:** The body varies from greyish to greenish-grey, sometimes appearing pink, and is densely speckled with dark spots. The eyes are dark brown, while the rostrum is black-brown. The basal one-third of the antennal flagella features narrow brown bands. The legs are generally whitish to pinkish. The uropods are dark reddish-brown with yellowish margins.

**Habits:** Nocturnal and omnivorous, feeding primarily on small zooplankton, phytoplankton, and organic debris.

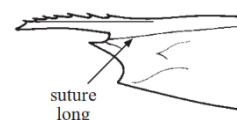
**Habitat:** Found from the coastline to depths of approximately 90 meters, but primarily inhabiting shallower waters of less than 20 meters on muddy, sandy-mud, or sandy bottoms. Juveniles are commonly found in estuaries and backwaters.

**Distribution:** Widely distributed in the Indo-West Pacific, ranging from Pakistan to Taiwan and Indonesia. Available throughout the coastal region of Bangladesh.

**Economic Importance:** Primarily marketed fresh for local consumption.

**Fishing Gear Used:** Caught using trawls and, occasionally, boat seines and stake nets.

**Key characteristics:** This species has a longer longitudinal suture compared to others, extending to about three-quarters or more of the carapace length. Unlike some related species, its body does not display distinct cross-banding.





***Mierspenaeopsis sculptilis* (Heller, 1862)****Family-Penaeidae**

**Synonyms:** *Parapenaeopsis sculptilis* (Heller, 1862); *Penaeus sculptilis* Heller, 1862

**English names:** Rainbow Shrimp.

**Local names:** Tiga Chingri, Baga Tara Ichha, Ruda Ichha.

**Description:** The rostrum with 6 to 9 dorsal teeth and a weak or sometime absent epigastric tooth. Males have teeth that reach up to the second segment of the antennular peduncle, while females have an edentate tip that extends beyond the peduncle. The hepatic carina is only distinct for the lower 1/2 sulcus, which begins below the hepatic spine and runs towards the sharp pterygostomial angle. The first and second pereopods have epipod and basal spines, while the ischial spines are absent. The antennal spine is large, with the carina reaching half distance between the spine and the hepatic spine. Petasma has proximolateral lobes that are very broad and curved dorsally; distolateral projections that are short and oriented anterolaterally; and long, rabbit-ear-shaped distomedian projections that are deeply concave ventrally. distolateral projections short, directed anterolaterally; proximolateral lobes very large, and curved dorsally. Thelycum with anterior plate distally rounded and broadly articulating with posterior plate, the latter with a median tubercle bearing a tuft of long setae (hairs).



**Figure 37.** *Mierspenaeopsis sculptilis*

**Coloration:** The body is pale with broad, dark brown to almost black transverse bands. The carapace is dark brown on the dorsal side, except for a distinct white band around its middle, while the lateral sides are significantly lighter, appearing yellow or orangish. The abdominal bands extend to the ventrolateral margin. The pereopods range from yellowish to pink, the pleopods vary from pink to dark red, and the uropods are yellow to pink with a prominent dark brown transverse band in the middle.

**Habits:** A nocturnal and omnivorous species, it feeds on small zooplankton, phytoplankton, and organic debris.

**Habitat:** Typically found in shallow waters, from the coastline down to depths of approximately 90 meters, though it is most commonly found at depths of less than 40 meters, inhabiting sandy, muddy, or mixed substrates.

**Distribution:** Widely distributed in the Indo-West Pacific, ranging from Pakistan to the Philippines and northern Australia. Collected from Teknaf, Cox's Bazar, Maheshkhali, Kuakata.

**Economic Importance:** Primarily sold fresh or frozen for local consumption.

**Fishing Gear Used:** Stake nets, seines, and trawls.

**Key characteristics:** Longitudinal suture long. Body strikingly cross-banded



***Acetes indicus* H. Milne Edwards, 1830****Family- Sergestidae**

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**Synonyms:** *Acetes indicus* Kemp, 1917; *Acetes indicus* George, 1969**English names:** Jawla Paste Shrimp**Local names:** Lailla Icha, Gura Icha, Banguri Chingri.

**Description:** Adult males possess a single large, curved clasping spine with a serrated inner margin on the lower antennular flagellum. In females, the basal segment of the antennular peduncle is approximately the same length as the combined length of the two distal segments. In males, the second segment is more slender compared to females, while the third segment is elongated and significantly longer than the first. The third maxilliped in males extends slightly beyond the tip of the third pereopod, whereas in females, it extends well past the end of the antennular peduncle. A large, forward-curving tooth is present between the bases of the first pleopods in both sexes. Each half of the petasma features a crescent-shaped outer lobe with a strongly thickened antero-external border. The telson has a sharply pointed apex that extends well beyond the middle of the inner uropod. The outer uropods have a distinct tooth on the external border, separating the ciliated and non-ciliated sections.

**Figure 38.** *Acetes indicus***Color:** Body semitranslucent, endopod of uropod with a pair of red spots**Habits:** Omnivorous, consuming planktonic diatoms (*Rhizosolenia*, *Nitzschia*, *Thalassiothrix*, etc.). copepods, sagitta, foraminiferans, shell fish fragments, detritus and amorphous materials. It feeds at night when the species performs vertical migration toward the surface.**Habitat:** Epipelagic, usually found in the estuarine or shallow coastal waters of tropical and subtropical regions, with denser patches of animals in the muddy or sandy bottom waters than surface waters. Found in marine and brackish waters, though it primarily inhabits brackish environments and is commonly fished in intertidal zones and estuaries with mangroves.**Distribution:** Widespread in the Indo-West Pacific, from India to Vietnam and Indonesia. Collected from Sundarban region of Bangladesh.**Economic Importance:** Sold in various forms, including dried, boiled, salted, or fermented with salt. It is mainly consumed locally as a seasoning, such as shrimp paste or shrimp sauce, and is occasionally exported.**Fishing Gear Used:** Caught using push nets, bag nets, and seines

***Solenocera crassicornis* (H. Milne Edwards, 1837)****Family- Solenoceridae**

**Synonyms:** *Solenocera sinensis* Yu, 1937; *Solenocera submuda* Kubo, 1949; *Solenocera kuboi* Hall, 1956; *Penaeus crassicornis* H. Milne Edwards, 1837

**English names:** Coastal Mud Shrimp

**Local names:** Ghora Chingri.

**Description:** The body is smooth and hairless, except at the base of the rostrum. The rostrum extends to the distal margin of the eye or slightly beyond and is armed with 8 to 10 (sometimes 12) dorsal teeth. Its ventral margin is either slightly convex or straight. The postrostral crest is low, rounded, and extends to the posterior margin of the carapace. The cervical groove is deep, reaching or nearly reaching the dorsal midline. A postorbital spine is present, while suprahepatic and branchiostegal spines are absent. The pterygostomian angle is unarmed. The hepatic crest curves ventrally in the anterior region, forming a broad, rounded loop slightly behind the carapace's frontal margin. The branchiocardiac crest is slightly sinuous and slopes anteroventrally. The telson is unarmed and not trifurcate. The fifth pereopod lacks a coxal spine.



**Figure 39.** *Solenocera crassicornis*

**Color:** The body, pereopods, and pleopods range from reddish-orange to red. The eyes are dark brown, with the posterior margin of each abdominal segment appearing darker. The antennae, pleopods, and uropods are uniformly red.

**Habits:** This species is nocturnal and burrowing. It primarily feeds on small zooplankton, phytoplankton, and organic debris. The tube-like antennular flagella protrude for respiration.

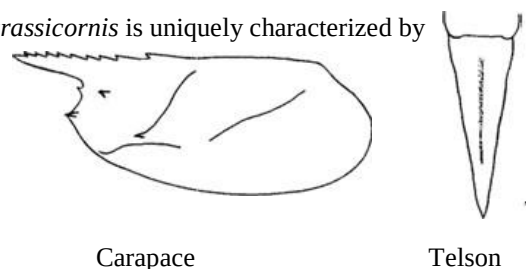
**Habitat:** Found on muddy seabeds near the shore.

**Distribution:** Widespread in the Indo-Pacific, ranging from the Persian Gulf to Japan and Indonesia. Collected from Cox's Bazar, Teknaf, Maheshkhali, Chattogram.

**Economic Importance:** Sold both fresh and frozen.

**Fishing Gear Used:** Caught using trawls, stake nets, and seines.

**Key characteristics:** Among *Solenocera* species, *S. crassicornis* is uniquely characterized by its unarmed telson.



Carapace

Telson

***Solenocera choprai* Nataraj, 1945****Family- Solenoceridae****Synonyms:** *Solenocera alticarinata* Kubo, 1949**English names:** Ridgeback Shrimp**Local names:** Not known

**Description:** The rostrum is short, extending to approximately two-thirds of the eye length. The upper border has 8 to 10 teeth, including four on the carapace, while the lower border is moderately convex. The postrostral crest is distinctly elevated and plate-like, with a slight interruption caused by a small notch above the cervical groove. The height of the posterior section gradually decreases towards the back. The carapace features orbital, postorbital, antennal, and hepatic spines but lacks pterygostomial spines. The antennular flagella are moderately long and tubular. The telson bears a pair of lateral spines.

**Figure 40.** *Solenocera choprai*

**Color:** The body, pereopods, and pleopods are red. The antennae have alternating dark red and white bands, while the uropods are primarily dark red with some white areas.

**Habits:** This species is nocturnal and burrowing. It primarily feeds on small zooplankton, phytoplankton, and organic debris. The tube-like antennular flagella protrude for respiration.

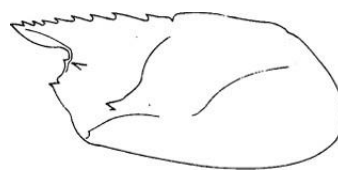
**Habitat:** It inhabits muddy seabeds near the shore, at depths ranging from 20 to 85 meters, and likely burrows into the mud during the daytime.

**Distribution:** Found throughout the Indo-West Pacific, from the eastern coast of Africa to the Philippines and Australia. Collected from Cox's Bazar, Teknaf, Maheshkhali, Chattogram.

**Economic Importance:** Primarily sold fresh for local consumption.

**Fishing Gear Used:** Otter trawls; stake nets, seine net.

**Key characteristics:** Telson armed with a pair of lateral spines



Carapace



Telson





***Alpheus microrhynchus* De Man, 1897**

**Family- Alpheidae**

**English names:** Giant mangrove snapping shrimp

**Local names:** Not known

**Description:** Carapace cylindrical; eyes fully covered by carapace. The species possesses a well-developed, asymmetrical pair of claws. The larger claw, also known as the "snapping" claw, is used for communication, defense, and hunting. The claw can generate a loud snapping sound that is believed to stun prey and deter predators.



**Figure 41.** *Alpheus microrhynchus*

**Color:** The species often exhibits a translucent body with pale coloration, sometimes with faint patterns or markings, though these can vary depending on the individual and its environment.

**Habits:** Nocturnal and opportunistic feeders, these creatures dig burrows beneath logs and roots using their enlarged claw.

**Habitat:** Marine

**Distribution:** Western Central Pacific: Singapore. In Bangladesh, the specimens collected from sundarban area.

**Economic importance:** Marketed mainly fresh for local consumption with other shrimp species or dried

**Fishing Gear Used:** Set bag net

***Alpheus malleator* Dana, 1852****Family- Alpheidae**

**Synonyms:** *Alpheus malleator* var. *edentates* (Zimmer, 1913); *Alpheus belli* (Coutiere, 1898); *Alpheus tuberculosus* (Osorio, 1892).

**English names:** Hammer-claw Snapping Shrimp

**Local names:** Not Known

**Description:** The body is stout and moderately large. The rostrum is short to moderately long, not extending to the mid-length of the first antennular peduncle article. It is dorsally flattened and widens towards the posterior, with sharp lateral margins defined by deep adrostral furrows. The tip is either subacute or blunt, often pointing downward. The post-rostral area lacks a median tubercle, and the pterygostomial angle is rounded. The cardiac notch is well-developed. The abdomen lacks distinct sternal features. The telson is broad, stout, and tapers posteriorly, slightly depressed along the mid-dorsal line. It bears two stout dorsal spiniform setae and two pairs of posterolateral spiniform setae, with the mesial setae being much longer than the lateral ones. The anal tubercles are well-developed. The major cheliped is very stout, with a very short ischium, a subtriangular, stout merus, a short, cup-shaped carpus, and a broadly ovoid chela. The minor cheliped is also stout, with a short ischium, a subtriangular, stout merus, and a short carpus.



**Figure 42.** *Alpheus malleator*

**Color:** Body color ranges from dark chocolate-brown to reddish-brown. The carapace features a whitish transverse band and various irregular patches and spots, many interconnected. The rostrum is dark brown and abdomen typically with irregular white transverse bands on each segment. The major and minor chelipeds are brown to red-brown, with paler areas and dark or pale tubercles, pleopods reddish. The tail fan is brown to red-brown, and the flagella are pale brown to green-yellowish.

**Habits:** Nocturnal and opportunistic feeders, these creatures dig burrows beneath logs and roots using their enlarged claw.

**Habitat:** Found along rocky and mixed sand-rock shores, as well as coral reef environments

**Distribution:** Western and eastern Atlantic: Gulf of Mexico, Florida, Caribbean Sea, Brazil, West Africa. In Bangladesh, the specimens collected from Kuakata.

**Economic importance:** Marketed mainly fresh for local consumption with other shrimp species.

**Fishing Gear Used:** Set bag net, sometimes through hand pick from the burrow of logs near shore

***Alpheus euphrosyne* De Man, 1897****Family- Alpheidae**

**Synonyms:** *Crangon euphrosyne* De Man, 1897; *Crangon euprosyne* De Man, 1897; *Crangon bisincisus* Urita 1921.

**English names:** Green Snapping Shrimp, Flathead Snapping Shrimp or Nymph Snapping Shrimp

**Local names:** Bhati chingri, Pinna Icha

**Description:** Carapace cylindrical; eyes fully covered by carapace; epipods present at bases of pereopods; sixth abdominal segment without posterolateral plate. First pair of pereopods highly unequal, movable finger of larger pincer with molar-shaped tooth fitting into cavity of immovable finger. Rostrum extremely small, without serrations



**Figure 43.** *Alpheus euphrosyne*

**Color:** Body flesh coloured with greyish small dots; greyish on the upper side. Telson, tail fin, second legs pale reddish

**Habits:** Nocturnal and opportunistic feeders, these creatures dig burrows beneath logs and roots using their enlarged claw, which features a specialized tooth on one finger that fits into a corresponding depression on the other.

**Habitat:** Marine species; construct burrows up to 30 cm deep in the mud, often beneath a surface rock

**Distribution:** Indo-West Pacific: South and East Africa to Japan, Indonesia, and New Caledonia. In Bangladesh, the specimens collected from sundarban area.

**Economic importance:** Marketed mainly fresh for local consumption with other shrimp species or dried.

**Fishing Gear Used:** Set bag net



## ***Macrobrachium equidens* (Dana, 1852)**

### **Family- Palaemonidae**

**Synonyms:** *Palaemon equidens* Dana, 1852; *Palaemon (Eupalaemon) nasutus* Nobili, 1903; *Palaemon sulcatus* Henderson & Matthai, 1910; *Palaemon sundaicus* Kemp, 1918; *Macrobrachium equidens* Holthuis, 1950.

**English names:** Rough River Prawn

**Local names:** Goda Ichha.

**Description:** The rostrum is long and curves upwards towards the distal end, reaching nearly or extending beyond the distal end of the antennal scale. The rostral formula is 3–4 + 8–9/4–6, with the teeth above the orbit generally more closely spaced, except at the tip. The carapace is smooth. The hepatic spine lies on a horizontal line passing through the antennal spine, and the branchiostegal suture does not extend posteriorly past the hepatic spine. The telson has a posterior apex that does not extend beyond the posterolateral spines. In adult males, the carapace is rough due to the presence of tiny spinules. The second pair of pereopods are long and strong, with the fingers covered by dense, velvety pubescence, while the rest of the limbs are not. The cutting edges of the fingers feature one or two enlarged proximal teeth, while the remainder of the edges are smooth, without any rows of granules along either side. The carpus is shorter than the propodus and distinctly longer than the merus.



**Figure 44.** *Macrobrachium equidens*

**Color:** Translucent, with a marbled or spotted pattern in shades of grey, green, or red. The second pair of pereopods, particularly the palms, are marbled with dark brownish hues.

**Habits:** It is a nocturnal and bottom feeder animal. Mainly feeds of organic matters, detritus and small invertebrates.

**Habitat:** Primarily found in mangrove areas and under crevices in river mouths, though it can occasionally be observed further upstream or in marine environments.

**Distribution:** Introduced to West Africa and Brazil, it is widely distributed throughout the Indo-West Pacific, extending from Madagascar to the Solomon Islands. Collected from Teknaf.

**Economic importance:** Marketed mainly fresh for local consumption.

**Fishing Gear Used:** Cast nets, set bag net, seine net, moi jals, trap and pushnets.

***Macrobrachium rosenbergii* (De Man, 1879)****Family- Palaemonidae**

**Synonyms:** *Macrobrachium carcinus* (Linnaeus), 1758; *Palaemon carcinus* Henderson & Matthai, 1910; *Palaemon carcinus* Kemp, 1918; *Macrobrachium rosenbergii dacqueti* Sunier, 1925

**English names:** Giant River Prawn, Freshwater Lobster.

**Local names:** Gholda Chingri, Shala Chingri, Moche Chingri, Mota Chingri, Boro Icha

**Description:** The rostrum is long and curves upwards distally, extending well beyond the antennal scale and forming a prominent basal crest above the eye. The upper edge is armed with 11 to 14 teeth, while the lower edge has 8 to 14 teeth. The hepatic spine is positioned distinctly below the antennal spine. The second pair of legs are large, robust, and of equal size, with the carpus longer than the merus. In adult males, there are only 1 or 2 large basal teeth on the cutting edges, with no rows of tubercles along either side. The movable finger is densely covered in hair except at the tip, and the carpus is shorter than the pincer. The telson tapers regularly to a sharp point, lacking a posterior margin, with the tip extending beyond the posterolateral spines.



**Figure 45.** *Macrobrachium rosenbergii*

**Color:** The body is typically dark green to greyish-blue, featuring longitudinal or irregular streaks of both darker and lighter shades. The hinges of the abdominal segments have a soft orange hue, while the eyes are dark brown. The antennal flagella range from dark blue to greyish, and the large pincer varies from bluish to deep blue.

**Habits:** It is nocturnal and omnivorous. Mainly feeds on small invertebrate, zooplanktons, phytoplanktons and debris.

**Habitat:** Inhabits mainly estuarine areas and rivers but sometimes also found at sea.

**Distribution:** Indo-Pacific region: Pakistan to Viet Nam, India, Malaysia, Singapore, Thailand, Borneo, New Guinea, the Philippines and Australia. In Bangladesh, it is found in estuary, mangrove area and rivers of southern region. Also cultured in southern region of Bangladesh (Satkhira, Khulna, Bagerhat, Gopalganj)

**Economic importance:** This freshwater lobster is highly esteemed as food and is well accepted by people of all nations. Marketed live, fresh or frozen, mainly for local consumption but sometimes also for export.

**Fishing Gear Used:** Cast nets, set bag nets, seine nets, moi jals, ESNB (set net), katta, chai, pushnets, bamboo barriers, fish corrals, traps, set nets, cast nets, hook-and-line, and artisanal gear.

***Macrobrachium lamarrei* (H. Milne Edwards, 1837)****Family- Palaemonidae**

**Synonyms:** *Palaemon lamarrei* H. Milne Edwards, 1837; *Palaemon (Eupalaemon) lamarrei* de Man, 1908; *Palaemon lamarrei* Kemp, 1915; *Palaemon lamarrei* Chopra and Tiwari, 1947;

**English names:** Kuncho River Prawn.

**Local names:** Kuncho Chingri, Gura Ichha.

**Description:** The rostrum is very long, featuring 7 to 11 dorsal teeth (including 1 or 2 post-orbital teeth) and 4 to 6 ventral teeth. The upper margin has a gap between the proximal series of 6 to 9 teeth and the distal 1 or 2 subterminal teeth, though this gap may sometimes be interrupted by 1 or 2 additional teeth. The rostrum is either equal to or slightly exceeds the length of the antennal scale and is tilted upwards distally. The basal crest is only moderately elevated. The palm of the second leg is not swollen, and the fingers are shorter than the palm. The second chelipeds are slender and either equal to or about 1/3 longer than the body length, with the chela shorter than the carpus. The second pleopod of the male has a slender, non-hairy appendix masculina that reaches the tip of the endopod.



**Figure 46.** *Macrobrachium lamarrei*

**Color:** Body flesh- coloured with brown pigments sparsely distributed on the rostrum, carapace and body. Some specimens with greyish band on body, the band also present on the telson and tail fin; inner flagellae of antennule reddish-brown in colour.

**Habits:** It is a nocturnal and bottom feeder. Mainly feeds on organic matter, detritus and small invertebrates.

**Habitat:** Fresh and brackish water.

**Distribution:** India, Myanmar. Collected from Kaliganj, Jhenaidah; Jibannagar, Chuadanga.

**Economic importance:** Marketed mainly fresh or dried for local consumption.

**Fishing Gear Used:** Cast nets, set bag net, seine net, moi jals, trap and pushnets.

**Key characteristics:** The species shows significant variation in the shape and length of the rostrum. Due to this wide range of differences, further research is needed to clarify the issue.



## ***Macrobrachium rude* (Heller, 1862)**

### **Family- Palaemonidae**

**Synonyms:** *Palaemon rudis* Heller, 1862; *Palaemon mossambicus* Hilgendorf, 1879; *Palaemon (Eupalaemon) rudis* CoutiÃre, 1900; *Palaemon (Eupalaemon) Alcocki Nobili*, 1903

**English names:** Hairy river prwan

**Local names:** Ghoda Chingri, Paitta Icha

**Description:** Rostrum straight and rather long, reaching nearly to the apex of antennal scale, tapering distally (Reddy, 1995); upper edge of rostrum with 10 to 17 (usually 9 to 12) and lower edge (ventral margin) 3 to 8 (usually 4 to 6) teeth. The hepatic spine is positioned lower than the antennal spine. The posterior edge of the telson is distinct and features two pairs of spines. In adult males, the carapace, particularly the front section, is covered with very short, stiff hairs but lacks spinules. The second pair of pereopods is notably long and robust, with all segments densely covered in short pubescence. The cutting edges of the fingers have one or two large proximal teeth, while the remaining edges are smooth but lined with a row of granules on each side. The carpus is shorter than the propodus but significantly longer than the merus, featuring 10-12 teeth on the upper edge and 3-6 on the lower edge.



**Figure 47.** *Macrobrachium rude*

**Color:** The body is translucent, with the largest legs of the male displaying a uniform dark reddish-brown color. The tips of the pereopods and the distal half of the uropods are a deep brownish shade.

**Habits:** Nocturnal and omnivorous. Feeds on small Zooplanktons, phytoplanktons and organic debris.

**Habitat:** Inhabits rivers and estuarine areas. Also found in hillstreams.

**Distribution:** India, Somalia, Natal (South Africa), Madagascar, Sri Lanka. Occurring throughout the coasts, estuaries, river, gher, lakes, beels and paddy fields of Bangladesh.

**Economic importance:** Marketed mainly fresh or frozen for local consumption.

**Fishing Gear Used:** Cast nets, set bag net, seine net, moi jals, trap and pushnets.





### ***Macrobrachium assamense* (Tiwari, 1958)**

#### **Family- Palaemonidae**

**Synonyms:** *Palaemon assamensis* Tiwari, 1958; *Palaemon assamensis* Tiwari, 1958

**English names:** Not known

**Local names:** Not known

**Description:** The rostrum, longer than the antennular peduncle, extends to the apex of the antennal scale. It measures 0.5 to 0.8 times the length of the carapace, with a broadly triangular profile, a horizontal upper edge, and an acute apex. The rostral formula ranges from 7-11/2-5, with usually three teeth on the carapace behind the orbital border. The carapace shows small, scattered prickles.



**Figure 48.** *Macrobrachium assamense*

Third maxillipeds, not extending beyond the middle of the antennal scale. The first pair of pereopods, with a chela slightly longer than half the carpus. The second pair of pereopods, subequal, subcylindrical, thinner than in *P. hendersoni*. In adult males, pereopods measure the length of the body, but in both sexes, never shorter than half the body length at any stage. The merus, always slightly longer than the carpus. The carpus, gradually thickened distally, measures more than three times but never exceeds five times its distal thickness. The palm, slightly wider than the carpus, compressed.

**Habitat:** It generally occurs in streams in hilly localities and does not seem to be present in plains.

**Distribution:** It has a very wide range of distribution in the Eastern Himalayan region, the Chota Nagpur Tract and the Satpuras in India and in Burma. In Bangladesh, caught from the hill stream of Sylhet region

**Economic importance:** consumed locally

**Key characteristics:** This species belongs to the hendersoni group due to longitudinal grooves on the fingers of the second pair of pereopods.



### ***Macrobrachium birmanicum* (Schenkel, 1902)**

#### **Family- Palaemonidae**

**Synonyms:** *Palaemon spinipes* var. *birmanicus* Schenkel, 1902; *Palaemon choprai birmanicus* Tiwari, 1955.

**English names:** Birma River Prawn

**Local names:** Shul Icha, Najari Icha, Thangua Chingri.

**Description:** The rostrum is moderately long, extending as far as or slightly beyond the antennal scale. It bears 12 to 13 dorsal teeth and 5 to 7 ventral teeth, with 2 post-orbital teeth. The basal crest is moderately elevated, and the distal end is upturned. The merus and carpus are shorter than the palm, with the carpus being shorter than the chela. The fingers are approximately 0.6 times the length of the palm. The palm is more slender than the distal carpus. Only the movable finger is entirely pubescent



**Figure 49.** *Macrobrachium birmanicum*

**Color:** Body greenish yellow; antennae greyish; thoracic legs light bluish; lower side of the 2nd chelipeds peacock blue; its upper side greyish; the remaining thoracic legs flesh coloured; the swimmerets bluish

**Habits:** Nocturnal and bottom feeder, mainly feeds on organic matter, detritus and small invertebrates.

**Habitat:** Inhabits in fresh and brackish water bodies like river.

**Distribution:** Indo-Pacific: Eastern India, Bangladesh, the lower Ganges basin, the lower Irawaddy basin and Myanmar (Holthuis, 1980).

**Economic importance:** Marketed mainly fresh or dried for local consumption.

**Fishing Gear Used:** Cast nets. set bag net, seine net, moi jals and pushnets.



## ***Macrobrachium dayanum* (Henderson, 1893)**

### **Family- Palaemonidae**

**Synonyms:** *Palaemon dayanus* Henderson, 1893; *Palaemon dayanus* Chopra and Tiwari, 1947; *Macrobrachium dayanum* Jalihal; Shenoy & Sankolli, 1988.

**English names:** Kaira River Prawn.

**Local names:** Ghoda Chingri, Kaira Icha, Daiya Chingri.

**Description:** The rostrum extends to the tip of the antennal scale, with its distal end distinctly upturned. The upper and lower edges of the rostrum are equipped with 7–11 and 4–7 teeth, respectively. The chela is tuberculate and shorter than the palm, while the carpus is subcylindrical. The second pereopod of the female is shorter than that of the male. The fingers are about two-thirds the length of the palm and are densely pubescent. The fixed finger has one tooth, while the movable finger has two conical teeth. The cutting edge may be either smooth or covered with short hairs.



**Figure 50.** *Macrobrachium dayanum*

**Color:** General colour flesh with black pigments extensively distributed on the body; in some cases, body ash- coloured; chelipeds, antennae and their flagellae with dark brown cross bands; carpus and chela of second chelipeds usually darker than other parts of the legs, swimmers of light ash colour.

**Habits:** It is nocturnal and bottom feeder. Mainly feeds on organic matter, detritus and small animals.

**Habitat:** Inhabits freshwater ponds and flowing waters, such as rivers and estuarine areas.

**Distribution:** Indo-Pacific: Pakistan; India, Bangladesh (collected from Nijhum Dwip) and Myanmar.

**Economic importance:** Marketed mainly fresh or dried for local consumption.

**Fishing Gear Used:** Cast nets, set bag net, seine net, trap and pushnets.



## ***Macrobrachium grandimanus* (Randall, 1840)**

### **Family- Palaemonidae**

**Synonyms:** *Palemon grandimanus* Randall, 1840; *Palaemon acutirostris* Dana, 1852

**English names:** Hawaiian river shrimp

**Local names:** Not known

**Description:** Rostrum straight, reaching end of third segment of antennular peduncle; dorsal margin with 13 or 14 teeth, including 3 or 4 on carapace posterior to orbital margin; ventral margin with 2–4 teeth ( $n = 7$ ). The first pereopod is slender, with the finger being 0.7–0.9 times shorter than the palm. The palm is 0.3–0.4 times shorter than the carpus, and the carpus is 1.1–1.2 times longer than the merus. The merus is 1.6–2.1 times longer than the ischium. The second pereopods differ in shape and size. The major second pereopod (left) is robust and longer than the total body length. The tips of the finger are curved inward, and the finger is slightly shorter than the palm. The surface of the palm has dense setae on the last two-thirds. The palm is 1.3 times longer than the carpus, which is 1.3 times longer than the merus. The merus is 2.4 times longer than the ischium. The minor second pereopod (right) is slender, with the finger being 2.1 times longer than the palm. The palm is 0.6 times shorter than the carpus, which is 1.2 times longer than the merus. The merus is 1.7 times longer than the ischium. Third pereopod is slender, with the dactylus being 0.3 times shorter than the propodus. The propodus is 1.5–1.8 times longer than the carpus, and the carpus is 0.5–0.6 times shorter than the merus. The merus is 2.1–2.3 times longer than the ischium.



**Figure 51.** *Macrobrachium grandimanus*

**Color:** Body appears semi-transparent, with some darker pigmentation concentrated along its back and tail. Tip of finger black

**Habits:** Nocturnal in habit

**Habitat:** Brackish and freshwater including stream

**Distribution:** Oceania, Japan. Collected from Jaflong, Sylhet.

**Economic importance:** Locally consumed and marketed with other shrimp.

***Macrobrachium scabriculum* (Heller, 1862)****Family- Palaemonidae**

**Synonyms:** *Macrobrachium abrahami* Pillai, Unnikrishnan & Suresh Kumar, 2014; *Macrobrachium prabhakarani* Pillai & Unnikrishnan, 2012; *Palaemon dubius* Henderson & Matthai, 1910; *Palaemon scabriculum* Heller, 1862

**English names:** Goda river prawn

**Local names:** Not known

**Description:** The rostrum almost reaches the tip pedicel antenular; rostrum formula 4–5 (5)+10/2, dorsal tooth behind the eye (posterior) has a distance between one with the others being at the front eyes (anterior) are closer together. Measurement carapace length using the term CL (Carapace Length) is used for states the measured carapace length from the postorbital border to the posterior carapace. Tepi behind the antennular stalk straight oblique almost rounded. Scaphocerite with edge with straight outer edge, with length 2.5 times the width. Length of the legs the first path beyond the tip of the scaphocerite with the tip of the claw having a little bit fine hairs; carpus length 1.3 times from the merus. The second walking leg is different measurement between left and right; foot of the road the left side has a larger size and longer than the right side; proximal part of the claw on the chela covered with dense, fine hairs; dactylus can stick perfectly to propodus without forming a gap; claw with 15-18 teeth on the dactylus, more many of the teeth on the propodus; long palmerus 2.6 times the width, wider compared to carpus and merus, covered by thick fine hairs from the middle part to the anterior, the length of the palmerus is 1.3 times carpus length; merus almost the same long with carpus. Third walking leg has a length that passes through scaphocerite; propodus with 9 spines on the ventral side with a length 4 times the length of the dactylus. Movable spines on uropods shorter than the distolar.



**Figure 52.** *Macrobrachium scabriculum*

**Color:** Like many species of *Macrobrachium*, *M. scabriculum* tends to have a translucent or lightly colored body, often with marbled patterns or spots in shades of gray, green, or reddish hues.

**Habits:** Nocturnal in habit

**Habitat:** Commonly found in a river with a fast flowing water sandy small rock group, tall vegetation

**Distribution:** Eastern Africa and Madagascar; Sri Lanka, India South, Peninsular Malaysia, Island Tioman, Singapore, Indonesia and coastal regions Indian Ocean. Collected from Jafalong, Sylhet.

**Economic importance:** Locally consumed and marketed with other shrimp.



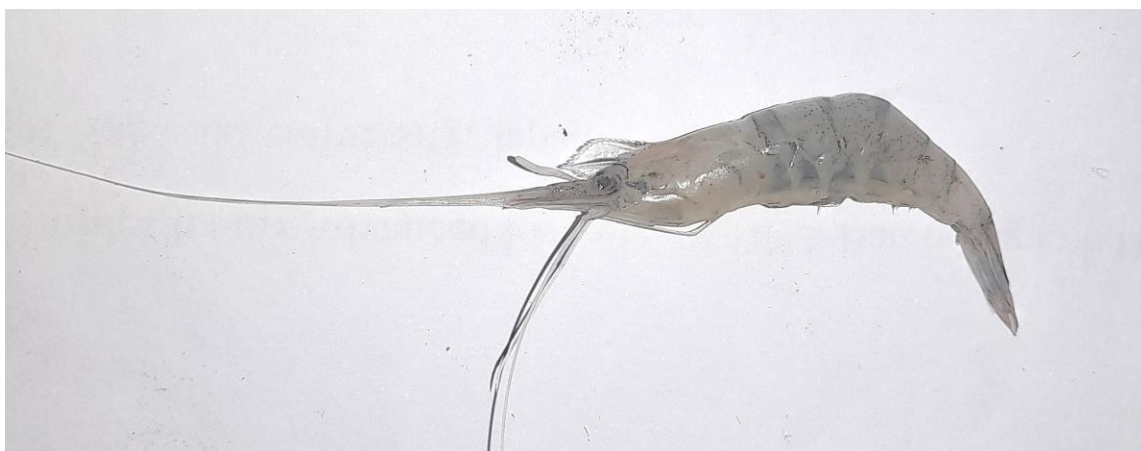
***Arachnochium mirabile* (Kemp, 1917)****Family- Palaemonidae**

**Synonyms:** *Macrobrachium mirabile* (Kemp, 1917) ; *Palaemon mirabilis* Kemp, 1917; *Macrobrachium mirabile* Holthuis, 1950; *Macrobrachium mirabile* George, 1969.

**English names:** Short Leg River Prawn

**Local names:** Lotia Icha

**Description:** The rostrum does not reach the distal end of the antennal scale and features a prominent dorsal crest. It is equipped with 12 to 16 dorsal teeth and 1 to 2 ventral teeth, with the dorsal teeth spaced nearly equally. The branchiostegal suture does not extend posteriorly past the hepatic spine, and the telson has a posterior apex that does not surpass the posterolateral spines. The first pereopod has a chela that is more than half the length of the carpus. The second pereopods are subequal in length and similar in form, with the palm being subcylindrical. The fingers are not covered by dense pubescence, are not dentate on the opposable margins, and do not gape. The fingers are approximately  $\frac{5}{3}$  times the length of the palm, which itself lacks dense pubescence. The chela is about  $\frac{7}{4}$  times the length of the carpus, and the palm is as long as the carpus. The carpus is more than  $\frac{3}{4}$  the length of the merus and is not longitudinally grooved. The third pereopod extends beyond the antennal scale by the length of the dactyl, and the propodus is not densely spinose or scaly. The fifth legs are noticeably longer than the fourth. The second legs of adult males are less than  $\frac{3}{4}$  smooth.



**Figure 53.** *Arachnochium mirabile*

**Color:** Body flesh coloured with greyish dots on the joints; end of the telson greyish; eggs yellowish.

**Habits:** It is a nocturnal and bottom feeder animal. Mainly feeds on organic matters, detritus and small invertebrates.

**Habitat:** Fresh and brackish water bodies.

**Distribution:** Indo-West Pacific, and recorded from eastern India, Bangladesh, Myanmar, Thailand, Malaysia, and Borneo.

**Economic importance:** Marketed mainly fresh or dried for local consumption.

**Fishing Gear Used:** Cast nets, set bag net, seine net, moi jals and pushnets.



## ***Macrobrachium nipponense* (De Haan, 1849)**

### **Family- Palaemonidae**

**Synonyms:** *Macrobrachium meishanense* Tan & Lu, 1992; *Macrobrachium obtusifrons* Dai, 1984; *Palaemon asper* Stimpson, 1860; *Palaemon nipponense* De Haan, 1849; *Palaemon sinensis* Heller, 1862

**English names:** Oriental river prawn

**Local names:** Not known

**Description:** Rostrum horizontal, can be slightly inclined upwards, almost straight, falling short of to slightly overreaching end of scaphocerite; rostral formula 2–4 + 8–11/3 4, posteriormost dorsal teeth well separated from the second. The carapace is smooth. The fourth thoracic sternite is equipped with a conical process. The pereopods are subequal and similar, with large individuals covered in microspinules. The male second pereopod has dense setae along the cutting edges in larger individuals. The dactylus is either unarmed or has 2 teeth along the proximal one-seventh to one-fourth, while the pollex is either unarmed or features a tooth at the proximal one-ninth to one-fifth, along with a low hump containing 2–4 denticles more proximally, which are often worn down.



**Figure 54.** *Macrobrachium nipponense*

**Color:** Body translucent to light greenish or brownish, often with a bluish or greenish tint on the appendages. The body may exhibit faint stripes or spots, and the chelae (claws) can have a more vivid coloration, such as bluish-green or orange, depending on age and environmental factors.

**Habits:** Short breeding cycle, low susceptibility to diseases, adaptability to various environments

**Habitat:** Found in streams, ponds, reservoirs, estuaries, and salt marshes,

**Distribution:** Native to China, Japan, Korea, Myanmar, Taiwan, Vietnam. Introduced to other places viz. Laos, Malaysia, Singapore, the Philippines, Bangladesh, Iran, Iraq, Kazakhstan, Uzbekistan, Russia, Belarus, Moldova, Ukraine. Collected from Kuakata

**Economic importance:** Marketed mainly fresh with other species but in very low quantities and rare occurrences.



***Macrobrachium neglectum* (De Man, 1905)****Family- Palaemonidae**

**Synonyms:** *Palaemon (Eupalaemon) neglectus* De Man, 1905

**English names:** Not Known

**Local names:** Not Known

**Description:** Rostrum short, reaching or slightly behind distal end of scaphocerite; moderately slender, maximum depth about equal to maximum dorsoventral diameter of cornea; dorsal carina straight above orbit, bent downwards in front of orbit with tip directed anteriorly, teeth subequally distributed, armed with 9–12 teeth, 2–4 teeth completely postorbital, ventral carina with 3 or 4 teeth. Carapace with tiny spinules. Epistome fully bilobed, with lobes having blunt, rounded margins. The second pereiopods have the distal quarter or half of the minor cheliped carpus extending beyond the end of the scaphocerite. The major cheliped has a chela covered with spines and a few scattered short, stiff setae, but the cutting edges remain exposed. The outer margin is slightly convex, while the inner margin is concave. The palm is sub-cylindrical, wider than the maximum width of the merus, slightly compressed, and gaping. The distal half of the palm features a row of sharp spines on each side of the cutting edge of each finger, with uncinat tips. The dactylus has 2 large teeth and 3 smaller teeth near the articulation of the fingers, with the teeth unequally distributed along the cutting edges. The minor cheliped closely resembles the major cheliped, with the chela also covered in spines and scattered short, stiff setae. The third pereiopods have the tip of the dactylus reaching the distal end of the scaphocerite. The dactylus is stout, curved, and has a poorly developed ventral carina. The pereiopods are covered with spinules and a few medium-sized stiff setae. The inter-uropodal sclerite is well-developed and elevated as a longitudinal preanal carina, which is medium-sized and slightly larger than the posterolateral teeth of the sixth abdominal somite. The telson is moderate, stout, and glabrous. The uropods have an acute distolateral tooth, and the mobile mesial spine is larger than the distolateral tooth.



**Figure 55.** *Macrobrachium neglectum*

**Color:** The coloration is typically transparent to pale brownish, often with subtle variations depending on the environment and diet

**Habits:** The waters they inhabit are not highly acidic, with moderate oxygen levels and cool temperatures.

**Habitat:** Favors large streams and small rivers with fast-moving waters, typically hiding in dense vegetation along the riverbanks or in submerged wood and logs.

**Distribution:** Myanmar, Thailand, Mergui Archipelago, Peninsular Malaysia, Singapore. Collected from Sirajganj.

**Economic importance:** Marketed with other shrimp

***Macrobrachium lantau* Chow, Chan & Tsang, 2022****Family- Palaemonidae**

**Synonyms:** *Macrobrachium equidens* Holthuis, 1950; *Palaemon sundaicus* Kubo, 1941

**English names:** Not Known

**Local names:** Not Known

**Description:** Rostrum straight to sinuous, curving upwards distally, with a rostral formula of 2–3 + 7–8/5 6; teeth above the orbit more closely spaced except at the tip. Carapace smooth. Fourth thoracic sternite with a subacute process. Ocular cornea well-developed. Inferior orbital margin moderately produced and angular, post-antennular carapace margin broadly rounded or straight. Antennal spine sharp, slender, continuing posteriorly as a ridge, located below the inferior orbital angle; hepatic spine smaller, positioned at the same level or slightly below the antennal spine. Branchiostegal suture extends from the hepatic spine to the carapace margin. Abdomen smooth, with the first to third pleurites broadly rounded, fourth and fifth pleurites slightly produced posteriorly, sub-rectangular. Telson relatively slender. Uropodal diaeresis with an acute, movable spine, longer than or equal to the outer angle.



**Figure 56.** *Macrobrachium lantau*

**Habitat:** Occasionally found co-existing with *M. equidens* and seemingly favours the sections of the river mouth with mangroves, plentiful leaf litter and silty substrate.

**Distribution:** Hongkong, Bangladesh (first report collected from Kuakata). Possibly also occurs in Japan, Taiwan, Singapore and the Philippines

**Economic importance:** Marketed with other shrimp



## ***Macrobrachium lar* (Fabricius, 1798)**

### **Family- Palaemonidae**

**Synonyms:** *Cancer teatae* Curtiss, 1938; *Palaemon lar* Fabricius, 1798; *Palaemon longimanus* Fabricius, 1798

**English names:** Monkey River Prawn, Hill Stream Prawn

**Local names:** Chara Chingri.

**Description:** The rostrum is short and nearly straight, with a prominent keel along its side, extending slightly beyond the antennular peduncle. The upper (dorsal) margin of the rostrum has 6 to 8 teeth, while the lower (ventral) margin features 3 to 4 teeth. The hepatic spine is positioned lower than the antennal spine. The posterior margin of the telson is clearly defined. In adult males, the second pair of pereopods is very long and robust, covered with numerous small tubercles. The carpus is shorter than the propodus and much longer than the merus.



**Figure 57.** *Macrobrachium lar*

**Color:** The body is translucent, with the carapace and abdomen exhibiting a reddish-brown color on a greyish background. The largest legs of the male are uniformly dark reddish-brown, while the tips of the pereopods and the distal half of the uropods are dark brownish.

**Habits:** This species is nocturnal and omnivorous, feeding on small zooplankton, plankton, and organic debris.

**Habitat:** Found in freshwater environments, primarily in the upper and middle reaches of rivers. It can tolerate short periods of desiccation and is occasionally seen crawling on land during heavy rainfall.

**Distribution:** Widespread across the Indo-West Pacific, from East Africa to the Marquesas Islands and extending to southern Japan. Collected from the hill streams of Sylhet.

**Economic importance:** This species is considered a good species but is not found in large quantities and is primarily sold locally, either live or fresh. It is not as consistently available in fish markets as *Macrobrachium rosenbergii*.

**Fishing Gear Used:** Usually caught by pushnet or hand pick at night from the hill stream



***Macrobrachium malcolmsonii* (H. Milne Edwards, 1844)**

**Family- Palaemonidae**

**Synonyms:** *Palaemon malcolmsonii* H. Milne Edwards, 1844

**English names:** Monsoon River Prawn.

**Local names:** Chatka Chinghri, Thangua Icha, Thenga Icha.

**Description:** The rostrum is of moderate length, extending just beyond the tip of the antennular peduncle but not reaching the antennal scale. The basal crest is moderately elevated, and the distal end is slightly upturned. The rostrum formula is 10-12/5-7, with three post-orbital teeth. The merus is shorter than the palm, while the carpus is longer than the palm but shorter than the chela. The fingers are approximately 0.6 times the length of the palm. The palm is cylindrical and has about the same thickness as the distal carpus. Only the movable finger is fully pubescent.



**Figure 58.** *Macrobrachium malcolmsonii*

**Color:** The body and the first two pairs of pereopods (chelipeds) are dark grey, with a paler ventral side. The antennae and inner flagella of the antennules are grey, while the outer flagella are brownish.

**Habits:** This species is nocturnal and feeds on the bottom, primarily consuming organic matter, detritus, and small organisms.

**Habitat:** It inhabits flowing waters like rivers and estuarine areas, requiring brackish water for spawning and nursing up to the postlarval stage.

**Distribution:** Found in Pakistan, along the west coast of India, and in Sri Lanka. It is also present along the east coast of India and in most rivers of Bangladesh.

**Economic Importance:** It is mainly marketed fresh or frozen for local consumption and exported frozen. The fishery is limited and typically occurs during the monsoon months.

**Fishing Gear Used:** Cast nets, set bag nets, seine nets, moi jals, traps, and pushnets.

**Key characteristics:** *M. malcolmsonii* and *M. birmanicum* are similar in appearance but can be easily distinguished by the nature and arrangement of teeth on the elevated basal crest of the rostrum, the number of post-orbital teeth, and the relationship between the carpus and palm of the second pereopods. *M. birmanicum* has a comparatively longer rostrum and more teeth (ranging from 10-11) on the elevated rostrum, with only two being clearly post-orbital. In contrast, *M. malcolmsonii* has fewer teeth (ranging from 8-10), with three consistently being post-orbital.



## ***Macrobrachium kistnense* (Tiwari, 1952)**

### **Family- Palaemonidae**

**Synonyms:** *Palaemon kistnensis* Tiwari, 1952

**English names:** Not Known

**Local names:** Not Known

**Description:** rostral formula ; rostrum straight without any distal gap on the upper margin, slightly longer or equal to 3rd segment of peduncle but shorter than antennal scale; carapace smooth, antennal spine and hepatic spine present, post antenular carapace margin evenly rounded; 1st chelipeds slender, equal and extending the tip of the antennal scale by chela, fingers sub equal to palm; 2nd chelipeds equal, slender, cutting edges of fingers without tubercles, palm is longer than fingers, Carpus longer than chela and merus, palm shorter than half of carpus, fingers smooth, non pubescent with weak teeth near the base; posterior margin of telson with 'T' shaped pointed median end, 2 pairs of setae between inner pair of spines; mobile mesial spine of exopod in uropod absent.



**Figure 59.** *Macrobrachium kistnense*

**Color:** Translucent or slightly reddish colored body. First half of antennae dark reddish brown in colour.

**Habits:** It is nocturnal and omnivorous. Mainly feeds on organic matter, planktons, detritus and small invertebrates.

**Habitat:** Inhabits in freshwater, ponds, rivers, beels and stream. Collected from Boidder bazar. Narayanganj.

**Distribution:** India: Andha Pradesh, M. P., Maharashtra, U. P., Rajasthan; Sri Lanka

**Economic importance:** Normally locally consumed as fresh.

***Macrobrachium dolichodactylus* (Hilgendorf, 1879)****Family- Palaemonidae**

LC

**Synonyms:** *Palaemon dolichodactylus* Hilgendorf, 1879 ·

**English names:** River Prawn.

**Local names:** Goda Chingri.

**Description:** Rostrum with 12 to 16 dorsal teeth and 2 ventral teeth. Rostrum reached antennular peduncle or extend little. The second chelipeds of male much stronger than the female, and unequal in length.



**Figure 60.** *Macrobrachium dolichodactylus*

**Color:** flesh-coloured; a median pale band runs from the last abdominal segment to the end of the rostrum along the mid dorsal line; on the first few segments of abdomen the band divided by an incomplete median greyish streak; larger chelipeds greyish in colour; dorsolateral part of the animal with greyish markings; in some cases a few greyish cross bands on the telson, traversing the longitudinal pale band; eggs yellowish in color.

**Habits:** It is a nocturnal and bottom feeder. Mainly feeds on small invertebrates, organic matters and detritus.

**Habitat:** Fresh and brackish water bodies, paddyfield.

**Distribution:** Indo-Pacific: Eastern India, Bangladesh and Myanmar. Collected from Rajbari and Madaripur.

**Economic importance:** Marketed mainly fresh or dried for local consumption.

**Fishing Gear Used:** Cast nets, set bag net, seine net, trap and pushnets.





## ***Macrobrachium villosimanus* (Tiwari, 1949)**

### **Family- Palaemonidae**

**Synonyms:** *Palaemon villosimanus* Tiwari, 1949

**English names:** Dimua River Prawn.

**Local names:** Dimua Icha, Dimoala Icha.

**Description:** The rostrum features a prominent elevated basal crest and is typically very long, often with a distinct bare section on the distal half of the upper margin. It usually carries 12 to 13 teeth along the upper edge and 8 to 9 teeth along the lower edge. The tip of the telson extends beyond the length of the longer posterior spines. In adult males, the carpus of the second pereiopod is approximately equal to, slightly longer, or slightly shorter than the chela, with the fingers of this leg measuring just under half the length of the palm.



**Figure 61.** *Macrobrachium villosimanus*

**Color:** body flesh coloured with or without dark brown dots; big blotches of yellowish and brownish on the lateral sides of abdominal segment at the union of the adjoining segments; flagellae brownish red in 2/3 of the distal part; eggs yellowish in colour and enormous in number.

**Habits:** It is nocturnal and a bottom feeder. Mainly feeds on organic matters, detritus and small invertebrates.

**Habitat:** Freshwater, ponds, rivers, beels and stream.

**Distribution:** Indo-West Pacific: India; Bangladesh (collected from Boidder bazar. Narayanganj) and Myanmar.

**Economic importance:** Marketed mainly fresh

**Fishing Gear Used:** Cast nets, bag net, seine net, moi jals and pushnets.





## *Leptocarpus potamiscus* (Kemp, 1917)

### Family- Palaemonidae

**Synonyms:** *Leander potamiscus* Kemp, 1917; *Leander potomiscus* Kemp, 1917; *Palaemon potamiscus* Kemp, 1917; *Palaemon potamiscus* Suvatti, 1937.

**English names:** Bombay Prawn.

**Local names:** Gura Icha, Kunco Chingri, Lona Chingri.

**Description:** The body is slender and sub-cylindrical, of medium size. The rostrum is long and well-developed, with a slightly raised basal crest; it has dorsal and ventral teeth. The upper (dorsal) margin features 7 teeth, with one subapical tooth separated from the basal teeth by a long unarmed gap. The lower (ventral) margin is armed with 6 equidistant teeth, and setae are present between the teeth on both margins. The mandible palp has 3 segments. The carapace is smooth, with only antennal spines present, and the branchiostegial region is sharply defined. The abdominal somites are smooth, with the first to third pleurae being broadly rounded. The fourth and fifth pleurae are directed backward, while the sixth pleuron is longer and somewhat pointed. The first and second pereopods are very slender and chelate, with unarmed fingers bearing tufts of setae, and the fingers are shorter than the palm. The carpus (c) is longer than the chela, and the ischium (i) is equal in length to the merus (m). The last three pairs of pereopods are non-chelate and have simple dactyli. The telson is elongate, slender, and triangular, with two pairs of spines on the dorsal side. The posterior end is sharp, with two pairs of flanked spines—the outer pair is much shorter than the inner, and the inner pair extends beyond the tip of the telson. Plumose setae are present between the longer spines and the tip of the telson. The uropod is distinctly longer than the telson, with the exopod bearing setae and distolateral teeth.



**Figure 62.** *Leptocarpus potamiscus*

**Color:** Transparent, with concentrated areas of chromatophores on the rostrum (forming a dotted line), carapace (featuring horizontal and diagonal red pigment lines), abdominal segments, and telson, all scattered with red-brown chromatophores. The pereopods are transparent. The eggs are olive green in color.

**Habits:** It is nocturnal and omnivorous. Feeds on small crustaceans, parts of fish and vegetable matter.

**Habitat:** Fresh water and brackish water species.

**Distribution:** Globally distributed across India, Indonesia (Java, Sumatra), Malaysia (Peninsular Malaya), Thailand, China and Vietnam. Collected from Teknaf.

**Economic importance:** It is marketed mostly fresh and frozen, consumed locally.

**Fishing Gear Used:** Trawls, drift nets and seine nets.



## ***Palaemon styliferus* H. Milne Edwards, 1840**

### **Family- Palaemonidae**

**Synonyms:** *Palemon styliferus* H. Milne Edwards, 1840; *Leander styliferus* (H. Milne Edwards, 1840); *Exopalaemon styliferus* (H. Milne Edwards, 1840)

**English names:** Roshma Prawn.

**Local names:** Gara Icha (Chittagong, Cox's Bazar), Gura Chingri (Khulna, Satkhira).

**Description:** Rostrum long and slender with a basal crest of 5-7 teeth above the eye, extending beyond the antennal scale. 1-3 dorsal subterminal teeth and 6-10 ventral teeth; epigastric tooth absent. Antennular peduncle with dorsal spine on basal segment barely over reaching adjacent distal margin of segment, free part of shorter branch of dorsolateral flagellum several times as long as fused part. The adrostral carina starts at the rostrum's distal end and fused at the orbital angle. The post-rostral carina reaches half the distance to the carapace border. The branchiostegal spine is long, and the hepatic spine is absent. Dactylus of last 3 pairs of pereopods always shorter than propodus; branchiostegal groove present on carapace. The first pereopod reaches the saphocerite apex, with the second pereopod reaching it as well. Third and fourth pairs fail to reach the apex of scaphocerite, Merus longer than propodus, which is longer than ischium; Carpus is longer than dactylus but shorter than ischium. Fifth pair fails to reach the apex of scaphocerite. Carpus and ischium sub-equal; merus shorter than propodus but is double the length of carpus or ischium, which are longer than dactylus. The telson is slightly swollen at the tip.



**Figure 63.** *Palaemon styliferus*

**Color:** Pale translucent, with the tip of the rostrum dark reddish-brown and a few darker spots at the ends of the uropods and telson.

**Habits:** Mainly nocturnal and omnivorous. Feed on living animals, vegetable matters as well as dead organic matter.

**Habitat:** This species is abundant in higher saline area in the coast, estuary and shallow coastal mudflat and occasionally in freshwater. Inhabit in the benthic region.

**Distribution:** Distributed in Indo Pacific from Pakistan and Indian waters to Malay Archipelago. In Bangladesh, found in the southern water bodies.

**Economic importance:** Locally consumed as fresh or dried.

**Fishing Gear Used:** Trawls, drift nets and seine nets.



### ***Palaemon carinicauda* Holthuis, 1950**

#### **Family- Palaemonidae**

**Synonyms:** *Palaemon* (*Exopalaemon*) *carinicauda* Holthuis, 1950 ; *Leander longirostris* var. *carinatus* Ortmann, 1890; *Exopalaemon carinicauda* (Holthuis, 1950)

**English names:** Oriental prawn

**Local names:** Not known

**Description:** The body is translucent, with a long, toothed rostrum and large chelae on the second pereopods. The rostrum is equal to or slightly shorter than the carapace, featuring an elevated basal crest that is longer than the slender distal portion. The anterior half of the dorsal margin of the rostrum is unarmed. The chelae on the first two pairs of walking legs are prominent, and the third thoracic segment slightly overlaps the second. The carpus of the second pereopod is shorter than the chela.



**Figure 64.** *Palaemon carinicauda*

**Color:** The body is pale and opaque, adorned with numerous small reddish dots. The posterior endopod of the uropod is reddish in color. Ovigerous females display four large blue-black spots on the pleurae: one on the first, two on the second, and one on the third pleuron. The eggs are yellowish-green.

**Habits:** It is mainly omnivorous and nocturnal. It feeds on living animals, vegetables and dead organic matter.

**Habitat:** This species is abundant in freshwater environment.

**Distribution:** From Korea to Singapore. Found coastal region of Bangladesh.

**Economic importance:** Marketed mainly fresh for local consumption.

**Key characteristics:** It closely resembles *Exopalaemon guangdongensis* in shape and size. A key diagnostic feature of this species is that the carpus of the second pereopod is equal in length to the palm. It can be distinguished from *P. modestus* by its larger chelae on the second pereopod and the small setae on the telson, which do not extend beyond the median telson process. In contrast, *P. modestus* has two distal spines that project beyond the tip of the median telson process.

***Palaemon adspersus* Rathke, 1836****Family- Palaemonidae**

NE

**Synonyms:** *Leander brandti* Czerniavsky, 1884; *Palaemon brandti* (Czerniavsky, 1884); *Palaemon fabricii* Rathke, 1843; *Palaemon rectirostris* Zaddack, 1944; *Palaemon squilla* Leach, 1816

**English names:** Baltic prawn

**Local names:** Not known

**Description:** The rostrum features 5 to 7 dorsal teeth, usually 5, along with 1 postorbital tooth. The lower half of the rostrum is marked with dark red spots. The body is a uniform yellowish-grey color, with yellow bands at the joints of the pereopods. The mandible is equipped with a palp.



**Figure 65.** *Palaemon adspersus*

**Color:** The body is consistently yellowish-grey, with yellow bands at the joints of the pereopods. The lower half of the rostrum displays red spot-like chromatophores. Both the long flagella and the peduncle of the antennules are intensely red-pigmented.

**Habits:** Nocturnal in habit. As an omnivorous species, *P. adspersus* feeds on a variety of organic matter, including small zooplankton, algae, and detritus

**Habitat:** This species thrives in sheltered, brackish waters found in lagoons, bays, and estuaries. It is commonly associated with seagrasses and algae.

**Distribution:** The species is found in the East Atlantic, ranging from Norway to Morocco, as well as in the Baltic, Mediterranean, and Black Seas.

**Economic importance:** Locally consumed

**Key characteristics:** Rostrum with dark red spots



***Nematopalaemon tenuipes* (Henderson, 1893)****Family- Palaemonidae**

**Synonyms:** *Palaemon tenuipes* (Henderson, 1893); *Palaemon luzonensis* Blanco, 1939 *Leander tenuipes* Henderson, 1893

**English names:** Spider Prawn.

**Local names:** Shada Chingri, Gura Chingri/Icha.

**Description:** The rostrum is long and slender, featuring an elevated basal crest with 4 to 7 teeth over the eye. Most of the distal portion of the dorsal margin is toothless, except for a subdistal tooth, while the ventral margin has 2 to 6 teeth. A branchiostegal spine is present, but the branchiostegal groove is absent. The abdomen has dorsally rounded segments, with no crinate features. The second pair of pereopods is longer and more robust than the first pair. The fingers of the pincer are longer than the palm, with the palm slightly swollen. The dactylus of the third to fifth pairs of pereopods is extremely long and thin, significantly longer than the combined length of the propodus and carpus.



**Figure 66.** *Nematopalaemon tenuipes*

**Color:** Pale translucent with the tip of the rostrum dark reddish-brown; a few reddish-brown spots on the antennae, antennules, and the outer edges of the uropods and telson; a reddish-brown spot at the base of the uropods.

**Habits:** It is nocturnal and omnivorous, mainly feeds on planktons, organic matter, detritus and small animals.

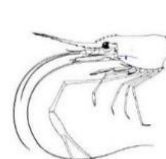
**Habitat:** Shallow coastal waters as well as in estuarine and brackish waters.

**Distribution:** It is found along the east coast of Africa, from South Africa to Somalia, and along the eastern Arabian Sea coast, from Pakistan to southern India. To the east, its range extends to Vietnam, the Philippines, and New Guinea. In Bangladesh, it is present in most coastal regions and river mouths.

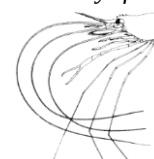
**Economic importance:** Marketed mainly fresh, dried or salted for local consumption.

**Fishing Gear Used:** Cast nets, seines, bag nets, moi jals, ESNB, trap and pushnets.

**Key characteristics:** *Nematopalaemon tenuipes* can be separated from *Exopalaemon styliferus* by the shape and teeth on the rostrum.



*Palaemon styliferus*



*Nematopalaemon tenuipes*



## *Caridina propinqua* De Man, 1908

### Family- Atyidae

**Synonyms:** *Caridina blancoi* Chace, 1997 *Caridina hainanensis* Liang & Yan, 1983

**English names:** Hairy-handed Prawn, Bengal Caridina.

**Local names:** Chuianni Icha, Chuanicha Chingri.

**Description:** Rostrum straight or sloping downward, extending to nearly the middle of the second segment of the antennular peduncle, reaching the end of the third segment. Rostral formula 3–4+9–16/1–7/1–6(3–4), with no apical teeth. Suborbital angle acute and clearly separated from the antennal spines, while the pterygostomian margin rounded. A spine presents on the preanal carina. The telson with three to four pairs of dorsal spines and a small posteromedial projection, with the lateral pair of spines being longer than the intermediate pairs. Antennular peduncle long and roughly equal in length to the carapace. The dactylus ends in two claws and has one to four spines along the flexor margin. The fifth pereopod has a propodus that is 2.5 times as long as the dactylus, with the dactylus ending in one claw and having 57–76 spinules along the flexor margin. The endopod of the male first pleopod lacks an appendix interna. The uropodal diaeresis has 13–19 spinules.



**Figure 67.** *Caridina propinqua*

**Color:** Translucent to a light brown or beige, often with slight reddish or orange hues on the body and limbs

**Habits:** Nocturnal and filter or detrital feeders and also feeds on microorganisms and dead animals.

**Habitat:** lower sections of rivers or mountain streams that flow into the sea, often located in mangrove creeks.

**Distribution:** Sri Lanka, India, Malay Peninsula, Philippines, and China. Collected from Rajbari.

**Economic importance:** Marketed mainly fresh and frozen, usually locally consumed.

**Key characteristics:** The hairy-handed pincer easily identified this species from other species of the genus *Caridina*.





*Palaemon adspersus*



*Macrobrachium lantau*



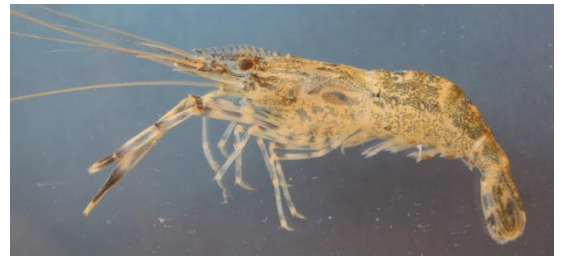
*Macrobrachium grandimanus*



*Macrobrachium scabriculum*



*Alpheus microrhynchus*



*Macrobrachium neglectum*



*Macrobrachium assamense*



*Metapenaeopsis toloensis*



*Parapenaeopsis incisa*



*Penaeus pulchricaudatus*



*Solenocera choprai*

**Plate 1.** Newly recorded (geographic) shrimp species from Bangladesh



## **5. Discussion**

Decapods are a highly diverse and species-rich group of crustaceans, comprising 11 infraorders and approximately 15,000 species, many of which hold significant commercial and medical value (Chávez, 2009; Chavez & Gorostieta, 2010; De Grave et al., 2009; Dobson, 2004). Compared to other crustacean groups, decapods have received considerable scientific attention. They have been extensively studied in various fields, particularly in research on reproductive endocrinology, molting, color change, carbohydrate metabolism, and water and ion regulation (Dircksen et al., 2009). They also provide vital ecological services in freshwater, marine, and terrestrial settings. They are popular food items in maximum parts of the world. In Bangladesh, Shrimps are popular food items and the demands for this increasing day by day. Total shrimp production, including both capture and aquaculture, has increased significantly from 1.00 lakh MT in 2002–03 to 2.71 lakh MT in 2022–23 (DoF, 2023).

No comprehensive survey has been conducted on the shrimp fauna of Bangladesh, and while there are a few scattered publications providing information on local shrimp species, there has been no thorough, systematic taxonomic study, particularly in the area of molecular taxonomy for decapod species. This gap in research is concerning, as many of the commercially important shrimp stocks are either overexploited or at risk. Despite the heavy exploitation of these species, their precise taxonomy and stock status remain poorly understood. This lack of knowledge hampers effective management and conservation efforts. Furthermore, it is likely that numerous new species or records remain undiscovered in the coastal waters of Bangladesh, underscoring the need for more targeted research to explore and document the full extent of shrimp biodiversity in the region.

This study provides a comprehensive account of shrimp species diversity in the region. A total of 50 species from 16 genera and 6 families were identified, with the Palaemonidae family being the most abundant. The genus *Macrobrachium* within this family was particularly notable, contributing a significant number of species, which aligns with its well-documented ecological importance in freshwater habitats.

The prevalence of the Penaeidae family, second in abundance, is also significant, reflecting the ecological and economic importance of penaeid species in many coastal and estuarine ecosystems. The relatively lower representation of families like

Alpheidae, Solenoceridae, Sergestidae, and Atyidae in this study may be attributed to the specific environmental conditions of the study area, as different families of shrimp exhibit varying habitat preferences and ecological niches. For instance, the species from the Atyidae family are often found in more specialized freshwater environments, which might not be as prevalent in the study region.

The conservation status of the shrimp species revealed several important insights. The 40% of species classified as *Least Concern (LC)* indicates a relatively stable population of shrimp in the region. However, the 28% of species listed as *Data Deficient (DD)* suggests that there is still much to learn about the ecology and conservation needs of many shrimp species in the region. The lack of sufficient data on these species highlights the need for further ecological studies and long-term monitoring to improve conservation strategies. Moreover, the 32% of species not evaluated points to a significant gap in our understanding of the regional shrimp fauna and the importance of continued taxonomic research in filling these gaps.

The development of a taxonomic key based on key morphological features, is especially valuable for fieldwork, where rapid identification is often necessary. However, as with all taxonomic keys, there are limitations, particularly when dealing with cryptic species that exhibit subtle morphological variations. In such cases, molecular techniques, like DNA barcoding, offer a more reliable means of species identification.

The use of molecular analysis in this study significantly enhanced the accuracy of species identification, especially for those species that were challenging to distinguish based on morphology alone. DNA barcoding using the mitochondrial COI gene was particularly effective in providing a higher level of certainty by comparing genetic sequences against established global databases. This molecular approach serves as an essential complement to traditional morphological methods, particularly in identifying species with similar physical traits or those that exhibit considerable intra-species variation. The integration of molecular data into shrimp biodiversity studies is becoming increasingly important, as it allows for a more precise understanding of species boundaries and supports the recognition of cryptic species that may be overlooked through morphological methods alone. The study recorded a total of 11 species from Bangladesh, marking their first geographic occurrence in the region. This highlights the potential for many more undiscovered species or records in the vast waters of Bangladesh. These species include *Macrobrachium lantau*, *M. neglectum*, *M.*

*scabriculum*, *M. grandimanus*, *M. assamense*, *Palaemon adspersus*, *Kishinouyepenaeopsis incisa*, *Penaeus pulchricaudatus*, *Metapenaeopsis toloensis*, *Solenocera choprai*, and *Alpheus microrhynchus*.

The study underscores the importance of combining traditional taxonomic techniques with modern molecular approaches to accurately assess and monitor biodiversity. The findings not only contribute to the existing knowledge of shrimp diversity in the region but also emphasize the need for further research to address data deficiencies and improve conservation efforts. The identification of *Data Deficient* species highlights the urgent need for more comprehensive ecological studies to assess population dynamics, distribution patterns, and potential threats to these species.

# **Chapter 2**

## **Molecular Taxonomy**

## 1. Introduction

### 1.1 Background

Bangladesh, with its vast network of rivers, coastal areas, and estuaries, is home to a rich diversity of aquatic species, including various shrimp species. These shrimps, classified under the order *Decapoda* in the class *Crustacea*, play a significant role in the marine and freshwater ecosystems of the region. They are economically valuable, forming an essential part of the local fisheries and aquaculture industries. Additionally, shrimps contribute to the ecological balance by serving as prey for many larger species and aiding in the decomposition of organic materials.

Genetic diversity in shrimp populations is a critical factor for their survival, adaptation, and resilience to environmental changes. It encompasses variations in genetic material that influence traits such as growth rate, disease resistance, and reproductive success. In Bangladesh, the genetic diversity of shrimp species is influenced by factors like habitat fragmentation, water quality, and climate change. Understanding this diversity is essential for effective conservation and management strategies, ensuring sustainable shrimp populations for both ecological health and economic benefits.

Phylogenetic relationships among shrimp species, based on genetic analysis, provide insights into their evolutionary history and classification. Molecular techniques, such as DNA sequencing and protein analysis, have advanced the study of shrimp phylogeny, helping to resolve species boundaries and clarify the evolutionary pathways of different shrimp groups. In Bangladesh, studies on the phylogenetic relationships of local shrimp species have uncovered valuable information about their origins, genetic exchange, and the ecological adaptations that enable them to thrive in diverse habitats, from brackish waters to freshwater systems.

The status of shrimps in Bangladesh is influenced by several factors, including overfishing, habitat loss due to pollution, and climate change, which threaten their populations. The native shrimp species, particularly those of economic importance like *Penaeus monodon* and *Macrobrachium rosenbergii*, face pressures from both natural and anthropogenic activities. Effective management of shrimp resources is crucial to maintaining biodiversity, promoting sustainable fisheries, and safeguarding the livelihoods of communities' dependent on shrimp farming and wild capture.

The genetic diversity, phylogenetic relationships, and status of shrimps in Bangladesh offer valuable insights into their ecological importance and conservation needs. A comprehensive understanding of these aspects is essential for the sustainable management and conservation of shrimp species, ensuring their continued role in both the environment and the economy of the region.

## 1.2 Molecular identification

Morphological identification of shrimp is highly critical due to the complexity of this group, which exhibits various larval stages, sexual dimorphism, and plasticity. Additionally, physical damage caused by rough handling can further complicate identification (Nicolè et al., 2012). Penaeid shrimps, for instance, can change color based on factors such as growth, background coloration, and the time of day, influenced by their chromatophores (CSIRO, 2013). As a result, misidentification is common, and distinguishing them at the genus or species level can be challenging. Accurate species identification becomes particularly difficult in groups that are species-rich or taxonomically complex, often requiring specialized expertise that may not always be readily available. However, proper identification is vital for enforcing regulations and ensuring the conservation of these species. The process becomes even more difficult when closely related species are involved. To address these challenges, DNA barcoding has emerged as a promising method. This technique involves identifying species through a short, universal DNA sequence that provides enough variation to distinguish among species (Hebert et al., 2003).

Each organism has a distinctive set of biological characteristics that improve its fitness for survival in a niche environment. Such a natural phenomenon offers molecular markers for detecting uniqueness of individuals or species (Sanger *et al.*, 1977). The method of molecular identification may improve the speed of unidentified organism detection. This method serves as a valuable rapid tool for examining ambiguous species, determining species composition, and identifying cryptic species (Spies et al., 2006). In identifying distinctions between species, this is more precise and helpful.

## 1.3 DNA Barcoding

DNA barcoding refers to the process of obtaining short DNA sequences that facilitate the identification, recognition, and discovery of species within a specific biological domain (Hebert et al., 2003a). Its main goal is to identify an unknown specimen by

matching it with known classifications (Miller, 2007; Stoeckle & Hebert, 2008). Rather than replacing traditional taxonomic methods, DNA barcoding complements them by offering an additional tool for species identification (Fig. 1). It is important to differentiate between DNA barcoding and DNA taxonomy. DNA taxonomy is centered on defining and classifying species using evolutionary species concepts, with DNA sequences serving as primary markers for classification (Vogler & Monaghan, 2006). In contrast, DNA barcoding focuses on identifying species by comparing sequence similarities to known references, rather than directly assigning species identity to a specific DNA sequence.

Ideally, barcoding and species discovery should work together, with DNA sequences serving as diagnostic tools that enhance traditional morphological taxonomy. While DNA barcoding helps identify species more efficiently, it does not replace the need for morphological characteristics (DeSalle et al., 2005). Barcoding is particularly useful for identifying species that might otherwise be overlooked due to subtle or complex morphological traits. Additionally, it can encourage the collection of further data, such as genetic, ecological, behavioral, and geographic information (Hebert et al., 2004; Smith et al., 2008; Bucklin & Frost, 2009; Steinke et al., 2009).

For metazoans, the mitochondrial cytochrome c oxidase subunit I (COI) gene is the most commonly used barcode region (Hebert et al., 2003a). This barcode region, typically around 648 base pairs long, is located at the gene's 5' end and is surrounded by conserved regions. These conserved areas are essential for designing PCR primers, such as the widely used Folmer primers (Folmer et al., 1994). The COI region has proven to exhibit substantial genetic divergence: within-species divergence is typically less than 3%, while between-species divergence often exceeds 10–25% (Hebert et al., 2003b). While DNA barcoding principles can be applied to other gene regions, this chapter primarily focuses on the COI barcode region as the standard for species identification.

#### **1.4 DNA Barcoding: A Powerful Tool for Identifying and Detecting Species Diversity**

DNA barcoding has emerged as a global bio-scanner, providing a powerful molecular approach for species identification using partial sequences of the mitochondrial COI gene. It has been widely recognized as an effective tool for identifying species across



various taxonomic groups and uncovering cryptic diversity (Hebert et al., 2004), earning credibility in scientific circles as a reliable taxonomic method (Blaxter, 2006).

More than a decade of research has demonstrated that DNA barcoding effectively distinguishes fish and other species across diverse geographic regions, including Australia (Ward et al., 2005), Bangladesh (Ahmed et al., 2021a, b; Datta et al., 2024; Arfin et al., 2023; Barua et al., 2021; Habib et al., 2023), Canada (Hubert et al., 2008), China (Zhang, 2011), India (Lakra et al., 2011), Taiwan (Chang et al., 2017), and Vietnam (Thu et al., 2019).

Beyond species identification, DNA barcoding has proven to be a versatile tool with numerous applications. It enables the identification of different developmental stages in insects (Ahrens et al., 2007) and serves as a valuable supplementary method in forensic science (Dawnay et al., 2007), feeding ecology research (Bourlat et al., 2008), and habitat conservation (Ward et al., 2008), among other fields. Notably, DNA barcoding is particularly useful for studying taxonomically challenging groups where morphological identification is complicated by cryptic diversity (Smith et al., 2006) or phenotypic plasticity (Derry et al., 2003; Adamowicz et al., 2004).

While DNA barcoding offers significant advantages, it is most effective when integrated with other methods, particularly for conservation purposes. As a result, it has gained widespread adoption in recent years as a reliable and widely accepted tool for species identification.

### **1.5 Reasons for DNA barcoding (BARCODE OF LIFE, modified from Shyam, and Narayanakumar, 2012)**

- a. **Works with fragments:** Barcoding enables species identification even from small fragments. Once implemented, it can quickly detect undesirable substances in processed foods and identify products derived from regulated species, such as protected whales served as sushi.
- b. **Applicable across life stages:** Barcoding can identify species in all developmental forms, such as the eggs and larvae of marine fish.
- c. **Distinguishes look-alikes:** Barcoding differentiates between visually similar species, revealing harmful organisms disguised as harmless ones and providing a clearer understanding of biodiversity, such as sibling species of planktonic copepods.

- d. **Eliminates ambiguity:** By encoding species identification as a unique DNA sequence (e.g., CATG) at a standardized genomic location, barcoding offers a precise, digital reference that complements traditional methods based on physical characteristics. This will aid in tracking species migrations and changes over time.
- e. **Extends expert capabilities:** With over 230,000 known marine species across 31 phyla and potentially 1,000,000 yet to be identified, barcoding equips scientists to expedite identification and recognize new species rapidly, overcoming the limits of morphology-based expertise.
- f. **Democratizes identification:** A standardized barcode library empowers a wider audience to identify marine species, promoting appreciation for biodiversity on local and global scales, and aiding the recognition of both common and invasive species.
- g. **Enables portable tools:** Barcoding integrates with advancements in DNA sequencing, electronics miniaturization, and data storage, paving the way for portable desktop devices and handheld field guides for species identification.
- h. **Sprouts new leaves on the tree of life:** Barcoding the almost 2 million species that have already been identified will offer a wealth of genetic information, aiding in the construction of the tree of life on Earth. Barcoding newly discovered species will help determine their place among existing species, adding new branches to the tree of life.
- i. **Highlights the value of collections:** Building the barcode library relies on specimens from museums, aquaria, and biological repositories, emphasizing their critical role in preserving marine biodiversity.
- j. **Accelerates the encyclopedia of life:** Linking barcode data to vouchered specimens and species names will facilitate the creation of an online encyclopedia of marine animals, offering a dedicated web page for every species and expanding access to biological knowledge.

## **1.6 Barcodes from Misidentified Specimens**

A key goal of DNA barcoding is to compile all barcodes in a centralized database (Hebert et al., 2003a). However, a significant challenge arises from the submission of barcodes associated with misidentified specimens. This issue has already been observed in databases like GenBank (Ruedas et al., 2000; Harris, 2003; Hebert et al., 2003b; Vilgalys, 2003; Seberg, 2004) and is expected to recur with barcode repositories.

Despite efforts to implement stringent vouchers policies, it is impractical to assume that most voucher specimens will undergo re-identification by taxonomic experts. Only the most obvious identification errors are likely to be detected (Ward et al., 2005). Concerns are amplified when DNA barcodes are derived from museum specimens and tissues from existing collections, as these sources often include misidentified specimens (Meier and Dikow, 2004) or lack robust vouchers practices.

Drawing parallels with issues in GenBank, misidentified barcodes are expected to contribute significantly to query misidentifications, potentially undermining the reliability of DNA barcoding for accurate species identification.

## **1.7 Mitochondrial DNA**

Mitochondrial DNA (mtDNA) is a circular chromosome housed within mitochondria, the cellular organelles responsible for energy production and various metabolic processes. Found in the cytoplasm, mitochondria play a crucial role in cellular function. Unlike nuclear DNA, mitochondrial DNA is exclusively inherited from the mother, as offspring receive their mitochondria solely through the maternal lineage.

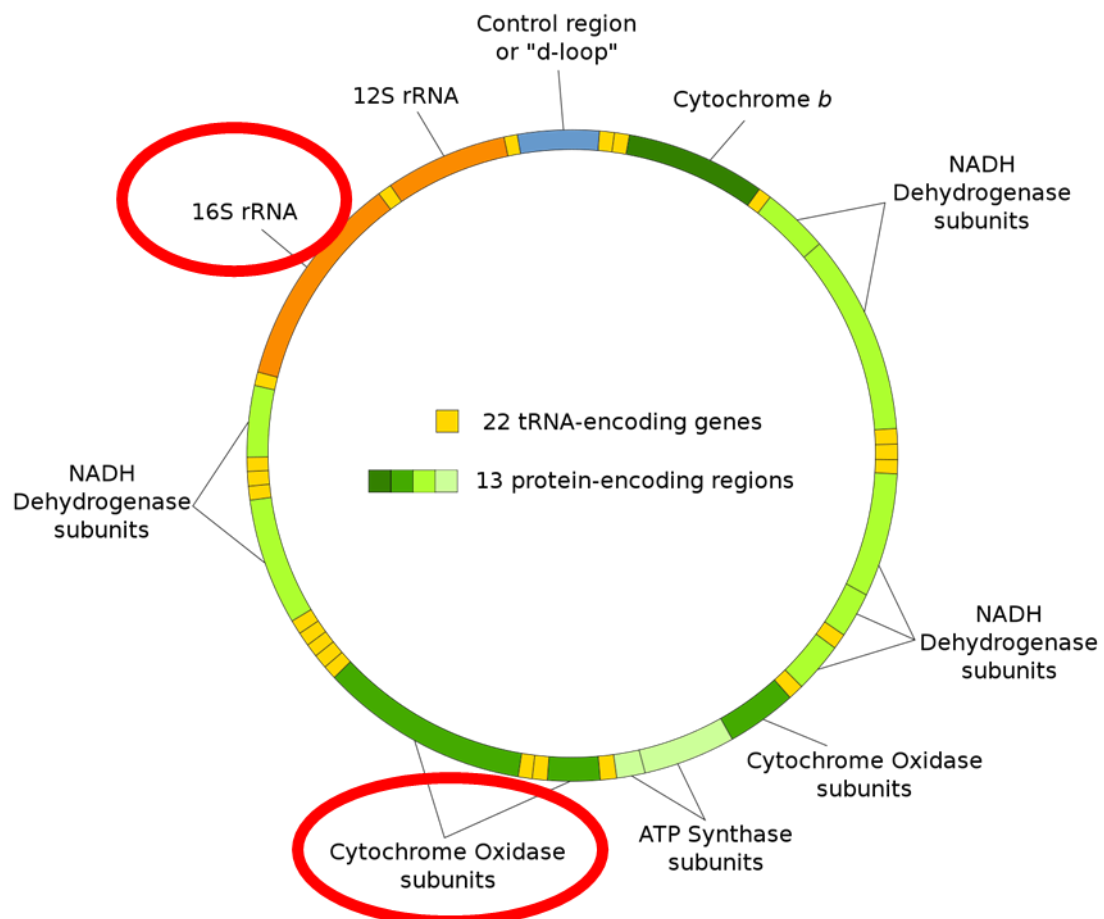
The majority of animals possess a circular mitochondrial genome. However, certain species within the Medusozoa and Calcarea clades exhibit linear mitochondrial chromosomes (Lavrov and Pett, 2016). Typically, animal mitochondrial DNA contains 37 genes: 13 encoding proteins, 22 for tRNAs, and 2 for rRNAs, with few exceptions (Boore, 1999) (Figure 68). On average, the mitochondrial genome in animals' spans approximately 16,000 base pairs (Boore, 1999).

### **1.7.1 Why Mitochondrial DNA**

For many of the processes that generate power within the mitochondria, mitochondrial DNA is critically essential. Mitochondrial DNA is inherited from the mother unlike nuclear DNA, whereas nuclear DNA is inherited from both parents. However, during early development, its transmission and replication are strictly controlled as they are essential to the viability and health of the descendants (John, 2014).

Mitochondrial DNA has some distinct and unique characteristics compared to other nuclear DNA. Mitochondrial DNA (mtDNA) is much easier to obtain from biological samples than nuclear DNA due to the abundance of mitochondria within a cell, each containing multiple mtDNA molecules, compared to the single copy of nuclear DNA

(Kormendy et al., 1993). mtDNA has a mutation rate 5 to 10 times faster than nuclear DNA, making its genome composition simpler to analyze and compare. Unlike nuclear DNA, mtDNA is maternally inherited, bypassing the complexities of biparental transmission, and it rarely contains duplicate or non-coding sequences.



**Figure 68.** Mitochondrial gene indicating COI and 16S rRNA gene (modified from Isogg.org, 2018)

Additionally, mtDNA lacks introns and evolves more rapidly than genomic DNA (Berschick, 1997). Being haploid, mtDNA is free from recombination, resulting in a smaller effective population size and greater susceptibility to genetic drift. The high point mutation rate of mtDNA makes it particularly effective for species identification (Berschick, 1997), while its relatively fast evolutionary rate enhances its potential as a barcoding gene (Brown, 1979). Furthermore, mtDNA is highly useful for tracing divergence in closely related taxa, even at the intra-species level.

### 1.7.2 Mitochondrial COI gene

Cytochrome c oxidase I (COX1), also known as mitochondrially encoded cytochrome c oxidase I (MT-CO1), is a protein encoded by the MT-CO1 gene in humans. In other eukaryotes, it is commonly referred to as COI, COX1, or CO1 (MT-COI gene) (Kosakyan et al., 2012).

The MT-CO1 gene is widely recognized as a key molecular marker for DNA barcoding, a technique used for species identification in animals. Its effectiveness stems from its mutation rate, which is typically fast enough to differentiate closely related species while remaining sufficiently conserved within species groups, making it an ideal target for taxonomic studies (Hebert et al., 2003a).

Among the 37 mitochondrial genes, MT-CO1 is located on the guanine-rich heavy (H) strand of mitochondrial DNA (mtDNA), spanning nucleotide positions 5904 to 7444 (Zong et al., 2013). The most extensive studies on MT-CO1 have been conducted on arthropods, as their high taxonomic diversity has led to detailed sequence information. However, COI gene divergences have also been analyzed across all major animal phyla for which data are available, enabling species identification in diverse groups.

For animal DNA barcoding, the COI gene can reliably identify individuals of the same species and distinguish between different species. Cytochrome c oxidase I (COI) serves as the cornerstone of a universal identification system for organisms (Hebert et al., 2003b). Such a system is not only robust but also cost-effective and digital, addressing long-standing challenges in species recognition.

In an influential study, Hebert and colleagues sequenced the DNA barcodes of 260 bird species out of the 667 species that breed in North America (Hebert et al., 2004). The results were remarkable: every species analyzed had a unique COI sequence. Moreover, multiple specimens from the same species exhibited sequences that were either identical or most similar to those of conspecific individuals. This study provided strong support for the utility of DNA barcoding.

Hebert et al. (2004) also introduced the concept of the "barcoding gap," a sequence threshold to identify new species. This threshold was defined as 10 times the mean intraspecific variation within the study group, providing a standardized approach to species delineation.

### **1.7.3 16S rRNA gene**

The 16S ribosomal RNA (rRNA) gene, universally present in prokaryotes, is a key tool in phylogenetic analysis. Woese and Fox (1977) were the first to propose using the small subunit of the 16S rRNA gene for phylogenetic studies, recognizing its slow evolutionary rate. They are regarded as pioneers in the field of 16S rRNA-based phylogenetics (Woese et al., 1990).

This gene possesses several characteristics that make it an excellent phylogenetic marker, including its universal presence in prokaryotes, a combination of conserved and variable regions, functional consistency, substantial size, and high information content (Woese, 1987; Ludwig and Klenk, 2005). Sequence data from the 16S rRNA gene is widely used in phylogenetic studies because of its effectiveness in distinguishing higher taxonomic groups and traditional species.

Moreover, 16S rRNA gene sequences are relatively easy to align and compare, supported by extensive online databases such as EMBL, DDBJ, and GenBank (Ludwig and Klenk, 2005). However, its resolution is typically limited to species-level or broader taxonomic classifications (Stackebrandt and Goebel, 1994).

## 2. Review of Literature

Morphological identification of shrimp is highly critical for its various larval stages, sexual dimorphism, and plasticity. The process becomes even more difficult when closely related species are involved. To address these challenges, DNA barcoding has emerged as a promising method. In this section, over 50 literature sources were reviewed, covering the period from 1991 to 2025.

In 1991, Palumbi and Benzie's study marked a pioneering effort in the application of mitochondrial DNA (mtDNA) sequencing to explore genetic differentiation in penaeid shrimp from the USA. The study revealed unexpectedly large genetic distances between species, even among those that appeared morphologically similar. Palumbi and Benzie's results raise important questions about the relationship between molecular and morphological evolution. The authors hypothesized that mtDNA evolution in shrimp may occur at an accelerated rate, or alternatively, that long-term stabilizing selection may have constrained morphological changes over time. This observation challenges the traditional reliance on morphology for taxonomic classification, particularly in cases where genetic differences are substantial but morphological characteristics remain conserved. Later in 1994, Bouchon and his team conducted an analysis of three laboratory strains of *Penaeus monodon* from Malaysia, Australia, and Fiji, along with a farm population of *P. japonicus*, using mitochondrial DNA (mtDNA). They found that the mtDNA molecule size of both penaeid species was similar, measuring approximately 16,000 base pairs. Based on RFLP data for *P. monodon*, a genetic divergence of 1.68% was observed between the Fiji strain and the Australia/Malaysia strains.

On the contrary, 13 species of this genus (*Penaeus*) revealed high genetic divergence (8–24%) between species, analyzing mitochondrial cytochrome oxidase subunit I (COI) DNA sequences that suggested low genetic diversity based on allozyme analysis (Baldwin et al., 1998). Murphy and Austin (2002) aimed to identify inconsistencies in the current classification of Australian *Macrobrachium* shrimps (Palaemonidae: Decapoda). A preliminary phylogenetic study was conducted on five species within the *Macrobrachium* genus using 16S rRNA mitochondrial gene sequences. Phylogenetic analyses revealed two key inconsistencies with the current classification: *M. intermedium* formed a distinct clade with *Palaemon serenus*, separate from *M.*



*australiense*, *M. atactum*, and *M. rosenbergii*. Additionally, *M. australiense* and *M. atactum* from inland Australia exhibited high genetic similarity, suggesting that they may represent conspecific populations. In the following year, the same authors revealed significant anomalies in the classification of Australian Palaemonidae using the 16S mitochondrial rRNA gene. They found that *Macrobrachium intermedium*, *Palaemon serenus*, and *Palaemonetes australis*—which belong to separate genera—are actually closely related, with genetic differences more closely resembling those typically found between congeneric species.

In 2004, Murphy and Austin conducted a study on seven endemic and six non-endemic Australian *Macrobrachium* species, along with five non-Australian species, using mitochondrial 16S rRNA gene sequences (Murphy & Austin, 2004). Their analysis produced phylogenetic trees with varying topologies, none of which supported a monophyletic origin for endemic Australian *Macrobrachium*. Instead, their findings suggest that these species arose from multiple evolutionary origins.

To further investigate whether this pattern of multiple origins extends to other regional *Macrobrachium* populations, the phylogeny of 30 species from Asia, Central/South America, and Australia was inferred using mitochondrial 16S rRNA sequences (Murphy & Austin, 2005). The phylogenetic analysis indicated that, although some regional diversification is evident, *Macrobrachium* species from Australia, Asia, and South America do not share a common ancestry. This suggests that large-scale dispersal has played a crucial role in shaping the evolutionary history of the genus. In the same year, Francisco and Galetti Junior (2005) examined the genetic relationships among five broodstocks of the white marine shrimp *Litopenaeus vannamei* (Penaeidae) from Brazil by sequencing the mitochondrial 16S rRNA and cytochrome c oxidase I (COI) regions. Their findings revealed no genetic divergence among the broodstocks for the highly conserved 16S rRNA gene and an 8.2% genetic distance between *L. vannamei* and *Farfantepenaeus subtilis*. However, COI sequence analysis showed only 0.2% to 1% genetic distance among the *L. vannamei* broodstocks, in contrast to a much higher mean distance of 10.9% between *L. vannamei* and *F. subtilis*.

For the first time in China, Zhang et al. (2010) sequenced the mitochondrial cytochrome c oxidase subunit I (COI) gene for three *Macrobrachium* species (*M. rosenbergii*, *M. nipponense*, and *M. qilianensis*). Their analysis revealed substantial genetic divergence

between different haplotypes of the three species, with genetic distances ranging from 19.87% to 23.84%, strongly supporting their distinction as separate species. Following a long hiatus in DNA barcoding research on shrimp, Pillai et al. (2014) described a new species, *Macrobrachium abrahami* (Decapoda: Palaemonidae), from Kerala, India, using Cytochrome B gene sequences. Phylogenetic analysis based on the Maximum Likelihood (ML) tree indicated that *M. abrahami* sp. nov. is closely related to *M. prabhakarani* at the genetic level but shares more morphological similarities with *M. scabriculum*.

In 2015, several studies from different regions, including China, India, and Turkey, advanced DNA barcoding research. Raupach and Radulovici (2015) conducted a comprehensive review of crustacean barcoding studies published between 2003 and 2014, using data from the Web of Science database. They reported a total of 164 studies, with a significant focus on malacostracan crustaceans, particularly Decapoda. These studies primarily aimed to establish reference libraries for species identification. The first DNA barcoding study of shrimp in the Turkish Seas was conducted by Bilgin et al. (2015), who analyzed COI gene sequences to assess the genetic diversity of 12 shrimp species along the Turkish coast. Notably, five of these species were barcoded for the first time. In the same year, DNA barcoding was employed in India to identify six marine shrimp species and five freshwater prawn species using mitochondrial COI gene sequences (Rajkumar et al., 2015; Udayasuriyan et al., 2015).

Cheng et al. (2015) barcoded the shrimp species of the genus *Metapenaeopsis* (Decapoda: Penaeidae) using mitochondrial and nuclear DNA sequences from China. In 2016, there was an increase in the number of published articles using molecular approaches to study shrimp. Jose et al. (2016) identified two congeneric species, *Macrobrachium striatum* and *M. equidens*, as two distinct species within the genus *Macrobrachium* through minimum evolution and neighbor-joining analyses, using two mitochondrial markers: 16S ribosomal RNA and cytochrome oxidase subunit I. To ensure food safety and detect fraud in seafood, Eischeid et al. (2016) employed DNA barcoding to identify commercial decapod crustacean species, including shrimp, crab, crayfish, and lobster. In the same year, Zodape et al. (2016) conducted the first attempt to use molecular genetic techniques for identifying *Parapenaeopsis sculptillis* and *Parapenaeopsis hardwickii* from Gorai Creek, Mumbai, on the west coast of India. This study utilized cytochrome oxidase subunit I (COI) gene sequencing with specific

primers LCO1490 and HCO2198. Samadi et al. (2016) established phylogenetic relationships among all commercial marine shrimp species (a total of 5 taxa) of the family Penaeidae from the Persian Gulf, Iran, and found that the Iranian species originated from the Indo-West Pacific species.

A study examining the proximate composition and DNA barcoding of marine shrimps from Thondi, Tamil Nadu, India, reaffirmed the reliability of DNA barcoding as an effective tool for species identification (Subbaiya et al., 2017). Similarly, Mantelatto et al. (2017) conducted a study to obtain mitochondrial COI and 16S gene sequences from decapod crustaceans along the São Paulo coastline, Brazil. Their research also assessed the accuracy of these molecular markers for species identification by comparing the newly generated sequences with those available in the GenBank database.

In Bangladesh, Alam et al. (2017) applied DNA barcoding for the first time to genetically differentiate the giant freshwater prawn, *Macrobrachium rosenbergii*, while also analyzing its historical demography. Gunther et al. (2017) conducted a DNA barcoding study on 118 seafood products, primarily fish and shrimp, purchased from supermarkets and fishmongers in northwest Germany. Using COI gene analysis, they identified discrepancies between product labeling and DNA barcode results. The mislabeled products were categorized into two groups: Category I (five samples) contained species that did not belong to the same genus as indicated on the label, while Category II (two samples) included species that belonged to the correct genus but were mislabeled at the species level.

Morphological identification of freshwater shrimp species is limited to adult and dominant males, restricting its application to only a few specimens. To address this limitation, Nursyahra et al. (2018) applied DNA barcoding techniques to identify several freshwater shrimp species from Indonesia. Meanwhile, in India, Chilika Lake, a highly productive habitat for shrimp and a hub for extensive commercial trade, had not been studied for the genetic diversity of penaeid shrimp species prior to 2018. To minimize this research gap, Kundu et al. (2018) generated DNA barcode data for six penaeid shrimp species that had been morphologically identified. This penaeid shrimp family comprises most of the economically important marine shrimp species. To address two objectives—(a) testing the monophyly of the Penaeidae family and its currently recognized genera using a reconstructed phylogeny, and (b) exploring species

diversity in Southeast Asian waters—Hurzaid et al. (2020) conducted a comprehensive analysis. For the first objective, they utilized a gene dataset comprising 109 ingroup and six outgroup taxa, incorporating mitochondrial genes (COI and 16S rRNA) and two nuclear genes (NaK and PEPCK).

To assess species diversity, a dataset comprising 371 COI gene sequences—231 newly generated and 140 retrieved from public databases—was analyzed using two species delimitation tools, ABGD and bPTP. The analysis identified 94 putative species within the 71 examined morph species, highlighting an underestimation of biodiversity within the Penaeidae family. Additionally, the findings suggest the potential discovery of new species within several morphospecies, including *Kishinouyepenaeopsis cornuta*, *K. incisa*, *Mierspenaeopsis sculptilis*, *M. hardwicki*, *Parapenaeopsis coromandelica*, and *Penaeus monodon*. Siriwut et al. (2021) found the evidence of cryptic diversity in freshwater *Macrobrachium* prawns from Indochinese riverine systems. This study explores the genetic diversity of *Macrobrachium* prawns in the Indochinese region, focusing on the Chao Phraya and Mekong River basins. Using morphological analysis, DNA barcoding, and molecular species delimitation, 27 nominal species were re-verified. The study revealed significant taxonomic ambiguity, with overlapping species boundaries and cryptic species in four complex species. It also identified diagnostic nucleotide positions for six species and proposed 18 additional lineages. Geographical distribution patterns suggest that historical river and landmass events have influenced genetic diversity. The findings highlight the Mekong River Basin's importance for freshwater biodiversity in Southeast Asia.

Ahmed et al. (2021a) initiated the first extensive effort in Bangladesh to establish a barcode reference library for shrimp. Their study included 24 sequences representing 14 species and documented four new records for Bangladesh's shrimp fauna: *Macrobrachium nipponense*, *Macrobrachium kistnense*, *Exopalaemon carinicauda*, and *Alpheus malleator*. In the same year, Alam and Palsson (2021) investigated phylogenetic relationships among seven *Parapenaeopsis* species, examined population genetic variation in *Parapenaeopsis sculptilis* along the Bangladesh coastline of the Bay of Bengal, and explored its phylogeography within the Indian Ocean. This study, based on COI barcode sequences, found no evidence of population structuring among *P. sculptilis* samples from two Bangladeshi coastal sites. The following year, three new species records were reported in Hong Kong: *M. equidens*, *M. lar*, and *M. venustum*.

Additionally, Chow et al. (2022) described a newly discovered species, *M. lantau* sp. nov., which was previously recorded only in Bangladesh, based on data retrieved from NCBI GenBank (Datta & Ahmed, 2023).

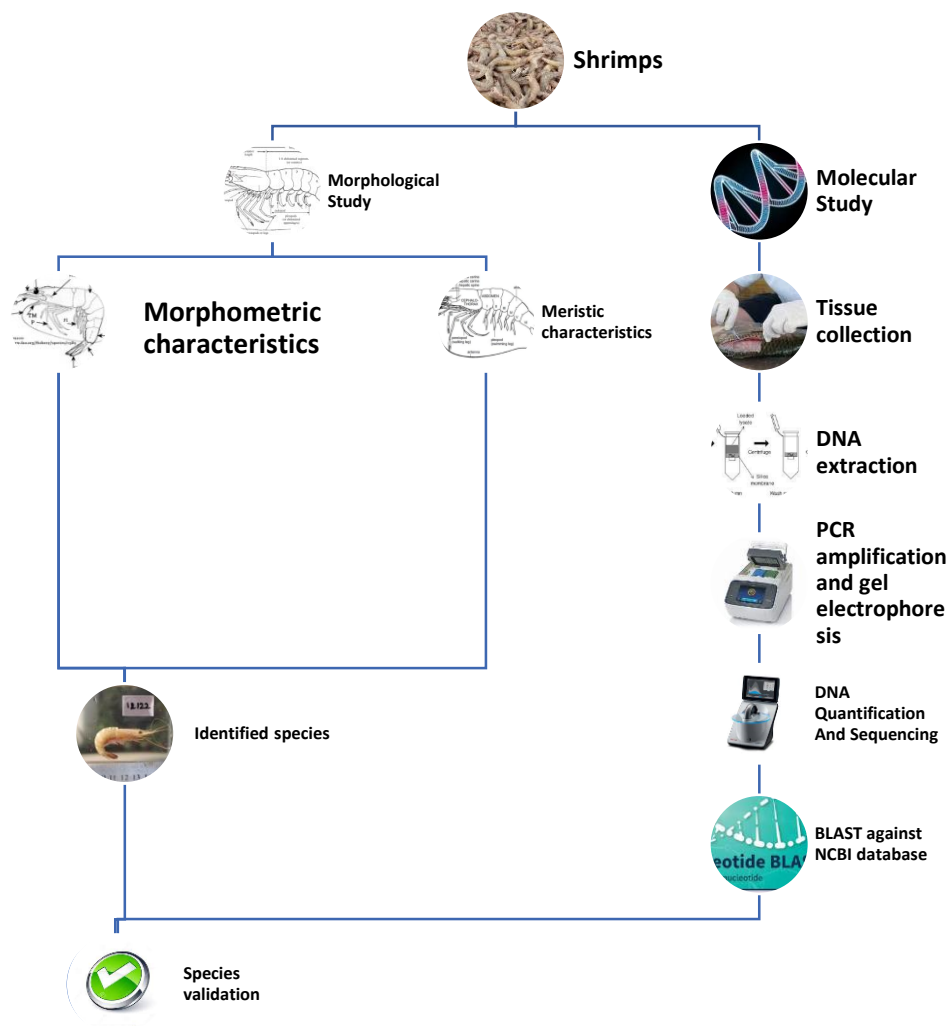
Abdul Halim et al. (2023) conducted a comprehensive assessment of penaeid shrimp diversity in northwestern Peninsular Malaysia by integrating taxonomy and phylogenetics. The molecular phylogeny of 12 penaeid shrimp species was reconstructed using COI gene sequences, with phylogenetic signals evaluated by mapping morphometric data onto three phylogenetic trees: Neighbor-Joining (NJ), Maximum Likelihood (ML), and Bayesian Inference (BI). While the NJ tree showed no significant phylogenetic signal, the ML and BI trees revealed strong signals, suggesting that morphological differences among penaeid shrimp species are closely linked to their evolutionary history.

More recently, Datta et al. (2024) documented *Penaeus pulchricaudatus* and *Kishinouyepenaeopsis incisa* as new records in Bangladeshi waters. Their study suggests that many more undocumented shrimp species may still be present in the region

### 3. Materials and Methods

#### 3.1 Tissue collection from sample

After morphological studies, collected samples were cut by a sharp sterilized blade and tissue was taken carefully and fat, scale or other unwanted debris were removed. Then tissue was used to DNA extractions and rest was kept with 100% alcohol at -20°C for further studies. The systematic experimental procedure of DNA barcoding was performed through the following procedural steps:



**Figure 69.** Steps of molecular study and species confirmation

#### 3.2 Genomic DNA Extraction

Genomic DNA was extracted from a 25 mg tissue sample using the Qiagen® DNeasy Blood & Tissue Kit (USA), following the manufacturer's protocol. The concentration and purity of the extracted DNA were assessed using a NanoDrop™ spectrophotometer.

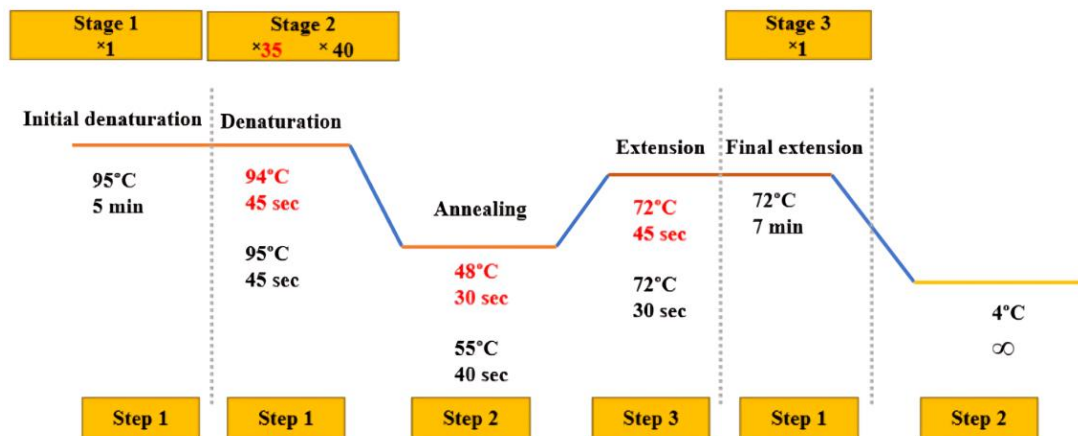
### 3.3 PCR Amplification

The contigs were amplified using polymerase chain reaction (PCR) with two set of primers (Table 3).

**Table 3. List of primers with their sequences**

| Primer Name        | Sequence (5'-3')               | Reference            |
|--------------------|--------------------------------|----------------------|
| LCO-1490 (forward) | 5'-TCAACAAATCATAAGGACATTGG-3'  | Folmer et al., 1994  |
| HCO-2198 (reverse) | 5-TAAACTTCAGGGTGTCCAAAGAATCA-3 |                      |
| 16Sar (forward)    | 5-CGCCTGTTTATCAAAAACAT-3'      | Palumbi et al., 1991 |
| 16Sbr (reverse)    | 5-CCGGTCTGAACTCAGATCATGT-3     |                      |

Polymerase chain reaction (PCR) was carried out in a total reaction volume of 25 µl, consisting of 23 µl PCR Master Mix (12.5 µl Taq Polymerase, 8.5 µl NanoPure water, 1 µl forward primer, and 1 µl reverse primer) along with 2 µl of the DNA template. The reaction mixture was thoroughly homogenized by brief spinning for 30 seconds. PCR amplification was conducted under the specified thermal cycling conditions (Figure 70).



**Figure 70.** Conditions of PCR (Red color for 16S and black color for COI)

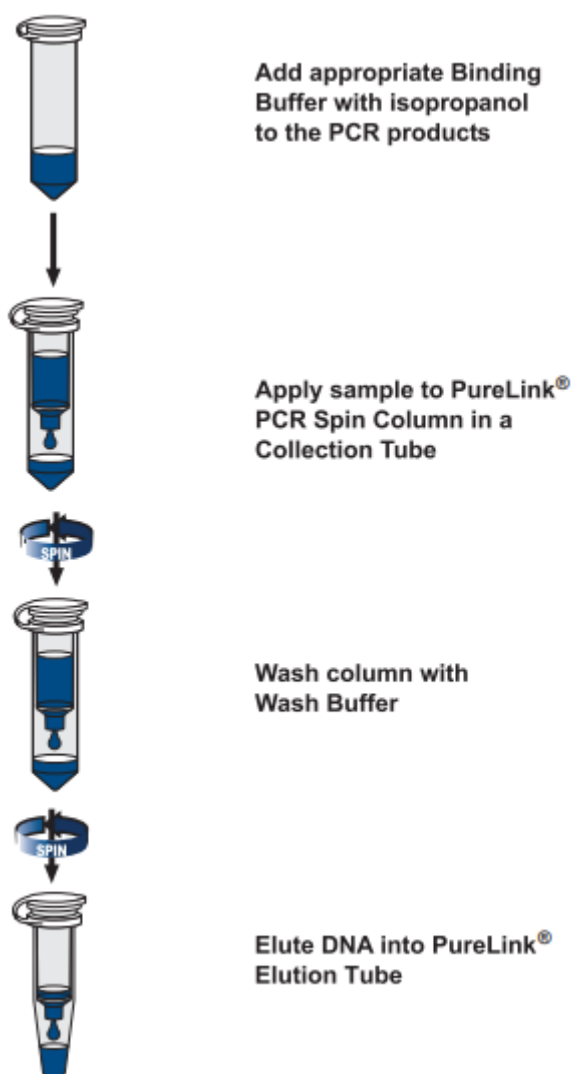
The PCR products were stored at -26 °C until further downstream application. The amplified gene bands were visualized on a 1% agarose gel.

### 3.4 Purification of PCR product and gel electrophoresis

Purification step was performed in order to isolate DNA from other macromolecules such as digested proteins, RNA, carbohydrates, lipids and other material using



Invitrogen PureLink™ PCR Purification Kit by ThermoFisher Scientific. The flow chart for purifying PCR products is given in Figure 71.



**Figure 71.** Flow chart for purifying PCR products (from the manual)

### 3.5 DNA quantification and sequencing

After purification, the purity and yield of the DNA were assessed using a Nanodrop spectrophotometer. High-quality purified PCR products with a DNA concentration greater than 10 ng/μl were then sent to First BASE laboratories in Malaysia for sequencing. Sequencing was conducted using Sanger dideoxy sequencing technology with an ABI PRISM 3730xl Genetic Analyzer and the BigDye R Terminator v3.1 cycle sequencing kit. Sequencing was also carried out by another outsourcing company,

Celeemics Inc. in Korea, where the direct PCR products were sent. The company performed the purification of the PCR products.

### **3.6 Bioinformatics**

#### **3.6.1 Sequence Analysis**

The raw sequences were initially examined using CHROMAS software. Unwanted and noisy bases were removed to improve sequence quality. The refined sequences were then converted into the FASTA file format (.fas).

#### **3.6.2 Sample Identification and Homology Analysis Using BLAST**

In bioinformatics, the Basic Local Alignment Search Tool (BLAST) is an algorithm used to compare primary biological sequence data, such as the amino acid sequences of proteins or the nucleotide sequences of DNA. BLAST was employed to identify homologies. Sequence identification was carried out by comparing the query sequences against the pre-existing data in the National Center for Biotechnology Information (NCBI) database to determine the closest match. Three key parameters-query coverage, E-value, and identity-were considered in the analysis. An identity score of >95% was generally deemed reliable for identifying individual species sequences.

#### **3.6.3 GenBank Submission**

Sequences showing the highest homology (>95%) were submitted to GenBank via the individual submission process to obtain accession numbers.

#### **3.6.4 Sequence Alignment and Genetic Variation Analysis**

Sequence alignment was performed to detect genetic variation among individuals of the same species, determine interspecies and intraspecies distances, and construct a phylogenetic tree. For this analysis, the Multiple Sequence Comparison by Log-Expectation (MUSCLE) tool (Edgar, 2004) was used within the Molecular Evolutionary Genetics Analysis (MEGA) 12 software (Kumar et al., 2024). FASTA files containing multiple sequences were utilized to identify genetic variations among individual specimens of the same species. To pinpoint nucleotide variation, the sequences analyzed in this study were aligned with at least three additional sequences from the same species using MEGA 12 (Kumar et al., 2024).

### ***3.6.5 Nucleotide composition and evolutionary divergence***

The nucleotide composition and GC content were determined using MEGA 12 software (Kumar et al., 2024). GC contents at different codon positions among species were also calculated by this software. The evolutionary distance was carried out by Kimura 2 parameter model (Kimura, 1980).

### ***3.6.6 Phylogenetic tree construction***

After the sequence alignment and homology search, the phylogenetic relationship was done by joining the best match homology. Phylogenetic trees were generated using the Neighbor-Joining (NJ) method, based on the Kimura 2-parameter model (Kimura, 1980). To assess the robustness of the tree topology, bootstrap analysis was performed with 1,000 replicates. The main advantage of NJ (Saitou and Nei, 1987) is that it is fast compared to least squares, maximum likelihood methods and thus suited for large datasets and for bootstrap analysis. But Maximum Likelihood (ML) is the most accurate one to construct phylogenetic relationship. The trees were visualized using iTOL v5 (Letunic and Bork, 2021).

### ***3.6.7 Statistical analysis***

Necessary Statistical Analysis was performed by using Microsoft Excel (Microsoft 365) software package. The output files of K2P distances were saved using this software.

## 4. Results

### 4.1 General Inference

A total of 127 partial sequences from the COI and 16S rRNA genes were successfully obtained from approximately 100 samples, comprising 55 COI and 72 16S rRNA sequences. All newly generated sequences have been deposited in both the BOLD and GenBank databases (Table 4). The barcode analysis project was assigned the code "SHRMP," while the dataset was labeled "DS-PRAWN" in BOLD. Through molecular analysis, 38 species were identified, representing 10 genera across three families. Additionally, two genera were recognized; however, species-level identification within these genera remains inconclusive.

### 4.2 Cytochrome c Oxidase I (COI) Gene

#### 4.2.1 Nucleotide composition

A total of 55 COI gene sequences were successfully generated, representing 29 species. All sequences were verified to ensure the absence of stop codon insertions. The nucleotide composition was determined as follows: G =  $18.55 \pm 0.24\%$ , C =  $22.31 \pm 0.33\%$ , A =  $27.90 \pm 0.21\%$ , and T =  $31.23 \pm 0.37\%$  (Table 5). The AT content (59.13%) was notably higher than the GC content ( $40.87 \pm 0.40\%$ ).

The GC content varied across codon positions, with  $52.54 \pm 0.52\%$  at the first position,  $43.65 \pm 0.37\%$  at the second, and  $26.41 \pm 0.90\%$  at the third. The distribution of GC composition across codon positions is illustrated in Figure 72. A statistically significant pattern was observed, following the order 1st > 2nd > 3rd codon position (p-value < 0.005).

**Table 4.** Sequences of shrimp samples used in this study with their accession no, bold process id, location and GPS coordinates

| Operational taxonomic unit ID      | BOLD Process ID | BIN          | Voucher No     | Marker    | GenBank Accession No | Locality                | GPS coordinates  |
|------------------------------------|-----------------|--------------|----------------|-----------|----------------------|-------------------------|------------------|
| <i>Acetes indicus</i>              | SHRMP069-25     |              | DUZM_CR_116    | 16S       | PV163918             | Dublar Char, Sundarban  | 21.75 N, 89.61 E |
| <i>Alpheus euprosyne</i>           | SHRMP073-25     |              | DUZM_CR_139.2  | 16S       | PV163923             | Dublar Char, Sundarban  | 21.75 N, 89.61E  |
|                                    | SHRMP074-25     |              | DUZM_CR_139    | 16S       | PV163922             | Dublar Char, Sundarban  | 21.75 N, 89.61 E |
| <i>Alpheus malleator</i>           | GBCM23992-19    | BOLD:ACQ8406 | DUZM_CR_139B   | COI       | MN200395             | Kuakata                 | 21.85 N, 90.03 E |
|                                    | SHRMP080-25     |              | DUZM_CR_139B.2 | 16S       | PV163930             | Kuakata                 | 21.85 N, 90.03 E |
| <i>Ganjampenaeopsis uncta</i>      | SHRMP054-25     |              | DUZM_CR_107    | COI       | PV123046             | Chattagram, Cox s Bazar | 21.23 N, 91.75 E |
|                                    | SHRMP079-25     |              | DUZM_CR_107.2  | 16S       | PV163929             | Cox s Bazar             | 21.23 N, 91.75 E |
| <i>Kishinouyepenaeopsis incisa</i> | SHRMP047-23     |              | DUZM_CR_107B   | 16S       | ON264685             | Kuakata                 | 21.84 N, 90.05 E |
| <i>Leptocarpus potamiscus</i>      | SHRMP068-25     |              | DUZM_CR_138    | 16S       | PV163917             | Joukura, Rajbari        | 23.79 N, 89.57 E |
| <i>Macrobrachium sp. 1</i>         | SHRMP084-25     |              | DUZM_CR_133D.2 | COI & 16S |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
|                                    | SHRMP085-25     |              | DUZM_CR_133D.3 | COI & 16S |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
|                                    | SHRMP086-25     |              | DUZM_CR_133D.4 | COI & 16S |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
|                                    | SHRMP087-25     |              | DUZM_CR_133D.5 | COI & 16S |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
|                                    | SHRMP083-25     |              | DUZM_CR_133D   | COI & 16S |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
|                                    | SHRMP088-25     |              | DUZM_CR_133D.6 | 16S       |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
|                                    | SHRMP089-25     |              | DUZM_CR_133D.7 | 16S       |                      | Adampur, Sylhet         | 24.26 N, 91.90 E |
| <i>Macrobrachium equidens</i>      | SHRMP007-23     |              | DUZM_CR_125.4S | 16S       | MW483132             | Teknaf                  | 20.75 N, 92.34 E |
|                                    | SHRMP016-23     |              | DUZM_CR_125.3S | 16S       | MW483123             | Teknaf                  | 20.75 N, 92.34 E |
|                                    | SHRMP017-23     |              | DUZM_CR_125.2S | 16S       | MW483122             | Teknaf                  | 20.75 N, 92.34 E |
|                                    | SHRMP018-23     |              | DUZM_CR_125S   | 16S       | MW483121             | Teknaf                  | 20.75 N, 92.34 E |
|                                    | GBMND16078-21   | BOLD:ADK5178 | DUZM_CR_125    | COI       | MW479974             | Teknaf                  | 20.75 N, 92.34 E |
|                                    | GBMND16081-21   | BOLD:ADK5178 | DUZM_CR_125.4  | COI       | MW479980             | Teknaf                  | 20.75 N, 92.34 E |

| Operational taxonomic unit ID  | BOLD Process ID | BIN          | Voucher No     | Marker | GenBank Accession No | Locality                              | GPS coordinates   |
|--------------------------------|-----------------|--------------|----------------|--------|----------------------|---------------------------------------|-------------------|
|                                | GBMND16080-21   | BOLD:ADK5178 | DUZM_CR_125.3  | COI    | MW479976             | Teknaf                                | 20.75 N, 92.34 E  |
|                                | GBMND16079-21   | BOLD:ADK5178 | DUZM_CR_125.2  | COI    | MW479975             | Teknaf                                | 20.75 N, 92.34 E  |
|                                | SHRMP019-23     |              | DUZM_CR_125.12 | 16S    | OP108369             | Teknaf                                | 20.75 N, 92.34 E  |
|                                | SHRMP024-23     |              | DUZM_CR_125.10 | 16S    | OP108364             | Teknaf                                | 20.75 N, 92.34 E  |
|                                | SHRMP026-23     |              | DUZM_CR_125.9  | 16S    | OP108362             | Teknaf                                | 20.75 N, 92.34 E  |
| <i>Macrobrachium sp. 2</i>     | SHRMP023-23     |              | DUZM_CR_125.11 | 16S    | OP108365             | Teknaf                                | 20.75 N, 92.34 E  |
|                                | SHRMP050-23     |              | DUZM_CR_125.5  | 16S    | ON264682             | Kuakata                               | 21.85 N, 90.031 E |
|                                | SHRMP040-23     |              | DUZM_CR_125.8  | 16S    | ON264692             | Kuakata                               | 21.84 N, 90.05 E  |
|                                | SHRMP041-23     |              | DUZM_CR_125.7  | 16S    | ON264691             | Cox's Bazar                           | 21.46 N, 91.92 E  |
| <i>Macrobrachium kistnense</i> | GBCM24008-19    | BOLD:ADH6513 |                | COI    | MN200413             | Padma River, Faridpur                 | 23.6 N, 89.84 E   |
|                                | SHRMP060-25     |              | DUZM_CR_133E.2 | COI    | PV123051             | Padma River, Faridpur                 | 23.6 N, 89.84 E   |
|                                | SHRMP061-25     |              | DUZM_CR_133E.3 | COI    | PV123052             | Padma River, Faridpur                 | 23.6 N, 89.84 E   |
|                                | SHRMP062-25     |              | DUZM_CR_133E.4 | COI    | PV123053             | Padma River, Faridpur                 | 23.6 N, 89.84 E   |
|                                | SHRMP064-25     |              | DUZM_CR_133E.5 | COI    | PV123055             | Padma River, Faridpur                 | 23.6 N, 89.84 E   |
|                                | SHRMP066-25     |              | DUZM_CR_133E.6 | COI    | PV123057             | Padma River, Faridpur                 | 23.6 N, 89.84 E   |
| <i>Macrobrachium lamarrei</i>  | SHRMP027-23     |              | DUZM_CR_127.3  | 16S    | OP108361             | Jibannagar, Chuadanga                 | 23.42 N, 88.81 E  |
|                                | SHRMP028-23     |              | DUZM_CR_127.2  | 16S    | OP108360             | Tailkupi, Jhenaidah                   | 23.42 N, 89.17 E  |
|                                | SHRMP029-23     |              | DUZM_CR_127    | 16S    | OP108359             | Tailkupi, Jhenaidah                   | 23.424 N, 89.17 E |
|                                | SHRMP056-25     |              | DUZM_CR_127.4  | COI    |                      | Tailkupi, Jhenaidah                   | 23.42 N, 89.17 E  |
| <i>Macrobrachium lantau</i>    | SHRMP045-23     |              | DUZM_CR_125.6  | 16S    | ON264687             | Kuakata                               | 21.85 N, 90.03 E  |
|                                | SHRMP067-25     |              | DUZM_CR_133.2  | COI    | PV123058             | Kuakata                               | 21.85 N, 89.84 E  |
|                                | SHRMP072-25     |              | DUZM_CR_133B.3 | 16S    | PV163921             | Kuakata                               | 21.85 N, 90.03 E  |
| <i>Macrobrachium neglectum</i> | SHRMP071-25     |              | DUZM_CR_133C   | 16S    | PV163920             | Brahmaputra river, Kazipur, Sirajganj | 24.68 N, 89.64 E  |

| Operational taxonomic unit ID     | BOLD Process ID | BIN          | Voucher No     | Marker | GenBank Accession No | Locality                              | GPS coordinates  |
|-----------------------------------|-----------------|--------------|----------------|--------|----------------------|---------------------------------------|------------------|
|                                   | SHRMP071-25     |              | DUZM_CR_133C.2 | COI    |                      | Brahmaputra river, Kazipur, Sirajganj | 24.68 N, 89.64 E |
| <i>Macrobrachium nipponense</i>   | GBCM24000-19    | BOLD:AAA7462 |                | COI    | MN200403             | Kuakata                               | 21.85 N, 90.03 E |
| <i>Macrobrachium rosenbergii</i>  | SHRMP020-23     |              | DUZM_CR_131.5  | 16S    | OP108368             | Teknaf                                | 20.75 N, 92.34 E |
|                                   | SHRMP039-23     |              | DUZM_CR_131.4  | 16S    | ON264693             | Kuakata                               | 21.84 N, 90.05 E |
|                                   | GBMNC67803-20   | BOLD:AAE0347 | DUZM_CR_131.3  | COI    | MT895788             | Boiddar Bazar Ghat, Sonargaon         | 23.65 N, 90.6 E  |
|                                   | GBMNC67804-20   | BOLD:AAE0347 | DUZM_CR_131.2  | COI    | MT895787             | Boiddar Bazar Ghat, Sonargaon         | 23.65 N, 90.6 E  |
|                                   | GBCMD30658-19   | BOLD:AAE0347 | DUZM_CR_131    | COI    | MH429358             | Bay of Bengal, Patuakhali             | 21.55 N, 90.16 E |
| <i>Macrobrachium rude</i>         | SHRMP025-23     |              | DUZM_CR_132    | 16S    | OP108363             | Teknaf                                | 20.75 N, 92.34 E |
| <i>Macrobrachium villosimanus</i> | GBMNC68682-20   | BOLD:AEG6708 | DUZM_CR_133.2  | COI    | MT890527             | Padma River, Faridpur                 | 23.6 N, 89.84 E  |
|                                   | GBMNC68683-20   |              | DUZM_CR_133    | COI    | MT890526             | Padma River, Faridpur                 | 23.6 N, 89.84 E  |
|                                   | SHRMP063-25     |              | DUZM_CR_133.4  | COI    | PV123054             | Padma River, Faridpur                 | 23.6 N, 89.84 E  |
| <i>Metapenaeopsis stridulans</i>  | SHRMP053-25     |              | DUZM_CR_109    | COI    | PV123045             | Chattagram, Cox s Bazar               | 21.23 N, 91.75 E |
|                                   | SHRMP077-25     |              | DUZM_CR_109.2  | 16S    | PV163927             | Cox s Bazar                           | 21.23 N, 91.75 E |
| <i>Metapenaeopsis toloensis</i>   | SHRMP052-25     |              | DUZM_CR_109B   | COI    | PV123044             | Chattagram, Cox s Bazar               | 21.23 N, 91.75E  |
| <i>Metapenaeus affinis</i>        | SHRMP011-23     |              | DUZM_CR_095.2S | 16S    | MW483128             | Teknaf                                | 20.78 N, 92.33 E |
|                                   | SHRMP012-23     |              | DUZM_CR_095S   | 16S    | MW483127             | Teknaf                                | 20.78 N, 92.33 E |
|                                   | SHRMP059-25     |              | DUZM_CR_95.3   | COI    | PV123050             | Chattagram, Teknaf                    | 20.78 N, 92.33 E |
| <i>Metapenaeus brevicornis</i>    | SHRMP002-23     |              | DUZM_CR_096.4S | 16S    | MW483137             | Teknaf                                | 20.78 N, 92.33 E |
|                                   | GBMND16790-21   | BOLD:ADL8268 | DUZM_CR_096.4  | COI    | MW479981             | Teknaf                                | 20.78 N, 92.33 E |
|                                   | GBCM24010-19    | BOLD:ADL8268 |                | COI    | MN200415             | Cox`s Bazar                           | 21.43 N, 91.97 E |
|                                   | GBMNC67918-20   |              | DUZM_CR_096.3  | COI    | MT890530             | Cox`s Bazar                           | 21.43 N, 91.97 E |

| Operational taxonomic unit ID     | BOLD Process ID | BIN          | Voucher No     | Marker | GenBank Accession No | Locality                   | GPS coordinates  |
|-----------------------------------|-----------------|--------------|----------------|--------|----------------------|----------------------------|------------------|
|                                   | GBCMD30685-19   | BOLD:ADL8268 | DUZM_CR_097    | COI    | MH429352             | Bay of Bengal, Patharghata | 21.27 N, 89.97 E |
| <i>Metapenaeus ensis</i>          | SHRMP021-23     |              | DUZM_CR_098.4  | 16S    | OP108367             | Teknaf                     | 20.75 N, 92.34 E |
|                                   | SHRMP036-23     |              | DUZM_CR_098.3  | 16S    | ON264696             | Dublar Char, Sundarban     | 21.75 N, 89.61 E |
|                                   | SHRMP037-23     |              | DUZM_CR_098.4  | 16S    | ON264695             | Kuakata                    | 21.84 N, 90.05 E |
|                                   | GBCMD30687-19   | BOLD:AAE3069 | DUZM_CR_098    | COI    | MH429353             | Bay of Bengal, Patharghata | 21.27 N, 89.97 E |
|                                   | GBCM23996-19    | BOLD:AAE3069 |                | COI    | MN200399             | Cox's Bazar                | 21.43 N, 91.97 E |
| <i>Metapenaeus lysianassa</i>     | SHRMP034-23     |              | DUZM_CR_099    | 16S    | OP108354             | Teknaf                     | 20.75 N, 92.34 E |
|                                   | SHRMP065-25     |              | DUZM_CR_98.3   | COI    | PV123056             | Chattagram, Cox s Bazar    | 21.23 N, 91.75 E |
| <i>Metapenaeus tenuipes</i>       | SHRMP042-23     |              | DUZM_CR_101    | 16S    | ON264690             | Cox's Bazar                | 21.46 N, 91.92 E |
| <i>Mierspenaeopsis hardwickii</i> | SHRMP030-23     |              | DUZM_CR_103.5  | 16S    | OP108358             | Teknaf                     | 20.75 N, 92.34 E |
|                                   | SHRMP032-23     |              | DUZM_CR_103.4  | 16S    | OP108356             | Cox's Bazar                | 21.28 N, 91.25 E |
|                                   | SHRMP033-23     |              | DUZM_CR_103.3  | 16S    | OP108355             | Cox's Bazar                | 21.28 N, 91.25 E |
|                                   | SHRMP049-23     |              | DUZM_CR_103.2  | 16S    | ON264683             | Kuakata                    | 21.82 N, 90.04 E |
|                                   | GBCM23999-19    | BOLD:ACU6977 |                | COI    | MN200402             | Cox's Bazar                | 21.43 N, 91.97 E |
| <i>Mierspenaeopsis sculptilis</i> | SHRMP013-23     |              | DUZM_CR_105.3S | 16S    | MW483126             | Teknaf                     | 20.80 N, 92.33 E |
|                                   | SHRMP014-23     |              | DUZM_CR_105.2S | 16S    | MW483125             | Teknaf                     | 20.80 N, 92.33 E |
|                                   | SHRMP046-23     |              | DUZM_CR_105.5  | 16S    | ON264686             | Kuakata                    | 21.84 N, 90.05 E |
|                                   | SHRMP048-23     |              | DUZM_CR_105.4  | 16S    | ON264684             | Kuakata                    | 21.82 N, 90.04 E |
|                                   | GBMND16791-21   | BOLD:ACR4868 | DUZM_CR_105.2  | COI    | MW479977             | Teknaf                     | 20.80 N, 92.33 E |
|                                   | GBMND16792-21   | BOLD:ACR4868 | DUZM_CR_105.3  | COI    | MW479978             | Teknaf                     | 20.80 N, 92.33 E |
|                                   | GBCMD30704-19   | BOLD:ACR4868 | DUZM_CR_105    | COI    | MH429355             | Bay of Bengal, Patharghata | 21.27 N, 89.97 E |
|                                   | GBCM23995-19    |              |                | COI    | MN200398             | Cox's Bazar                | 21.43 N, 91.97 E |

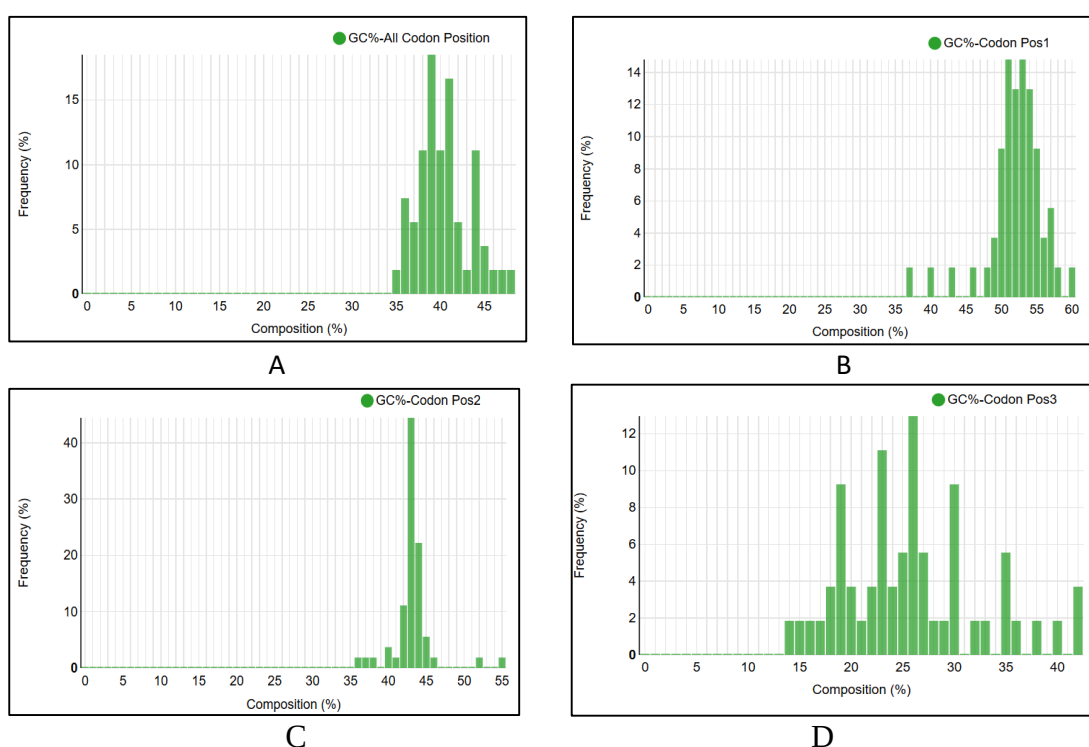


| Operational taxonomic unit ID      | BOLD Process ID | BIN          | Voucher No     | Marker    | GenBank Accession No | Locality                      | GPS coordinates  |
|------------------------------------|-----------------|--------------|----------------|-----------|----------------------|-------------------------------|------------------|
| <i>Nematopalaemon tenuipes</i>     | GBMNC68673-20   | BOLD:ADL6821 | DUZM_CR_153    | COI       | MT895789             | Boiddar Bazar Ghat, Sonargaon | 23.65 N, 90.6 E  |
|                                    | SHRMP075-25     |              | DUZM_CR_135.2  | 16S       | PV163924             | Cox s Bazar                   | 21.23 N, 91.75 E |
| <i>Palaemon adspersus</i>          | SHRMP082-25     |              | DUZM_CR_136B   | COI & 16S |                      |                               |                  |
| <i>Palaemon carinicauda</i>        | GBCM23990-19    | BOLD:AAJ0314 |                | COI       | MN200393             | Kuakata                       | 21.82 N, 90.04 E |
| <i>Palaemon styliferus</i>         | SHRMP022-23     |              | DUZM_CR_134.4  | 16S       | OP108366             | Teknaf                        | 20.75 N, 92.34 E |
|                                    | GBCM24012-19    |              |                | COI       | MN200417             | Cox`s Bazar                   | 21.43 N, 91.97 E |
|                                    | GBMNC68679-20   | BOLD:AEG6765 | DUZM_CR_134.3  | COI       | MT890529             | Cox's Bazar                   | 21.43 N, 91.97 E |
|                                    | GBMNC68680-20   | BOLD:AEB6292 | DUZM_CR_134.2  | COI       | MT890528             | Cox's Bazar                   | 21.43 N, 91.97 E |
| <i>Parapenaopsis coromandelica</i> | SHRMP057-25     |              | DUZM_CR_102    | COI       | PV123048             | Chattagram, Cox s Bazar       | 21.23 N, 91.75 E |
|                                    | SHRMP058-25     |              | DUZM_CR_102.2  | COI       | PV123049             | Chattagram, Cox s Bazar       | 21.23 N, 91.75 E |
|                                    | SHRMP078-25     |              | DUZM_CR_102.3  | 16S       | PV163928             | Cox's Bazar                   | 21.23 N, 91.75 E |
| <i>Parapenaopsis stylifera</i>     | SHRMP006-23     |              | DUZM_CR_106.3S | 16S       | MW483133             | Teknaf                        | 20.80 N, 92.33 E |
|                                    | SHRMP008-23     |              | DUZM_CR_106.2S | 16S       | MW483131             | Teknaf                        | 20.80 N, 92.33 E |
|                                    | SHRMP015-23     |              | DUZM_CR_106S   | 16S       | MW483124             | Teknaf                        | 20.80 N, 92.33 E |
| <i>Penaeus indicus</i>             | SHRMP038-23     |              | DUZM_CR_088.3  | 16S       | ON264694             | Kuakata                       | 21.84 N, 90.05 E |
|                                    | SHRMP044-23     |              | DUZM_CR_088.2  | 16S       | ON264688             | Kuakata                       | 21.85 N, 90.03 E |
|                                    | SHRMP051-23     |              | DUZM_CR_088    | 16S       | ON264681             | Dublar Char, Sundarban        | 21.75 N, 89.61 E |
|                                    | GBCM23993-19    |              |                | COI       | MN200396             | Kuakata                       | 21.85 N, 90.03 E |
| <i>Penaeus japonicus</i>           | SHRMP070-25     |              | DUZM_CR_89     | 16S       | PV163919             | Cox s Bazar                   | 21.23 N, 91.75 E |
| <i>Penaeus merguensis</i>          | SHRMP010-23     |              | DUZM_CR_091S   | 16S       | MW483129             | Bay of Bengal, Teknaf         | 20.72 N, 92.35 E |
|                                    | GBMND16798-21   | BOLD:ACH6846 | DUZM_CR_091    | COI       | MW479979             | Bay of Bengal, Teknaf         | 20.72 N, 92.35 E |
| <i>Penaeus monodon</i>             | SHRMP003-23     |              | DUZM_CR_092.2S | 16S       | MW483136             | Bay of Bengal, Teknaf         | 20.72 N, 92.35 E |
|                                    | SHRMP035-23     |              | DUZM_CR_092.4  | 16S       | ON264697             | Hatiya                        | 22.21 N, 91.05 E |

| Operational taxonomic unit ID  | BOLD Process ID | BIN          | Voucher No     | Marker | GenBank Accession No | Locality                  | GPS coordinates   |
|--------------------------------|-----------------|--------------|----------------|--------|----------------------|---------------------------|-------------------|
|                                | SHRMP043-23     |              | DUZM_CR_092.3  | 16S    | ON264689             | Kuakata                   | 21.85 N, 90.03 E  |
|                                | GBCMD31214-19   | BOLD:ABA2373 | DUZM_CR_092    | COI    | MH429357             | Bay of Bengal, Patuakhali | 21.568 N, 90.16 E |
|                                | GBCM23998-19    | BOLD:ABA2373 | DUZM_CR_092.2  | COI    | MN200401             | Kuakata                   | 21.85 N, 90.03 E  |
| <i>Penaeus pulchricaudatus</i> | SHRMP009-23     |              | DUZM_CR_094BS  | 16S    | MW483130             | Bay of Bengal, Teknaf     | 20.72 N, 92.35 E  |
| <i>Penaeus semisulcatus</i>    | SHRMP055-25     |              | DUZM_CR_94     | COI    | PV123047             | Chattagram, Cox s Bazar   | 21.23 N, 91.75 E  |
|                                | SHRMP076-25     |              | DUZM_CR_94     | 16S    | PV163925             | Cox s Bazar               | 21.23 N, 91.766 E |
| <i>Penaeus canaliculatus</i>   | SHRMP081-25     |              | DUZM_CR_87     | 16S    | PV163926             | Cox s Bazar               | 21.23 N, 91.75 E  |
| <i>Solenocera crassicornis</i> | SHRMP004-23     |              | DUZM_CR_110.2S | 16S    | MW483135             | Teknaf                    | 20.80 N, 92.33 E  |
|                                | SHRMP005-23     |              | DUZM_CR_110S   | 16S    | MW483134             | Teknaf                    | 20.80 N, 92.33 E  |
|                                | SHRMP031-23     |              | DUZM_CR_110.3  | 16S    | OP108357             | Teknaf                    | 20.75 N, 92.34 E  |

**Table 5. Composition Summary Statistics for nucleotide frequency distribution**

|                  | <u>Min</u> | <u>Mean</u> | <u>Max</u> | <u>SE</u> |
|------------------|------------|-------------|------------|-----------|
| G %              | 15.23      | 18.55       | 27.57      | 0.246     |
| C %              | 15.64      | 22.31       | 27.79      | 0.337     |
| A %              | 25.19      | 27.90       | 32.86      | 0.210     |
| T %              | 24.63      | 31.23       | 36.74      | 0.378     |
| GC %             | 35.84      | 40.87       | 48.77      | 0.396     |
| GC % Codon Pos 1 | 37.37      | 52.54       | 60.29      | 0.528     |
| GC % Codon Pos 2 | 36.55      | 43.65       | 55.50      | 0.369     |
| GC % Codon Pos 3 | 14.12      | 26.41       | 42.31      | 0.902     |

**Figure 72. GC% - Composition per Codon Position A. all codon position; B. 1<sup>st</sup> codon; C. 2<sup>nd</sup> codon and D. 3<sup>rd</sup> codon position**

#### 4.2.2 Genetic divergence analyses

The genetic divergence distances calculated from the 55 sequences in the dataset were 1.18%, 23.53%, and 28.29% within species, genus, and family, respectively (Table 6).

**Table 6. Distribution of sequence divergence at each taxonomic level**

| Label          | n  | Taxa | Comparisons | Min Dist (%) | Mean Dist (%) | Max Dist (%) | SE Dist (%) |
|----------------|----|------|-------------|--------------|---------------|--------------|-------------|
| Within Species | 29 | 9    | 39          | 0.00         | 1.18          | 3.02         | 0.02        |
| Within Genus   | 44 | 6    | 203         | 0.17         | 23.53         | 75.00        | 0.08        |
| Within Family  | 47 | 2    | 293         | 15.04        | 28.29         | 75.00        | 0.05        |

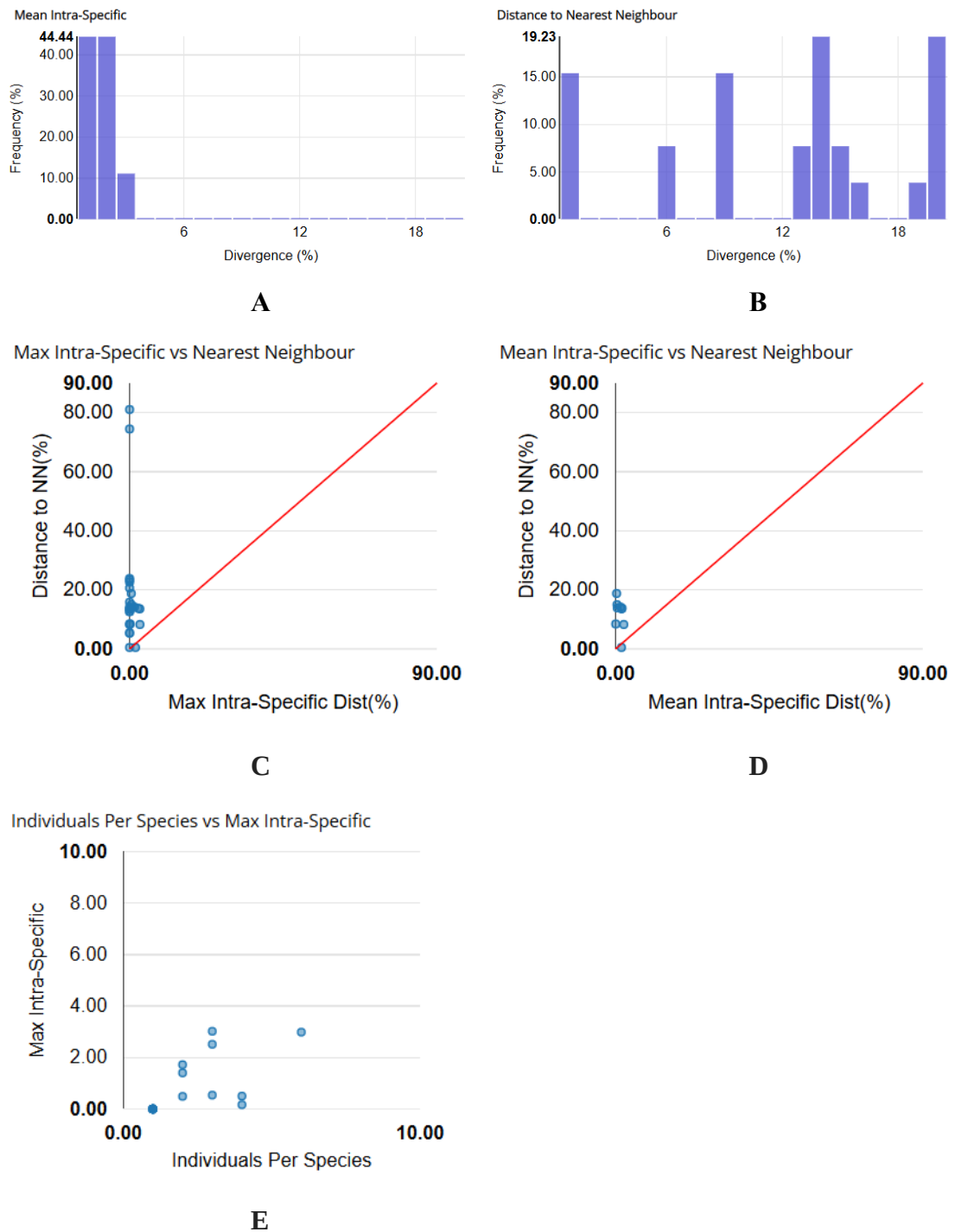
### 4.2.3 Barcode gap analyses

The barcode gap analysis was performed by comparing the mean intraspecific and interspecific variations to the nearest-neighbor distance using the Kimura 2-parameter (K2P) distance model. Additionally, the barcode gap was assessed by comparing the mean intra- and interspecific variations, revealing a value of 38.54, which was 34 times higher than the mean interspecific distance.

For each species, both the mean and maximum intraspecific distances were evaluated against the nearest-neighbor distance (Table 7). For singleton species, intraspecific values were marked as "N/A" since they were not applicable. Distances were highlighted if the nearest-neighbor distance was less than 2% divergent or if it was smaller than the maximum intraspecific distance, in which case they were flagged as potential warning values. Notably, two species—*Metapenaeus affinis* and *M. ensis*—triggered a warning signal due to their lower genetic divergence compared to their nearest-neighbor species (Table 7).

The comparison results for singleton species were excluded from the calculations due to their inapplicability. Within the K2P distance model, nine species exhibited both maximum and mean intraspecific distances that exceeded those of their nearest-neighbor species.

To further validate the presence and extent of the barcode gap, two scatter plots were generated, illustrating the overlap between maximum and mean intraspecific distances against interspecific (nearest-neighbor) distances (Figure 73 C and D). Another scatter plot was generated, illustrating the individuals per species vs max intra specific distance (Figure 73 E). A comprehensive summary of barcode gap comparisons across all identified shrimp species is provided in Table 7.



**Figure 73.** Results of genetic distance obtained from BOLD under K2-parameter model using COI gene sequences; **A.** Mean intra sequence divergence **B.** Distance to nearest-neighbor species based on sequence divergence **C.** Comparison of maximum intraspecific variation and distance to nearest-neighbor species **D.** Comparison of mean intraspecific variation and distance to nearest-neighbor species **E.** Comparison of individuals per species and max-intraspecific distance

**Table 7.** Summary of Mean-Max intraspecific variation in each shrimp species and the distance to nearest-neighbor species (warning values are highlighted)

| SL No | Species                             | Mean Intra-Sp | Max Intra-Sp | Nearest Species                   | Nearest Neighbour | Distance to NN |
|-------|-------------------------------------|---------------|--------------|-----------------------------------|-------------------|----------------|
| 1     | <i>Alpheus malleator</i>            | N/A           | 0            | <i>Macrobrachium equidens</i>     | GBMND16078-21     | 23.33          |
| 2     | <i>Macrobrachium equidens</i>       | 0.3           | 0.5          | <i>Macrobrachium neglectum</i>    | SHRMP071-25       | 18.77          |
| 3     | <i>Macrobrachium kistnense</i>      | 1.75          | 2.99         | <i>Macrobrachium lamarrei</i>     | SHRMP056-25       | 13.57          |
| 4     | <i>Macrobrachium lamarrei</i>       | N/A           | 0            | <i>Macrobrachium kistnense</i>    | SHRMP064-25       | 13.57          |
| 5     | <i>Macrobrachium lantau</i>         | N/A           | 0            | <i>Macrobrachium villosimanus</i> | GBMNC68683-20     | 81.05          |
| 6     | <i>Macrobrachium neglectum</i>      | N/A           | 0            | <i>Macrobrachium nipponense</i>   | GBCM24000-19      | 13.51          |
| 7     | <i>Macrobrachium nipponense</i>     | N/A           | 0            | <i>Macrobrachium neglectum</i>    | SHRMP071-25       | 13.51          |
| 8     | <i>Macrobrachium rosenbergii</i>    | 0.42          | 0.54         | <i>Macrobrachium villosimanus</i> | GBMNC68682-20     | 14.99          |
| 9     | <i>Macrobrachium villosimanus</i>   | 1.9           | 2.51         | <i>Macrobrachium kistnense</i>    | SHRMP060-25       | 13.77          |
| 10    | <i>Nematopalaemon tenuipes</i>      | N/A           | 0            | <i>Macrobrachium kistnense</i>    | SHRMP066-25       | 23.85          |
| 11    | <i>Palaemon adspersus</i>           | N/A           | 0            | <i>Penaeus indicus</i>            | GBCM23993-19      | 20.64          |
| 12    | <i>Palaemon carinicauda</i>         | N/A           | 0            | <i>Palaemon styliferus</i>        | GBMNC68680-20     | 8.28           |
| 13    | <i>Palaemon styliferus</i>          | 2.39          | 3.02         | <i>Palaemon carinicauda</i>       | GBCM23990-19      | 8.28           |
| 14    | <i>Ganjampenaeopsis uncta</i>       | N/A           | 0            | <i>Penaeus indicus</i>            | GBCM23993-19      | 22.62          |
| 15    | <i>Metapenaeopsis stridulans</i>    | N/A           | 0            | <i>Metapenaeopsis toloensis</i>   | SHRMP052-25       | 12.64          |
| 16    | <i>Metapenaeopsis toloensis</i>     | N/A           | 0            | <i>Metapenaeopsis stridulans</i>  | SHRMP053-25       | 12.64          |
| 17    | <i>Metapenaeus affinis</i>          | N/A           | 0            | <i>Metapenaeus ensis</i>          | GBCM23996-19      | 0.49           |
| 18    | <i>Metapenaeus brevicornis</i>      | 1.4           | 1.4          | <i>Metapenaeus lysianassa</i>     | SHRMP065-25       | 14.19          |
| 19    | <i>Metapenaeus ensis</i>            | 1.72          | 1.72         | <i>Metapenaeus affinis</i>        | SHRMP059-25       | 0.49           |
| 20    | <i>Metapenaeus lysianassa</i>       | N/A           | 0            | <i>Metapenaeus brevicornis</i>    | GBMND16790-21     | 14.19          |
| 21    | <i>Mierspenaeopsis hardwickii</i>   | N/A           | 0            | <i>Mierspenaeopsis sculptilis</i> | GBCM23995-19      | 8.44           |
| 22    | <i>Mierspenaeopsis sculptilis</i>   | 0.06          | 0.17         | <i>Mierspenaeopsis hardwickii</i> | GBCM23999-19      | 8.44           |
| 23    | <i>Parapenaeopsis coromandelica</i> | N/A           | 0            | <i>Mierspenaeopsis sculptilis</i> | GBCM23995-19      | 74.46          |
| 24    | <i>Penaeus indicus</i>              | N/A           | 0            | <i>Penaeus merguensis</i>         | GBMND16798-21     | 5.39           |
| 25    | <i>Penaeus merguensis</i>           | N/A           | 0            | <i>Penaeus indicus</i>            | GBCM23993-19      | 5.39           |
| 26    | <i>Penaeus monodon</i>              | 0.49          | 0.49         | <i>Penaeus indicus</i>            | GBCM23993-19      | 13.88          |
| 27    | <i>Penaeus semisulcatus</i>         | N/A           | 0            | <i>Penaeus monodon</i>            | GBCM23998-19      | 15.81          |

#### 4.2.4 Phylogenetic Analysis and Species Delineation

The phylogenetic tree generated from COI gene sequences using Neighbor-Joining (NJ) methods successfully delineates the evolutionary relationships among shrimp taxa, forming distinct clades with varying degrees of bootstrap support (Figure 74). The dataset included 136 conservative sites, 561 variable sites, and 321 parsimony-informative sites. The tree includes representatives from multiple families, with strong clustering patterns supporting the taxonomic classification of the analyzed specimens.

Within Palaemonidae, the genus *Macrobrachium* forms a well-supported monophyletic group with high bootstrap values (>90%) for most species clusters, although certain *Macrobrachium* specimens exhibit paraphyly, indicating possible cryptic diversity or taxonomic misidentification. Samples of *M. kistnense* form a strong cluster with high bootstrap value (>80%). Another three *Macrobrachium* species, *M. rosenbergii*, *M. villosimanus* and *M. lamarrei* are closely clustered, but the relationship has low statistical value. High intraspecific genetic divergence among some *Macrobrachium* spp. suggests the presence of unrecognized species or significant population structuring. *M. neglectum* and *M. nipponense* form a single cluster with 88% bootstrap support. Other species of the family Palaemonidae (*P. adspersus*, *P. carinicauda* and *P. styliferus*), forms well-supported clades with high bootstrap values more than 88% (88-99%).

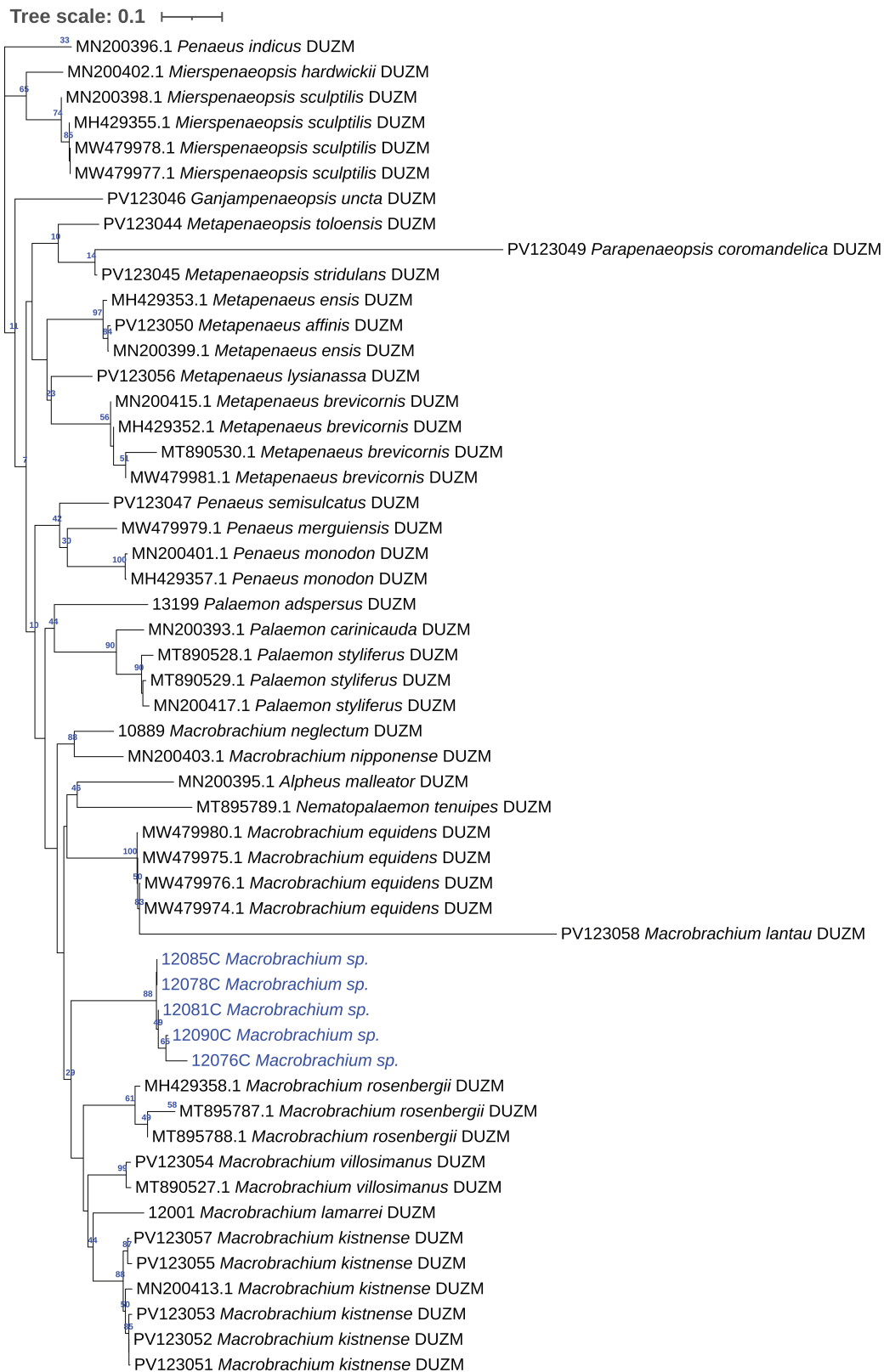
In Penaeidae, *Penaeus* and other penaeid shrimp form a distinct, strongly supported clade (bootstrap values >95%), confirming their evolutionary separation from Palaemonidae, with genetic distances between *Penaeus* spp. being higher compared to intra-genus variation in *Macrobrachium*, reflecting their distinct evolutionary histories.

*Penaeus indicus* forms a strongly supported clade (bootstrap ~100) with *Mierspenaeopsis hardwickii* and *Mierspenaeopsis sculptilis*, confirming their close evolutionary ties. *Metapenaeopsis toloensis* is highly supported (~97-100) as part of a subgroup with *Metapenaeopsis stridulans*, *Metapenaeus ensis*, and *Metapenaeus brevicornis*, indicating a well-defined evolutionary lineage. Additionally, *Metapenaeus brevicornis* and *Metapenaeus ensis* share a bootstrap value of 100, reinforcing their close relationship. *Penaeus monodon* and *Penaeus merguensis* also exhibit a strong genetic connection (bootstrap 98), suggesting a recent common ancestor. The

*Parapenaeopsis coromandelica* is distinctly separated (bootstrap 100), reflecting its early divergence from the main penaeid lineage.

Other shrimp families cluster into separate clades with moderate to high bootstrap support (>80%), and their branching order aligns with known phylogenies, reinforcing the reliability of COI as a genetic marker for species differentiation. Most major clades are well-supported, with bootstrap values exceeding 80%, ensuring the robustness of the phylogenetic relationships, while some deeper branches exhibit lower bootstrap values (<70%), suggesting areas where additional genetic markers could improve resolution. The presence of strong support for monophyly in multiple families further validates the effectiveness of COI for taxonomic classification.





**Figure 75.** Phylogenetic tree of shrimp species based on COI gene sequences, analyzed using the Neighbor-Joining (NJ) method in MEGA 12 and visualized in iTOL v5. All sequences were generated in the present study.

### 4.3 16S rRNA gene

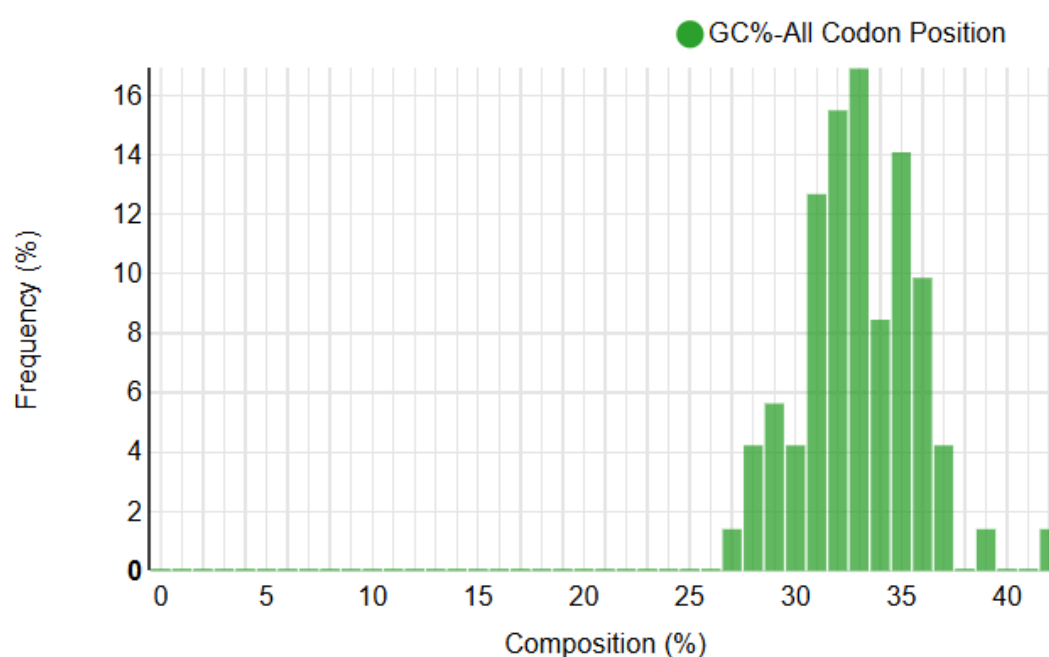
#### 4.3.1 Nucleotide composition

A total of 72 sequences of the 16S rRNA gene were successfully generated, representing 32 identified species, with two classified only at the genus level. The lengths of the barcode sequences ranged from 311 to 562 base pairs (bp), with an average length of 440 bp. Notably, no stop codons, insertions, or deletions were detected in any of the sequences.

The final dataset consisted of 881 nucleotide positions, comprising 101 conserved sites, 583 variable sites, 372 parsimony-informative sites, and 176 singleton sites. The nucleotide composition frequencies were determined as follows: G = 21.70±0.27%, C = 11.79±0.16%, A = 31.49±0.25%, and T = 35.02±0.19% (Table 8). The AT content (66.51%) was significantly higher than the GC content (33.49±0.32%). A graphical representation of GC composition across codon positions is provided in Figure 75.

**Table 8. Composition Summary Statistics for nucleotide frequency distribution**

|             | <u>Min</u> | <u>Mean</u> | <u>Max</u> | <u>SE</u> |
|-------------|------------|-------------|------------|-----------|
| <b>G %</b>  | 12.89      | 21.70       | 27.98      | 0.2718    |
| <b>C %</b>  | 9.25       | 11.79       | 17.24      | 0.1652    |
| <b>A %</b>  | 26.54      | 31.49       | 35.57      | 0.2465    |
| <b>T %</b>  | 31.28      | 35.02       | 38.27      | 0.1884    |
| <b>GC %</b> | 27.55      | 33.49       | 42.18      | 0.3213    |



**Figure 75.** Distribution graphs for the GC composition by codon position

### 4.3.2 Genetic divergence

The average genetic distance within species, genus and family was found to be  $2.94 \pm 0.09$ ,  $13.91 \pm 0.06$  and  $25.26 \pm 0.04$ , respectively (Table 9). Mean inter-species distance was found to be 43.85.

**Table 9. Distribution of sequence divergence at each taxonomic level**

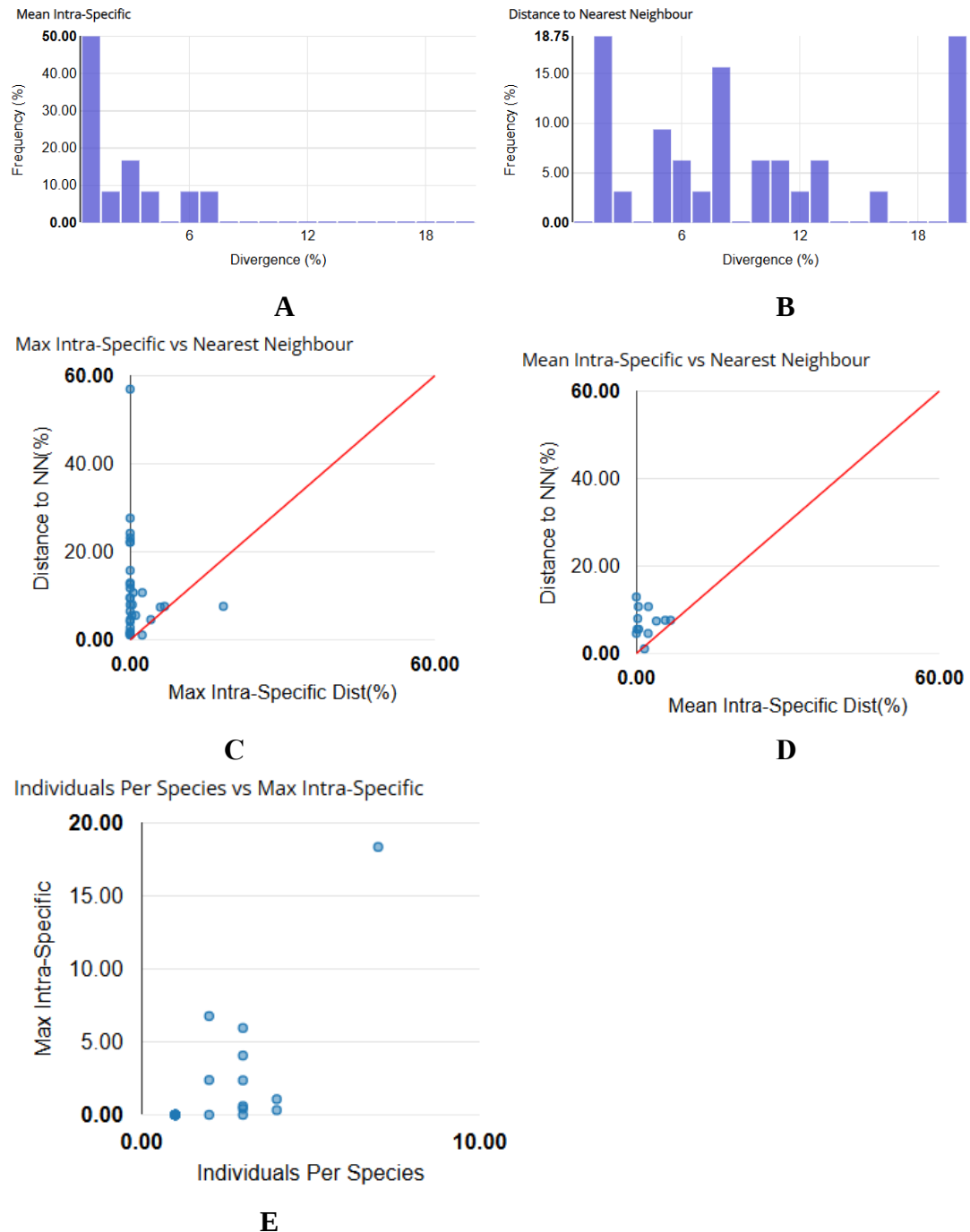
| Label          | n  | Taxa | Comparisons | Min Dist(%) | Mean Dist(%) | Max Dist(%) | SE Dist(%) |
|----------------|----|------|-------------|-------------|--------------|-------------|------------|
| Within Species | 39 | 12   | 54          | 0.00        | 2.94         | 18.35       | 0.09       |
| Within Genus   | 50 | 7    | 178         | 1.08        | 13.91        | 75.00       | 0.06       |
| Within Family  | 53 | 2    | 504         | 1.27        | 25.26        | 75.00       | 0.04       |

### 4.3.3 Barcode gap analyses

The barcode gap analysis was conducted using the K2P distance model by comparing the mean intraspecific and interspecific variations with the nearest-neighbor distance. For each species, both the mean and maximum intraspecific distances were assessed against the nearest-neighbor distance (Table 10). Singleton species, for which intraspecific comparisons were not applicable, were marked as "N/A."

Distances were flagged as a warning if the nearest neighbor exhibited less than 2% divergence or if the distance to the nearest neighbor was smaller than the maximum intraspecific distance. The comparison results for singleton species were excluded due to the inapplicability of the data in these calculations. The K2P distance analysis identified nine species with both maximum and mean intraspecific distances exceeding those of their nearest neighboring species.

The mean interspecific distance (43.85) was found to be 15 times greater than the intraspecific distance, resulting in a barcode gap of 40.91. To further illustrate the presence and magnitude of the barcode gap, two scatter plots are provided, showing the overlap between maximum and mean intraspecific distances compared to interspecific (nearest-neighbor) distances (Figure 76 C and D). Another scatter plot was generated, illustrating the individuals per species vs max intra specific distance (Figure 76 E). A comprehensive summary of barcode gap comparisons across all identified shrimp species is presented in Table 10.



**Figure 76.** Results of genetic distance obtained from BOLD under K2-parameter model using 16S rRNA gene sequences; **A.** Mean intra sequence divergence **B.** Distance to nearest-neighbor species based on sequence divergence **C.** Comparison of maximum intraspecific variation and distance to nearest-neighbor species **D.** Comparison of mean intraspecific variation and distance to nearest-neighbor species **E.** Comparison of individuals per species and max-intraspecific distance

**Table 10.** Summary of Mean-Max intraspecific variation in each shrimp species and the distance to nearest-neighbor species (warning values are highlighted)

| SL No | Family        | Species                             | Mean Intra-Sp | Max Intra-Sp | Nearest Neighbour | Nearest Species                     | Distance to NN |
|-------|---------------|-------------------------------------|---------------|--------------|-------------------|-------------------------------------|----------------|
| 1     | Alpheidae     | <i>Alpheus euphrosyne</i>           | N/A           | 0            | SHRMP080-25       | <i>Alpheus malleator</i>            | 22.19          |
| 2     | Alpheidae     | <i>Alpheus malleator</i>            | N/A           | 0            | SHRMP073-25       | <i>Alpheus euphrosyne</i>           | 22.19          |
| 3     | Palaemonidae  | <i>Macrobrachium equidens</i>       | 5.72          | 18.35        | SHRMP045-23       | <i>Macrobrachium lantau</i>         | 7.61           |
| 4     | Palaemonidae  | <i>Macrobrachium lamarrei</i>       | 0.4           | 0.6          | SHRMP039-23       | <i>Macrobrachium rosenbergii</i>    | 10.72          |
| 5     | Palaemonidae  | <i>Macrobrachium lantau</i>         | 6.77          | 6.77         | SHRMP016-23       | <i>Macrobrachium equidens</i>       | 7.61           |
| 6     | Palaemonidae  | <i>Macrobrachium neglectum</i>      | N/A           | 0            | SHRMP016-23       | <i>Macrobrachium equidens</i>       | 15.77          |
| 7     | Palaemonidae  | <i>Macrobrachium rosenbergii</i>    | 2.38          | 2.38         | SHRMP029-23       | <i>Macrobrachium lamarrei</i>       | 10.72          |
| 8     | Palaemonidae  | <i>Macrobrachium rude</i>           | N/A           | 0            | SHRMP026-23       | <i>Macrobrachium equidens</i>       | 11.75          |
| 9     | Palaemonidae  | <i>Nematopalaemon tenuipes</i>      | N/A           | 0            | SHRMP071-25       | <i>Macrobrachium neglectum</i>      | 23.16          |
| 10    | Palaemonidae  | <i>Palaemon adspersus</i>           | N/A           | 0            | SHRMP018-23       | <i>Macrobrachium equidens</i>       | 24.2           |
| 11    | Palaemonidae  | <i>Palaemon styliferus</i>          | N/A           | 0            | SHRMP082-25       | <i>Palaemon adspersus</i>           | 27.64          |
| 12    | Penaeidae     | <i>Ganjampenaeopsis uncta</i>       | N/A           | 0            | SHRMP078-25       | <i>Parapenaeopsis coromandelica</i> | 9.53           |
| 13    | Penaeidae     | <i>Kishinouyepenaeopsis incisa</i>  | N/A           | 0            | SHRMP008-23       | <i>Parapenaeopsis stylifera</i>     | 7.99           |
| 14    | Penaeidae     | <i>Melicertus canaliculatus</i>     | N/A           | 0            | SHRMP009-23       | <i>Penaeus pulchricaudatus</i>      | 1.27           |
| 15    | Penaeidae     | <i>Metapenaeopsis stridulans</i>    | N/A           | 0            | SHRMP044-23       | <i>Penaeus indicus</i>              | 12.6           |
| 16    | Penaeidae     | <i>Metapenaeus affinis</i>          | 0             | 0            | SHRMP036-23       | <i>Metapenaeus ensis</i>            | 4.59           |
| 17    | Penaeidae     | <i>Metapenaeus brevicornis</i>      | N/A           | 0            | SHRMP042-23       | <i>Metapenaeus tenuipes</i>         | 1.78           |
| 18    | Penaeidae     | <i>Metapenaeus ensis</i>            | 2.33          | 4.06         | SHRMP012-23       | <i>Metapenaeus affinis</i>          | 4.59           |
| 19    | Penaeidae     | <i>Metapenaeus lysianassa</i>       | N/A           | 0            | SHRMP042-23       | <i>Metapenaeus tenuipes</i>         | 2.75           |
| 20    | Penaeidae     | <i>Metapenaeus tenuipes</i>         | N/A           | 0            | SHRMP002-23       | <i>Metapenaeus brevicornis</i>      | 1.78           |
| 21    | Penaeidae     | <i>Mierspenaeopsis hardwickii</i>   | 0.16          | 0.32         | SHRMP048-23       | <i>Mierspenaeopsis sculptilis</i>   | 5.55           |
| 22    | Penaeidae     | <i>Mierspenaeopsis sculptilis</i>   | 0.46          | 1.07         | SHRMP049-23       | <i>Mierspenaeopsis hardwickii</i>   | 5.55           |
| 23    | Penaeidae     | <i>Parapenaeopsis coromandelica</i> | N/A           | 0            | SHRMP079-25       | <i>Ganjampenaeopsis uncta</i>       | 9.53           |
| 24    | Penaeidae     | <i>Parapenaeopsis stylifera</i>     | 0.28          | 0.42         | SHRMP047-23       | <i>Kishinouyepenaeopsis incisa</i>  | 7.99           |
| 25    | Penaeidae     | <i>Penaeus indicus</i>              | 1.61          | 2.36         | SHRMP010-23       | <i>Penaeus merguensis</i>           | 1.08           |
| 26    | Penaeidae     | <i>Penaeus japonicus</i>            | N/A           | 0            | SHRMP009-23       | <i>Penaeus pulchricaudatus</i>      | 4.14           |
| 27    | Penaeidae     | <i>Penaeus merguensis</i>           | N/A           | 0            | SHRMP051-23       | <i>Penaeus indicus</i>              | 1.08           |
| 28    | Penaeidae     | <i>Penaeus monodon</i>              | 3.97          | 5.95         | SHRMP010-23       | <i>Penaeus merguensis</i>           | 7.43           |
| 29    | Penaeidae     | <i>Penaeus pulchricaudatus</i>      | N/A           | 0            | SHRMP081-25       | <i>Melicertus canaliculatus</i>     | 1.27           |
| 30    | Penaeidae     | <i>Penaeus semisulcatus</i>         | N/A           | 0            | SHRMP044-23       | <i>Penaeus indicus</i>              | 6.47           |
| 31    | Sergestidae   | <i>Acetes indicus</i>               | N/A           | 0            | SHRMP032-23       | <i>Mierspenaeopsis hardwickii</i>   | 56.95          |
| 32    | Solenoceridae | <i>Solenocera crassicornis</i>      | 0             | 0            | SHRMP076-25       | <i>Penaeus semisulcatus</i>         | 12.94          |

#### 4.3.4 Phylogenetic Analysis and Species Delineation

The phylogenetic tree constructed using Neighbor-Joining (NJ) methods represents the evolutionary relationships among various shrimp species based on 16S rRNA gene sequences, with bootstrap values indicating the confidence level of each clade (Figure 77).

Within the Penaeidae family, *Penaeus monodon* forms a strongly supported clade with *Penaeus canaliculatus* and *Penaeus japonicus* (bootstrap ~100), confirming their close evolutionary ties. *Penaeus indicus* is closely grouped with *Penaeus merguensis* (bootstrap ~100), further supporting their genetic similarity. *Metapenaeus ensis* and *Metapenaeus affinis* exhibit a well-supported relationship (bootstrap ~100), indicating a shared evolutionary lineage. *Mierspenaeopsis hardwickii* and *Mierspenaeopsis sculptilis* form a highly supported cluster (~98-100), confirming their distinct placement within the family. *Parapenaeopsis coromandelica* and *Ganjampenaeopsis uncta* act as outgroup representatives, displaying early divergence from other Penaeid species.

Within the Palaemonidae family, *Palaemon styliferus* and *P. adspersus* show moderate support (~82), indicating their evolutionary relationship, though with potential genetic variability. *Nematopalaemon tenuipes* clusters closely with them, but with slightly lower support, suggesting a less stable classification. *Leptocarpus potamiscus* forms a distinct group, highlighting its divergence from other Palaemonid species.

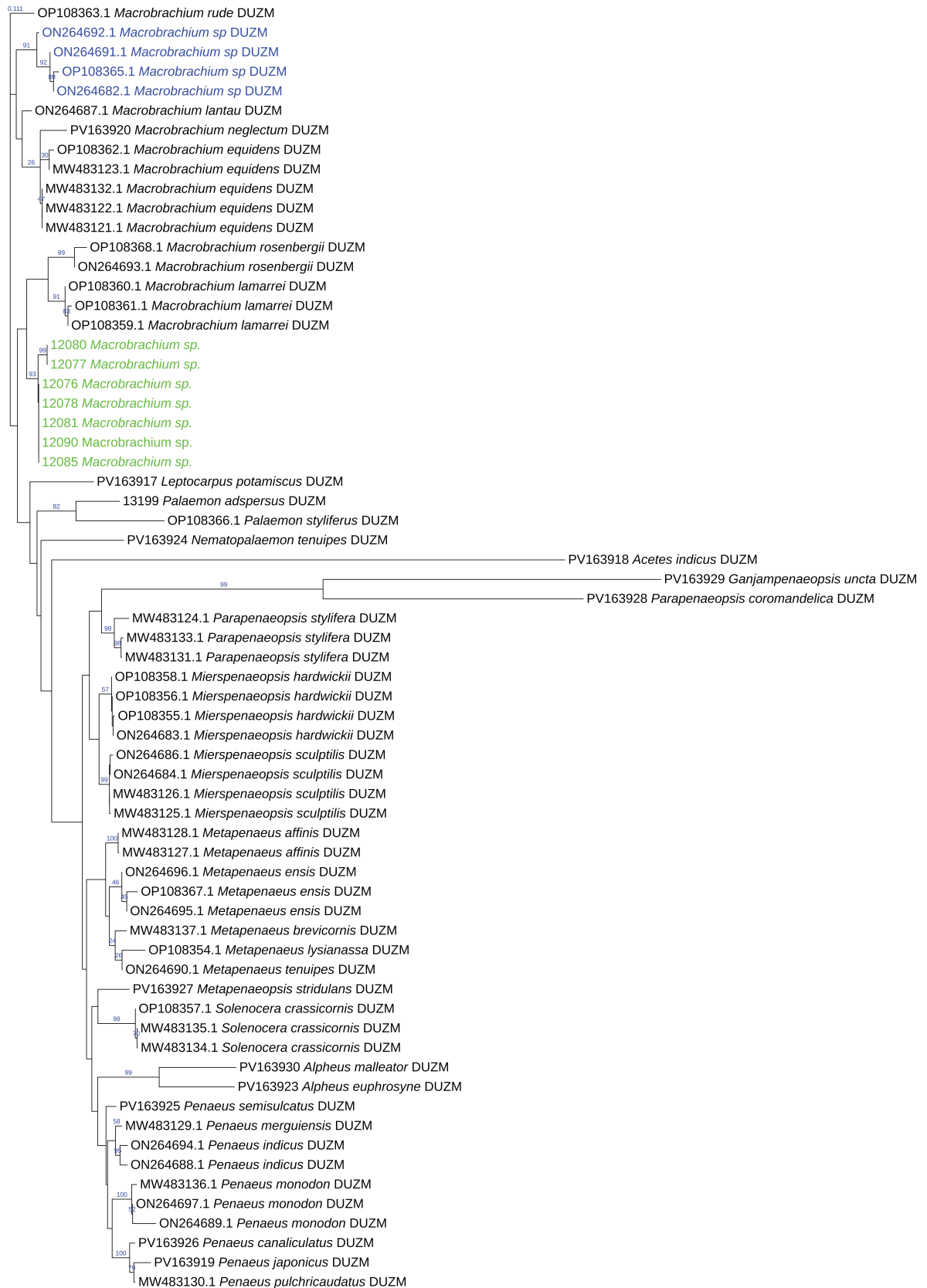
The *Macrobrachium* genus (Family Palaemonidae) displays varied support values. *M. equidens* forms a highly supported clade (~100), indicating strong genetic similarity among its sampled individuals. *M. rosenbergii* and *M. lamarrei* also show high bootstrap support (~98-100), affirming their evolutionary distinctiveness. However, the unidentified *Macrobrachium* sp. samples (12076, 12077, 12078, 12080, 12081, 12085, 12090) form a moderately supported cluster (~70-85), suggesting cryptic species or unresolved taxonomy. Another unidentified *Macrobrachium* sp. samples (ON264682, ON264691, ON264692, OP108365) showed highly supported cluster (89-92).

Beyond the *Macrobrachium* genus, other shrimp families are represented in the tree. Each family forms distinct clusters, with moderate to high bootstrap values supporting

their monophyly. Some branches, however, exhibit lower bootstrap values (<70%), indicating uncertainty in specific relationships, which may be attributed to low sequence divergence or limited taxon sampling.

Overall, high bootstrap values in Penaeidae indicate strong evolutionary relationships among species, whereas Palaemonidae exhibits slightly weaker support, reflecting greater genetic diversity. The distinct placement of *Parapenaeopsis coromandelica* and *Ganjampenaeopsis uncta* like outgroups highlights their early divergence.

Tree scale: 0.1



**Figure 78.** Phylogenetic tree of shrimp species based on 16S rRNA gene sequences, analyzed using the Neighbor-Joining (NJ) method in MEGA 12 and visualized in iTOL v5. All sequences were generated in the present study.



## 5. Discussion

DNA barcoding is widely recognized as a rapid and reliable method for the accurate identification of species, including crustaceans, mollusks, fish, and other organisms, in various countries such as Bangladesh, Australia, China, Turkey, Malaysia, Vietnam, and India (Murphy and Austin, 2004; Zhang et al., 2009; Bilgil et al., 2015; Rajkumar et al., 2015; Ahmed et al., 2021a; Abdul Halim et al., 2023; Siriwtut et al., 2021). In this study, DNA barcoding was successfully used to generate 127 partial sequences from the COI and 16S rRNA genes. These molecular markers enabled the identification of 38 species from 10 genera and three families, demonstrating the effectiveness of DNA barcoding in species differentiation and enhancing taxonomic resolution. The analysis of these barcode sequences provided valuable insights into sequence length, nucleotide composition, and genetic divergence across different taxonomic levels. Notably, the absence of stop codons, insertions, or deletions confirmed that the sequences were intact and suitable for precise analysis, ensuring no disruptions that might impede accurate interpretation.

### 5.1 COI Gene Analysis

The analysis of the COI gene yielded 55 sequences corresponding to 29 species. The analyses of COI gene sequences found 136 conservative sites, 561 variable sites, and 321 parsimony-informative sites. The nucleotide composition frequencies were found to be: G = 18.55±0.24%, C = 22.31±0.33%, A = 27.90±0.21%, and T = 31.23±0.37% indicating the higher value of A and T. The nucleotide composition of these sequences exhibited a higher AT content (59.13%) compared to GC content (40.87%) which is similar to results found in Thailand (Siriwtut et al., 2021). This distribution aligns well with typical barcode sequences, suggesting a conserved region. The genetic divergence at different taxonomic levels revealed an average intraspecific divergence of 1.18%, while intraspecific distances at the genus and family levels were 23.53% (20.25% found by Siriwtut et al., 2021) and 28.29%, respectively. These values demonstrate the effectiveness of the COI gene as a reliable marker for species identification, with minimal overlap in genetic variation between taxonomic groups.

The barcode gap analysis further confirmed the utility of COI sequences, with clear distinctions observed between species. The barcode gap was found to be 38.54 which was 33-fold higher than the mean interspecific distance. In this study, the BIN

discordance function in BOLD served as an alert for taxa exhibiting low genetic distance in comparison to their nearest-neighbor species. For instance, the deposited COI sequences of *Metapenaeus affinis* and *M. ensis* exhibit genetic affinity and are possibly closely related species. However, certain species exhibited mean and maximum intraspecific distances higher than their nearest neighboring species. For example, *Parapenaeopsis coromandelica* and *Mierspenaeopsis sculptilis* showed higher level of distance (74.46). This phenomenon is necessitating further investigation into potential cryptic diversity or hybridization events.

The phylogenetic tree generated from COI gene sequences using the Neighbor-Joining (NJ) method effectively delineates evolutionary relationships among shrimp taxa, forming well-defined clades with varying levels of bootstrap support. The conservative sites, variable sites, and parsimony-informative sites, allowing for robust species classification. The inclusion of multiple shrimp families within the analysis enabled a comprehensive examination of genetic relationships and taxonomic placements.

In the phylogenetic tree, all the species belonging to the different families form distinct clades with varying degrees of bootstrap support. Bootstrap values (BP) represent the degree of support for each clade, with 100% indicating the highest level of confidence. Values between 95% and just under 100% suggest strong support, while those ranging from 75% to under 95% indicate moderate support. Bootstrap values between 50% and 75% reflect weak support, whereas values below 50% signify minimal or unreliable support.

Within Palaemonidae, *Macrobrachium* forms a monophyletic group (bootstrap >90%), though some species exhibit paraphyly, indicating cryptic diversity. *M. kistnense* clusters strongly (>80%), while *M. rosenbergii*, *M. villosimanus*, and *M. lamarrei* form a related group with lower support. Other species, including *P. adspersus* and *P. styliferus*, show strong clustering (88–99%). However, some species exhibit unexpectedly high intraspecific variation, which could indicate: possible cryptic species, hybridization events or geographic population structuring. *Parapenaeopsis coromandelica* and *Macrobrachium lantau* showed a larger branch length suggesting a greater amount of evolutionary change or divergence has occurred along that lineage. Some specimens are not identified upto species yet labeled as *Macrobrachium* sp that is closely related to *M. rosenbergii* need further analyses both morphology and molecular to confirm the species.

In Penaeidae, *Penaeus* species form a distinct clade (bootstrap >95%), with *P. indicus* clustering strongly (~100) with *Mierspenaeopsis hardwickii* and *M. sculptilis*. Close relationships exist between *Metapenaeus brevicornis* and *M. ensis* (bootstrap 100) and between *P. monodon* and *P. merguensis* (bootstrap 98). Other shrimp families form well-supported clades (>80%), confirming the robustness of COI for species delineation, though lower bootstrap values (<70%) in deeper branches suggest the need for additional genetic markers.

The COI marker proves reliable for species differentiation within Penaeidae, making it particularly useful for identifying commercially important shrimp species. From a taxonomic and conservation perspective, the phylogenetic tree suggests that some specimens currently classified as a single species may represent distinct evolutionary lineages, necessitating further taxonomic revision. Additionally, the high genetic variation detected within certain *Macrobrachium* species highlights potential cryptic diversity, emphasizing the need for an integrative taxonomic approach that combines molecular, morphological, and ecological data.

## 5.2 16S rRNA Gene Analysis

The study also generated 72 sequences from the 16S rRNA gene, which facilitated the identification of 32 species with an average sequence length of 440 bp. Notably, no stop codons, insertions, or deletions were observed in any of the obtained sequences. The absence of such disruptions confirms the integrity of the sequences, ensuring they are well-preserved and suitable for reliable analysis. The final dataset consisted of 881 positions, with 583 variable sites, 372 informative sites crucial for reconstructing evolutionary relationships, and 176 singletons contributing minimally to phylogenetic analysis. Similar to the COI results, the AT content (66.51%) was found to be higher than the GC content (33.49%). Genetic distance analysis revealed an average intraspecific divergence of 2.94%, with genus- and family-level divergences of 13.91% and 25.26%, respectively. These results are consistent with previous studies that highlight the conservative nature of the 16S rRNA gene at higher taxonomic levels, while still providing sufficient resolution for species-level differentiation.

The barcode gap analysis results for 16S sequences also showed that nine species exhibited higher intraspecific variation compared to their nearest neighboring species.

The barcode gap was found to be 40.91. The mean interspecies distance was 15-fold higher than intraspecies distances.

The overall tree topology highlights the evolutionary divergence of shrimp families and genera, with well-supported major clades and some areas of weak resolution. The tree also shows a close relationship among certain species, with low genetic distances separating them. This suggests the presence of recently diverged species or ongoing gene flow. However, the high bootstrap values provide strong support for most species-level identifications, reinforcing the reliability of the molecular markers used in this study. The presence of strong support for monophyly in multiple families further validates the effectiveness of 16S for taxonomic classification.

### **5.3 Comparative Analysis and Implications**

The combined results from COI and 16S rRNA genes provide a robust framework for species identification. The barcode gap analysis for both markers demonstrated distinct clustering of species, reinforcing the reliability of these genetic markers. However, discrepancies in genetic distances between closely related species highlight the need for additional markers or morphological verification in some cases. Notably, certain genera contained species with unresolved taxonomy, suggesting potential new or cryptic species that require further phylogenetic and morphological assessment. The study also identified species with unusually high intraspecific divergence, which may be indicative of population structuring or cryptic speciation.

The findings from this DNA barcoding study offer valuable insights into shrimp species diversity and genetic relationships. The successful identification of multiple species using COI and 16S rRNA markers underscores their effectiveness in molecular taxonomy. The phylogenetic analysis provides additional evidence for species boundaries and evolutionary relationships. Future studies should incorporate additional genetic markers, broader geographic sampling, and morphological verification to enhance species resolution and address unresolved taxonomic ambiguities. Overall, this study contributes to the growing body of knowledge supporting DNA barcoding as a powerful tool for biodiversity assessment and conservation management.

# **Conclusion and Recommendations**

## Conclusion

This study provides a thorough taxonomic analysis of shrimp species in Bangladesh, integrating both morphological identification and molecular techniques, such as DNA barcoding and phylogenetic analysis. A total of 50 shrimp species were identified morphologically, with 38 species and two genera further confirmed through molecular methods. The study revealed significant genetic divergence both within and between species, demonstrating the importance of molecular markers in taxonomy. The successful identification of multiple species using COI and 16S rRNA markers highlights their reliability and effectiveness in molecular taxonomy. Notably, the research identified 11 previously unrecorded species, significantly contributing to the understanding of Bangladesh's biodiversity. By combining molecular and morphological data, the study enhances knowledge of shrimp diversity, systematics, and phylogenetic relationships in the region. As the first comprehensive study to integrate morpho-taxonomy, molecular analysis, and phylogenetic relationships of shrimps in Bangladesh, this research emphasizes the critical need for conservation strategies to preserve the nation's rich shrimp diversity. Furthermore, the findings provide a strong foundation for future ecological and evolutionary research, offering valuable insights to inform conservation and policy decisions aimed at protecting these essential species.

## Recommendations

- Habitat destruction and over-exploitation of shrimp should be addressed to prevent local extinction.
- A national database for a reference library of shrimp should be developed and maintained by the concerned authorities.
- Develop a comprehensive pictorial guide featuring detailed illustrations and photographs of various shrimp species, highlighting their distinct characteristics, habitats, and ecological roles.
- Comprehensive DNA barcoding, combined with genomic sequencing, should be employed to increase the accuracy of species identification and understand the genetic structure of local shrimp populations.
- Next-generation sequencing (NGS) technologies, such as whole-genome sequencing or RAD-seq (Restriction site-associated DNA sequencing), could be applied to enable researchers to identify specific genetic markers, population structures, and adaptive traits linked to environmental factors.
- It is recommended to correlate genetic data with environmental parameters such as water quality, salinity, and habitat types in shrimp habitats. Understanding these correlations will help assess the impact of environmental stressors on shrimp populations and guide the establishment of protected areas or sustainable shrimp farming practices.
- Specific management programs, such as captive breeding, restocking, or habitat restoration, could be implemented for threatened species identified during the research.
- Promoting the use of locally adapted and genetically diverse shrimp populations for aquaculture could improve both the productivity and sustainability of the industry.
- Interdisciplinary approaches should be promoted to create integrated conservation and management plans, leveraging both scientific research and local knowledge.

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# Appendix

**Supplementary Table 1.** Checklist of the shrimps reported from Bangladesh

| SL No | Family       | Species                              | Ahmed et al., (2008) | IUCN BD 2015 | Hossain, (2013) | Paul, (2001) | Present Study |
|-------|--------------|--------------------------------------|----------------------|--------------|-----------------|--------------|---------------|
| 1     | Palaemonidae | <i>Macrobrachium equidens</i>        | +                    | +            |                 |              | +             |
| 2     | Palaemonidae | <i>Macrobrachium rosenbergii</i>     | +                    | +            | +               | +            | +             |
| 3     | Palaemonidae | <i>Macrobrachium lamarrei</i>        | +                    | +            | +               | +            | +             |
| 4     | Palaemonidae | <i>Macrobrachium rude</i>            | +                    | +            | +               | +            | +             |
| 5     | Palaemonidae | <i>Macrobrachium assamense</i>       |                      |              |                 |              | +             |
| 6     | Palaemonidae | <i>Macrobrachium birmanicum</i>      | +                    | +            |                 | +            | +             |
| 7     | Palaemonidae | <i>Macrobrachium dayanum</i>         | +                    | +            | +               | +            | +             |
| 8     | Palaemonidae | <i>Macrobrachium grandimanus</i>     |                      |              |                 |              | +             |
| 9     | Palaemonidae | <i>Macrobrachium scabriculum</i>     |                      |              | +               |              | +             |
| 10    | Palaemonidae | <i>Macrobrachium nipponense</i>      |                      |              |                 |              | +             |
| 11    | Palaemonidae | <i>Macrobrachium neglectum</i>       |                      |              |                 |              | +             |
| 12    | Palaemonidae | <i>Macrobrachium lantau</i>          |                      |              |                 |              | +             |
| 13    | Palaemonidae | <i>Macrobrachium lar</i>             | +                    | +            |                 |              | +             |
| 14    | Palaemonidae | <i>Macrobrachium malcomsonii.</i>    | +                    | +            | +               | +            | +             |
| 15    | Palaemonidae | <i>Macrobrachium kistnense</i>       |                      |              |                 |              | +             |
| 16    | Palaemonidae | <i>Macrobrachium dolichodactylus</i> | +                    | +            |                 | +            | +             |
| 17    | Palaemonidae | <i>Macrobrachium villosimanus</i>    | +                    | +            | +               | +            | +             |
| 18    | Palaemonidae | <i>Macrobrachium idella</i>          | +                    | +            | +               | +            |               |
| 19    | Palaemonidae | <i>Macrobrachium lancesteri</i>      |                      | +            | +               | +            |               |
| 20    | Palaemonidae | <i>Macrobrachium kemp</i>            |                      |              |                 |              |               |
| 21    | Palaemonidae | <i>Macrobrachium superbum</i>        |                      |              |                 |              |               |
| 22    | Palaemonidae | <i>Macrobrachium choprai*</i>        |                      |              | +               |              |               |
| 23    | Palaemonidae | <i>Macrobrachium idae</i>            |                      |              | +               |              |               |
| 24    | Palaemonidae | <i>Tenuipedium palaemonoides</i>     |                      |              | +               |              |               |
| 25    | Palaemonidae | <i>Arachnochium mirabile</i>         | +                    | +            | +               | +            | +             |
| 26    | Palaemonidae | <i>Leptocarpus potamiscus</i>        | +                    | +            | +               | +            | +             |

| SL No | Family       | Species                              | Ahmed et al., (2008) | IUCN BD 2015 | Hossain, (2013) | Paul, (2001) | Present Study |
|-------|--------------|--------------------------------------|----------------------|--------------|-----------------|--------------|---------------|
| 27    | Palaemonidae | <i>Leptocarpus fluminicola</i>       |                      |              | +               | +            |               |
| 28    | Palaemonidae | <i>Palaemon styliferus</i>           | +                    | +            | +               | +            | +             |
| 29    | Palaemonidae | <i>Palaemon carinicauda</i>          |                      |              |                 |              | +             |
| 30    | Palaemonidae | <i>Palaemon adspersus</i>            |                      |              |                 |              | +             |
| 31    | Palaemonidae | <i>Palaemon serrifer</i>             |                      | +            | +               | +            |               |
| 32    | Palaemonidae | <i>Palaemon modestus</i>             |                      | +            | +               |              |               |
| 33    | Palaemonidae | <i>Nematopalaemon karnafuliensis</i> | +                    | +            | +               | +            |               |
| 34    | Palaemonidae | <i>Nematopalaemon tenuipes</i>       | +                    | +            | +               | +            | +             |
| 35    | Palaemonidae | <i>Leandrites celebensis</i>         | +                    | +            |                 | +            |               |
| 36    | Penaeidae    | <i>Penaeus merguensis</i>            | +                    | +            | +               | +            | +             |
| 37    | Penaeidae    | <i>Penaeus pulchricaudatus</i>       |                      |              |                 |              | +             |
| 38    | Penaeidae    | <i>Penaeus japonicus</i>             | +                    | +            | +               | +            | +             |
| 39    | Penaeidae    | <i>Penaeus monodon</i>               | +                    | +            | +               | +            | +             |
| 40    | Penaeidae    | <i>Penaeus semisulcatus</i>          | +                    | +            | +               | +            | +             |
| 41    | Penaeidae    | <i>Penaeus indicus</i>               | +                    | +            | +               | +            | +             |
| 42    | Penaeidae    | <i>Penaeus canaliculatus</i>         | +                    | +            | +               | +            | +             |
| 43    | Penaeidae    | <i>Penaeus penicillatus</i>          | +                    | +            | +               | +            |               |
| 44    | Penaeidae    | <i>Penaeus latisulcatus</i>          | +                    | +            |                 |              |               |
| 45    | Penaeidae    | <i>Penaeus chinensis</i>             |                      |              | +               | +            |               |
| 46    | Penaeidae    | <i>Trachysalambria curvirostris</i>  | +                    | +            | +               | +            |               |
| 47    | Penaeidae    | <i>Metapenaeus brevicornis</i>       | +                    | +            | +               | +            | +             |
| 48    | Penaeidae    | <i>Metapenaeus affinis</i>           | +                    | +            | +               | +            | +             |
| 49    | Penaeidae    | <i>Metapenaeus tenuipes</i>          | +                    | +            | +               | +            | +             |
| 50    | Penaeidae    | <i>Metapenaeus ensis</i>             | +                    | +            |                 |              | +             |
| 51    | Penaeidae    | <i>Metapenaeus lysianassa</i>        | +                    | +            | +               | +            | +             |
| 52    | Penaeidae    | <i>Metapenaeus dobsoni</i>           | +                    | +            | +               | +            |               |
| 53    | Penaeidae    | <i>Metapenaeus monoceros</i>         | +                    | +            | +               | +            |               |

| SL No | Family        | Species                             | Ahmed et al., (2008) | IUCN BD 2015 | Hossain, (2013) | Paul, (2001) | Present Study |
|-------|---------------|-------------------------------------|----------------------|--------------|-----------------|--------------|---------------|
| 54    | Penaeidae     | <i>Metapenaeopsis stridulans</i>    | +                    | +            | +               | +            | +             |
| 55    | Penaeidae     | <i>Metapenaeopsis toloensis</i>     |                      |              |                 |              | +             |
| 56    | Penaeidae     | <i>Metapenaeopsis andamanensis</i>  |                      | +            | +               | +            |               |
| 57    | Penaeidae     | <i>Mierspenaeopsis sculptilis</i>   | +                    | +            | +               | +            | +             |
| 58    | Penaeidae     | <i>Mierspenaeopsis hardwickii</i>   | +                    | +            | +               | +            | +             |
| 59    | Penaeidae     | <i>Parapenaeopsis stylifera</i>     | +                    | +            | +               | +            | +             |
| 60    | Penaeidae     | <i>Parapenaeopsis coromandelica</i> | +                    | +            |                 | +            | +             |
| 61    | Penaeidae     | <i>Parapenaeopsis incisa</i>        |                      |              |                 |              | +             |
| 62    | Penaeidae     | <i>Parapenaeopsis maxillipedo</i>   | +                    | +            |                 |              |               |
| 63    | Penaeidae     | <i>Parapenaeopsis cornuta</i>       |                      |              | +               | +            |               |
| 64    | Penaeidae     | <i>Batepenaeopsis tenella</i>       |                      |              | +               |              |               |
| 65    | Penaeidae     | <i>Ganjampenaeopsis uncta</i>       | +                    | +            | +               | +            | +             |
| 66    | Sergestidae   | <i>Acetes indicus</i>               | +                    | +            | +               | +            | +             |
| 67    | Sergestidae   | <i>Acetes japonicus</i>             | +                    | +            | +               | +            |               |
| 68    | Sergestidae   | <i>Acetes erythraeus</i>            | +                    | +            | +               | +            |               |
| 69    | Sergestidae   | <i>Acetes chinensis</i>             | +                    | +            | +               | +            |               |
| 70    | Sergestidae   | <i>Acetes intermedius</i>           |                      | +            | +               | +            |               |
| 71    | Sergestidae   | <i>Acetes vulgaris</i>              |                      | +            | +               |              |               |
| 72    | Solenoceridae | <i>Solenocera crassicornis</i>      | +                    | +            | +               | +            | +             |
| 73    | Solenoceridae | <i>Solenocera choprai</i>           |                      |              |                 |              | +             |
| 74    | Solenoceridae | <i>Solenocera hextii</i>            | +                    | +            | +               | +            |               |
| 75    | Solenoceridae | <i>Solenocera indica</i>            | +                    | +            |                 | +            |               |
| 76    | Solenoceridae | <i>Solenocera melantho</i>          | +                    | +            | +               | +            |               |
| 77    | Alpheidae     | <i>Alpheus microrhynchus</i>        |                      |              |                 |              | +             |
| 78    | Alpheidae     | <i>Alpheus malleator</i>            |                      |              |                 |              | +             |
| 79    | Alpheidae     | <i>Alpheus euphrosyne</i>           | +                    | +            | +               | +            | +             |
| 80    | Lysmatidae    | <i>Exhippolysmata ensirostris</i>   | +                    | +            | +               | +            |               |

| SL No                   | Family       | Species                        | Ahmed et al., (2008) | IUCN BD 2015 | Hossain, (2013) | Paul, (2001) | Present Study |
|-------------------------|--------------|--------------------------------|----------------------|--------------|-----------------|--------------|---------------|
| 81                      | Lysmatidae   | <i>Lysmata vittata</i>         |                      | +            | +               | +            |               |
| 82                      | Hippolytidae | <i>Latreutes anoplonyx</i>     |                      |              |                 | +            |               |
| 83                      | Atyidae      | <i>Caridina propinqua</i>      | +                    | +            | +               | +            | +             |
| 84                      | Atyidae      | <i>Caridina gracilirostris</i> | +                    | +            | +               | +            |               |
| 85                      | Atyidae      | <i>Caridina weberi</i>         | +                    | +            |                 |              |               |
| 86                      | Atyidae      | <i>Caridina nilotica</i>       |                      |              | +               | +            |               |
| 87                      | Atyidae      | <i>Atyopsis spinipes</i>       | +                    | +            |                 |              |               |
| 88                      | Pandalidae   | <i>Heterocarpus woodmasoni</i> | +                    | +            | +               | +            |               |
| 89                      | Pandalidae   | <i>Heterocarpus gibbosus</i>   |                      | +            | +               | +            |               |
| 90                      | Pandalidae   | <i>Plesionika martia</i>       |                      | +            | +               | +            |               |
| Number of total species |              |                                | 55                   | 64           | 61              | 63           | 50            |

\**Trachypenaues curvirostris* **unaccepted > superseded combination** *Trachysalambria curvirostris* (Stimpson, 1860) (Accepted)

\**Penaeus orientalis* **unaccepted > junior subjective** synonym *Penaeus chinensis* (Osbeck, 1765) (Accepted)

\**Solenocera subnuda* **unaccepted > junior subjective synonym** *Solenocera crassicornis* (H. Milne Edwards, 1837) (Accepted)

\**Macrobrachium dayanus* (IUCN, 2015) **would be** *Macrobrachium dayanum* (Henderson, 1893) (Accepted)

\* *Macrobrachium choprai* **unaccepted > junior subjective synonym** *Macrobrachium gangeticum* Spence Bate, 1868 (Accepted)

\* *Macrobrachium palaemonoides* **unaccepted > superseded combination** *Tenuipedium palaemonoides* (Holthuis, 1950) (Accepted)

\**Metapenaeus spinulatus* **unaccepted > junior subjective synonym** *Metapenaeus tenuipes* Kubo, 1949 (Accepted)

\**Parapenaeopsis stylifera stylifera* **unaccepted > superseded combination** *Parapenaeopsis stylifera* (H. Milne Edwards, 1837) (Accepted)

\**Parapenaeopsis tenella* **unaccepted > superseded combination** *Batepenaeopsis tenella* (Spence Bate, 1888) (Accepted)