



TAXONOMIC REVIEW OF GENUS *METAPENAEUS* WOOD-MASON, 1891 FROM INDIAN WATERS USING MORPHOLOGICAL AND MOLECULAR TOOLS

Dissertation submitted in partial fulfillment
of the requirements
for the degree of

M.F.Sc. (Fisheries Resource Management)

By

**Mr. Chennuri Sathish, B.F.Sc.
(FRM- MA5 -05)**

ICAR- CENTRAL INSTITUTE OF FISHERIES EDUCATION

(University under UGC Sec 3 of UGC Act 1956)

Panchmarg, Off Yari Road, Versova

Andheri (W), Mumbai – 400 061

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DECLARATION

I hereby declare that the dissertation entitled **“TAXONOMIC REVIEW OF GENUS *METAPENAEUS* WOOD-MASON, 1891 FROM INDIAN WATERS USING MORPHOLOGICAL AND MOLECULAR TOOLS”** is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

Date: 30 June, 2017

Place: Mumbai

(CHENNURI SATHISH)

M. F. Sc. Student
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मेटपेनियस वर्ग की कुल 9 प्रजातियां एम. एफिनिसमिलने एडवर्ड्स) , (1837, एम. अल्कोकीजॉर्ज और राव) , (1966, एम. ब्रेविकोर्निसमिलने एडवर्ड्स) , (1837, एम. डोबसोनीमीर्स) , (1878, एम. एनसिसडी हान) , (1844 एम. कचेनसिस जॉर्ज और राव, (1966 , एम. लिसियानासाडी मैन) , (1888, एम. मोनोसेरोसफैब्रिकियस) , (1798 और एम. मोएबीकिशिनौये) , (1896, अगस्त, 2017 से अप्रैल 2017 के दौरान भारत के पूर्वी और पश्चिमी तट के विभिन्न लैंडिंग केंद्रों से एकत्रित की गईं । कुल माप 41 और 12 आकारिकी चर कारक विश्लेषण में आयत्त थे । कुल लंबाई के के सन्दर्भ में CL, CW, 6ASD, 1ILP, 3TLP, 3ILP, 4TLP और 4ILP 0.95 से अधिक के सहसंबंध गुणांक पाया गया था । 2PLP और 2FLP के लिए 0.9 से 0.95 तक सहसंबंध गुणांक देखा गया । गुणक के अपेक्षाकृत कम मूल्य (0.9) 5 TLP और 5 DLP के लिए पाये गए । प्रामाणिक चर के माध्यम से पता चलता है कि रूट 1 और 2 सफलतापूर्वक अधिकांश संबंधित प्रजातियों को पृथक करते हैं । कारक मैट्रिक्स ने 3 TLP और 5 DLP को रूट 1 के मुख्य योगदानकर्ता के रूप में दर्शाया, जबकि रूट 2 के लिए प्रमुख योगदानकर्ता 2 FLP और 4ILP थे, रूट 3 के लिए प्रमुख योगदानकर्ता 2 FLP और 3 FLP थे और चौथे रूट के लिए प्रमुख योगदानकर्ता 4TLP, 5TLP, 5DLP और 4ILP थे । चरणबद्ध भेदभावपूर्ण कार्य विश्लेषण, 8 प्रजातियों के 12 परिवर्तनशील चर के लिए किया गया था । वर्गीकरण आव्यूह ने प्रजातियों के बीच 100% वर्गीकरण दिखाया । रूट 1 और रूट 4 के बीच स्कैटर ग्राम से पता चलता है कि ज्यादातर प्रजातियों को 3TLP, 5DLP और 2FLP जैसे वर्णों के आधार पर अलग किया जा सकता है । वर्तमान अध्ययन के परिणाम इन संसाधनों के संवहनीय प्रबंधन में उपयोग किए जा सकते हैं । डीएनए बारकोडिंग जीनस मेटापिनास की सात प्रजातियों के लिए किया गया था डी.एन.ए. बारकोड पहली बार एम कुतेचेन्सिस और एम। एल्कोकी के लिए किया गया था। इसके अलावा , डीएनए बारकोडिंग और आकृति विज्ञान के आधार पर एक प्रजाति को विज्ञान के रूप में नया माना जाता है। आणविक अध्ययन के आधार पर सभी सात प्रजातियों को दूसरों से अलग किया गया था।

Abstract

A total of 9 species belongs to genus *Metapenaeus* were collected from different landing centres along the East and West coast of India during August 2016 to April 2017 and identified as *M. affinis* (Milne Edwards, 1837), *M. alcocki* (George and Rao, 1966), *M. brevicornis* (milne Edwards, 1837), *M. dobsoni* (Miers, 1878), *M. ensis* (De Haan, 1844), *M. kutchensis* (George, George and Rao), *M. lysianassa* (De man, 1888), *M. monoceros* (Fabricius, 1798) and *M. moyebi* (kishinouye, 1896). A total of 41 morphometric measurements were taken for all species. 12 morphometric variables showed high contribution in factor analysis. Correlation coefficient of more than 0.95 was observed for CL, CW, 6ASD, 1ILP, 3TLP, 3ILP, 4TLP and 4ILP with total length. Correlation coefficient ranging from 0.9 to 0.95 was observed for 2PLP and 2FLP. Relatively lower values of coefficients (0.9) were observed for 5TLP and 5DLP. The means of canonical variables shows that root 1 and 2 successfully discriminates between most of the concerned species. The factor matrix indicated 3TLP and 5DLP as main contributors to root1, whereas for root 2, major contributors were 2FLP, and 4ILP. While major contributors for third were 2FLP and 3TLP and contributors for fourth root were 4TLP, 5TLP, 5DLP and 4ILP. The stepwise discriminant function analysis was performed for 12 transformed variables of 8 species. Classification matrix showed 100% classification between the species. Scattergram between root 1 and root 4 shows that most of the species can be separated based on characters like 3TLP, 5DLP and 2FLP. DNA barcoding was done for seven species of genus *Metapenaeus*. DNA barcode was done for the first time for *M. kutchensis* and *M. alcocki*. In addition, one species considered as new to the science revealed based on DNA barcoding and morphologically. All the seven species were distinguished from others based on the molecular study.

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1. INTRODUCTION

Taxonomy, the science and art of identifying biological entities and classifying them based on shared characters is fundamental to biological science. Even though it is considered as an oldest profession in the world (Knapp, 2014), it is the only way for effective communication among biologists regarding different forms of life (Cotterill, 1997). Taxonomy and species conservation are often considered to be completely interdependent activities and play important role in biodiversity conservation (Mace, 2004)). Taxonomy provides a critical baseline upon which all other biological research depends. An authentic and established taxonomy is imperative to address biological questions. Effectiveness in conservation of any species depends on knowledge of taxonomy and systematics. However, taxonomy and conservation are not the same thing. Describing the world's species and their relationships is not equivalent to saving them. Completed species lists, regional taxonomies and guides on their own do nothing to conserve species. But it is not possible to develop the necessary plans and mechanisms for species conservation without adequate knowledge and description of species (Rojas 1992; Samper 2004). Further accurate identification of species is a prerequisite to address any biological question relating to that species or ecosystem. However, due to anthropogenic activities and other reasons, the biodiversity is decimating before their identification and description (Myers 1996).

Crustaceans are highly diversified organisms both on the land and in the water. They are present in fresh, brackish and marine waters. Among the crustaceans, decapods are highly valued group. Marine crustaceans, especially shrimp¹ play an important role in maintaining ecological balance, providing animal protein to human, livelihood for fishermen and up-surging economy of the respective country. Production of shrimp from wild or from culture has gained a

¹ Chan (1998) indicates that the terms “shrimp” and “prawn” have no definite reference to any known taxonomic group. Although “shrimp” is sometimes applied to smaller species, while “prawn” is more often used for larger ones, there is no clear distinction between them and their usage is often confused or even inverted in different countries or regions. Some references use the cumbersome term “shrimps and prawns throughout the text but, for simplicity, this report uses “shrimp”

momentum attributed by the demand in domestic and international market. At present shrimp have become the most economic crustacean resource and important for aquaculture industry (Dall *et al.*, 1990; Holthius, 1980; Pérez-Farfante and Kensley, 1997). The world catch of shrimp in 2000 was recorded over three million tonnes; from 1970 to 2000, shrimps of family Penaeidae contributed an average 42.2% of the world catch of shrimps (FAO, 2002). The recent world shrimp catch is about 3.4 million tonnes per year, with Asia as the most noteworthy area for shrimp fishing. World production of shrimp, both captured and farmed, is about 6 million tonnes, of which about 60% of shrimp production in the world comes from fishing, while 40% from farming. Annual exports of shrimp are currently worth more than US\$10 billion, or 16% of all fishery exports (Gillett, 2008). According to the estimates of UN Food and Agriculture Organization, Asia generates about 75% of the total world production of farmed shrimp (FAO, 2010). India has emerged as one of the major contributors to the world production of marine crustaceans. Frozen shrimp have maintained its position as the top item of export, accounting for 38.28% in quantity and 64.50% of the total earnings in dollar terms. Shrimp exports increased by 16.21% in terms of quantity and 20.33% in dollar terms when compared with earlier year (MPEDA, 2016-17). A total of 3,047 species of shrimp have been reported in the world (FAO, 1998) and around 142 species of shrimp have been reported from India (Radhakrishnan *et al.*, 2012).

The taxonomic revision of the shrimp, classifying *Penaeus s.l.* into six genera is still widely debated. Although these prawns can be easily separated into several groups morphologically, whether these subdivisions are truly monophyletic and warrant a generic rank, continues to be hotly debated among taxonomists (Ma *et al.*, 2011). While some taxonomists have accepted the revision, others are questioning the necessity of such a classification. Ma *et al.* (2011) refuted the six genera classification of *Penaeus s.l.* on the basis of examination of mitochondrial and nuclear genes and advocated the restoration of the old genus *Penaeus* (*Penaeus s.l.*), as the classification scheme is in agreement with both morphological and the molecular data. The debate is expected to continue in future as more information will be generated.

Traditionally, identification of prawn species is based on external morphological features *i.e* body shape, pattern of microscopic pubescence over the body, colour pattern, number of rostral teeth, type of grooves and ridges on the carapace, shape of thelycum and petasma, type of telsonic spines and number, length of the pereopods etc. However, these tools may not be able to differentiate species during larval stages and in some instances, because of environmental influence, convergent selection would occur and genetically divergent organisms seem to be similar (cryptic species). Further, due to phenotype plasticity individuals of similar species may appear as different species. Also, the traditional techniques sometime ignore the genetic variability of the characters used for species recognition. These limitations may lead to misidentification of species causing erroneous grouping of different taxa and faulty synonymous taxonomies (Pavan *et al.*, 2016). In such cases the modern techniques based on molecular tools play an important role.

DNA barcoding is the recent method in the line of DNA based methods of identification of different species. It is a rapid, cost-effective and broadly applicable tool for species identification which targets a small fragment of the cytochrome c oxidase I (COI) mitochondrial gene (Hebert, 2003) and as a molecular diagnostic technique, holds great promise. The target 650 bp fragment of the COI gene is PCR amplified and sequenced to produce reference sequences or DNA barcodes that act as molecular identification tags for each species. Thus it enables to generate the database of the all fish and shell fish species available in the world. DNA barcoding employs a standardized methodology to populate a publicly accessible database for species identification, which is explicitly derived from expertidentified reference materials.

Arabian Sea and Bay of Bengal are the most productive ecosystems in terms of shrimp and *Metapenaeus* group in particular. Species of genus *Metapenaeus* are commercially important prawns and are widely spread throughout the Indo-Pacific region (George, 1969). The adults can occur up to 37 m depth in the coastal ocean while juveniles can be seen in estuaries, backwaters and paddy fields. The commercially important prawn *Metpenaeus monoceros* can be found up to 100 m depth in the ocean. *Metapenaeus kutchensis* (George) is endemic to Gujarat and Maharashtra coasts of India

(Deshmukh, 2006). *M. alcocki* is endemic to gulf of kutchh. *M. affinis*, *M. monceros*, *M. brevicornis*, *M. dobsoni* are distributed on both the coasts. In India, 17 species of genus *Metapenaeus* are recorded (Samuel, et al., 2016). Due to the ambiguity in morphological characters within this group, it is believed that more number of species are yet to be identified. Further the evolutionary relationship among these species has not been studied so far using molecular markers. Most commercially important species like *M. kutchensis*, and *M. alcoki* do not have barcodes.

In view of lack of detailed taxonomic study, present investigation was planned to resolve the taxonomic ambiguity among the species of genus *Metapenaeus* through morphological and molecular approach which will lay strong foundation for studies concerning resource status assessment, biodiversity assessment, conservation and management.

Objectives

1. To differentiate the species of genus *Metapenaeus* based on the morphological characters from Indian waters.
2. To develop DNA barcodes for species of genus *Metapenaeus* from Indian waters.

2. REVIEW OF LITERATURE

Shrimp taxonomy- *Metapenaeus*

The genus *Penaeus* (type *P. monodon*) was established in 1798 by Fabricius for three species from the Indian Ocean one of which (*P. planicornis*) perhaps, be transferred to the genus *Solenocera* of Lucas since its antennular flagella are described as compressed.

Smith (1885) proposed to restrict the name *Peneus* to those species in which (1) the endopodite of the maxillules is elongate and segmented, (2) the third maxillipeds have an epipodite, and (3) the last thoracic somite carries a pleurobranch. To the species not thus characterized, he applied the name *Parapeneus*.

In 1891, Wood-Mason, pointed out that certain *Parapeneus* differed from the type species (*Parapeneus membranaceus*, Ilisso, = *P. longirostris*, Lucas) in not possessing the characteristic sutures of the carapace and in having a filamentous vestige of an anterior arthrobranch on the penultimate thoracic appendage. To these forms he gave the name *Metapenaeus*. He also recognized, among the *Penei* lying outside the limits of Smith's restricted genus *Peneus*, that *P. styliferus* Edw. constituted a fourth distinct type, to which he gave the name *Parapeneopsis*.

Miers (1878) created the genus *Mangalura* with *Mangalura dobsoni* as type species from the coast of Mangalore, West Coast of India. Nobili (1903) transferred the species of the genus *Mangalura* to the genus *Metapenaeus* Wood-Mason (1891). *Metapenaeus* has been placed on the official list of Generic Names in Zoology, International Commission on Zoological Nomenclature Alcocki (1906) reported and described many species under different genera. He included *Metapenaeopsis* species under the genus *Metapenaeus*.

Dall (1956) described twenty-eight Australian species of *Penaeinae*, of which six are new. He described the new species, *M. eboracensis* from genus

Metapenaeus. Full keys to genera and species, and a glossary of special terms, was included. The zoogeography of Australian and Indo-West Pacific Penaeinae was also discussed

George et al. (1963) reported a new species *Metapenaeus kutchensis* from gulf of kutchh. George and Vedavyasa Rao repoted a new species, *Metapenaeus alcocki*, from the Gulf of Kutch in 1966.

Racek, and yaldwyn (1970) reported *M. affinis* and *M. dobsoni* from New Guinea for the first time. Silas et al. (1976) collected and described 16 species of penaeid prawns from Andaman, out of 16 species 8 species belonged to genus *Metapenaeus*. Kagwade (1978) redescribed the *M. Kutchensis* based on adult specimens from Bombay coast, whereas George et al. (1963) had described based on juvenile specimen of *Metapenaeus kutchensis*.

Muthu (1965) first recorded the occurrence of *M. ensis* from the Bay of Bengal. The specimens doubtfully recorded as *M. ensis* (De Haan) by Alcoki (1906) do not seem to belong to *M. ensis* (De Haan) as they possess three pairs of telson spines. De man (1922) opined that Alcock's specimens were probably *Penaeus intermedius* (Kishinouye) var. *Anchista*, now it has been synonymised as *Metapenaeus intermedius* (Kishinouye) by Hall (1962).

George (1979) studied the genus *Metapenaeus* in a comprehensive manner along with other genus under family Penaeidae and listed 11 species under the genus *Metapenaeus* in India. He also studied the distribution, life history, behaviour and movements, reproduction, fishing season etc.

Miquel (1983) re-described some species of the genus *Metapenaeus* which were overlooked by their original author. He divided the *Metapenaeus* species into different groups based on the similarity of the species. He described characters for twenty six species of *Metapenaeus* genus in French language.

For the differentiation of taxa several features are being used and are referred as taxonomic characters. Characters are variation among homologous features and they are taxonomically important only if it shows variation among

taxa under consideration (Helfman et al., 1997). Meristic characters are the countable feature of a taxon viz. number of rostral teeth, telsonic spines, so on.

Ma et al. (2011) falsified the six genera classification of *Penaeus* s.l on the basis of examination of mitochondrial and nuclear genes and advocated the restoration of the old genus *Penaeus* (= *Penaeus* s.l.) as the classification scheme is in agreement with both morphological and the molecular.

Radhakrishnan et al. (2012) published a checklist of prawns comprised of 142 species under 43 genera of the suborder Dendrobranchiata and 295 species under 88 genera of the suborder Pleocyemata. From India, They included fourteen species under the *Metapenaeus*.

Chanda (2014) attempted to study the taxonomic status, distribution, diagnosis and key to the species of genus *Metapenaeus* found in Indian water. He opined that fourteen species of genus *Metapenaeus* are found along the Indian coast. He also recorded two Australian species one under *Metapenaeopsis* and another under *Metapenaeus* from Indian water in 2014.

Rajakumaran et al. (2014) studied diversity of *Penaeidae* species in south east coast of India. He also reported *Metapenaeus papuensis* and *Metapenaeus anchistus* for the first time in India.

Samuel et al. (2016) reported a checklist of marine shrimps found along the coast of Indian subcontinent and its islands viz. Andaman & Nicobar and Lakshadweep. According to them 17 species were under the genus *Metapenaeus*.

A new species of penaeid, *Metapenaeus motohi* sp. nov. was described based on material from the Philippines. This new species is most closely similar to *M. ensis* (De Haan, 1844) from Japan in the morphology of the thelycum, but differs in rostral teeth mostly number 8-9, the 2nd, 3rd and 5th Pereiopods are elongate, and the distal portion of the petasma forms a narrow lobule with a small genital pore. (Shinomiya and Sakai, 2009)

Mevlut et al. (2006) stated the pattern of taxonomic relationship and morphological divergence of three species of shrimp, *Penaeus semisulcatus*,

Metapenaeus monoceros and *Melicertus kerathurus*, collected from Iskenderun bay of north eastern Mediterranean sea using multivariate ANOVA.

Literature on DNA barcoding

The number of taxonomists is declining and at present there is insufficient number of specialists in this field to handle existing species (Rubinoff, 2006; Hebert et al., 2003; Carvalho et al., 2007; Packer et al., 2009). In addition to falling short of all its stated goals, the method abandons the benefits of morphological studies in favor of a limited molecular identification system that would ultimately impede our understanding of biodiversity (Will and Rubinoff, 2004). Few taxonomists can critically identify more than 0.01% of the estimated 10–15 million species (Hammond, 1992; Hawksworth & Kalin-Arroyo, 1995).

Herbert et al. (2003) proposed that a single gene sequence would be sufficient to differentiate all, or at least the vast majority of animal species, and proposed the use of the mitochondrial DNA gene cytochrome oxidase subunit I (COI) as a global bioidentification system (GBS) for animals. The sequence was assigned as a barcode, with species being delineated by a particular sequence or by a tight cluster of very similar sequences.

Dooh et al. (2007) tested the ability of COI to provide identifications in crustacean group, examining two disparate levels in the taxonomic hierarchy - orders and species. The first phase of the study involved the development of a sequence profile for 23 dominant crustacean orders, based upon the analysis of 150 species, each belonging to a different family. These studies revealed that levels of nucleotide sequence divergence were 19 to 48 times greater between congeneric species than between individuals of a species. Study concluded that sequence variation in the COI barcode region will be very effective for discriminating species of Crustacea.

Radulovici et al. (2009) expand the DNA barcode database with a case study involving 80 malacostracan species from the Estuary and Gulf of St Lawrence. DNA sequences for 460 specimens grouped into clusters

corresponding to known morphological species in 95% of cases. Genetic distances between species were on an average 25 times higher than within species. Intraspecific divergence was high (3.78–13.6%) in specimens belonging to four morphological species, suggesting the occurrence of cryptic species.

Raupach et al. (2015) revealed a total number of 164 barcoding studies for crustaceans with a preference for malacostracan crustaceans, in particular Decapoda, and for building reference libraries in order to identify organisms. In this review they have provided an update regarding the progress of DNA barcoding in crustaceans based on descriptive statistics. Major points of the review are: taxonomic coverage, subject areas, and the use of BOLD as a major platform for the standardization of barcoding studies.

Rajkumar et al. (2015) conducted molecular identification of six species (*P. semisulcatus*, *M. dobsoni*, *M. brevicornis*, *F. indicus*, *P. stylifera* and *S. crassicornis*) by adopting DNA barcoding of mitochondrial cytochrome c oxidase subunit I (COI) gene. 650 bp sequences were obtained when universal primers (LCO1490 and HCO2198) were used. Their similarity was checked with BLAST-NCBI, and each and every species showed > 80% identity. Maximum intra specific divergence was calculated as 0.8% in *F. indicus* of India, Thailand and China. Inter specific divergence was found to be maximum (3.95%) between *S. crassicornis* and *S. koelbeli* of India and China. They observed minimum divergence (0.00%) between two Indian haplotypes, *M. dobsoni* and *M. brevicornis*, which overlaps each other.

Zaki et al. (2016) found the species collected from Egyptian coast of the Mediterranean and Red sea as *Metapenaeus monooceros* through DNA barcoding.

3. MATERIALS AND METHODS

3.1. Description of study area and geographical location

India is surrounded by Indian Ocean on its south, Arabian Sea on its West and Bay of Bengal on its East. Species of genus *Metapenaeus* are distributed in all waters surrounding the India. Samples of *Metapenaeus* species were collected from landings of shrimp trawlers from different landing centres along the East and West coast of mainland of India (fig. 3.1), such as Gujarat, Maharashtra, Kerala, Tamil Nadu, Andhra Pradesh, and West Bengal during March 2016 to April 2017.

3.2. Sampling stations:

Sampling stations, latitude & longitude and type of species collected are given below in the table 3.1.

Table: 3.1. Sampling station, its latitude and longitude and type of species (Fig: 3.1)

S.No	Sampling site	Latitude and longitude	Type of species collected
1	Chennai, TN	13° 7' 35.6844" N 80° 17' 51.8316" E	<i>M. ensis</i> , <i>M. monoceros</i>
2	Digha, W.B	21° 38' 28.5756" N 87° 34' 13.2708" E	<i>M. lysianassa</i>
3	Kakinada, AP	16° 58' 58.134" N 82° 16' 52.0212" E	<i>M. affinis</i> , <i>M. brevicornis</i> , <i>M. dobsoni</i>
4	Kochi, Kerala	9° 56' 10.7556" N 76° 15' 39.7188" E	<i>M. brevicornis</i> , <i>M. dobsoni</i>
5	Kutchh, Gujarat	23° 9' 4.9932" N 70° 49' 9.4332" E	<i>M. alcocki</i> , <i>M. kutchensis</i>
6	Mumbai, Maharashtra	18° 54' 52.2" N 72° 49' 27.9372" E	<i>M. affinis</i> , <i>M. monoceros</i> , <i>M. kutchensis</i> , <i>M. brevicornis</i>
7	Rameswaram	9° 16' 52.1256" N 79° 18' 54.3744" E	<i>M. moyebi</i> , <i>M. monoceros</i>
8	Tuticorin, TN	8° 47' 41.298" N 78° 9' 36.1908" E	<i>M. moyebi</i> , <i>M. monoceros</i>
9	Veraval, Gujarat	20° 54' 18.6912" N 70° 22' 31.8756" E	<i>M. kutchensis</i> , <i>M. affinis</i> , <i>M. monoceros</i>
10	Visakhapatnam, AP	17° 41' 40.0488" N 83° 18' 14.2632" E	<i>M. ensis</i> , <i>M. monoceros</i> ,

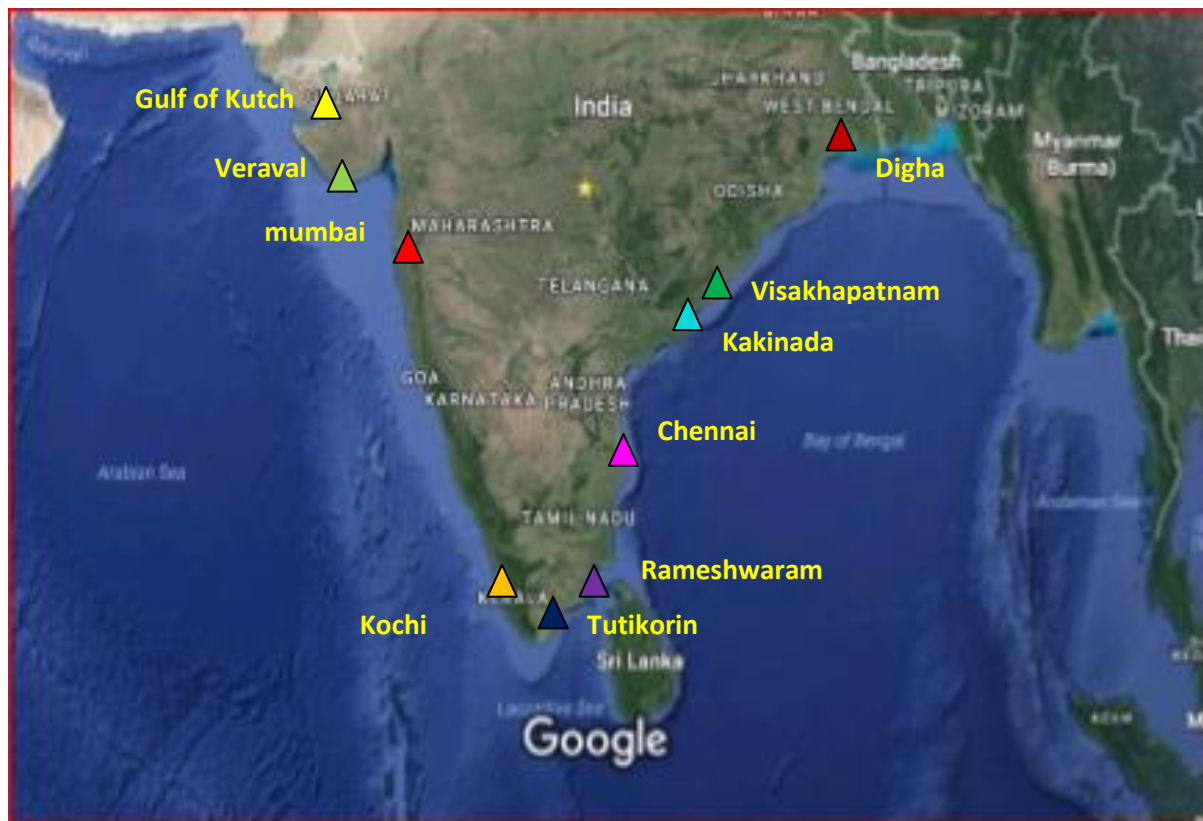


Fig: 3.1. Sampling sites along the India coast. (Source: Imagery ©2017 Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat / Copernicus, Map data ©2017 Google, Mapa GISrael, ORION-ME, ZENRIN)

3.3. Specimen photograph and its preservation

Specimens were photographed immediately after collection, in the fresh condition. For DNA barcoding tissue samples were stored in the absolute alcohol with proper labelling. Bigger size specimen were preserved in ice box with gel ice packets while bringing from landing centres and finally stored in refrigerator (-20) for further study. Medium and smaller sized specimens were preserved in sampling bottle (15×10 cm) with absolute alcohol.

3.4. Taxonomic Identification

The specimens were identified by using “Catalogue of the Indian Decapod Crustacea in the collection of the Indian Museum, Part III” by Alcock A. (1906), “Revision of the Australian species of Penaeinae (Crustacea, Decapoda: Penaeidae)” by Dall W. A (1957), “Taxonomy of Indian prawns (Crustacea, Decapoda, Penaeidae) ‘In contribution to Marine Science’, dedicated to Dr. C.V. Kurian” by George MJ. (1979), “LE GENRE *METAPENAEUS* (CRUSTACEA, PENAEIDAE): TAXONOMIE, BIOLOGIE ET PECHEES MONDIALES” by J. C. E. Miquel (1983) and. “A systematic study on genus *Metapenaeus* wood-mason, 1891 with special reference to extended distribution of four species from Indian water” by Chanda A. (2013). Stereo zoom microscope was used to examine the microscopic parts of the shrimp and to photograph them. Morphometric characters (total length, carapace length etc.) of the shrimp were taken with the help of measuring scale and digital Vernier callipers.

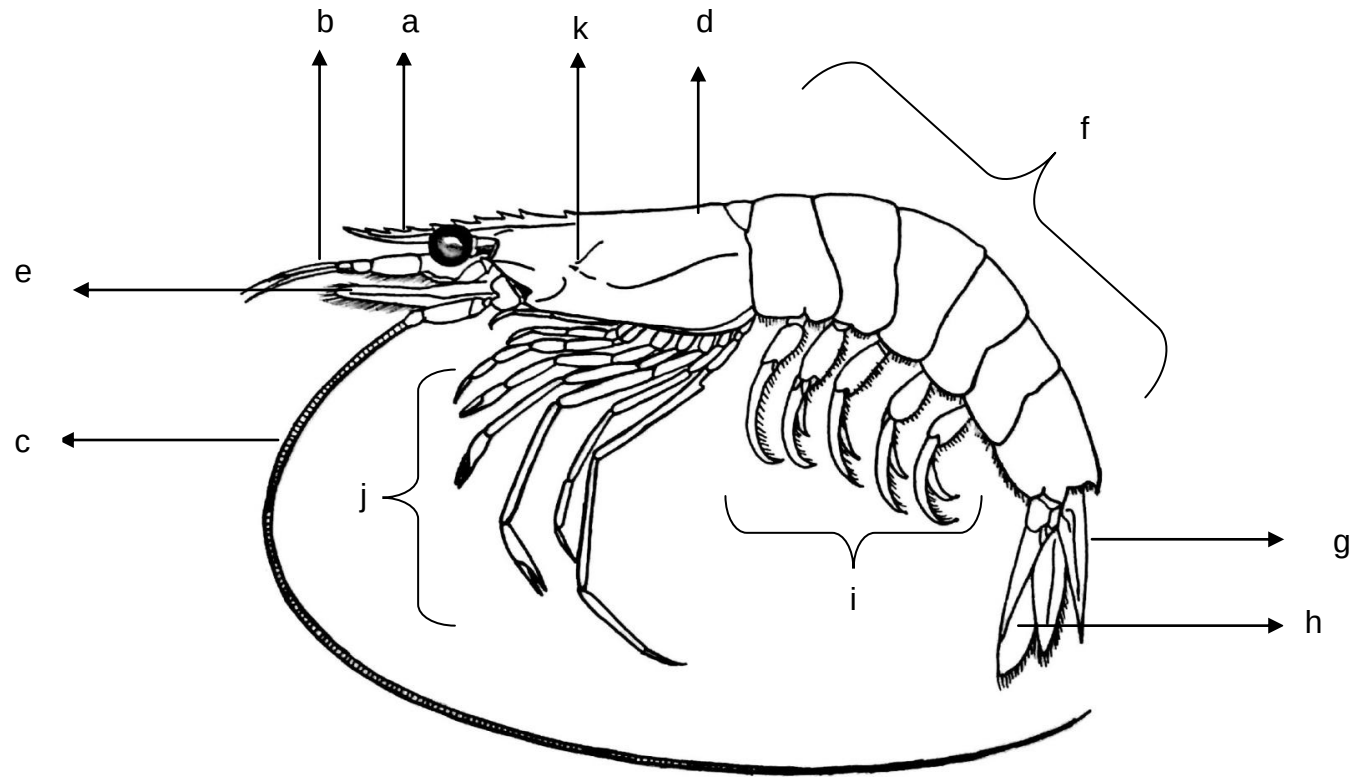


Fig: 3.2. General morphological characters of taxonomic importance present in *Metapenaeus* sps. (a) Rostrum, (b) Antennule, (c) Antenna, (d) Carapace, (e) Antennal scale, (f) Abdomen, (g) Telson, (h) Uropod, (i) Pleopods, (j) Periopods, (k) Hepatic spine

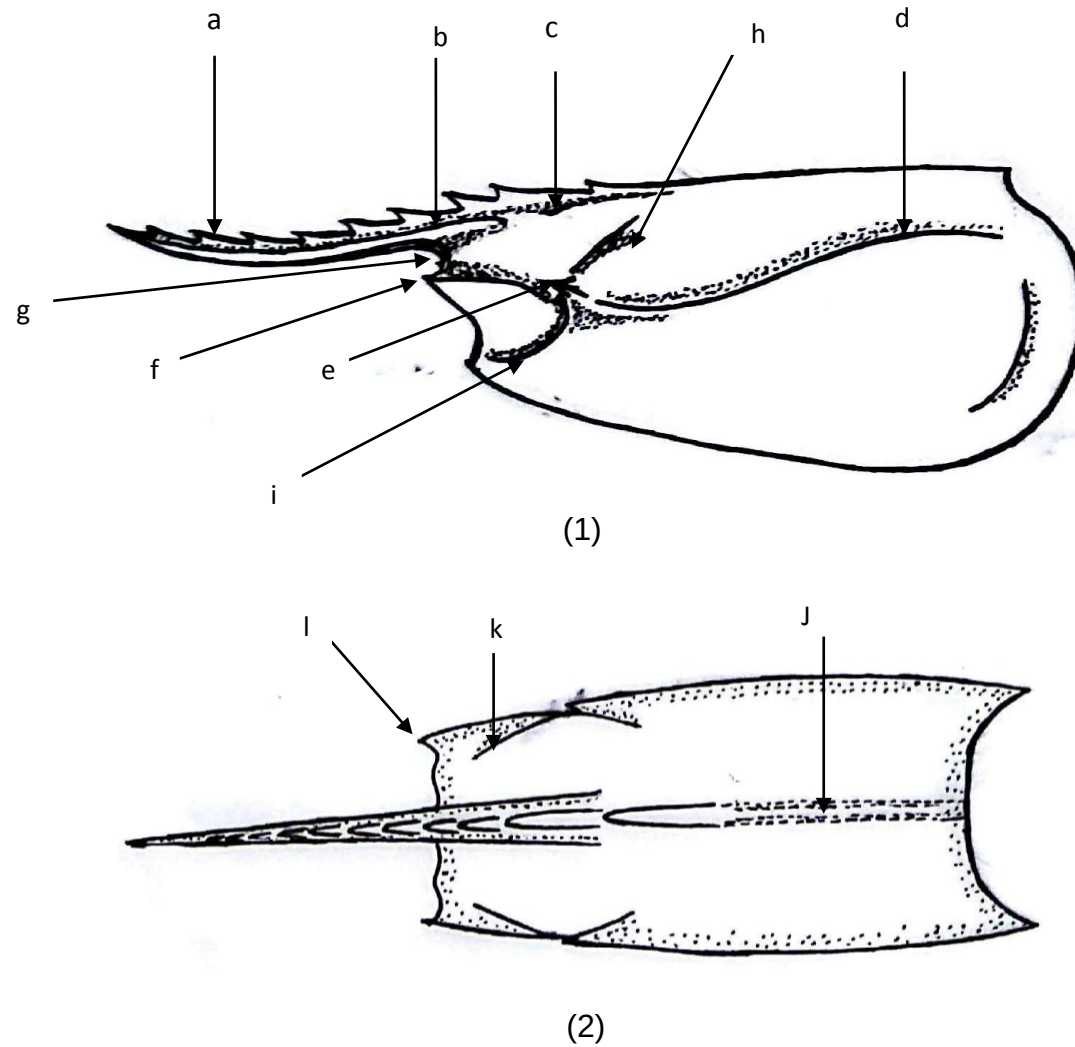
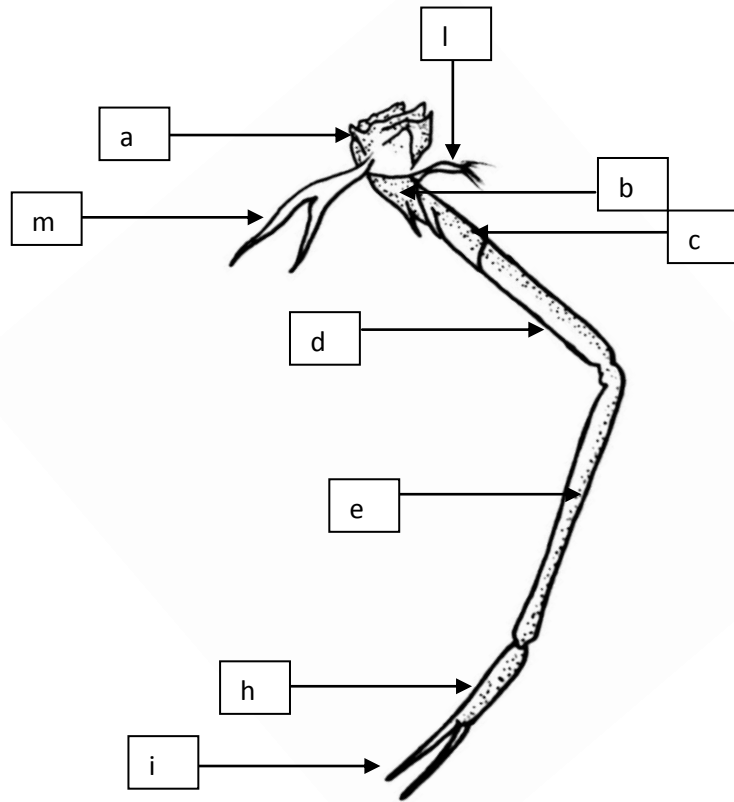
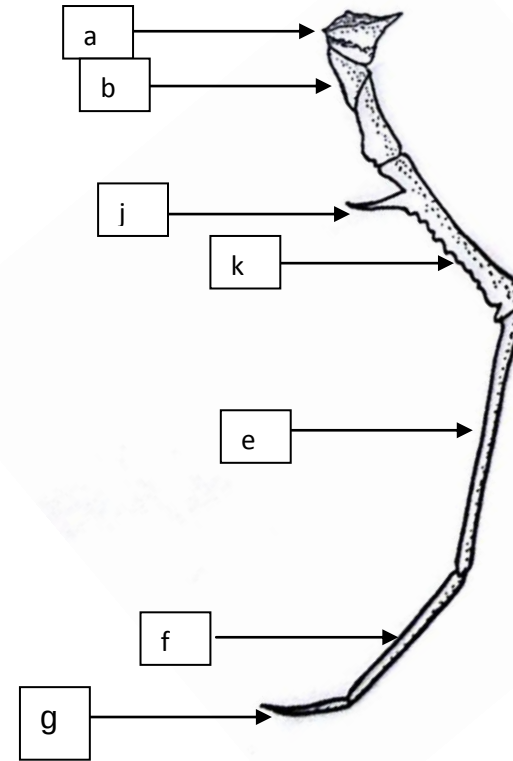


Figure 3.3: General morphological characters of taxonomic importance present in *Metapenaeus* sps. (1): lateral view of a carapace (a) Rostral teeth,(b) Adrostral carina, (c) Adrostral sulcus, (d) Branchiocardiac carina, (e) Hepatic spine, (f) Antennal spine (g) Orbit, (h) cervical carina, (i) Hepatic carina, (2): top view of carapace, (J) postrostral carina, (k) Gastroorbital carina, (l) Antennal spine.



(1)



(2)

Figure: 3.4. Typical diagram of pereopods of *Metapenaeus* sps. showing (1) Chelated and (2) Non-chelated: (a) Coxa, (b) Basis, (c) Ischium, (d) Merus, (e) Carpus, (f) Propodus, (g) Dactylus, (h) Palm, (i) Finger, (j) Spine, (k) Tubercles, (l) Exopod, (m) Epipod.

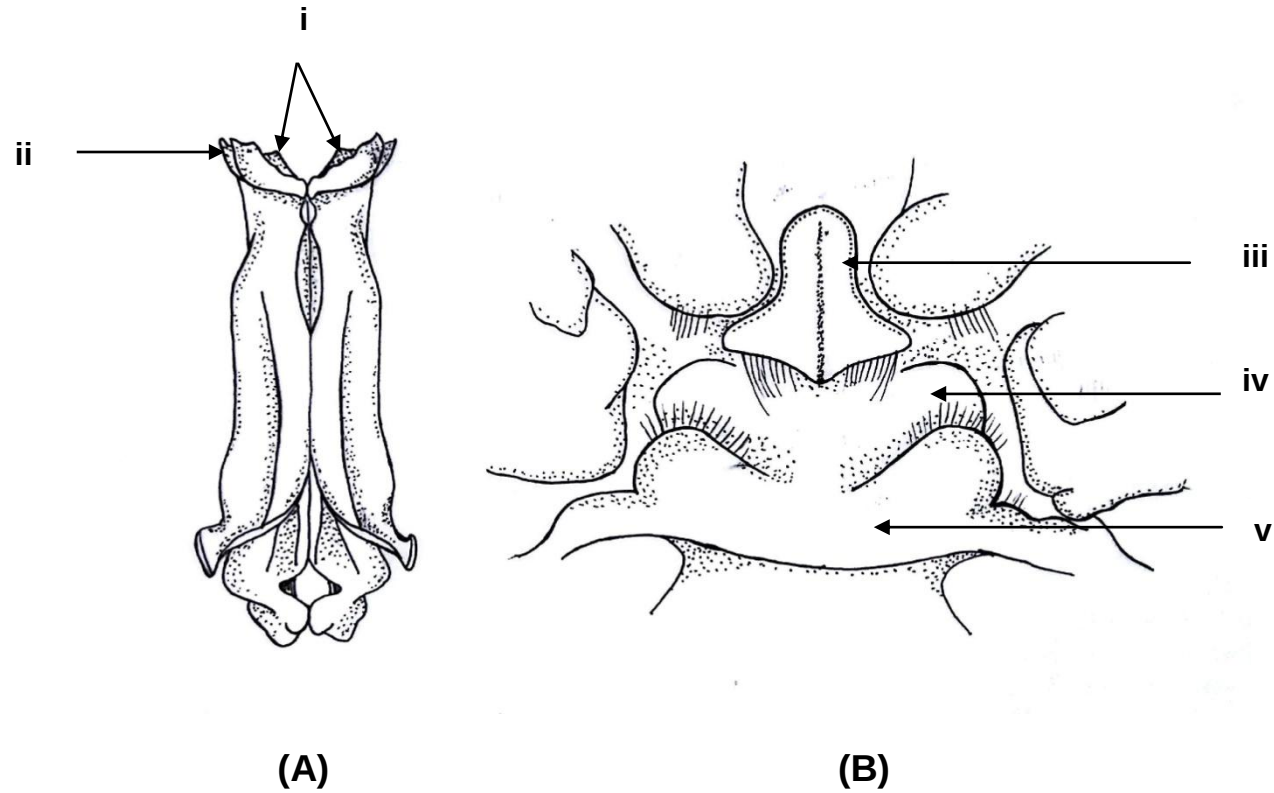


Figure: 3.5. Morphological characters of (A) Petasma: (i) distomedian projections, (ii) distolateral projections and (B) Thelycum: (iii) anterior median plate, (iv) lateral plates, (v) posterior transverse ridge.

3.5: Morphometric measurements

Total length (TL): Length between the tips of the rostrum and the telson.

Carapace length (CL): Distance from the orbital margin to posterior margin of carapace

Carapace width (CW): Maximum distance between two lateral points of the carapace

Carapace depth (CD): Maximum distance between the upper and lower points of the carapace

Rostral length (RL): Distance from orbit to the tip of rostrum.

Antennular peduncle length (APL): Distance between first and last segments of the antennular peduncle.

Dorsal antennular flagella length (DAL): Distance from the base to the tip of the dorsal antennular flagella.

Ventral antennular flagella length (VAL): Distance from the base to the tip of the ventral antennular flagella.

Length of telson (LT): Distance from proximal margin of the telson to the tip.

Length of sixth abdominal segment (6ASL): Distance between the anterior and posterior margin of the sixth abdominal segment.

Depth of sixth abdominal segment (6ASD): Distance between dorsal and ventral margins of the sixth abdominal segment.

Antennal scale length (ASL): Distance from base to the distal margin of the antennal scale.

First pereopod length (1TLP): Distance from proximal to the distal end of the first pereopod.

Second pereopod length (2TLP): Distance from proximal to distal end of the second pereopod.

Third pereopod length (3TLP): Distance between proximal to the distal end of the third pereopod.

Fourth pereopod length (4TLP): Distance from proximal to the distal end of the fourth pereopod.

Fifth pereopod length (5TLP): Distance from proximal to the distal end of the fifth pereopod.

Ischium length of first pereopod (1ILP): Distance from proximal to the distal end of ischium

Merus length of first pereopod (1MLP): Distance from proximal to the distal end of merus

Carpus length of first pereopod (1CLP): Distance from proximal to the distal end of carpus

Palm length of first pereopod (1PLP): Distance from proximal to the distal end of palm

Finger length of first pereopod (1FLP): Distance from proximal to the distal end of fingers

Ischium length of second pereopod (2ILP): Distance from proximal to the distal end of ischium

Merus length of second pereopod (2MLP): Distance from proximal to the distal end of merus

Carpus length of second pereopod (2CLP): Distance from proximal to the distal end of carpus

Palm length of second pereopod (2PLP): Distance from proximal to the distal end of palm

Fingers length of second pereopod (2FLP): Distance from proximal to the distal end of fingers

Ischium length of third pereopod (3ILP): Distance from proximal to the distal end of ischium

Merus length of third pereopod (3MLP): Distance from proximal to the distal end of merus

Carpus length of third pereopod (3CLP): Distance from proximal to the distal end of carpus

Palm length of third pereopod (3PLP): Distance from proximal to the distal end of palm

Fingers length of third pereopod (3FLP): Distance from proximal to the distal end of fingers

Ischium length of fourth pereopod (4ILP): Distance from proximal to the distal end of ischium

Merus length of fourth pereopod (4MLP): Distance from proximal to the distal end of merus

Carpus length of fourth pereopod (4CLP): Distance from proximal to the distal end of carpus

Propodus length of fourth pereopod (4PLP): Distance from proximal to the distal end of palm

dactylus length of fourth pereopod (4DLP): Distance from proximal to the distal end of fingers

Ischium length of fifth pereopod (5ILP): Distance from proximal to the distal end of ischium

Merus length of fifth pereopod (5MLP): Distance from proximal to the distal end of merus

Carpus length of fifth pereopod (5CLP): Distance from proximal to the distal end of carpus

Propodus length of fifth pereopod (5PLP): Distance from proximal to the distal end of propodus

Dactylus length of fifth pereopod (5DLP): Distance from proximal to the distal end of dactylus

3.6. Meristic characters

Number of rostral teeth (RTN), starting from proximal teeth to distal teeth of rostrum along with epigastric tooth, were counted for each specimen.

3.7. Analysis of data

The data for fulfilling objectives of study was entered in spreadsheets and analysed using statistical tools. Microsoft Excel, Primer, Statistica, Trail Ver. 12 statistical tools used for data analysis.

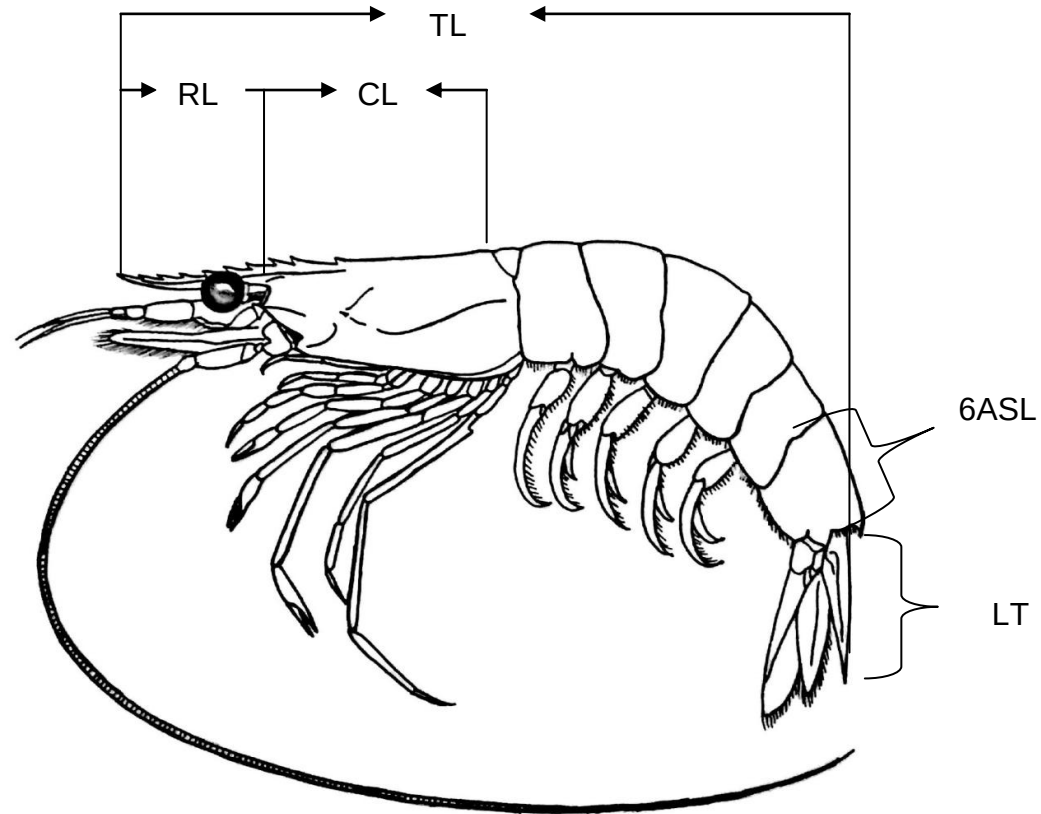


Figure: 3.6. Pattern of morphometric measurements of *Metapenaeus* spp. TL – Total length, RL – Rostral length, CL – Carapace length, LT– Length of Telson, 6ASL–Sixth Abdominal Segment Length.

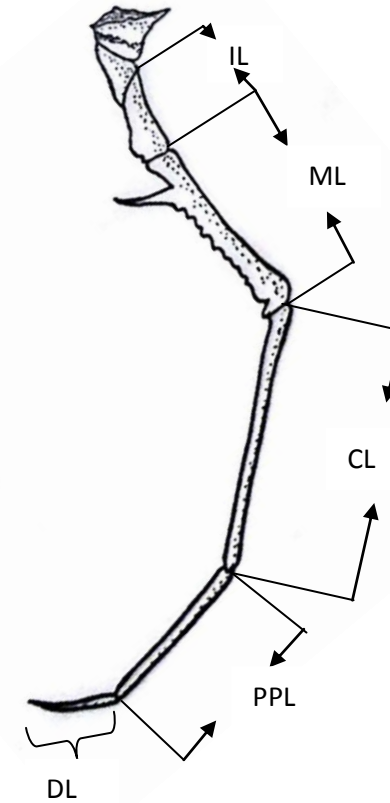
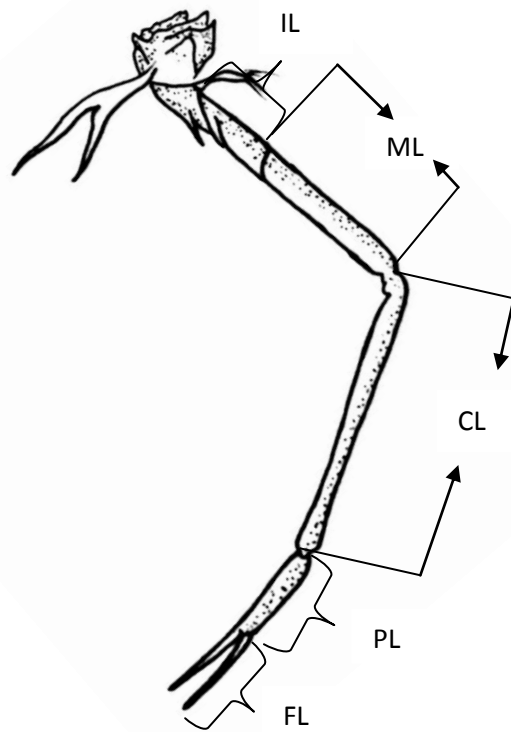


Figure: 3.7. Pattern of morphometric measurements of chelate leg and non-chelate legs of *Metapenaeus* spp. (a) IL – Length of Ichium, ML – Length of merus, CL – Length of carpus, PL – Palm length of chelate leg, FL – Length of finger, PPL – Length of Propodus in non-chelate leg, DL – Dactylus length

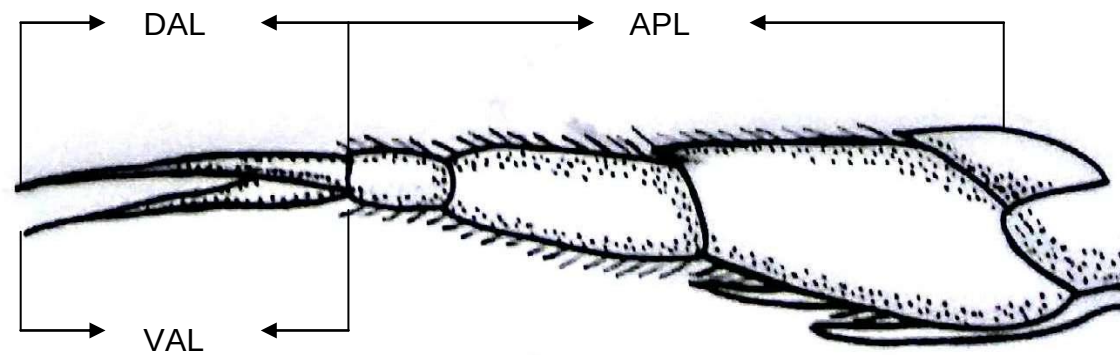


Figure: 3.8. Morphometric characters of Antennular Peduncle: APL- Antennulat peduncle length, DAL- Dorsal antennular flabella length, VAL- Ventral antennular flagella length

3.8. DNA Barcoding

Tissue samples from five specimens of each species were used for DNA extraction for DNA Barcoding (if the total number of specimens was less than five all the specimens were used). The Pleopods and muscles were dissected and preserved in absolute alcohol and stored in -20° C, for future molecular work.

3.8.1. DNA isolation procedure

Simple salting out method (Miller *et al.*, 1988)

Steps

- About 20- 50 mg of tissue was taken and washed in Millipore water and dried it on a tissue paper, later the tissue was homogenized using the scissors in a 2ml tube after adding in 700µl solution I in the tube.
- 7-10µl of proteinase K was added in the tube, the solution was mixed properly with the help of a stirrer and the lid was closed properly by wrapping with paraffin film.
- The solution in the tube was kept in water bath of temperature 55° C overnight (18-20 hrs) for incubation
- After incubation, tubes were taken out from the water bath and were kept immediately in the ice (at 4° C) for about 10 minutes.
- 200 µl of solution II (Annexure II) was added to the mixture and the aliquot was mixed properly by inverting the vial up and down.
- Again the tubes were kept in ice (at 4° C) for 5 minutes and tube was centrifuged at 8000 rpm for 15 minutes at 4° C temperature.
- 1ml of transparent supernatant was transferred into 1.5 ml tube. Later a 500 µl molecular grade absolute alcohol was added and tubes were kept in -20°C for 1 hour.
- Tubes were centrifuged at 10000 rpm for 10 minutes at 4° C. The supernatant was removed after centrifugation and the pellet was washed twice with 70% alcohol at 10000 rpm for 10 minutes

- The pellet was dried in the laminar air flow and it was suspended in the 30 μ l TAE (10X) buffer. For removing contaminated RNA, 1 μ l RNase enzyme was added and incubated for 1 hour at 37° C.

3.8.2. Checking quantity and quality of DNA

The concentration of DNA was estimated with the help of nanodrop. The concentration of DNA was made up to 100 nano gram per micro litre by using nuclease free water. Quality was checked by running the DNA on agarose gel.

3.8.3. Agarose Gel electrophoresis

Reagents for electrophoresis

1. Agarose
2. Ethidium Bromide: 10mg/ml
3. DNA sample
4. Electrophoresis buffer, 0.5X TAE (Diluted from 50X stock solution)
5. 6x DNA loading dye (0.25% bromophenol blue 0.25% xylene Cyanol and 30% glycerol)
6. DNA marker (100 plus)

Protocol for Agarose gel electrophoresis

The extracted DNA was diluted up to the concentration of 100 μ mol. Agarose 1% was prepared in 0.5X TAE buffer by heating in microwave oven till the agarose completely dissolved. Appropriate amount of Ethidium Bromide was added and mixed properly before casting in tray. The tray set by arranging the comb and pouring the melted agarose in to the tray, within 20-25 minutes the gel solidified. The comb was removed after solidification and kept the tray in to the buffer tank unit of electrophoresis unit. DNA sample (1 μ l) was mixed with 0.5X TAE buffer (5 μ l) and 6X loading dye (2 μ l), and loaded in to the wells. Electrophoresis was carried at a voltage of 80V till the dye migrated up to sufficient distance. The photograph of the gel was taken by using the Biorad gel

documentation unit. For checking PCR product, 2% gel was used for electrophoresis.

3.8.4. PCR amplification of mitochondrial COI gene

Mitochondrial cytochrome c oxidase subunit I gene was amplified with Primers CrustDF1: 5'-GGTCWACAAAYCATAAAGAYATTGG-3' and CrustDR1: 5'-TAAACY TCAGGRTGACCRAARAAYCA-3' (da Silva *et al.*, 2011). PCR was performed in 25µl reaction volume containing 100ng template DNA, 10pmol of each specific primer, 200µM of each dNTPs, 1.0 units of Taq DNA polymerase and 1xTaq buffer containing 1.5mM MgCl₂. The amplification reaction was carried out in 0.2ml PCR tubes in a heated lid thermocycler. The thermocycler was programmed for initial denaturation at 95°C for 5 min, followed by 35 cycles of 94°C for 30 sec, annealing temperature specific to the primer pair 45°C for 30 sec, 72°C for 1 min for denaturation, annealing and extension, with final extension at 72°C for 10 min. Hold temperature was set at 4°C.

3.8.5. PCR product purification & Sequencing

The PCR amplification products were purified with PCR purification Kit (Fermentas) or Gel extraction kit (Fermentas) following the manufacturer's protocols. The purified PCR products were sent for sequencing to Scigenom, Kochi, Kerala.

4. RESULTS

During the present study, nine species belonging to genus *Metapenaeus*, were collected from different coasts of India and identified using available identification keys. The descriptions of the species with important characters are presented here.

4.1. Description of the genus *Metapenaeus*

Cephalothorax and abdomen covered with pubescence (microscopic hair); rostrum possesses teeth solely on dorsal side; orbital spine short and blunt, antennal and hepatic spines prominent on the carapace; pterygostomian spine and gastroorbital carina absent; postocular sulcus deep; orbital, antennal, cervical and hepatic sulcus prominent, accompanied by ventral carina, hepatic carina descends vertically from spine; branchiocardiac carina developed variably in different species, sometimes indistinct; transverse and longitudinal suture absent; telson lacking subapical fixed spine (except in few species), numerous posterolateral spines present; antennule lacking parapeneid spine, flagella moderate, slender, shorter than carapace; basal spine present on first, second and third pereopod; in some species, ischial spine present on first pereopod; ischium and merus of 5th pereopod often modified in adult male; exopod on 5th pereopod lacking, this is the most unique character of the genus; petasma symmetrical, semi closed, depressed, median lobes usually vary from species to species; sclerotized lateral lobes produced distally in spoutlike obliquely or fully lateral projections and with ventrolateral recurved, flaplike to complex medial process; appendix masculina longer than wide, narrow basally, expanded distally and convex ventrally; thelycum closed, with paired lateral plate on sternite XIV, often continuous across sternite, usually more or less enveloping posterior end of elongate median protuberance of sternite XIII.

4.2. Taxonomic classification:

Phylum	: Arthropoda
Class	: Crustacea
Sub class	: Malacostraca
Super order	: Eucarida
Order	: Decapoda
Sub order	: Penaeidea
Superfamily	: Penaeoidea
Family	: Penaeidae
Genus	: <i>Metapenaeus</i>

4.3. Description of species

Metapenaeus affinis (H. Milne Edwards, 1837): Jinga Shrimp



(A)



(B)



(C)



(D)

Plate no: 4.1. (A) *Metapenaeus affinis* (H. Milne Edwards, 1837); (B) thelycum; (C) petasma; (D) merus of male 5th pereopod

Synonyms: *Penaeus affinis* (H. Milne Edwards, 1837), *Metapenaeus mutatus* (Lanchester, 1901), *Metapeneus affinis* (Alcock, 1906) *Metapenaeus alcocki* (George and Rao, 1968)

Materials examined: A total of 30 specimens of *Metapenaeus affinis*, collected from Kakinada (A.P) landing centre, Sasoon dock & Versova (Mumbai) landing centre, were studied.

Description:

Most of the body covered with pubescence; rostrum long, slender, slightly uptilted tip and reaching distal end of antennular peduncle, armed with 8-11+1 dorsal teeth; post rostral carina extend upto the posterior margin of carapace, adrostral carina ending in between first and second rostral tooth; adrostral sulcus extending beyond epigastric tooth, antennal, cervical and hepatic carina prominent, branchiocardiac carina distinct and curved, reaching hepatic spine, hepatic carina maintain angle towards anteroventral side of carapace, dorsal carination start from posterior part of fourth abdominal segment and ends at posterior margin of sixth somite with a small spine; cicatrix long, seen on last two abdominal segments; lateral side of telson with very minute movable spines; antennular flagella sub equal to equal, shorter than carapace.

5th pereopod (male): ischium with a keel and merus with a notch, followed by a twisted, keeled tubercle.

Petasma: distomedian projection of petasma crescent shaped, transversely placed on distolateral projection, partly concealing them; distolateral projections directed anterolaterally.

Thelycum: anterior plate of thelycum deeply grooved longitudinally and partly hidden between coxa of fourth pair of pereopods, considerably wide posteriorly; posterior transverse ridge with 2 anterolateral rounded projections partly covering median lateral plates; impregnated female occasionally with white irregular conjoined pads on thelycum.

Colour: pale green to pinkish tinge or pink brownish with green or red brown specks. Antennae red; pereopods white or of same colour as body; pleopods

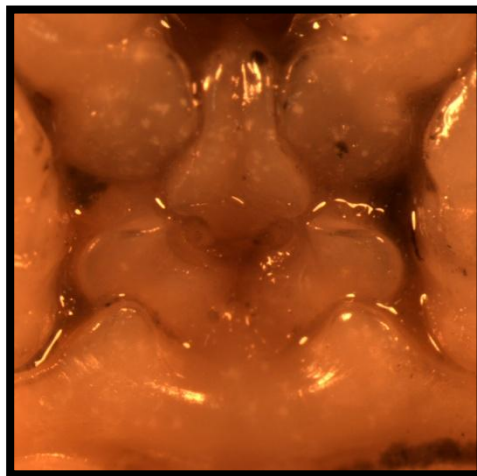
reddish to whitish; distal half of uropods translucent green or rust coloured, tips usually whitish to yellowish.

Distribution in India: Entire east and west coasts of India & Andaman Sea.

Metapenaeus alcocki (George and Rao, 1966)



(A)



(B)

Plate no: 4.2. (A) *Metapenaeus alcocki* (George and Rao, 1966), (B) thelycum

Material examined: A total of 16 female were collected from different locations at Gulf of Kutch, Gujarath. Male specimen characters were taken from the original description, since no male specimen could be collected during study.

Description:

Body pubescence confined on some location of shell (frontal, gastric and dorsal part of cardiac location of carapace), branchiocardiac place glabrous; abdomen irregularly setose; rostrum straight, barely uptilted at tip, extending beyond third segment of antennular peduncle, armed with 8-9+1 dorsal teeth; adrostral carina expand behind penultimate tooth and sulcus at the back of epigastric tooth; post rostral carina ends before posterior margin of carapace; gastro-frontal sulcus absent, post ocular sulcus prominent, hepatic sulcus distinguished and descend with pterygostomian one; cervical sulcus straight and transverse, branchiocardiac carina prominent and continuous to hepatic spine; antennal and hepatic spine prominent; antennular flagella subequal, dorsal one longer; dorsal carination of abdomen start from fourth somite ending in a sharp spine at posterior end of sixth somite; minute spines on lateral margin of telson.

5th pereopod: ischium of first pereopod with a pointed spine, basis of first, second and third with a strong spine;

Petasma: distomedian projection slender, trilobed and anterolaterally directed (original author described based on sub adult specimen)

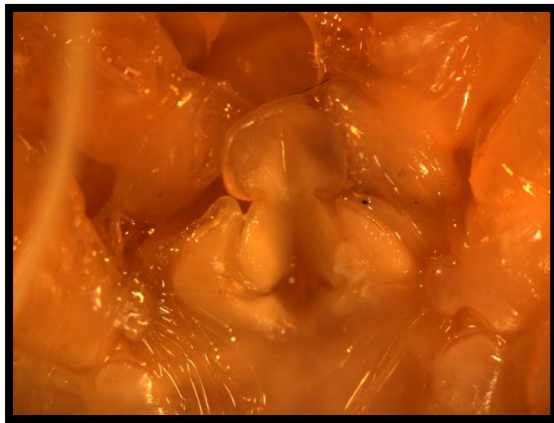
Thelycum: anterior plate of thelycum tongue like with a deep median longitudinal groove, small oval plates located in between anterior plate and lateral plates. median boss oval; posterior plate on sternite XIV glabrous, posteriorly curved inward and medially grooved.

Distribution: Endemic to Gujarat coast, Gulf of Kutch to Porbandar.

Metapenaeus brevicornis (H. Milne Edwards, 1837): Yellow Shrimp



(A)



(B)



(C)



(D)

Plate: 4.3. (A) *Metapenaeus brevicornis* (H. Milne Edwards, 1837); (B) thelycum; (C) petasma; (D) 5th pereopod of male

Synonyms: *Penaeus brevicornis* (H. Milne Edwards, 1837), *Metapeneus brevicornis* (Alcock, 1906)

Materials examined: A total of 31 specimens collected from Mumbai and Kakinada were examined.

Description:

Body smooth and glabrous; rostrum short, not exceeding second segment of antennular peduncle, rostral crest elevated, armed with 4-6+1 dorsal teeth only; epigastric tooth considerably close to penultimate tooth; more than 2/3 of distal part without teeth, straight, post rostral carina distinct ending before posterior border of carapace, adrostral carina and sulcus reaching upto the level between first and second rostral tooth; branchiocardiac carina feeble, not reaching middle of carapace; dorsal carination begins from posterior part of fourth somite, ending at terminal end of sixth somite with a short spine; telson armed with two lateral strong spines and numerous minute spines; antennular flagella subequal (dorsal one longer).

5th pereopod: proximal part of the merus of fifth pereopod with a notch, followed by a keel- shaped tubercule.

Petasma: disto-median projections of the petasma with a long and slender apical filament.

Thelycum: anterior plate of thelycum large square and grooved; lateral plates are boomerang shaped and enclosing two pear shaped plates. In impregnated females a pair white conjoined pads present on thelycum.

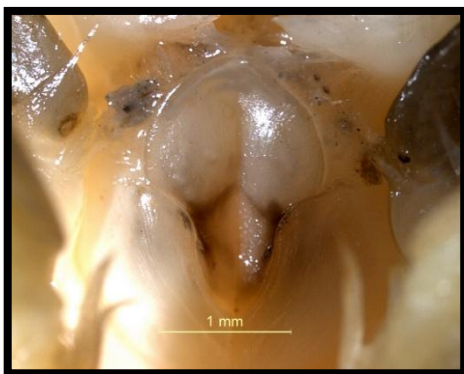
Colour: body yellow to white, sometimes greyish, with distinct dark green to bluish-brown specks.

Distribution: Northwest and northeast coasts of India & Andaman waters.

Metapenaeus dobsoni (Miers, 1878): Kadal Shrimp



(A)



(B)



(C)



(D)

Plate: 4.4. (A) *Metapenaeus dobsoni* (Miers, 1878); (B) thelycum; (C) petasma; (D) 5th pereopod of male

Synonyms: *Mangalura dobsoni* (Miers, 1878), *Metapenaeus dobsoni* (Nobili, 1903), *Penaeopsis dobsoni* (Kemp, 1915), *Metapenaeus dobsoni choprai* (Nataraj, 1942).

Material examined:

A total of 18 specimens were collected from different landing centres of Kochi (Kerala), Kakinada (A.P) and Mumbai and studied.

Description:

Almost entire body pubescent, rostrum long, sigmoidal in adult males, distal one-third toothless, sharply pointed at tip, armed with 7-9+1 dorsal teeth; epigastric tooth conspicuously separated from penultimate tooth; Post-rostral carina ending almost near posterior margin of carapace; adrostral carina and sulcus extend beyond epigastric tooth; branchiocrdiac carina indistinct, not reaching hepatic spine; branchiocardiac sulcus distinct, postocular sulcus oblique, cervical sulcus shallow, hepatic sulcus and carina slope downwards and anteroventrally but above pterygostomian angle; hepatic spine and antennular spine small, antennal carina short, dorsal carina starts from fourth segment ending in a short straight spine at the mid-posterior margin of sixth segment; chelate pereopod weak, basal spine of third pereopod extremely long and barbed; antennular flagella subequal, ventral one longer; telson armed only with row of small lateral spine.

5th pereopod: merus of fifth pereopod with 2 large, triangular teeth; fifth pereopod of adult female reduced to coxa and basis.

Petasma: each distomedian projection of petasma with a short filament on ventral surface and another on dorsal surface;

Thelycum: a long grooved tongue-like anterior plate partially en-sheathed in a horse-shoe-like process formed by the lateral plates. In impregnated females thelycum covered by a pair of white triangular conjoined pad.

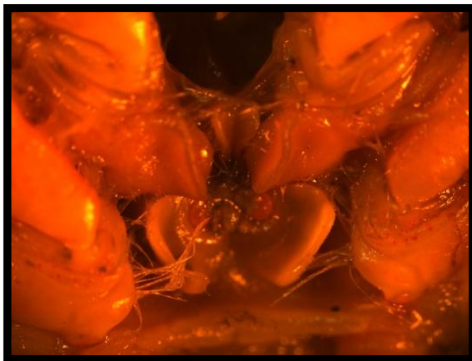
Colour: body pale yellow to brownish with red, brownish or greenish specks; antennae red; pereopods and pleopods white to pinkish; uropods grey-brownish, darker distally.

Distribution: found in Orissa, Andhra Pradesh, Tamil Nadu on the East coast of India; Kerala, Karnataka, Goa, Maharashtra on the West coast of India; Andaman Sea.

***Metapenaeus ensis* (De Haan, 1844): Greasy Back Shrimp**



(A)



(B)



(C)



(D)

Plate: 4.5. (A) *Metapenaeus ensis* (De Haan, 1844); (B) thelycum; (C) petasma; (D) male 5th pereopod

Synonyms: *Penaeus monoceros ensis* (de Haan 1850), *Penaeus incisipes* (Bate 1888), *Penaeus incisipes* (Kishinouye 1900), *Penaeopsis monoceros* (de Man 1911), *Metapenaeus monoceros* (Kubo 1949), *Metapenaeus incisipes* (Racek 1955 a), *Metapenaeus monoceros* (Dall 1957).

Materials examined: A total of 9 specimens collected from Chennai (T.N), Visakhapatnam (A.P) were used for examination.

Description:

Entire body covered with pubescence except carina; rostrum armed with 8 to 10+1 teeth along entire dorsal margin, nearly straight, and reaching to, or nearly to, tip of antennular peduncle; postrostral crest reaching to, or almost to posterior margin of carapace; adrostral crest ending behind second rostral tooth, adrostral groove behind epigastric tooth; branchiocardiac ridge usually sinuous, reaching posterior extension of hepatic spine; telson armed only with spinules; a small ischial spine on first pereopod.

5th pereopod: In adult males, merus of fifth pereopod with a proximal notch followed by a long, inwardly curved spiniform process and a row of tubercles.

Petasma: distomedian projections of petasma convoluted, greatly swollen (broad base and tapering towards the end) and directed forward, triangular in shape and concealing almost entirely distolateral projections in ventral view.

Thelycum: Anterior plate of thelycum lone and deeply grooved; lateral plates with strongly raised lateral margins forming posteriorly 2 inwardly curved triangular projections.

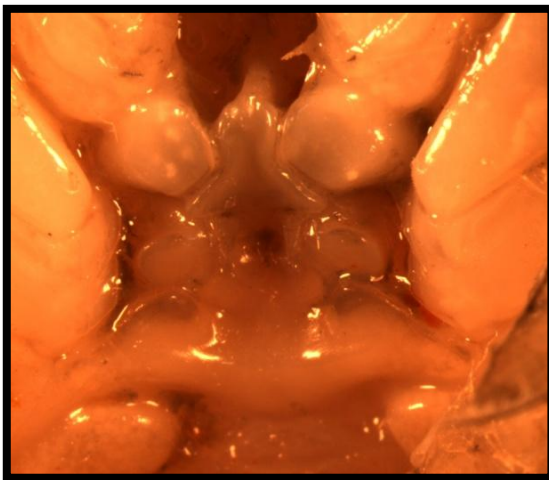
Colour: body pink to greenish-grey; middorsal abdominal crest brown; antennae red; pereopods and pleopods of same colour as body or red, the former with white stripes on ischium and merus; distal part of uropods purple-blue, external margins of exopods red-brown.

Distribution: Andhra Pradesh, Orissa, West Bengal and Andaman & Nicobar Islands; minor fishery at upper east coast and Paradeep.

Metapenaeus kutchensis (George and Rao, 1963): Ginger Shrimp



(A)



(B)



(C)



(D)

Plate no: 4.6. (A) *M. kutchensis* (George and Rao, 1963), (B) thelycum, (C) petasma, (D) male 5th pereopod.

Material examined: A total of 31 (18 male+ 13 female) specimen collected from Gulf of Kutch and Versova (Mumbai), were examined during the study.

Description:

Body irregularly pubescent; rostrum armed with 7-8+1 dorsal teeth, straight with a small crest, extending slightly beyond distal end of antennular peduncle; epigastric spine conspicuously separated from penultimate tooth; adrostral carina ending between epigastric tooth and penultimate tooth, adrostral sulcus beyond epigastric tooth; post-rostral carina ending in a glabrous expansion before posterior margin of carapace; carapace with strong antennal spine, hepatic spine; post-ocular sulcus oblique, orbitoantennal sulcus distinct, meeting the hepatic sulcus below hepatic spine; hepatic sulcus descend vertically, distal portion curves anteroventrally towards pterygostamian angle; cervical sulcus obliquely straight behind hepatic spine; branchiocardiac sulcus distinct, branchiocardiac carina meeting with hepatic spine; antennular flagella equal, stylocerite extend upto half basal segment; ischium of first pereopod with a spine, smaller than basal spine; dorsal carina conspicuous only from fourth to sixth somite and terminate in a short spine; telson with very minute numerous dorsolateral spine.

5th pereopod: merus of adult male with a shallow notch followed by an anterior small tooth.

Petasma: petasma quite similar to that of *M. affinis*, differs in distomedian lobes placed more transversely with the proximal end narrow and distal end broad.

Thelycum: anterior plate of thelycum tongue shaped, wide posteriorly, median groove widens posteriorly; posterior plate on sternite XIV concave, glabrous transversely cut into two unequal segments; lateral edges of these segments curve up and placed one behind the other.

Colour: body reddish orange in the shade of carrot in fresh condition; pubescence present in shallow grooves and in irregular patches on the carapace and abdomen.

Distribution: Northwest coast of India and minor fishery at Mumbai, Veraval and Kandla.

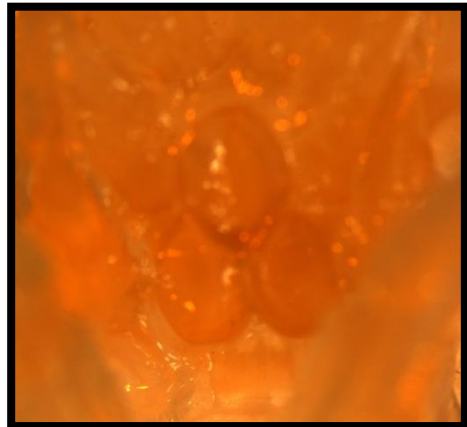
***Metapenaeus lysianassa* (De Man, 1888): Bird Shrimp**



(A)



(B)



(C)

Plate No: 4.7. (A) *Metapeneus lysianassa*; (B)rostrum; (C) thelycum

Synonyms: *Penaeus lysianasa* (De Man, 1888), *Metapeneus lysianasa* (Alcock, 1906)

Material examined: A total of 3 (all are females) specimen collected from Digha (West Bengal) were examined.

Description

Almost entire body pubescent; rostrum very short, reaching as far as middle of first antennular article and armed with 6 or 7 teeth along entire dorsal margin, rostral crest high; postrostral ridge ending near posterior margin of carapace; adrostral crest and groove reaching as far as third rostral tooth; branchiocardiac groove not reaching to middle of carapace; telson armed only with spinules; ischial spine on first pereopod absent or minute.

5th pereopod: In adult males, merus of fifth pereopod with a proximal notch followed by a large, slightly arcuate triangular tooth.

Petasma: distolateral projections of petasma bifurcate distally; distomedian projections with a minute filament on their median margins.

Thelycum: In females, anterior and lateral plates of thelycum subequal in size, anterior plate tongue-like and grooved, posterior plates suboval with thick median margins; impregnated fertilized specimens with white conjoined pads on thelycum.

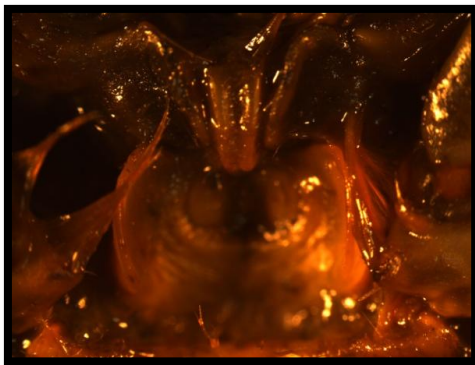
Colour: body, pereopods and pleopods pale yellow with grey specks; antennae and distal part of uropods grey.

Distribution: Middle and southwest and east coasts of India & Andaman waters.

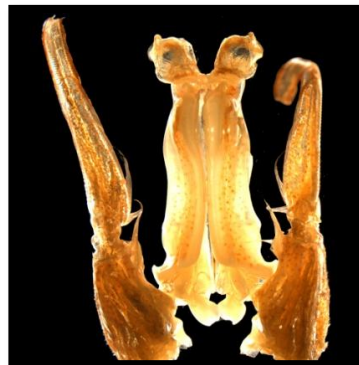
***Metapenaeus monoceros* (Fabricius, 1798): Speckled Shrimp**



(A)



(B)



(C)



(D)

Plate: 4.8. (A) *Metapenaeus monoceros* (Fabricius, 1798), (B) thelycum, (C) petasma, (D) merus of 5th pereopod male.

Synonyms: *Penaeus monoceros* (Fabricius, 1798); *Metapenaeus monoceros* (Alcock, 1906); *Penaeopsis monoceros* (de Man, 1911); *Penaeus incisipes* (Bate, 1888); *Metapenaeus incisipes* (Racek, 1955).

Materials examined: A total of 30 specimens collected from Kakinada (A.P), Visakhapatnam (A.P), Versova (Mumbai) were studied.

Description:

Body covered with stiff, very short tomentum; rostrum nearly straight, uptilted, teeth 8-10 + epigastric; Adrostral carina ending between epigastric and 1st tooth, sulcus extending behind epigastric, Postrostral carina distinct, continuing to posterior border of carapace; A small blunt ischial spine on 1st pereopod.

5th pereopod: A large triangular distoventral keel on ischium of 5th pereopod in mature male, followed by a deep notch on merus, bounded by a prominent spinous process twisted ventrally at angle 90° to axis of merus, usually followed by a ventral row of conical tubercles, which end in a small keel at distal merus; tubercles sometimes reduced or absent.

Petasma: Apex of petasma barely reaching bases of 2nd pereopods. Distomedian projections overlying distolateral projections, with openings facing dorsolaterally; openings closed by convex flap on distoventral edge of opening; Apices of projections with 1 or 2 rows minute setae.

Thelycum: Anterior plate level with and bounded on either side by expanded coxal projections of 4th pereopods; with median groove deepening posteriorly; Posterior plates strongly concave; anterior part with angular projections facing inwards under anterior plate, enclosing 2 flat plates lying on either side of posterior tongue-like extension of anterior plate; the whole having a cup-shaped appearance, but open posteriorly.

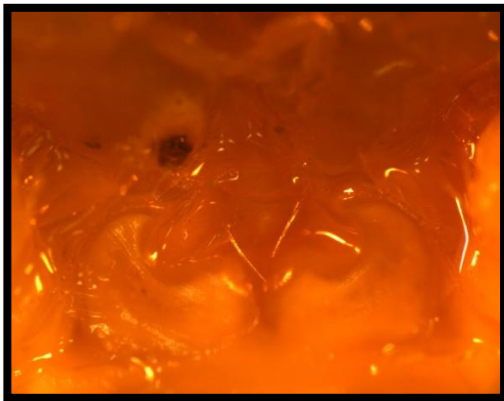
Colour: body pink, green-greyish or whitish with brown specks; distal part of uropods purpleblue.

Distribution: All along the west and east coasts of India.

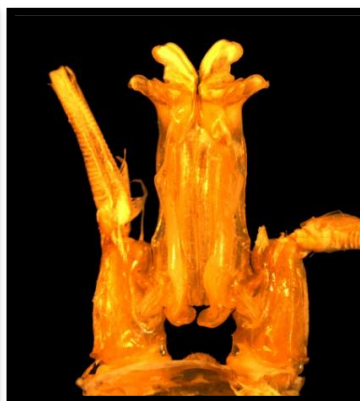
Metapenaeus moyebi (Kishinouye, 1896): Moyebi prawn



(A)



(B)



(C)



(D)

Plate no: 4.9. (A) *Metapenaeus moyebi* (Kishinouye, 1896), (B) thelycum; (C) petasma; (D) merus of male 5th pereopod

Synonyms: *Penaeus moyebi* (Kishinouye, 1896), *Metapenaeus burkenroadi* (Kubo, 1954), *Metapenaeus moyebi* (Miquel, 1982)

Description:

Pubescence covering almost entire body or confined to dorsal carapace and a few abdominal patches; rostrum armed with 7 to 10 teeth along entire dorsal margin, nearly straight, slightly uptilted and reaching distal half of third antennular article or just beyond; postrostral ridge low, generally ending near posterior margin of carapace; adrostral crest ending behind second rostral tooth, adrostral groove behind epigastric tooth; branchiocardiac ridge feeble, ending near posterior third of carapace; telson armed only with spinules; ischial spine on first pereopod minute or absent.

5th pereopod: In adult males, merus of fifth pereopod with a proximal notch followed by a twisted keeled tubercle;

Petasma: distomedian projections of petasma laminose and diverging; distolateral projections directed anterolaterally.

Thelycum: In females, anterior plate of thelycum flask-shaped, its anterior margin slightly convex and bearing 3 tubercles of subequal size; lateral plates kidney-shaped, often with angular contours.

Colour: body semi-translucent pale green with brownish-green specks; pereopods and pleopods of same colour as body; distal part of uropods green.

Distribution: South and Middle West coast, southeast coast and Andaman Islands.

4.4. Morphometric Characters

4.4.1. Descriptive statistics of morphometric data

Descriptive statistics (minimum, maximum, mean, standard deviation and coefficient of variation) were obtained for 42 morphometric characters (all scaled to TL) for 8 species, measure during the study. Most of the morphometric variables found to be important in differentiating the species. Even in closely resembling species, some characters were found to differ. (Table No 4.1 to 4.9)

The mean proportion of carapace length to total length (CL/TL) ranged from 0.212676 in *M. lysianassa* to 0.255982 in *M. monoceros*. Means found in between two extremes were *M. moyebi* (0.228962), *M. dobsoni* (0.223380), *M. alcocki* (0.238301), *M. ensis* (0.239774), *M. brevicornis* (0.245630), *M. affinis* (0.244680) and *M. kutchensis* (0.246606). The mean proportion of carapace width to total length (CW/TL) was ranged from 0.111954 (*M. dobsoni*) to 0.123571 (*M. monoceros*). The mean proportion of carapace depth to total length (CD/TL) ranged from 0.117361 (*M. dobsoni*) to 0.137015 (*M. moyebi*). The mean proportion of rostral length to total length (RL/TL) ranged from 0.050259 (*M. lysianassa*) to 0.156966 (*M. moyebi*). The mean proportion of antennular peduncle length to total length (APL/TL) ranged from 0.144108 (*M. alcocki*) to 0.165284 (*M. lysianassa*). The mean proportion of DAL/TL ranged from 0.062099 (*M. moyebi*) to 0.187792 (*M. lysianassa*). The mean proportion of VAL/TL ranged from 0.067394 (*M. alcocki*) to 0.193817 (*M. lysianassa*). The mean proportion of LT/TL ranged from 0.136784 (*M. brevicornis*) to 0.152070 (*M. lysianassa*). The mean proportion of 6ASL/TL ranged from 0.109272 (*M. affinis*) to 0.151034 (*M. lysianassa*). The mean proportion of 6 ASD/TL was ranged from 0.092314 (*M. monoceros*) to 0.119672 (*M. lysianassa*). The mean proportion of ASL/TL ranged from 0.144438 (*M. alcocki*) to 0.182724 (*M. lysianassa*). The mean proportion of 1TLP/TL ranged from 0.231983 (*M. affinis*) to 0.173875 (*M. dobsoni*). The mean proportion of 1ILP/TL ranged from 0.021435 (*M. lysianassa*) to 0.040189 (*M. ensis*). The mean proportion of 1MLP/TL was ranged from 0.046434 (*M. moyebi*) to 0.059937 (*M. brevicornis*). The mean proportion of 1CLP/TL ranged from 0.040914 (*M. moyebi*) to 0.059253 (*M. lysianassa*).

The mean proportion of 1PLP/TL ranged from 0.013386 (*M. lysianassa*) to 0.023299 (*M. dobsoni*).

The mean proportion of 1FLP/TL ranged from 0.017861 (*M. lysianassa*) to 0.038568 (*M. affinis*). The mean proportion of 2TLP/TL was ranged from 0.240593 (*M. dobsoni*) to 0.310174 (*M. affinis*). The mean proportion of 2ILP/TL ranged from 0.022020 (*M. lysianassa*) to 0.043052 (*M. monoceros*). The mean proportion of 2MLP/TL was ranged from 0.064764 (*M. dobsoni*) to 0.082063 (*M. brevicornis*). The mean proportion of 2CLP/TL ranged from 0.075983 (*M. dobsoni*) to 0.095654 (*M. affinis*). The mean proportion of 2PLP/TL ranged from 0.017391 (*M. lysianassa*) to 0.033967 (*M. dobsoni*). The mean proportion of 2FLP/TL ranged from 0.017732 (*M. dobsoni*) to 0.041810 (*M. affinis*). The mean proportion of 3TLP/TL ranged from 0.302173 (*M. dobsoni*) to 0.403346 (*M. ensis*). The mean proportion of 3ILP/TL ranged from 0.026581 (*lysianassa*) to 0.046376 (*M. ensis*). The mean proportion of 3MLP/TL ranged from 0.083239 (*M. dobsoni*) to 0.103410 (*M. brevicornis*). The mean proportion of 3CLP/TL ranged from 0.104760 (*M. dobsoni*) to 0.147398 (*M. ensis*). The mean proportion of 3PLP/TL ranged from 0.025330 (*M. moyebi*) to 0.042079 (*M. dobsoni*). The mean proportion of 3FLP/TL was ranged from 0.018625 (*M. dobsoni*) to 0.048460 (*M. affinis*). The mean proportion of 4TLP/TL ranged from 0.204081 (*dobsoni*) to 0.321186 (*M. affinis*). The mean proportion of 4ILP/TL was ranged from 0.022892 (*M. lysianassa*) to 0.040672 (*M. monoceros*). The mean proportion of 4MLP/TL ranged from 0.060091 (*M. dobsoni*) to 0.093989 (*M. brevicornis*).

The mean proportion of 4CLP/TL ranged from 0.045247 (*M. dobsoni*) to 0.082517 (*M. affinis*). The mean proportion of 4PLP/TL ranged from 0.033716 (*M. dobsoni*) to 0.049215 (*M. affinis*). The mean proportion of 4DLP/TL ranged from 0.020611 (*lysianassa*) to .039332 (*brevicornis*). The mean proportion of 5TLP/TL ranged from 0.261119 (*M. dobsoni*) to 0.500349 (*M. brevicornis*). The mean proportion of 5ILP/TL ranged from 0.026264 (*M. lysianassa*) to 0.046679 (*M. moyebi*). The mean proportion of 5MLP/TL ranged from 0.068948 (*M. dobsoni*) to 0.146001 (*M. brevicornis*). The mean proportion of 5CLP/TL ranged from 0.054872 (*M. dobsoni*) to 0.134660 (*M. brevicornis*). The mean proportion of 5PLP/TL ranged from 0.047476 (*M. dobsoni*) to 0.086221 (*M. affinis*). The mean proportion of

5DLP/TL was ranged from 0.031190 (*M. moyebi*) to 0.068248 (*M. brevicornis*). (Table: 4.3 and 4.8)

Table: 4.1 Descriptive Statistics of morphometric characters of *M. affinis*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	30	0.244680	0.211290	0.267089	0.013599	5.55771
CW/TL	30	0.120051	0.103175	0.133113	0.008900	7.41316
CD/TL	30	0.132481	0.115000	0.150331	0.011052	8.34217
RL/TL	30	0.153745	0.132911	0.180000	0.013418	8.72770
APL/TL	30	0.145637	0.130464	0.158036	0.005299	3.63883
DAL/TL	30	0.090450	0.061667	0.139683	0.021664	23.95132
VAL/TL	30	0.083324	0.060833	0.117460	0.015896	19.07696
LT/TL	30	0.147484	0.134194	0.155263	0.005559	3.76953
6ASL/TL	30	0.109272	0.104380	0.115000	0.002696	2.46683
6ASD/TL	30	0.097130	0.088710	0.101333	0.002993	3.08138
ASL/TL	30	0.149720	0.139683	0.183824	0.008401	5.61132
1TLP/TL	30	0.231983	0.209934	0.269853	0.012850	5.53938
1ILP/TL	30	0.036879	0.032143	0.041481	0.002415	6.54786
1MLP/TL	30	0.056401	0.049669	0.062774	0.004351	7.71445
1CLP/TL	30	0.057429	0.049669	0.088235	0.006710	11.68368
1PLP/TL	30	0.022895	0.015873	0.067647	0.008894	38.84448
1FLP/TL	30	0.038568	0.033333	0.042222	0.002416	6.26349
2TLP/TL	30	0.310174	0.276667	0.334559	0.016609	5.35484
2ILP/TL	30	0.040823	0.033824	0.046835	0.003522	8.62740
2MLP/TL	30	0.074401	0.064286	0.082222	0.005370	7.21779
2CLP/TL	30	0.095654	0.084167	0.105839	0.007212	7.54003
2PLP/TL	30	0.028369	0.023214	0.033108	0.002761	9.73156
2FLP/TL	30	0.041810	0.029167	0.046970	0.005014	11.99163
3TLP/TL	30	0.400948	0.355000	0.465563	0.025261	6.30023
3ILP/TL	30	0.043986	0.037500	0.050370	0.003598	8.17908
3MLP/TL	30	0.101222	0.087500	0.108889	0.007445	7.35468
3CLP/TL	30	0.140826	0.119167	0.155034	0.011059	7.85292
3PLP/TL	30	0.036887	0.024675	0.043919	0.005816	15.76753
3FLP/TL	30	0.048460	0.033766	0.060403	0.006747	13.92231
4TLP/TL	30	0.321186	0.290000	0.347407	0.018702	5.82266
4ILP/TL	30	0.039461	0.032143	0.044000	0.003062	7.75984
4MLP/TL	30	0.088560	0.077500	0.097810	0.006128	6.91961
4CLP/TL	30	0.082517	0.069737	0.092593	0.006493	7.86892
4PLP/TL	30	0.049215	0.043421	0.056296	0.003917	7.95929
4DLP/TL	30	0.036149	0.029032	0.040268	0.003056	8.45481
5TLP/TL	30	0.486930	0.436420	0.529197	0.031310	6.43001
5ILP/TL	30	0.042732	0.035833	0.048175	0.003684	8.62117
5MLP/TL	30	0.140463	0.126667	0.154074	0.009401	6.69309
5CLP/TL	30	0.133632	0.116176	0.147407	0.009292	6.95326
5PLP/TL	30	0.086221	0.043885	0.097037	0.009816	11.38497
5DLP/TL	30	0.056325	0.042593	0.064286	0.005443	9.66382

Table: 4.2. Descriptive Statistics of orphometric characters of *M. alcocki*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	16	0.238301	0.225263	0.255319	0.008068	3.38558
CW/TL	16	0.113761	0.104054	0.122093	0.004794	4.21398
CD/TL	16	0.120449	0.111828	0.128421	0.004788	3.97535
RL//TL	16	0.142459	0.130337	0.158763	0.007801	5.47570
APL/TL	16	0.144108	0.129348	0.155789	0.006543	4.54056
DAL/TL	16	0.071636	0.062791	0.081111	0.005181	7.23176
VAL/TL	16	0.067394	0.060465	0.077895	0.004683	6.94797
LT//TL	16	0.143539	0.131429	0.148837	0.004783	3.33200
6ASL/TL	16	0.123104	0.117895	0.129213	0.003708	3.01204
6ASD/TL	16	0.099615	0.095652	0.106977	0.003289	3.30165
ASL/TL	16	0.144438	0.134783	0.152703	0.005259	3.64113
1TLP/TL	16	0.193415	0.185870	0.213514	0.006446	3.33259
1ILP/TL	16	0.033023	0.027835	0.037634	0.003011	9.11918
1MLP/TL	16	0.049232	0.041892	0.057447	0.004423	8.98441
1CLP/TL	16	0.041764	0.038144	0.047368	0.002783	6.66394
1PLP/TL	16	0.020713	0.016495	0.026316	0.003279	15.83032
1FLP/TL	16	0.026207	0.020225	0.032258	0.003392	12.94439
2TLP/TL	16	0.259693	0.241304	0.285135	0.011391	4.38647
2ILP/TL	16	0.036609	0.030526	0.040449	0.002961	8.08887
2MLP/TL	16	0.065467	0.061053	0.075581	0.003767	5.75439
2CLP/TL	15	0.078302	0.070526	0.083784	0.004691	5.99114
2PLP/TL	16	0.023435	0.018478	0.028090	0.002783	11.87429
2FLP/TL	16	0.028762	0.025263	0.032609	0.002255	7.83886
3TLP/TL	16	0.347311	0.323913	0.378378	0.014702	4.23314
3ILP/TL	16	0.037994	0.032632	0.042697	0.003316	8.72713
3MLP/TL	16	0.086630	0.077895	0.104054	0.007072	8.16296
3CLP/TL	16	0.125755	0.114737	0.139189	0.007283	5.79135
3PLP/TL	16	0.033047	0.027174	0.038372	0.003122	9.44742
3FLP/TL	16	0.030829	0.026087	0.035135	0.002441	7.91931
4TLP/TL	16	0.259262	0.237234	0.285135	0.010051	3.87685
4ILP/TL	16	0.035824	0.031579	0.040426	0.002611	7.28879
4MLP/TL	16	0.073532	0.067010	0.082432	0.004431	6.02539
4CLP/TL	16	0.060680	0.054639	0.066304	0.003147	5.18650
4PLP/TL	16	0.037713	0.032990	0.043023	0.003001	7.95809
4DLP/TL	16	0.026675	0.021649	0.031429	0.002588	9.70171
5TLP/TL	16	0.348211	0.327174	0.390541	0.017199	4.93920
5ILP/TL	16	0.039879	0.031461	0.047872	0.004929	12.35874
5MLP/TL	16	0.104239	0.097849	0.122973	0.006426	6.16505
5CLP/TL	16	0.092225	0.079348	0.100000	0.005306	5.75364
5PLP/TL	16	0.055332	0.049474	0.060811	0.004146	7.49368
5DLP/TL	16	0.032096	0.027660	0.035789	0.002683	8.35889

Table: 4.3. Descriptive Statistics of Morphometric characters of *M. brevicornis*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	31	0.245630	0.231343	0.269286	0.008041	3.27376
CW/TL	31	0.119381	0.107463	0.124409	0.003213	2.69110
CD/TL	31	0.132931	0.121008	0.143478	0.005768	4.33904
RL/TL	31	0.127618	0.089552	0.165546	0.014884	11.66291
APL/TL	31	0.147999	0.135294	0.170149	0.007521	5.08205
DAL/TL	31	0.112615	0.093220	0.128205	0.011381	10.10589
VAL/TL	31	0.099166	0.085593	0.141791	0.010025	10.10919
LT//TL	31	0.136784	0.128814	0.144286	0.004141	3.02718
6ASL/TL	31	0.127423	0.114655	0.138806	0.004400	3.45276
6ASD/TL	31	0.105661	0.100840	0.110448	0.002249	2.12888
ASL/TL	31	0.155968	0.147244	0.171642	0.005772	3.70045
1TLP/TL	31	0.224096	0.200000	0.318333	0.023014	10.26955
1ILP/TL	31	0.035561	0.027928	0.042636	0.004055	11.40430
1MLP/TL	31	0.059937	0.050877	0.096694	0.008583	14.31986
1CLP/TL	31	0.049409	0.042537	0.090083	0.008757	17.72428
1PLP/TL	31	0.021337	0.016667	0.026866	0.002463	11.54300
1FLP/TL	31	0.037066	0.030000	0.040650	0.002668	7.19743
2TLP/TL	31	0.305754	0.278862	0.400000	0.023235	7.59914
2ILP/TL	31	0.042721	0.034513	0.051938	0.005284	12.36926
2MLP/TL	31	0.082063	0.070370	0.092857	0.004939	6.01875
2CLP/TL	31	0.087237	0.051639	0.097143	0.007806	8.94787
2PLP/TL	31	0.026834	0.022314	0.034286	0.003783	14.09901
2FLP/TL	31	0.039733	0.025410	0.050714	0.006321	15.90917
3TLP/TL	31	0.388936	0.319167	0.528358	0.036481	9.37975
3ILP/TL	31	0.044652	0.036937	0.052941	0.004121	9.22932
3MLP/TL	31	0.103410	0.084615	0.141429	0.013403	12.96137
3CLP/TL	31	0.131898	0.076923	0.191429	0.019476	14.76591
3PLP/TL	31	0.036455	0.024324	0.070000	0.009928	27.23301
3FLP/TL	31	0.044337	0.035156	0.075373	0.009090	20.50142
4TLP/TL	31	0.318680	0.277778	0.401493	0.022622	7.09860
4ILP/TL	31	0.038953	0.034188	0.056716	0.005085	13.05293
4MLP/TL	31	0.093989	0.081982	0.167910	0.014765	15.70878
4CLP/TL	31	0.074554	0.064179	0.084286	0.003655	4.90235
4PLP/TL	31	0.047285	0.031343	0.053488	0.004903	10.36919
4DLP/TL	31	0.039332	0.028358	0.051181	0.005422	13.78563
5TLP/TL	31	0.500349	0.420149	0.600000	0.034900	6.97505
5ILP/TL	31	0.042301	0.028319	0.051163	0.007089	16.75916
5MLP/TL	31	0.146001	0.132331	0.158333	0.006909	4.73196
5CLP/TL	31	0.134660	0.111940	0.147863	0.010933	8.11927
5PLP/TL	31	0.084490	0.034483	0.116514	0.026138	30.93666
5DLP/TL	31	0.068248	0.045872	0.080328	0.011645	17.06227

Table: 4.4. Descriptive statistics of morphometric characters of *M. dobsoni*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	18	0.223380	0.208235	0.239326	0.009020	4.03782
CW/TL	18	0.111954	0.103947	0.117241	0.003448	3.07974
CD/TL	18	0.117361	0.110667	0.125843	0.004850	4.13220
RL/TL	18	0.152265	0.138356	0.177381	0.010890	7.15218
APL/TL	18	0.148171	0.137234	0.157534	0.006910	4.66359
DAL/TL	18	0.108261	0.100000	0.114118	0.003938	3.63742
VAL/TL	18	0.140841	0.126437	0.168519	0.011381	8.08081
LT//TL	18	0.143644	0.135484	0.150000	0.003823	2.66170
6ASL/TL	18	0.134212	0.125882	0.140741	0.005282	3.93526
6ASD/TL	18	0.096023	0.086842	0.100000	0.003314	3.45096
ASL/TL	18	0.161663	0.151613	0.169767	0.005667	3.50513
1TLP/TL	18	0.173875	0.165517	0.188889	0.005672	3.26237
1ILP/TL	18	0.029889	0.025926	0.033333	0.001883	6.30069
1MLP/TL	18	0.054941	0.047191	0.070370	0.005218	9.49778
1CLP/TL	18	0.038016	0.032143	0.044186	0.002686	7.06491
1PLP/TL	18	0.023299	0.018519	0.025843	0.001864	7.99912
1FLP/TL	18	0.018317	0.016216	0.021918	0.001851	10.10590
2TLP/TL	18	0.240593	0.232184	0.252809	0.006089	2.53066
2ILP/TL	18	0.032265	0.027632	0.038356	0.003428	10.62319
2MLP/TL	18	0.064764	0.059459	0.070930	0.003098	4.78395
2CLP/TL	18	0.075983	0.070213	0.080952	0.003173	4.17579
2PLP/TL	18	0.033967	0.027778	0.040449	0.003515	10.34944
2FLP/TL	18	0.017732	0.015116	0.020968	0.001925	10.85449
3TLP/TL	18	0.302173	0.285882	0.321348	0.010163	3.36317
3ILP/TL	18	0.034551	0.032184	0.038202	0.001533	4.43814
3MLP/TL	18	0.083239	0.070968	0.088372	0.004358	5.23562
3CLP/TL	18	0.104760	0.091935	0.115730	0.005516	5.26534
3PLP/TL	18	0.042079	0.034884	0.050000	0.004671	11.09990
3FLP/TL	18	0.018625	0.012791	0.024194	0.002322	12.46487
4TLP/TL	18	0.204081	0.192941	0.224074	0.008427	4.12946
4ILP/TL	18	0.030905	0.025882	0.035616	0.002342	7.57789
4MLP/TL	18	0.060091	0.056471	0.068605	0.003117	5.18726
4CLP/TL	18	0.045247	0.038824	0.055556	0.003455	7.63478
4PLP/TL	18	0.033716	0.025333	0.048148	0.006115	18.13627
4DLP/TL	18	0.021137	0.014865	0.025926	0.003308	15.65010
5TLP/TL	18	0.261119	0.238298	0.352941	0.025685	9.83666
5ILP/TL	18	0.033992	0.031395	0.038667	0.002265	6.66251
5MLP/TL	18	0.068948	0.062353	0.085057	0.005601	8.12290
5CLP/TL	18	0.054872	0.048235	0.068519	0.005288	9.63739
5PLP/TL	18	0.047476	0.041176	0.057407	0.003731	7.85939
5DLP/TL	18	0.034020	0.029070	0.038889	0.002378	6.99099

Table: 4.5. Descriptive statistics of morphometric characters of *M. ensis*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	9	0.239774	0.228455	0.263529	0.010773	4.49298
CW/TL	9	0.117755	0.107317	0.126667	0.007497	6.36692
CD/TL	9	0.133557	0.117886	0.158235	0.012618	9.44797
RL//TL	9	0.141380	0.131818	0.148780	0.006525	4.61507
APL/TL	9	0.154611	0.134545	0.167769	0.010136	6.55587
DAL/TL	9	0.088000	0.068182	0.107353	0.013400	15.22715
VAL/TL	9	0.087362	0.068182	0.107353	0.013051	14.93871
LT//TL	9	0.146490	0.133898	0.152500	0.006562	4.47975
6ASL/TL	9	0.118284	0.112353	0.121970	0.002612	2.20839
6ASD/TL	9	0.097904	0.095588	0.100833	0.001789	1.82705
ASL/TL	9	0.152106	0.142727	0.161364	0.006352	4.17621
1TLP/TL	9	0.225262	0.216667	0.248824	0.009589	4.25695
1ILP/TL	9	0.040189	0.037288	0.042941	0.002323	5.78062
1MLP/TL	9	0.053718	0.049167	0.059412	0.002955	5.50146
1CLP/TL	9	0.051821	0.047059	0.054706	0.002361	4.55643
1PLP/TL	9	0.023238	0.020455	0.027642	0.002591	11.14796
1FLP/TL	9	0.035219	0.031818	0.041176	0.002817	7.99785
2TLP/TL	9	0.302606	0.291818	0.332353	0.011684	3.86102
2ILP/TL	9	0.042542	0.035294	0.047154	0.004393	10.32567
2MLP/TL	9	0.077095	0.072500	0.081176	0.003102	4.02300
2CLP/TL	9	0.091983	0.082353	0.097458	0.004495	4.88708
2PLP/TL	9	0.029275	0.026271	0.033529	0.002141	7.31510
2FLP/TL	9	0.037727	0.035455	0.045882	0.003172	8.40670
3TLP/TL	9	0.403346	0.382727	0.451765	0.019803	4.90974
3ILP/TL	9	0.046376	0.041818	0.050833	0.003169	6.83371
3MLP/TL	9	0.100218	0.091818	0.111765	0.005752	5.73935
3CLP/TL	9	0.147398	0.136364	0.160588	0.007745	5.25456
3PLP/TL	9	0.039539	0.036364	0.044118	0.002417	6.11264
3FLP/TL	9	0.041547	0.036667	0.047059	0.003190	7.67802
4TLP/TL	9	0.299344	0.291667	0.332353	0.012737	4.25500
4ILP/TL	9	0.038798	0.037190	0.044706	0.002275	5.86475
4MLP/TL	9	0.081402	0.077273	0.087647	0.003155	3.87566
4CLP/TL	9	0.073564	0.069091	0.079661	0.003625	4.92805
4PLP/TL	9	0.047568	0.044915	0.050588	0.001863	3.91698
4DLP/TL	9	0.034199	0.029091	0.036667	0.002587	7.56428
5TLP/TL	9	0.405576	0.387500	0.439412	0.014218	3.50552
5ILP/TL	9	0.044187	0.041667	0.048333	0.002426	5.49065
5MLP/TL	9	0.113154	0.105455	0.122941	0.005224	4.61697
5CLP/TL	9	0.109107	0.098333	0.119412	0.006493	5.95120
5PLP/TL	9	0.066591	0.061017	0.072059	0.004184	6.28285
5DLP/TL	9	0.041438	0.036364	0.045833	0.003153	7.60837

Table: 4.6. Descriptive statistics of morphometric characters of *M. kutchensis*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	31	0.246606	0.223810	0.275676	0.016698	6.77101
CW/TL	31	0.118087	0.103125	0.136170	0.009749	8.25552
CD/TL	31	0.125674	0.103125	0.145946	0.010883	8.65957
RL//TL	31	0.149257	0.133333	0.162088	0.007845	5.25630
APL/TL	31	0.145860	0.135260	0.207619	0.012637	8.66398
DAL/TL	31	0.114371	0.075275	0.195625	0.032145	28.10548
VAL/TL	31	0.103477	0.069298	0.143750	0.024723	23.89192
LT//TL	31	0.149836	0.135811	0.162179	0.006744	4.50102
6ASL/TL	31	0.113318	0.106557	0.123656	0.004554	4.01874
6ASD/TL	31	0.095597	0.090385	0.100000	0.003052	3.19221
ASL/TL	31	0.146464	0.132967	0.153020	0.004434	3.02712
1TLP/TL	31	0.222466	0.178788	0.252809	0.019819	8.90866
1ILP/TL	31	0.035240	0.025714	0.042000	0.003910	11.09629
1MLP/TL	31	0.051270	0.043011	0.057333	0.003979	7.76084
1CLP/TL	31	0.048570	0.038710	0.053158	0.003863	7.95248
1PLP/TL	31	0.021451	0.015054	0.026000	0.002876	13.40954
1FLP/TL	31	0.036994	0.022581	0.045503	0.006648	17.97000
2TLP/TL	31	0.300565	0.239785	0.357838	0.030828	10.25667
2ILP/TL	31	0.042308	0.031313	0.050267	0.005915	13.98158
2MLP/TL	31	0.069709	0.059140	0.080000	0.005533	7.93761
2CLP/TL	31	0.087627	0.074747	0.096667	0.006206	7.08207
2PLP/TL	31	0.026948	0.018280	0.032000	0.003248	12.05423
2FLP/TL	31	0.041764	0.022581	0.051596	0.008093	19.37786
3TLP/TL	31	0.387944	0.319355	0.442781	0.033191	8.55554
3ILP/TL	31	0.043801	0.033673	0.051064	0.004060	9.26875
3MLP/TL	31	0.097330	0.078495	0.111230	0.009989	10.26348
3CLP/TL	31	0.138308	0.117172	0.153333	0.009686	7.00339
3PLP/TL	31	0.035648	0.027957	0.045333	0.005729	16.07030
3FLP/TL	31	0.039971	0.029032	0.049630	0.006225	15.57406
4TLP/TL	31	0.295566	0.241414	0.340437	0.025891	8.75997
4ILP/TL	31	0.039342	0.030612	0.045745	0.004912	12.48472
4MLP/TL	31	0.082635	0.065591	0.091351	0.007246	8.76914
4CLP/TL	31	0.074900	0.058065	0.084270	0.007255	9.68596
4PLP/TL	31	0.043119	0.034409	0.048667	0.003691	8.56042
4DLP/TL	31	0.034276	0.022819	0.041011	0.005344	15.59063
5TLP/TL	31	0.379316	0.328571	0.415508	0.031746	8.36932
5ILP/TL	31	0.043164	0.033333	0.050000	0.005082	11.77266
5MLP/TL	31	0.119954	0.100000	0.135393	0.010406	8.67539
5CLP/TL	31	0.102701	0.078788	0.120000	0.010785	10.50164
5PLP/TL	31	0.056821	0.049359	0.063415	0.004207	7.40327
5DLP/TL	31	0.039534	0.028947	0.047333	0.004952	12.52636

Table: 4.7. Descriptive statistics of morphometric characters of *M. monoceros*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	31	0.255982	0.237589	0.282407	0.013940	5.44564
CW/TL	31	0.123571	0.109155	0.144444	0.011207	9.06937
CD/TL	31	0.127380	0.104225	0.162595	0.013683	10.74173
RL/TL	31	0.130133	0.105344	0.149057	0.009721	7.47006
APL/TL	31	0.149166	0.140741	0.160305	0.005492	3.68199
DAL/TL	31	0.073220	0.057042	0.108280	0.011064	15.11039
VAL/TL	31	0.070831	0.055901	0.093631	0.009361	13.21617
LT/TL	31	0.147827	0.129630	0.157237	0.006312	4.27001
6ASL/TL	31	0.113262	0.105759	0.118321	0.003338	2.94737
6ASD/TL	31	0.094036	0.090789	0.099371	0.002695	2.86620
ASL/TL	31	0.146962	0.139490	0.154658	0.004712	3.20658
1TLP/TL	31	0.217352	0.199296	0.236025	0.010671	4.90944
1ILP/TL	31	0.037091	0.030263	0.052778	0.003784	10.20097
1MLP/TL	31	0.053505	0.050000	0.074074	0.004375	8.17735
1CLP/TL	31	0.050257	0.045513	0.071759	0.004584	9.12030
1PLP/TL	31	0.022414	0.019847	0.031481	0.002254	10.05643
1FLP/TL	31	0.031735	0.028369	0.034722	0.001863	5.87135
2TLP/TL	31	0.288843	0.262879	0.346429	0.016402	5.67865
2ILP/TL	31	0.043052	0.037173	0.047183	0.002735	6.35281
2MLP/TL	31	0.072011	0.065957	0.089352	0.005057	7.02269
2CLP/TL	31	0.085635	0.080282	0.097685	0.004204	4.90950
2PLP/TL	31	0.026294	0.023026	0.032407	0.002082	7.91672
2FLP/TL	31	0.032516	0.029078	0.035648	0.001712	5.26386
3TLP/TL	31	0.367293	0.325758	0.413889	0.021116	5.74904
3ILP/TL	31	0.043485	0.040698	0.047685	0.001737	3.99522
3MLP/TL	31	0.091815	0.084733	0.115741	0.007191	7.83247
3CLP/TL	31	0.132420	0.123188	0.146073	0.007248	5.47368
3PLP/TL	31	0.034860	0.028042	0.059722	0.005111	14.66250
3FLP/TL	31	0.035392	0.029630	0.039352	0.002181	6.16280
4TLP/TL	31	0.282242	0.259574	0.333333	0.015532	5.50314
4ILP/TL	31	0.040672	0.037405	0.046296	0.001768	4.34638
4MLP/TL	31	0.075103	0.065649	0.088426	0.005637	7.50603
4CLP/TL	31	0.070588	0.067296	0.086111	0.003208	4.54438
4PLP/TL	31	0.045088	0.042105	0.055093	0.002455	5.44539
4DLP/TL	31	0.031247	0.026923	0.045665	0.003715	11.88788
5TLP/TL	31	0.362728	0.346073	0.391329	0.011499	3.17018
5ILP/TL	31	0.043250	0.039535	0.048148	0.002531	5.85284
5MLP/TL	31	0.104376	0.025926	0.116402	0.015349	14.70546
5CLP/TL	31	0.101019	0.095745	0.112963	0.003561	3.52497
5PLP/TL	31	0.052840	0.041885	0.062179	0.006353	12.02234
5DLP/TL	31	0.034382	0.028796	0.038365	0.002948	8.57544

Table: 4.8. Descriptive statistics of morphometric characters of *M.moyebi*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	30	0.228962	0.204348	0.245545	0.011406	4.9815
CW/TL	30	0.120406	0.111765	0.127723	0.004570	3.7951
CD/TL	30	0.137015	0.116176	0.150000	0.008078	5.8956
RL//TL	30	0.156966	0.143023	0.170588	0.006853	4.3657
APL/TL	30	0.159665	0.137500	0.170330	0.006560	4.1084
DAL/TL	30	0.062099	0.049462	0.081053	0.008129	13.0905
VAL/TL	30	0.087773	0.060215	0.648352	0.106102	120.8818
LT//TL	30	0.137220	0.127174	0.145361	0.004021	2.9304
6ASL/TL	30	0.126117	0.119767	0.132967	0.003552	2.8167
6ASD/TL	30	0.092314	0.087629	0.096703	0.002129	2.3067
ASL/TL	30	0.160073	0.148039	0.169231	0.005454	3.4069
1TLP/TL	30	0.180681	0.154412	0.195050	0.012024	6.6550
1ILP/TL	30	0.032856	0.027551	0.038947	0.003205	9.7533
1MLP/TL	30	0.046434	0.038372	0.051648	0.003356	7.2272
1CLP/TL	30	0.040914	0.035165	0.048352	0.003527	8.6208
1PLP/TL	30	0.018154	0.012745	0.024638	0.002672	14.7199
1FLP/TL	30	0.023549	0.018605	0.026374	0.001852	7.8643
2TLP/TL	30	0.252376	0.174419	0.278218	0.020549	8.1421
2ILP/TL	30	0.037051	0.030928	0.045055	0.003108	8.3877
2MLP/TL	30	0.068786	0.058696	0.079121	0.005927	8.6173
2CLP/TL	30	0.080202	0.061765	0.091209	0.006223	7.7595
2PLP/TL	30	0.019295	0.013187	0.023077	0.002753	14.2673
2FLP/TL	30	0.024221	0.019767	0.027551	0.002324	9.5963
3TLP/TL	30	0.331562	0.280000	0.368116	0.019399	5.8507
3ILP/TL	30	0.039811	0.034884	0.043478	0.002389	6.0020
3MLP/TL	30	0.086438	0.072059	0.094624	0.006229	7.2066
3CLP/TL	30	0.123187	0.093684	0.139175	0.009099	7.3867
3PLP/TL	30	0.025330	0.019118	0.031183	0.003628	14.3246
3FLP/TL	30	0.024817	0.017647	0.028866	0.002675	10.7791
4TLP/TL	30	0.265361	0.224490	0.281633	0.015309	5.7692
4ILP/TL	30	0.038065	0.032632	0.041584	0.002263	5.9463
4MLP/TL	30	0.072512	0.060294	0.101053	0.007721	10.6479
4CLP/TL	30	0.065592	0.059551	0.073684	0.004133	6.3012
4PLP/TL	30	0.040235	0.030612	0.044211	0.003326	8.2663
4DLP/TL	30	0.026098	0.019767	0.032292	0.002740	10.5005
5TLP/TL	30	0.363807	0.261053	0.393407	0.025563	7.0266
5ILP/TL	30	0.046679	0.036842	0.094059	0.010108	21.6536
5MLP/TL	30	0.100649	0.090217	0.120290	0.006747	6.7034
5CLP/TL	30	0.093599	0.045263	0.107692	0.014076	15.0390
5PLP/TL	30	0.062379	0.027368	0.073913	0.013106	21.0097
5DLP/TL	30	0.031190	0.018947	0.037634	0.004269	13.6876

Table: 4.9. Descriptive statistics of morphometric characters *M. lysianassa*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.	Coef.Var.
CL/TL	3	0.212676	0.200000	0.238028	0.021956	10.32348
CW/TL	3	0.114440	0.110526	0.121127	0.005819	5.08475
CD/TL	3	0.118483	0.112281	0.128169	0.008498	7.17199
RL/TL	3	0.050259	0.046479	0.052632	0.003309	6.58405
APL/TL	3	0.165284	0.163333	0.167606	0.002160	1.30699
DAL/TL	3	0.187792	0.187324	0.188333	0.000509	0.27085
VAL/TL	3	0.193817	0.187719	0.205000	0.009698	5.00358
LT//TL	3	0.152070	0.145070	0.156140	0.006089	4.00393
6ASL/TL	3	0.151034	0.145614	0.159155	0.007163	4.74268
6ASD/TL	3	0.119672	0.119298	0.120000	0.000353	0.29509
ASL/TL	3	0.182724	0.178873	0.185965	0.003585	1.96193
1TLP/TL	3	0.179512	0.175439	0.183099	0.003853	2.14648
1ILP/TL	3	0.021435	0.017544	0.026761	0.004773	22.26722
1MLP/TL	3	0.057808	0.047368	0.076056	0.015858	27.43205
1CLP/TL	3	0.059253	0.036842	0.085915	0.024812	41.87422
1PLP/TL	3	0.013386	0.008772	0.019718	0.005672	42.37402
1FLP/TL	3	0.017861	0.015789	0.021127	0.002862	16.02414
2TLP/TL	3	0.251245	0.243333	0.264789	0.011784	4.69032
2ILP/TL	3	0.022020	0.019298	0.026761	0.004121	18.71404
2MLP/TL	3	0.070323	0.064912	0.076056	0.005579	7.93346
2CLP/TL	3	0.081036	0.077193	0.085915	0.004453	5.49460
2PLP/TL	3	0.017391	0.015789	0.019718	0.002062	11.85793
2FLP/TL	3	0.018446	0.016667	0.021127	0.002363	12.80986
3TLP/TL	3	0.317756	0.310000	0.330986	0.011514	3.62368
3ILP/TL	3	0.026581	0.026316	0.026761	0.000234	0.88196
3MLP/TL	3	0.087859	0.084211	0.094366	0.005649	6.42995
3CLP/TL	3	0.118129	0.114035	0.125352	0.006274	5.31107
3PLP/TL	3	0.026264	0.022807	0.030986	0.004233	16.11880
3FLP/TL	3	0.022221	0.021053	0.023944	0.001523	6.85453
4TLP/TL	3	0.226073	0.216667	0.242254	0.014075	6.22567
4ILP/TL	3	0.022892	0.022535	0.023333	0.000406	1.77254
4MLP/TL	3	0.064584	0.061404	0.069014	0.003956	6.12593
4CLP/TL	3	0.049387	0.048333	0.050704	0.001207	2.44456
4PLP/TL	3	0.034429	0.033333	0.036620	0.001897	5.51107
4DLP/TL	3	0.020611	0.019298	0.022535	0.001703	8.26167
5TLP/TL	3	0.363296	0.338596	0.392958	0.027518	7.57462
5ILP/TL	3	0.026264	0.022807	0.030986	0.004233	16.11880
5MLP/TL	3	0.095908	0.092982	0.101408	0.004767	4.97006
5CLP/TL	3	0.077615	0.071930	0.085915	0.007350	9.47036
5PLP/TL	3	0.066931	0.061404	0.076056	0.007961	11.89494
5DLP/TL	3	0.040753	0.038596	0.043662	0.002615	6.41749

4.4.2. Correlation among morphometric traits

The correlation matrix of 13 morphometric measurements which are contributing more was generated where all the morphometric characters showed prominent correlation ($p < 0.0500$) with total length. Correlation coefficient of more than 0.95 was observed for CL, CW, 6ASD, 1ILP, 3TLP, 3ILP, 4TLP and 4ILP with total length. Correlation coefficient ranging from 0.9 to 0.95 was observed for 2PLP and 2FLP. Relatively lower values of coefficients (0.9) were observed for 5TLP and 5DLP.

4.4.3. Factor analysis

The 42 morphometric traits after log transformation and allometric correction were subjected to factor analysis to generate two factors. The factors loadings after varimax rotation for the morphometric were analysed. The characters having factor loading (table: 4.11) of above 0.8 on any of the two factors were selected for subsequent stepwise discriminant analysis. The selected variables are (12) are CL, CW, 6ASD, 1ILP, 2PLP, 2FLP, 3TLP, 3ILP, 4TLP, 4ILP, 5TLP and 5DLP.

4.4.4. Stepwise (forward) discriminant analysis

The variables after factor loading were subjected to stepwise discriminant analysis (SDFA). Discriminant analysis generated 7 functions (Table: 4.12). The means of canonical variables (Table: 4.13) shows that root 1 successfully discriminates between most of the concerned species especially *M. affinis*, *M. moyebi*, *M. alcocki* and *M. brevicornis*. Root 2 and root 3 discriminates remaining species like *M. kutchensis*, *M. dobsoni*, *M. ensis* and *M. monoceros*.

The factor matrix (Table: 4.14) indicated 3TLP and 5DLP as main contributors to root1, whereas for root 2, major contributors were 2FLP, and 4ILP. While major contributors for third were 2FLP and 3TLP while contributors for fourth root were 4TLP, 5TLP, 5DLP and 4ILP.

Scattergram (Fig: 4.1) between root 1 and root 2 shows that most of the species can be separated based on characters like 3TLP, 5DLP and 2FLP.

Table: 4.15 shows the summary of stepwise inclusion of morphometric variables and its respective significance level. A classification matrix (Table: 4.16) was also generated shows successful classification of 100%.

4.4.5. Squared Mahalanabis Distance Analysis

Squared Mahalanabis distance revealed significant difference among the species of genus *Metapenaeus* given in the Table 4.17. Maximum distance (8827.033) was showed between *M. ensis* and *M. alcocki* followed by *M. moyebi* and *M. alcocki* (7802.619), which means they are distantly related to each other. Minimum distance was showed between *M. ensis* and *M. kutchensism* (1658.081), which means they are closely related to each other in most of the characters.

Variable	Means	Std.Dev.	TL	CL	CW	6ASD	1ILP	2PLP	2FLP	3TLP	3ILP	4TLP	4ILP	5TLP	5DLP
TL	122.9045	33.1226	1	0.98958	0.97699	0.98203	0.95952	0.91635	0.91897	0.97322	0.97611	0.96576	0.97469	0.87298	0.65350
CL	30.0789	9.7945	0.98958	1	0.98832	0.98095	0.95337	0.91028	0.90953	0.96126	0.96585	0.95664	0.96993	0.85928	0.63119
CW	14.7452	4.6792	0.97699	0.98832	1	0.96864	0.93726	0.89477	0.89369	0.95041	0.95489	0.94413	0.96278	0.85173	0.61685
6ASD	11.9613	3.2133	0.98203	0.98095	0.96864	1	0.94595	0.91551	0.93414	0.97070	0.96783	0.97172	0.95764	0.90978	0.72619
1ILP	4.3668	1.5407	0.95952	0.95337	0.93726	0.94595	1	0.89777	0.89075	0.94842	0.95953	0.94896	0.95736	0.85061	0.64702
2PLP	3.2709	1.1790	0.91635	0.91028	0.89477	0.91551	0.89777	1	0.86877	0.92153	0.90361	0.89168	0.89338	0.80835	0.67275
2FLP	4.3603	2.1128	0.91897	0.90953	0.89369	0.93414	0.89075	0.86877	1	0.94686	0.93558	0.95649	0.92075	0.91071	0.75865
3TLP	45.9558	15.7403	0.97322	0.96126	0.95041	0.97070	0.94842	0.92153	0.94686	1	0.97528	0.97811	0.96480	0.90996	0.71717
3ILP	5.2513	1.8100	0.97611	0.96585	0.95489	0.96783	0.95953	0.90361	0.93558	0.97528	1	0.96786	0.97062	0.89164	0.70077
4TLP	35.7312	12.5484	0.96576	0.95664	0.94413	0.97172	0.94896	0.89168	0.95649	0.97811	0.96786	1	0.96417	0.94198	0.76137
4ILP	4.7663	1.6797	0.97469	0.96993	0.96278	0.95764	0.95736	0.89338	0.92075	0.96480	0.97062	0.96417	1	0.85978	0.64552
5TLP	49.6075	17.2726	0.87298	0.85928	0.85173	0.90978	0.85061	0.80835	0.91071	0.90996	0.89164	0.94198	0.85978	1	0.88157
5DLP	5.4221	2.3165	0.65350	0.63119	0.61685	0.72619	0.64702	0.67275	0.75865	0.71717	0.70077	0.76137	0.64552	0.88157	1

Table: 4.10. Correlation matrix of morphometric characters of six species of genus *Metapenaeus*

Variables	Factor 1	Factor 2
CL	0.88504	0.266072
CW	0.86784	-0.050383
CD	0.82331	-0.075137
RL	-0.32755	0.777430
APL	0.57877	0.434060
DAL	-0.12792	0.512482
VAL	0.22619	0.148828
LT	0.33802	0.732816
6ASL	0.57439	0.560715
6ASD	0.86696	0.091744
ASL	0.80857	0.280953
1TLP	0.76770	0.363360
1ILP	0.87373	0.219579
1MLP	0.43211	0.635633
1CLP	0.55558	0.533298
1PLP	0.81707	-0.298259
1FLP	0.82053	0.422551
2TLP	0.80922	0.084638
2ILP	0.80509	0.358426
2MLP	0.79446	0.273599
2CLP	0.77405	0.172620
2PLP	0.89345	0.138774
2FLP	0.85969	0.261454
3TLP	0.91699	-0.128634
3ILP	0.93574	-0.023696
3MLP	0.63845	0.512978
3CLP	0.52830	0.413969
3PLP	-0.34955	0.692531
3FLP	0.45177	0.812987
4TLP	0.93898	0.246022
4ILP	0.94492	0.033894
4MLP	0.67162	0.551109
4CLP	0.66104	0.729188
4PLP	0.45333	0.819545
4DLP	0.70224	0.415869
5TLP	0.89313	0.200456
5ILP	0.74071	0.193340
5MLP	0.82331	0.317372
5CLP	0.34151	0.634561
5PLP	-0.22909	0.798566
5DLP	0.05848	0.855412

Table: 4.11. Factor Analysis of morphometric characters

Table: 4.12. Standardised coefficient for canonical variables of 8 species of genus *Metapenaeus* in stepwise (forward) discriminant analysis.

Variable	Root 1	Root 2	Root 3	Root 4	Root 5	Root 6	Root 7
2FLP	-0.1496	1.1227	-0.7016	1.2237	0.58896	-0.42649	1.43005
3TLP	1.4318	0.2985	2.1979	0.5886	0.94015	-0.91755	0.82005
5DLP	-1.1801	-0.1534	-0.0600	-0.0969	0.70347	-0.54073	0.17218
4ILP	0.6536	0.6012	-1.1556	-1.4428	-0.39944	1.91267	0.16231
CW	1.9445	-1.1774	-2.4557	-0.3929	-0.85448	-2.39911	-0.58079
CL	-2.8144	1.5741	2.0060	1.5713	-2.45749	1.47172	-1.24144
6ASD	0.1104	-2.3913	0.1690	-0.6583	1.91116	1.45940	3.29277
3ILP	0.4839	-0.1322	-0.8394	0.9859	0.63400	0.53739	-1.97088
4TLP	-1.0229	0.0952	0.6221	-1.1456	-1.05046	-1.83988	-0.79518
5TLP	0.4356	1.1384	0.1014	-1.0496	-0.08925	0.70569	-0.55416
1ILP	0.2037	-0.5977	0.0124	-0.3754	0.36363	-0.77984	-0.23494
2PLP	-0.1316	-0.0948	0.0088	0.7612	-0.23196	0.28785	-0.20600
Eigenval	646.5110	498.7102	254.2334	198.7926	90.21131	44.13842	18.08993
Cum.Prop	0.3693	0.6542	0.7994	0.9129	0.96445	0.98967	1.00000

Table: 4.13. Means of canonical variables of 8 species of genus *Metapenaeus* in stepwise (forward) discriminant analysis.

Group	Root 1	Root 2	Root 3	Root 4	Root 5	Root 6	Root 7
<i>M. affinis</i>	32.7255	16.4471	-11.1322	17.6530	-8.4271	3.41315	0.20559
<i>M. alcocki</i>	28.6475	-44.8776	-25.2222	-15.7543	10.5953	4.47781	0.77874
<i>M. brevicorn</i>	-27.2365	-15.8274	-2.9474	17.4839	3.2304	-6.25620	3.99276
<i>M. dobsoni</i>	2.7145	-22.2674	30.7660	12.1889	5.2690	6.15870	-7.17025
<i>M. ensis</i>	0.2109	25.6358	27.4341	-10.7539	9.9948	14.59327	12.85674
<i>M. kutchensis</i>	2.2094	30.1978	-3.3765	-6.1182	12.9853	-5.49400	-2.95626
<i>M. monoceros</i>	14.8845	-7.1315	14.2435	-14.9141	-11.1591	-7.55852	1.11741
<i>M. moyebi</i>	-39.2154	5.6772	-10.2894	-9.6712	-8.6087	6.07783	-2.40149

Table: 4.14. Factor structure matrix for 8 species of metapenaeus in stepwise (forward) discriminant analysis.

Variable	Root 1	Root 2	Root 3	Root 4	Root 5	Root 6	Root 7
2FLP	0.079203	0.441927	-0.176135	0.092212	-0.061629	-0.412552	0.391189
3TLP	0.256268	0.268896	0.177029	-0.019986	-0.030709	-0.433044	0.250672
5DLP	-0.274556	0.206464	-0.070656	-0.159514	0.274118	-0.447981	0.127396
4ILP	0.164888	0.335991	-0.113166	-0.172284	-0.090762	-0.302047	0.272496
CW	0.146104	0.099556	-0.089640	-0.014498	-0.269111	-0.452888	0.285906
CL	0.043185	0.166257	0.021396	0.017563	-0.279183	-0.366672	0.287125
6ASD	0.093326	0.073998	0.018661	-0.054317	-0.154692	-0.341167	0.372702
3ILP	0.163806	0.230442	-0.064793	0.056323	0.040334	-0.367707	0.077696
4TLP	0.080216	0.281579	0.039009	-0.148828	-0.160046	-0.478715	0.242004
5TLP	0.083897	0.330544	0.071455	-0.208320	-0.048349	-0.338960	0.196691
1ILP	0.088228	0.120519	-0.034704	-0.125400	0.005254	-0.473955	0.166896
2PLP	0.086851	0.157478	0.072523	0.097355	-0.067935	-0.348722	0.204332

Table: 4.15. Summary of Stepwise Analysis.

Variable entered	Step	F to	df 1	df 2	p-level	No. of var.	Lambda	F-value	df 1	df 2	p-level
2FLP -(E)	1	3267.284	7	188	0.000000	1.00000	0.008153	3267.285	7	188	0.00
3TLP -(E)	2	5357.231	7	187	0.000000	2.00000	0.000040	4173.421	14	374	0.00
5DLP -(E)	3	3309.346	7	186	0.000000	3.00000	0.000000	4616.042	21	535	0.00
4ILP -(E)	4	2893.115	7	185	0.000000	4.00000	0.000000	5536.654	28	668	0.00
CW -(E)	5	1878.551	7	184	0.000000	5.00000	0.000000	6542.311	35	776	0.00
CL -(E)	6	2606.271	7	183	0.000000	6.00000	0.000000	9004.864	42	862	0.00
6ASD -(E)	7	429.660	7	182	0.000000	7.00000	0.000000	9198.909	49	928	0.00
3ILP -(E)	8	80.936	7	181	0.000000	8.00000	0.000000	7756.885	56	980	0.00
4TLP -(E)	9	37.635	7	180	0.000000	9.00000	0.000000	6444.632	63	1020	0.00
5TLP -(E)	10	25.092	7	179	0.000000	10.00000	0.000000	5475.349	70	1051	0.00
1ILP -(E)	11	6.654	7	178	0.000001	11.00000	0.000000	4510.945	77	1074	0.00
2PLP -(E)	12	4.121	7	177	0.000320	12.00000	0.000000	3802.367	84	1092	0.00

Table: 4.16. classification matrix of different species of *Metapenaeus* in stepwise (forward) discriminant analysis.

Group	Percent	<i>M. affinis</i>	<i>M. alcocki</i>	<i>M. brevicornis</i>	<i>M. dobsoni</i>	<i>M. ensis</i>	<i>M. kutchensis</i>	<i>M. monoceros</i>	<i>M. moyebi</i>
<i>M. affinis</i>	100	30	0	0	0	0	0	0	0
<i>M. Alcocki</i>	100	0	16	0	0	0	0	0	0
<i>M. brevicorn</i>	100	0	0	31	0	0	0	0	0
<i>M. dobsoni</i>	100	0	0	0	18	0	0	0	0
<i>M. ensis</i>	100	0	0	0	0	9	0	0	0
<i>M. kutchensis</i>	100	0	0	0	0	0	31	0	0
<i>M. monoceros</i>	100	0	0	0	0	0	0	31	0
<i>M. moyebi</i>	100	0	0	0	0	0	0	0	30
Total	100	30	16	31	18	9	31	31	30

SPECIES	affinis	alcocki	brevicorn	Dobsoni	ensis	kutchensis	monoceros	moyebi
affinis	0.000	5455.246	4947.847	4434.317	4060.359	2293.363	2707.466	6052.735
alcocki	5455.246	0.000	5747.668	5193.618	8827.033	7024.484	3790.671	7802.619
brevicorn	4947.847	5747.668	0.000	2386.066	4751.995	3686.652	3411.979	1730.424
dobsoni	4434.317	5193.618	2386.066	0.000	3333.013	4466.799	1911.499	4917.764
ensis	4060.359	8827.033	4751.995	3333.013	0.000	1658.081	2556.319	4028.436
kutchensis	2293.363	7024.484	3686.652	4466.799	1658.081	0.000	2545.782	2978.203
monoceros	2707.466	3790.671	3411.979	1911.499	2556.319	2545.782	0.000	3925.054
moyebi	6052.735	7802.619	1730.424	4917.764	4028.436	2978.203	3925.054	0.000

Table: 4.17. Squared mahalanobis distances showing the closeness among the sps of genus *Metapnaeus*.

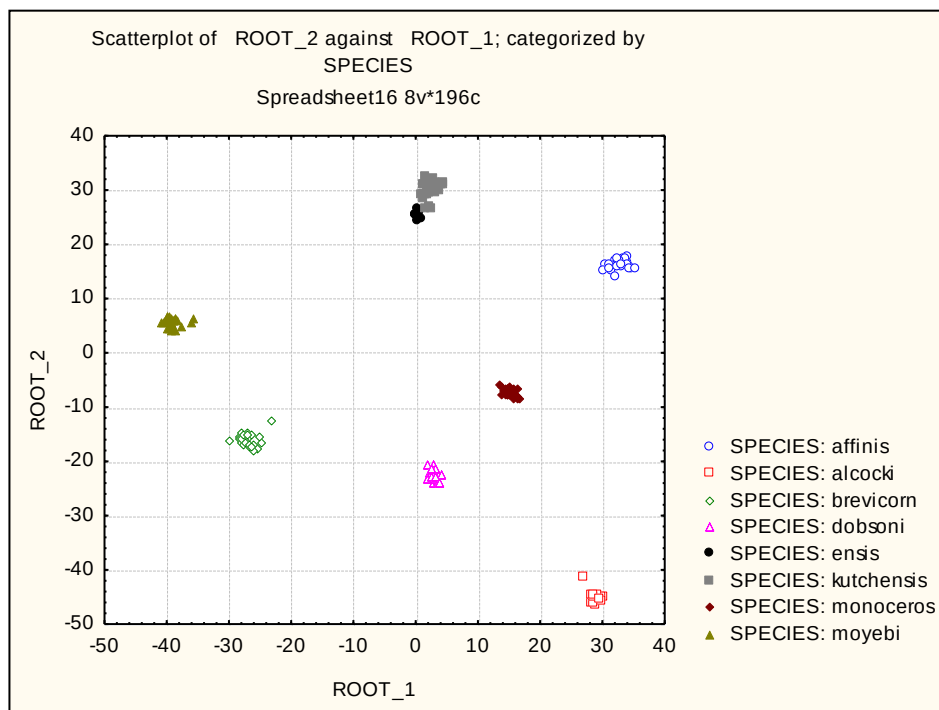


Fig: 4.1. Scatter plot of discriminant functions of root1 and 2

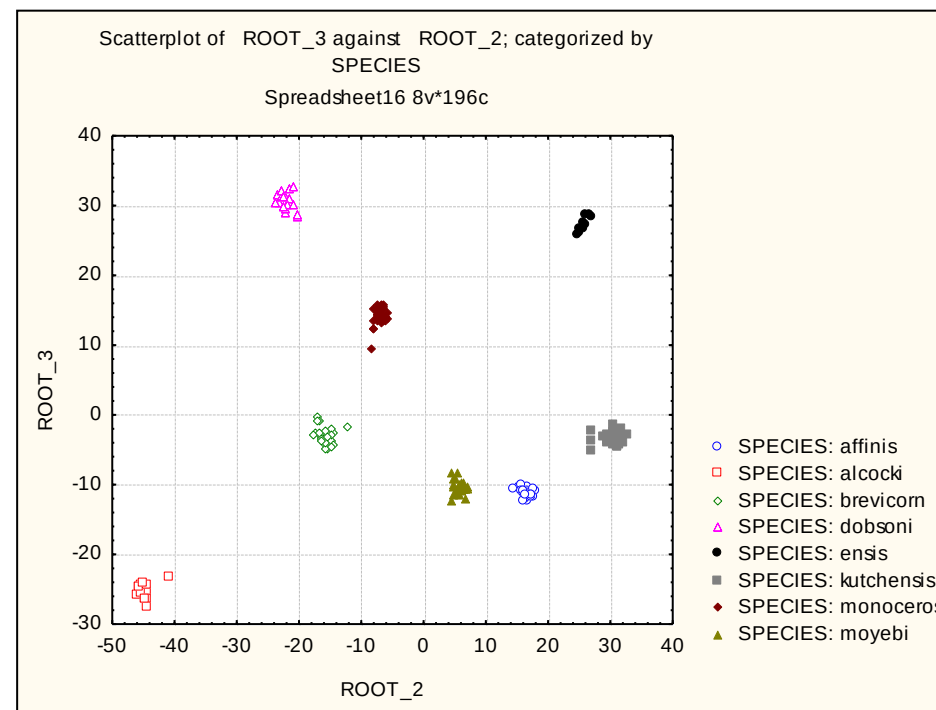


Fig: 4.2. Scatter plot of discriminant functions of root 2 and 3

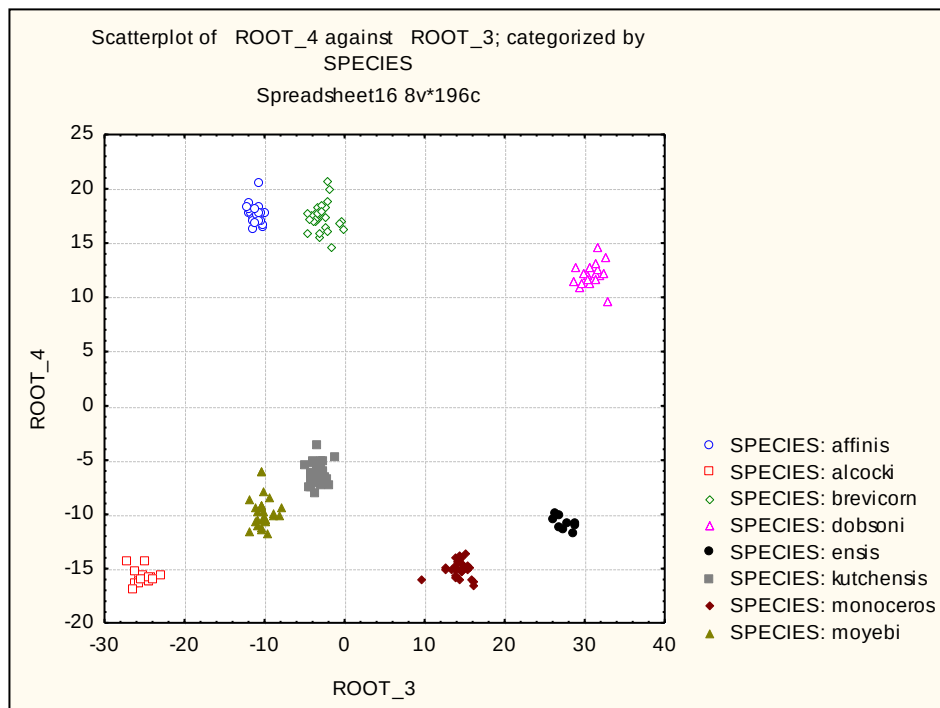


Fig: 4.3. Scatter plot of discriminant functions of root 3 and 4

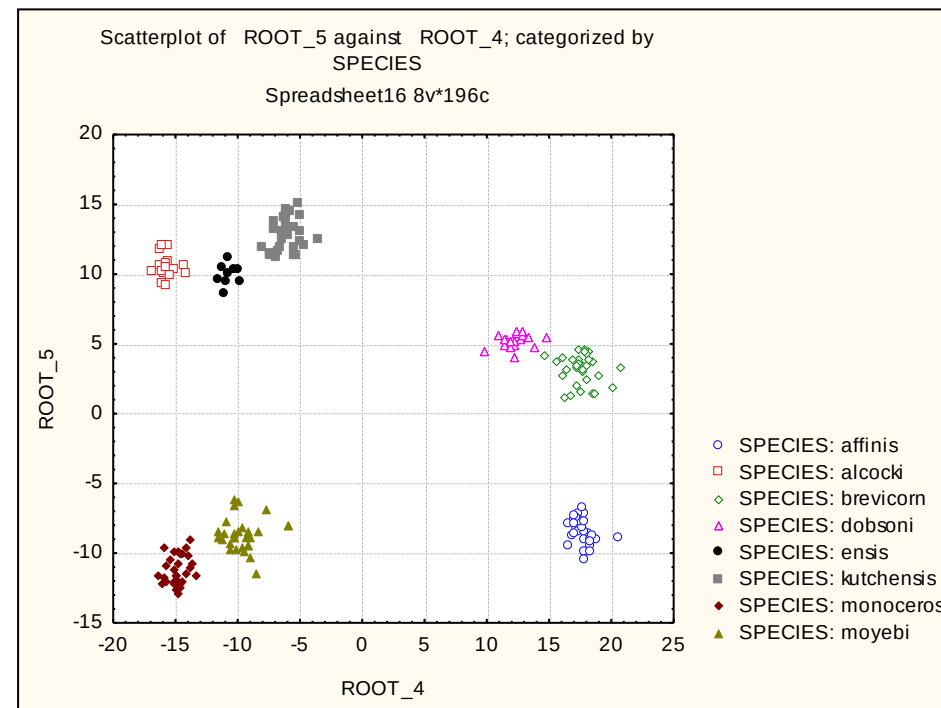


Fig: 4.4. Scatter plot of discriminant functions of root 4 and 5

4.5. Meristic Character

Maximum, minimum. Median, mode and correlation of variation are presented in Table 4.18. Among all the species *M. affinis* and *M. alcocki* shows highest mode for Rostral teeth number (> 10), while *M. brevicornis* shows lowest value.

M. lysianassa and *M. dobsoni* have the mean values below 9. Remaining species (*M. alcocki*, *M. affinis*, *M. moyebi*, *M. kutchensis* and *M. monoceros*)

Table: 4.18. Variation in rostral teeth number in the species of genus *Metapenaeus*

	No.	Min.	Max.	median	mean	mode	St. Dev	Coeff.var
<i>M. affinis</i>	30	7	10	10	9.4	10	0.77	0.082
<i>M. alcocki</i>	16	8	11	10	9.625	10	0.806	0.084
<i>M. brevicornis</i>	31	5	7	6	6.194	6	0.703	0.114
<i>M. dobsoni</i>	18	7	9	8	8.111	8	0.758	0.094
<i>M.ensis</i>	9	8	11	9	9	9	0.577	0.064
<i>M. kutchensis</i>	31	8	11	9	9	9	0.577	0.064
<i>M. monoceros</i>	31	6	10	9	9	9	1.095	0.122
<i>M. moyebi</i>	30	8	10	9	9.333	9	0.547	0.059
<i>M. lysianassa</i>	3	7	7	7	7	7	0	0

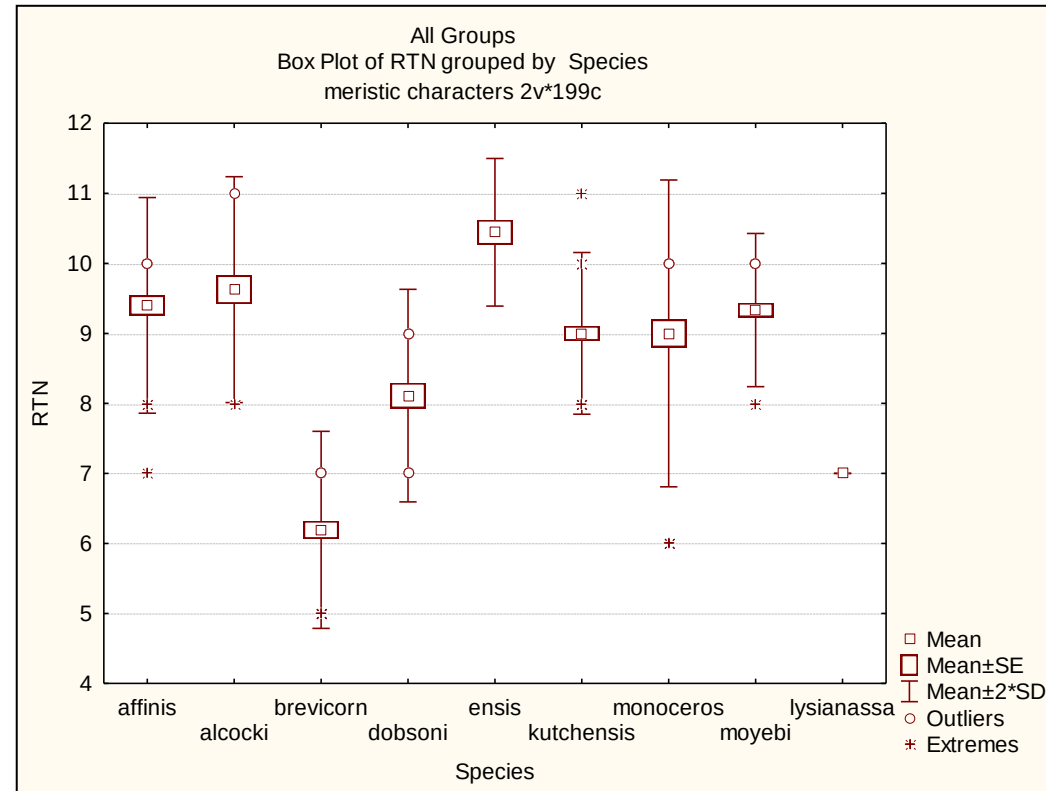


Figure: 4.5. Variation in rostral teeth number in species of genus *Metapenaeus*

4.6. Phylogenetic relationship among the sps. of genus *Metapenaeus*

A cladogram based on morphometric traits of different species was created to know the phylogenetic relationship among species of genus *Metapenaeus*. Cladistics relationship and monophyletic groups were defined by synomorphies (Fig. 4.6). This cladogram was divided into small monophyletic units, providing information on synophomorphies and automorphies.

Cladogram for genus *Metapenaeus* clearly bifurcates into two main branches. The first branch is again divided into two sub-branches, one represented by *M. lysianassa*. Another sub branch divided into two groups, one is represented by *M. dobsoni* and other by *M. moyebi* and *M. alcocki*.

The second main branch divided into two sub branches. One sub branch is represented by *M. brevicornis* and *M. affinis*. The second sub branch is divided into two groups, one in represented by *M. ensis* and other group members were *M. kutchensis* and *M.monoceros*.

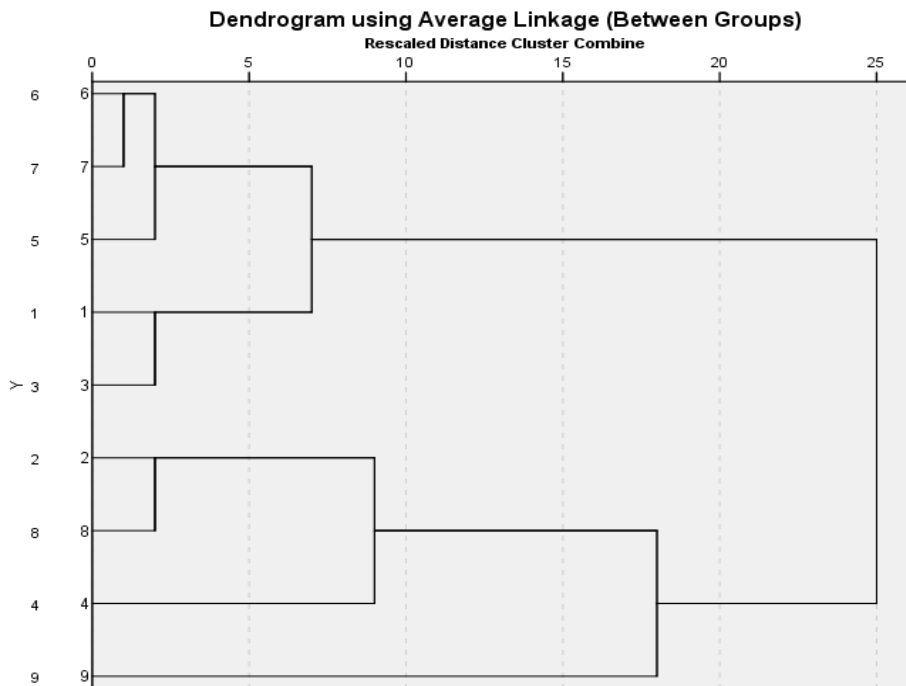


Figure: 4.6. A cladogram based on morphometric traits of different species of genus *Metapenaeus* (1-*M. affinis*, 2- *M. alcocki*, 3- *M. brevicornis*, 4- *M. dobsoni*, 5- *M. ensis*, 6- *M. kutchensis*, 7- *M. monoceros*, 8- *M. moyebi* and 9- *M. lysianassa*)

4.7. DNA barcoding

Total fifteen specimens comprising seven species were collected from different landing centers of Indian coast. Cytochrome c oxidase subunit I (COI) partial gene (650bp) was amplified from all 7 species with forward and reverse primers (**Fig. 4.7**). The COI amplicon was purified and sequenced in both forward and reverse orientation and the average sequence length was 650bp. DNA barcodes were developed for all species using the using the fragment of the COI gene with an average length of ~570-600 base pairs. The COI sequences were checked for the presence of insertions, deletions and stop codons. The lack of stop codons and indels was consistent with all the amplified COI sequences suggesting that NUMTs (Nuclear DNA sequences originating from mitochondrial DNA sequences) were not sequenced.

Among species, variation in GC content for 3rd codon position was higher than for position 1, with variation at position 2 being very limited (**Fig. 4.8**). This showed the absence of synonymous mutations at position 2.

The divergence value (Kimura 2 Parameter) was low for conspecific individuals (**Table 4.18**). The NJ tree was constructed based on K2P values of the COI gene revealed distinct clusters of conspecific individuals with significant bootstrap value (**Fig. 4.9**.)

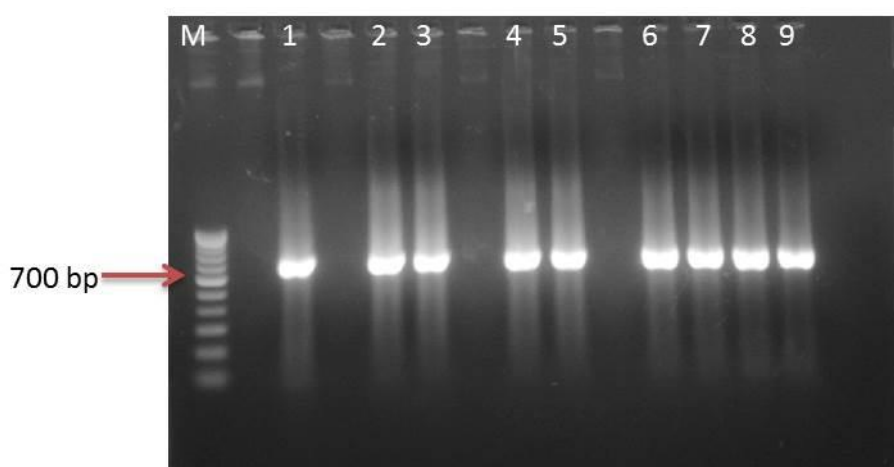


Fig: 4.7. PCR amplification of mitochondrial cytochrome c oxidase subunit I amplification from sps. of *Metapenaeus*. Lane M: 100bp DNA ladder; Lane 1-9: Different species of *Metapenaeids*.

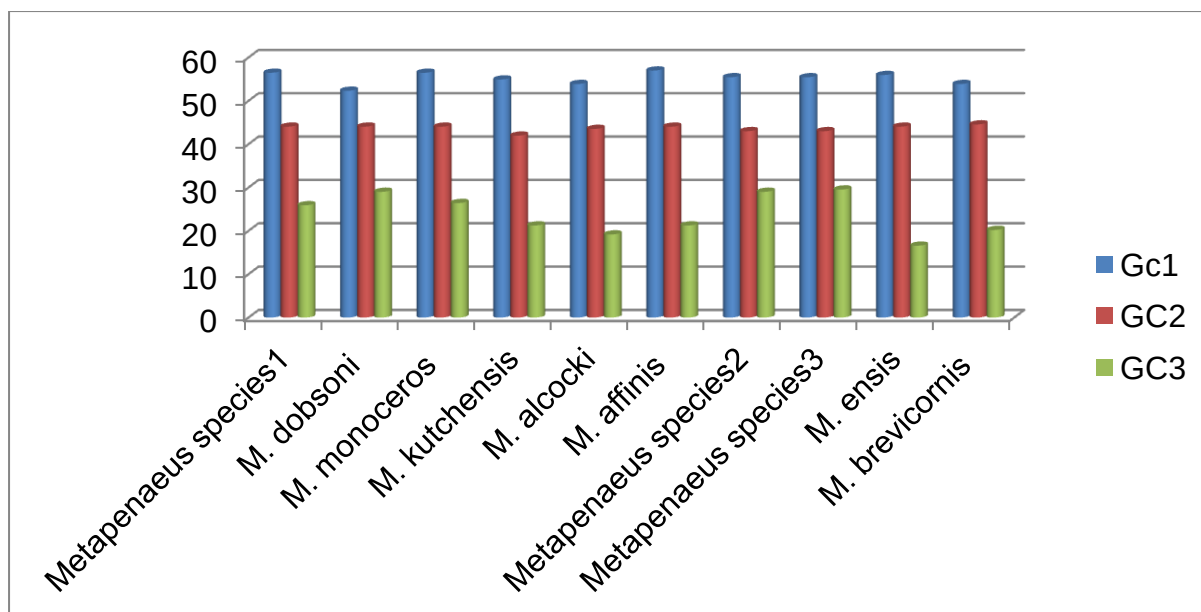


Fig. 4.8 GC composition of COI gene across species of genus *Metapenaeus*

Table: 19. Distance (K2P model) values of COI gene across *Metapenaeus* sps

Species and its code															
Metapenaeus sp 1 New species (MA2)		0.004	0.022	0.021	0.010	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.019	0.020	0.008
Metapenaeus sp 1 New species (Big)	0.009		0.022	0.022	0.010	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.019	0.021	0.009
Metapenaeus brevicornis (4)	0.210	0.212		0.006	0.020	0.025	0.020	0.019	0.020	0.020	0.018	0.020	0.020	0.020	0.020
Metapenaeus brevicornis (M)	0.207	0.214	0.019		0.021	0.024	0.021	0.021	0.019	0.019	0.020	0.021	0.020	0.020	0.021
Metapenaeus dobsoni (I)	0.050	0.056	0.185	0.197		0.023	0.020	0.020	0.022	0.022	0.020	0.021	0.022	0.021	0.007
Metapenaeus dobsoni (J)	0.228	0.232	0.261	0.256	0.237		0.026	0.026	0.026	0.026	0.026	0.026	0.025	0.025	0.024
Metapenaeus affinis (Aff6)	0.211	0.217	0.180	0.193	0.177	0.291		0.003	0.015	0.015	0.013	0.015	0.016	0.015	0.020
Metapenaeus affinis (Aff7)	0.211	0.213	0.175	0.193	0.177	0.291	0.005		0.015	0.015	0.013	0.015	0.015	0.015	0.020
Metapenaeus sp 2 (met 2)	0.205	0.209	0.187	0.171	0.210	0.278	0.115	0.113		0.000	0.009	0.009	0.008	0.008	0.021
Metapenaeus sp 3 (met 3)	0.205	0.209	0.187	0.171	0.210	0.278	0.115	0.113	0.000		0.009	0.009	0.008	0.008	0.021
Metapenaeus ensis (EN1)	0.203	0.203	0.160	0.180	0.181	0.278	0.091	0.085	0.041	0.041		0.009	0.009	0.009	0.019
Metapenaeus kutchensis (kut 3)	0.180	0.184	0.184	0.195	0.198	0.268	0.113	0.111	0.043	0.043	0.041		0.005	0.006	0.020
Metapenaeus kutchensis (kut 2)	0.174	0.176	0.191	0.191	0.208	0.266	0.119	0.115	0.035	0.035	0.043	0.016		0.007	0.021
Metapenaeus alcocki (A6)	0.189	0.194	0.186	0.181	0.203	0.260	0.111	0.109	0.035	0.035	0.041	0.023	0.026		0.021
Metapeaneus_monoceros_(E)	0.035	0.041	0.187	0.196	0.028	0.234	0.185	0.185	0.203	0.203	0.171	0.193	0.203	0.194	

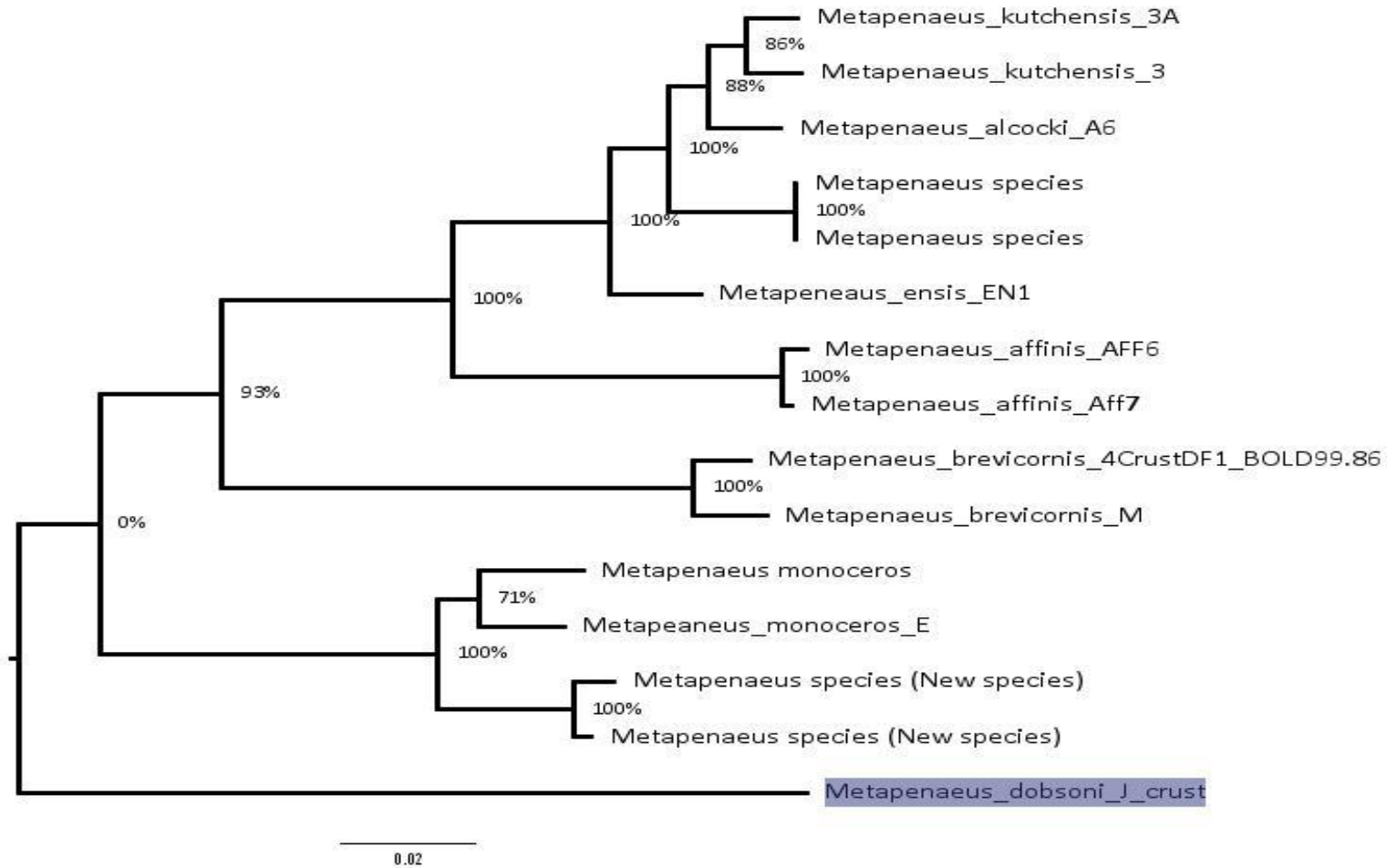


Fig: 4.9. NJ tree constructed using COI divergence values of *Metapenaeus* sps.

5. DISCUSSION

The genus *Metapenaeus* is a second commercially important genus after *Penaeus* having large number of commercially important species (owing to their large size of body like, *M. monoceros*, *M. affinis*, having attractive body colour like *M. kutchensis*) under family *Penaeidae* in Indian waters. The vast number of species and their morphological specialization adapted to diverse habits and habitats make the classification of the *Metapenaeus* very difficult. Some species are found only in particular location but now a days, due to unknown reasons they are being fished in new localities. Because of the similar structure of petasma and thelycum in most of the species of genus *Metapenaeus* which making more difficult to identify and segregate them. This suggest the need of molecular identification of the species to complement traditional taxonomic identification. Herbert *et al.* (2003) proposed that a single gene sequence would be sufficient to differentiate all, or at least the vast majority of animal species, and proposed the use of the mitochondrial DNA gene cytochrome oxidase subunit I (COI) as a global bioidentification system for animals. The sequence was assigned as a barcode, with species being delineated by a particular sequence or by a tight cluster of very similar sequences. In the present study, DNA barcoding of 7 species under genus *Metapenaeus* using mitochondrial COI (primers used Crust DF1, Crust DR1) was carried out.

Genus *Metapenaeus* is represenred by morphologically diverse species. Among the 9 species studied, the morphometric measurements varied significantly.

5.1. Gross morphometric and meristic characters

***Metapenaeus affinis*:** In Indian waters *Metapenaeus affinis* is distributed along the East and West coast. It has long and up tilted rostrum, distinct and curved branchiocardiac carina, notched merus of fifth pereopod followed by a twisted and keeled tubercle, crescent-shaped distomedian projection, longitudinal deeply grooved anterior plate of thelycum, two anterolateral rounded projections of posterior transverse ridge. Similar findings were reported by Lanchester (1901) and Alcock

(1906) and many authors. The proportion of rostral length to total length was showed highest (0.153745) for *M. affinis* after *M. moyebi*. In Lanchester's (1901), Hall's (1961) and De bruin's (1965) descriptions the disto-median protuberances of the petasma are directed laterally while in Hall's (1956) description these protuberances are stated to be directed antero-laterally, while in the present study distomedian projections were found to be antero-laterally projected. Fifth pereopod surpasses the scaphocerite. Similar findings were reported by Hall's (1956). Rostral teeth number (modal value) was 10 which is similar to George (1979) but two specimen found to be with 8 teeth and one specimen with 7 teeth.

***Metapenaeus alcocki*:** The species possesses slightly up tilted rostrum, glabrous branchiocardiac region, subequal antennular flagella, dorsal one longer; longitudinally grooved and tongue like anterior thelycal plate, small oval plates located in between anterior plate and lateral plates. Similar findings were also reported by George and Rao from Gulf of Kutch. APL/TL was 0.144108 which is found to be smaller than any other *Metapenaeus* species. The mean proportion of VAL/TL was smallest for *M.alcocki* (0.067394). The mean proportion of ASL/TL was 0.144438 (largest among all other *Metapenaeus* group).

***Metapenaeus brevicornis*:** *M. brevicornis* was originally described as *Penaeus brevicornis* by Milne Edwards from Ganjam, Orissa, east coast of India. The species has smooth and glabrous body; short rostrum with elevated crest, armed with 4-6+1 dorsal teeth; telson armed with 2-3 lateral strong spines; merus of fifth pereopod with a notch and a keel- shaped tubercle; disto-median projections of the petasma with a long and slender apical filament, anterior plate of thelycum large square and grooved; lateral plates are boomerang shaped and enclosing two pear shaped plates. Similar findings were reported by Alcock (1906). The mean proportion of 1MLP, 2MLP, 3MLP, 4MLP, 5MLP with total length was observed highest for *M. brevicornis* among other species of *Metapenaeus*. The mean proportion of 5TLP, 5CLP and 5DLP was found to be highest in this study.

***Metapenaeus dobsoni*:** *M. dobsoni* was originally described as *Mangalura dobsoni* by Miers from Mangalore, Karnataka, West Coast of India. It is observed to have long and sigmoidal rostrum with distal one-third toothless, armed with 7-9+1 dorsal

teeth; basal spine of third pereopod extremely long and barbed; antennular flagella subequal, ventral one longer; merus of fifth pereopod with 2 large, triangular teeth; fifth pereopod of adult female reduced to coxa and basis. each distomedian projection of petasma with a short filament on ventral surface and another on dorsal surface; a long grooved tonguelike anterior plate partially ensheathed in a horse-shoelike process formed by the lateral plates. Similar findings were also reported by Nobili (1903).

***Metapenaeus ensis*:** The specimen was doubtfully recorded as *Metapenaeus ensis* (de Haan) by Alcock (1906) from Indian waters. De man (1922) was of opinion that Alcock's specimens were probably *Penaeopsis intermedia* (Kishinouye). This species is now synonymised under *Metapenaeus intermedius* (Kishinouye) by Hall (1962). Later *Metapenaeus ensis* was first time recorded by M. S. Muthu (1965) from Indian waters. The species shows pubescence on whole body except carina; rostrum nearly straight and armed with 8 to 10+1 teeth; fifth pereopod merus with a proximal notch followed by a long, inwardly curved spiniform process and a row of tubercles; distomedian projections of petasma convoluted, greatly swollen and directed forward; Anterior plate of thelycum lone and deeply grooved; lateral plates with strongly raised lateral margins forming posteriorly 2 inwardly curved triangular projections. Similar findings were reported by M. S. Muthu (1965).

***Metapenaeus kutchensis*:** George *et al.* (1963) described *M. kutchensis* from the Gulf of Kutch area. According to them the anterior median plate of the thelycum is convex and the plates glabrous. However, Kagwade (1978) redescribed the *M. kutchensis* from Mumbai waters as the original description based on sub adult specimen, noticed that the anterior median plate is crown shaped and the emarginate anterior and is beset with tuft of setae. The distomedian lobes of petasma are distinctly bifid as against the indented border shown in George's description. It shows affinity to *M. affinis* in the type of petasma and the presence of a notch and a tooth at the base of the merus of fifth pereopod. However, there are striking differences between these two species. The fifth pereopod is shorter in *M. kutchensis*. The crown shaped median plate of the thelycum with emarginate anterior border. But this plate in *M. affinis* is tongue shaped with its anterior and hidden under the coxal projections of the fourth pereopod. The part of the thelycum comprising the lateral plates in *M. kutchensis* is more circular while the same in *M. affinis* is antero-

posteriorly compressed and shallower. The distomedian lobes of the petasma are similar in both the species. But the protuberances projecting from the posterior border of the dorsal lobes are shorter and almost meet each other leaving a small circular hole in between in *M. affinis* while there is a gap between these protuberances in the present species. The space between the petasma and the sternum of the first abdominal segment is narrow in *M. affinis* and wider in *M. kutchensis*. Present observation are agreeing with Kagwade (1978) description.

***Metapenaeus lysianassa*:** *M. lysianassa* was originally described as *Penaeus lysanasa* by De Man (1888) from Margui Archipelago, Myanmar. It was first recorded from India (Orissa & Hooghly Delta) by Alcock as *Metapeneus lysanasa*. Body almost entirely pubescent; Very short rostrum reaching the middle of the first antennular segment and armed with 6 or 7 teeth all along the dorsal margin, high rostral carina; Postrostral hull ending in a glabrous expansion near the posterior border of the carapace; Hull and adrostraal furrow reaching the third rostral tooth; Very weak postocular groove, just in front of the third rostral tooth; Indistinct antenna hull; Right anteroventrally inclined hepatic sulcus, vertical posterior part of this absent furrow; Gill-to-heart pathway not reaching the middle of the carapace; Telson armed laterally with a single row of small spinules; Ischial spine on the first pereopod absent, basal spine of the third pereopoda very long but simple. In males, presence a proximal notch on the merus of the fifth pereopod followed by a large slightly arched triangular tooth; In females, anterior plate and lateral plates of the thelycum are of the same size, furrowed anterior plate, posterior plates most often suboval. Similar findings were reported by Alcock (1906)

***Metapenaeus monoceros*:** *M. monoceros* was originally described as *Penaeus monoceros* by Fabricius in the year 1798, from Jakarta, Indonesia. It was first recorded from India by Milne Edwards. Body covered very short tomentum; rostrum nearly straight and little uptilted, teeth 8-10 + epigastric; adrostral carina ending between epigastric and 1st tooth, sulcus extending behind epigastric; postrostral, continuing to posterior border of carapace; a large triangular distoventral keel on ischium of 5th pereopod in mature male, followed by a deep notch on merus, bounded by a prominent spinous process twisted ventrally at angle 90⁰ to axis of

merus, usually followed by a ventral row of conical tubercles, which end in a small keel at distal merus; tubercles sometimes reduced or absent. Distomedian projections overlying distolateral projections, with openings facing dorsolaterally; openings closed by convex flap on distoventral edge of opening; this flap sometimes flat and projecting laterally, when distomedian projections appear quadrangular, sometimes reflected back, when projections appear triangular. Anterior plate level with and bounded on either side by expanded coxal projections of 4th pereopods; with median groove deepening posteriorly; posterior plates strongly concave. Similar findings were reported by Alcock (1906) also.

***Metapenaeus moyebi*:** *M. moyebi* was originally described as *Penaeus moyebi* by Kishinouye in 1896 from Japanese water. It was first recorded from India by George under the name *M. burkenroadi* Kubo (1949), which was later on synonymized with *M. moyebi* by Miquel. The specimens collected for this study shows all the distinguishing characters of the species given by the original authors. Thomas (1969) reported this species from Andaman and Nicobar islands and noticed the pubescence on the dorsal surface of the carapace more prominent in females than males. Although, in both the sexes the fifth and sixth segments are more pubescent than the preceding segments. De bruin (1965) noticed the relationships among the three anterior teeth of the rostrum also show variation. In female specimens examined (10), the distance between the first and second was equal to the distance between the second and third in four specimens, while in the rest the distance between the first and second was less than the distance between the second and third. *Metapenaeus moyebi* collected for this study showed lateral plates of thelycum slightly rounded for 10 specimens and rectangular in 20 specimens. Dorsal carination starts from the middle of the 4th segment. Rostral pattern also varied, 14 specimens showed distance between the first (penultimate) and the second teeth is less than the second and third. 6 specimens showed equal distance between the teeth. 10 specimens showed more gap between the first and the second teeth compared to second and the third.

5.2. Field Identification Key

1. Rostrum short, not exceeding second segment of antennular peduncle; epigastric tooth close to penultimate tooth on rostrum and entire margin of the rostrum bear teeth 2

---- Rostrum moderate, exceeding second segment of antennular peduncle; epigastric tooth conspicuously separated from penultimate tooth on rostrum; distal part ($\frac{1}{4}$ th length of the rostrum) of the rostrum doesn't bear teeth 3

2. Rostrum very short, not exceeding first segment of antennular peduncle; telson without lateral movable spine; body pubescent; distomedian projection of petasma with a minute filament on distomedian margin ***M. lysanasa***

---- Rostrum exceeding first segment of antennular peduncle; telson with two pairs of lateral movable spine; body smooth; distomedian projection of petasma with a long, slender apical filament on either side ***M. brevicornis***

3. Entire body pubescent 4

---- Pubescence restricted on some regions of carapace and abdomen 7

4. Branchiocardiac carina mostly indistinct, when distinct not continuous with the hepatic spine; anterior thelycal narrow, distolateral projection of petasma, bearing, a short filament on both ventral and dorsal sides ***M. dobsoni***

---- Branchiocardiac carina always distinct and continuous with hepatic spine; anterior thecal broad, distolateral projection of petasma without, filament 5

5. Distomedian projection of petasma crescent-shaped; anterior plate of thelycum wide posteriorly, deeply grooved ***M. affinis***

---- Distomedian projection of petasma convoluted and swollen; anterior plate of thelycum narrow, long and deeply grooved 6

6. Antennular flagella unequal, upper one longer; distomedian projection of petasma bisected into two bulbiform structure; lateral plate of thelycum with strongly raised lateral margins forming two longitudinal crests.....***M. monoceros***

---- Antennular flagella equal; distomedian projection of the lobe bisected anteriorly into two conical structure tip of which has a small pore through which a fine needle can be inserted; lateral plate of thelycum with strongly raised lateral margins, curving inward like two flap of collar***M. ensis***

7. Postrostral carina ending before posterior margin of carapace; anterior plate of thelycum not flask-shaped, no tubercle on anterior margin; distomedian projection of petasma not laminose.....8

---- Postrostral carina ending near posterior margin of carapace; anterior plate of thelycum flask-shaped, its anterior margin with three apical tubercles; distomedian projection of petasma laminose.....***M. moyebi***

8. Distomedian projection of median lobe of petasma crescent shaped, placed transversely, its distal end broad; posterior extension of anterior median plate not bounded laterally by a plate on either side; merus of fifth pereopod of adult male proximally with a notch followed by a keeled tubercle.....***M. kutchensis***

---- Distomedian projection of median lobe of petasma slender, directed anterolaterally with distal end broad and trilobed; posterior extension of anterior median plate bounded laterally by a pair of oval flat plate on either side; merus of fifth pereopod of adult male proximally has a notch followed by a spine***M. alcocki***

7.SUMMARY

The species of genus *Metapenaeus* form the major components of penaeid landings of India. The genus represents 17 valid species from Indian waters as per the recently published checklist of species from Indian waters. Majority of the species are predominantly distributed in coastal waters. Although several attempts were made on phylogenetic and systematic aspect of the genus, the outcomes seems to be tentative and open for investigation. To differentiate the species of the genus *Metapenaeus* samples were obtained from landing centres of Digha, Vishakhapatnam, Kakinada, Chennai, Rameswaram and Tuticorin on the East coast and Gulf of Kutch, Veraval, Mumbai and Kochi on the West coast.

Several characters like pattern of pubescence, carapace type of petasma and thelycum and morphometric characters like total length, carapace length, length of pereopods, rostral length, telson length, antennular peduncle and its flagella length etc. rostral teeth number were used in past for the species differentiation. In the present study along with above said characters and morphometrics like length of segments of pereopods (ischium length, merus length, carpus length, propodus length and dactylus length), antennal scale length, 6th abdominal segment length and its depth were considered in differentiating species. Nine species were analysed for different mentioned aspect.

High correlation coefficients were obtained for all the combination of morphometric measurements. Very high correlation coefficient were obtained for Correlation coefficient of more than 0.95 was observed for CL, CW, 6ASD, 1ILP, 3TLP, 3ILP, 4TLP and 4ILP with total length. Correlation coefficient ranging from 0.9 to 0.95 was observed for 2PLP and 2FLP. Relatively lower values of coefficients (0.9) were observed for 5TLP and 5DLP. Descriptive statistics of different morphometric variable scaled to total length show reasonable discriminating power between species belonging to same genera.

The 41 morphometric variables of 8 species of genus *Metapenaeus* were transformed and corrected for allometry. The transformed variables were analysed for significant variation between species using ANOVA. Significant differences

between species were observed. The morphometric variables were subjected to factor analysis. A total of 12 variables were found to have higher loadings on either first or second factor. The above mentioned 12 variables were subjected to Stepwise Discriminant Function Analysis. 3TLP, 5DLP, 2FLP and 4ILP were among the major contributors to the first two discriminant functions. Means of canonical variables shows the sufficiency of Root 4 in discrimination of most of the considered species which can be clearly observed in scattergram of Root 4 vs. Root 3.

DNA barcoding was done for seven species of genus *Metapenaeus*. DNA barcode was done for the first time for *M. kutchensis* and *M. alcocki*. In addition, one species considered as new to the science revealed based on DNA barcoding and morphologically. All the seven species were distinguished from others based on the molecular study.

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