A TAXONOMIC STUDY OF HERMIT CRABS ALONG SELECTED DISTRICTS OF MAHARASHTRA COAST

Dissertation submitted in partial fulfilment
of the requirements
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M.F.Sc. (Fisheries Resource Management)

by

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Dedicated to my Mother,

brother and Nila

Dated: 30th June 2015

CERTIFICATE

Certified that the dissertation entitled **"A TAXONOMIC STUDY OF HERMIT CRAB ALONG SELECTED DISTRICTS OF MAHARASHTRA COAST"** is a record of independent bonafide research work carried out by **Mr. T. NIRMAL** during the period of study from August 2014 to June 2015 under our supervision and guidance for thedegree of **Master of Fisheries Science (Fisheries Resource Management)**and that the dissertation has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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DECLARATION

I hereby declare that the dissertation entitled "**A TAXONOMIC STUDY OF HERMIT CRAB ALONG SELECTED DISTRICTS OF MAHARASHTRA COAST**" 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.

30th June 2015

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<u>सारांश</u>

प्रस्तुत अध्ययन के दौरान हरमिट केकड़ो की ८ प्रजातियों का उल्लेख किया गया हें। जिन्हें महाराष्ट्र के विभिन्न समुद्री तटों से एकत्रित किया गया था। आठों प्रजातियों को इनके चेलिपेड़ को चौड़ाई , आँख धारक को लंबाई , कॉर्निया का व्यास , केरापेस की चौड़ाई और डेकटाइलस की लंबाई की विभिन्नता के आधार पर अलग किया गया। विभिन्न संख्याकित विश्लेषण यह सिद्ध करते हें कि ५ प्रजातियो को विभिन्न शारीरिक मापों के आधार पर अलग किया जा सकता हे । वर्तमान अध्ययन से प्राप्त गुणों के आधार पर प्रजातियों को पहचानने व उन्हें अलग करने के लिए पहचान कुंजी बनाई है जो किं अन्य शोधकर्ताओं के लिए उपयुक्त होगी। ५६ गुणों के आधार पर तैयार किया गया क्लेडोग्राम ट्री प्रमुख क्लेड (समुह) दर्शाते हें। पहले मे ६ प्रजातियों का समावेश है जबकि दूसरे समुह में मात्र २ प्रजातियों का समावेश हे ।

Abstract

A total of 8 species were identified after examining taxonomic characters of the hermit crabs collected from different parts of Maharashtra coast (Aksha, Bandstand and Versova of Mumbai and Alibaug and Srivardhan of Raigad district) during August 2014 to May 2015. Descriptive statistics of morphometric variables of the 8 species viz. *Clibanarius infraspinatus, C. padavensis, C. arethusa, C. longitarsus, Diogene alias, D. dubius, Paguruskulkarni*and *P. pitragsaleei* revealed significant differences in their characters. The cheliped width,eye peduncle length, corneal diameter, carapace width, palm length and dactyl length were found to be more important from taxonomic differentiation. The Stepwise Discriminant Function Analysis (SDFA) was performed for 12 transformed morphometric variables of 5 hermit crab species. SDFA gives a correct classification of 92.5% for 5 species with first two canonical variable explaining 99.2481 % of the variance. A field identification key for identifying hermit crabs available along Maharashtra coast has also been proposed. Colour pattern, teeth on cutting edge of cheliped and spine on terminal margin of telson were among major morphological features useful in field identification of the concerned species. Within genera, differences were minimal. The hierarchical cluster analysis (Ward's minimum variance method) based on 56 characters was performed to study the affinity among species. Species belonging to particular genera were grouped together affirming the existing generic assignment to the species.

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1. INTRODUCTION

Taxonomy is the essential foundation for all biodiversity studies. It is a scientific discipline that explores, discovers, interprets, name and recognize the organisms. The word taxonomy is derived from Greek word *'taxis'* meaning order or arrangement and *'nomos'* meaning law or science (Deshmukh, 2012). It is important to know the living organisms around us; discovering and describing them remains a fundamental quest of biology (Zhang, 2011). In spite of an increasing rate of species discovery, as much as 95 percent of the world's oceans remain unexplored (http://www.noaa.gov/ocean.html). One of these challenges is the immense task of discovering and describing the 90% of the world's biodiversity that remains unknown to science. With so many important issues *viz.* invasive species, climate change, habitat destruction and loss of biological diversity, in particular, there is a need for authoritative taxonomic information and cataloguing of species before they are lost. So there is a need for the conservation and management of biodiversity, and to focus on the need for our challenge for the future. On the other side, the number of taxonomic workers is getting reduced because of many obvious reasons. In view of these facts, the United Nations declared 2010 as "The International Year of Biodiversity", and this is celebrated throughout the world.

Among the diverse group of organisms in the marine environment, hermit crab placed under Decapoda (Class - Crustacea) of infra-order - Anomura are easily recognized by having naked, asymmetrical, unsegmented and soft spiral shaped abdomen which are concealed within empty gastropod shell or else protected by living anthozoans except for terrestrial coconut crab (Reese, 1969; Conover, 1978; Hazlett, 1981). The abdomen is characteristically coiled to right in healthy individuals (Lancaster, 1988). Most hermit crabs possess abdomen with asymmetrical sixth abdominal tergites, while only 42 species belonging to Pylochelidae and Parapylochelidae have symmetrical ones (De Grave *et al.,* 2009). Important differentiating characters are (1) loosely fitting carapace covering cephalothorax of body (2) fourth and fifth pair of walking legs are reduced (3) the antennae placed outside the eyes (Ingle, 1980; McLaughlin *et al*., 2010). Hermit crab can move in a straight line rather than sideways that are another differentiating character between the brachyuran crabs (Lancaster, 1988). Like other crustaceans, the growth of hermit crabs involves a series of moulting during which they will increase their size (Anger *et al*., 1990)

The order Decapoda is subdivided into two suborders Dendrobranchiata (prawns) and Pleocyemata (shrimps, true crabs and lobsters). All Pleocyemata share an important character that the fertilised eggs are incubated by the female and kept at pleopods. This Pleocyemata is further divided into seven infra-orders the Stenopodidea, the Caridea, the Astacidae, the Thalassinidea, the Palinura, the Anomura and the Brachyura. Infraorder Anomura comprises of 7 superfamilies, 17 families, 200 genera, and about 1500 species (Martin and Davis, 2001). He gave a classification of five families of hermit crabs:

- Coenobitidae, land hermit crabs
- Diogenidae, left-handed hermit crabs
- Paguridae, right-handed hermit crabs
- Parapaguridae, deep-water hermit crabs
- Pylochelidae, non- gastropod shelter using hermit crabs

Most hermit crabs are of marine origin with some few exceptions that are semi-terrestrial species classified under the family Coenobitidae. The distribution of gastropod shell has a strong influence on the distribution pattern of hermit crabs. They are distributed in varied habitats ranging from the deep ocean floor to terrestrial habitats and from poles to tropics. In general, hermit crabs are extensively distributed in the intertidal and sub-tidal zones of tropical and subtropical regions. The intertidal areas are the zone of interaction between sea and land, is one of the fascinating parts of marine biota. The inhabitants of this region, due to extreme changes in tide, exposure, desiccation and submergence are known to be hardy and diverse (Parulekar, 1981). This area harbours a large number of hermit crabs which are omnivorous and employ three modes of feeding; detritivore; filter feeding; and macrophages scavenging (Elwood & Neil, 1992). The hermit crabs consume all types of carrion (dead animals) when available and this flexible behaviour in feeding increases the success of feeding (Lancaster, 1988; Scully, 1983).

Anomurans exhibit a high diversity in their body forms. The body is divided into cephalothorax (head and thorax) and abdomen. The carapace of the hermit crab is composed of a shield with a pair of longitudinal sulci and a soft membranous part dorsally. Appendages of the cephalothorax are antennae, antennule, all mouthparts and five pairs of pereiopods. Ocular acicle located near the base of each ocular peduncle with a single or paired ocular extension. The ocular peduncle is either two or three segmented (Forest *et al*., 2000). Antennules are situated sub dorsally and more or less between the bases of the eyestalk. Antennae are placed on the outer side of the eyestalk. The appendages attached to the abdomen are pleopods. The presence and absence of pleopods and number developed are features of taxonomic value. The abdomen is an elongated twisted sac with a proximal extension termed as an abdominal process. The telson has a median cleft; in each side a process may be present or extended to the lateral margin. The sternal plate is located on the ventral side of the cephalothorax of 3rd pereiopods. The 1st pair of pereiopods is the cheliped. The chelipeds are composed of seven segments, five of which include dactylus, propodus, carpus, merus, and ischium. The paired pereiopods 2 and 3 are much longer than pereiopods 4 and 5. Pleon is soft, membranous and twisted in right side mostly.

More than 30,000 marine crustacean species are reported on a global scale (Rajakumaran and Vaseeharan, 2014). Crustacean exhibit fourth largest diversity among the animal group on the planet and includes commercially important shrimps, prawns, lobsters and crabs while the other major groups like stomatopods, branchiopods, cephalocarids, ostracods, etc. They form an important link in the food chain of the tropical marine ecosystem and indirectly contribute to the fishery production. Hence, conservation of these resources is important from commercial as well as the ecological point of view (Dineshbabu *et al*., 2011).

India is one among 12 mega biodiversity countries and has 25 hotspots of the richest and highly endangered eco-regions of the world. India lies between 8°4 to 37°6 North and 68° 71 to 97° 25 East. It is surrounded on the south by the Indian Ocean, on the west by Arabian Sea and by on the east side Bay of Bengal. With a coastline of 8129km it harbours 923 shellfish resources (http://www.nbfgr.res.in/). The coastal region of Maharashtra state having six districts *viz.* Thane, Greater Mumbai, Navi Mumbai, Raigad, Ratnagiri and Sindhdurg, popularly known as Konkan with a coastline of 720 km and a continental shelf area of 1,11,512 km^2 has a rich potential for marine fish production. Hence to provide basic information on taxonomy of hermit crabs for conservation and management of demersal fisheries resources indirectly, the present endeavour is the first of its kind to identify the hermit crabs and provide taxonomic keys for hermit crabs recorded from Maharashtra regions with the following objective:

- To identify the hermit crabs available along selected districts of Maharashtra coast based on morphological characters.

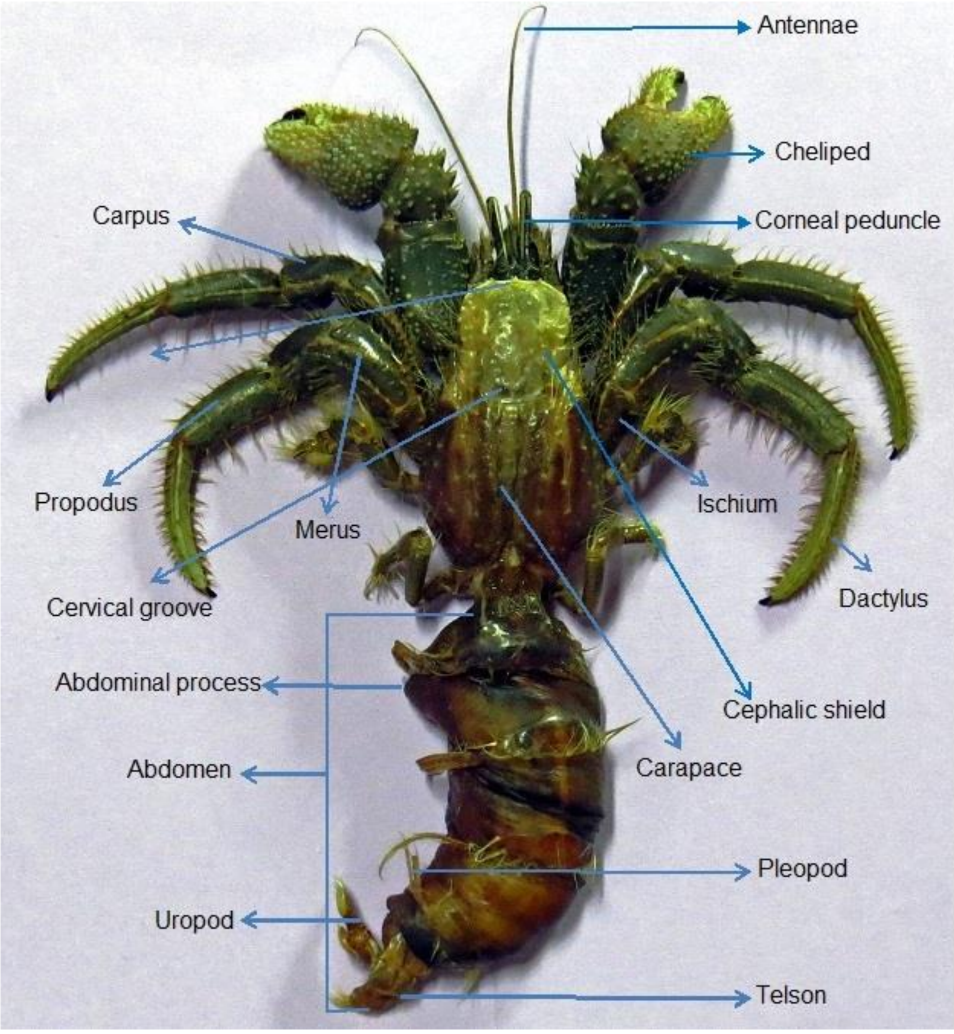


Fig 1.1.a. General morphology of hermit crab

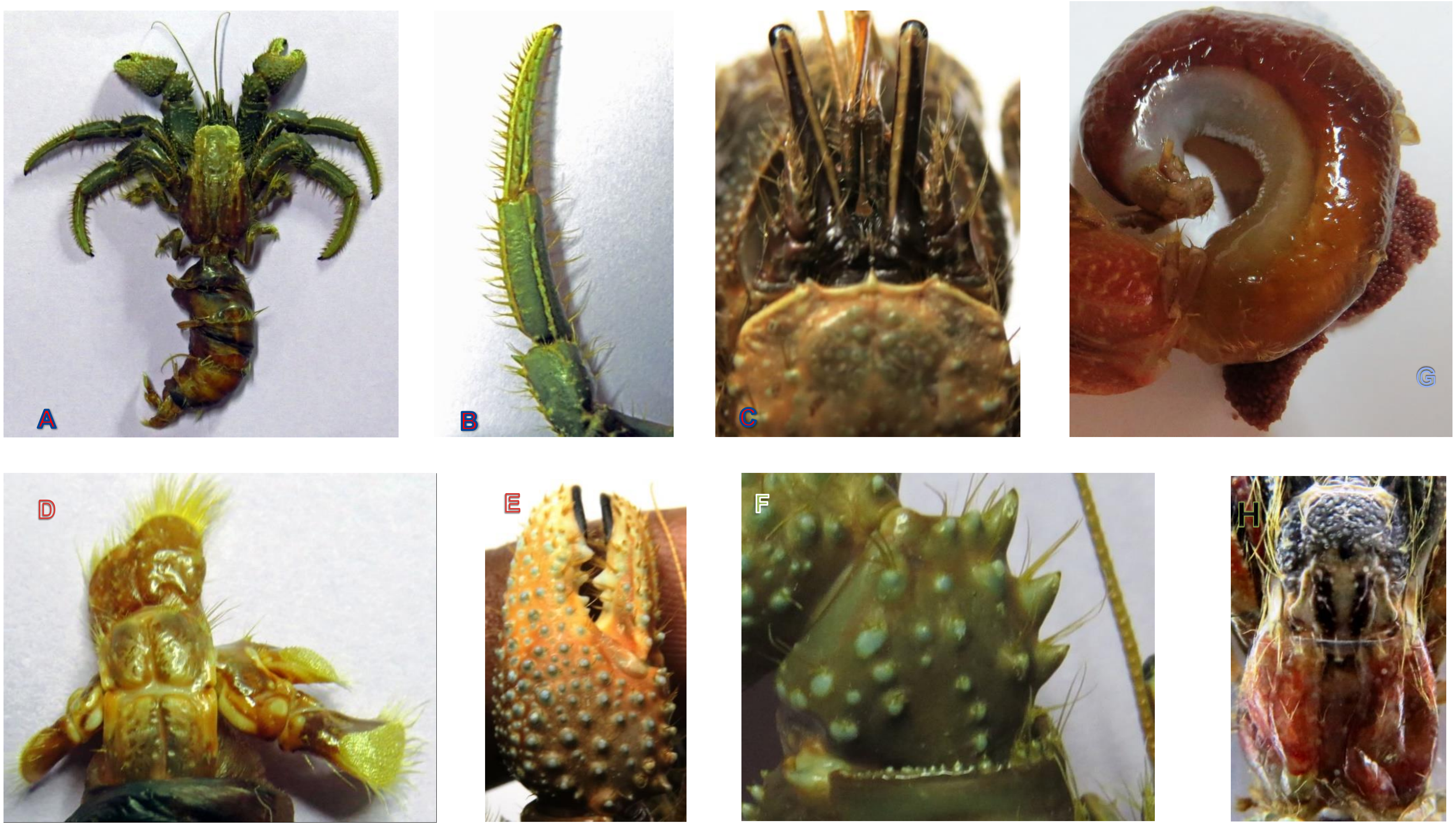


Fig 1.1.b: Different body parts of hermit crabs: *C. infraspinatus* A) whole animal B) pereiopods C) rostrum, anterolateral spine and eye D) telson E) cheliped F) Carpus spine; *Diogene. alias* G) abdomen; *C. longitarsus* H) carapace having both shield and membranous part

2. REVIEW OF LITERATURE

The study of marine fauna in India was a fascination to many naturalists from the eighteenth century onwards. As a result, Westerners have conducted many expeditions and surveys in India. Out of 34 known phyla, 32 are reported to occur in marine ecosystems of the world. However in India, majority of the studies have been concentrated on the organisms having a high market value such as fishes, crustaceans, mollusc, holothurian and other higher invertebrates. Marine groups lacking commercial values have been neglected especially hermit crabs, though the group is ecologically very important; forms food for many demersal fish species. The Anomura McLeay, 1838 have an appearance like crabs and lobsters which is the reason for classifying them in this group.

In the tenth edition of *Systema Naturae*, Linnaeus, (1758) recognised two anomuran species *Cancer maja* (Linnaeus, 1758) and *Cancer benhardus* (Linnaeus, 1758) as first decapod. The origin of hermit crabs has been traced to be during lower Jurassic period, some way around 200 million years ago (Glassener, 1969). During the start of last decade, a Symposium on Biology of the Anomura, the Fifth International Crustacean Congress was conducted where importance of decapod crustacean, especially hermit crab and king crabs by various authors was emphasized (Elwood and Neil, 1992; Tudge, 1992; McLaughlin and Lemaitre, 1997, etc.).

McLaughlin (1983a) classified four superfamilies of Anomuran representatives such as Paguroidea, Lomidea, Galathoidea and Hippoidea. The name of the group was debated for a long time with little confusion to call it as either Anomura or Anomala. McLaughlin and Holthuis (1985) reviewed this classification based on historical aspects and stressed on the use of name Anomura which contain three superfamilies, one for hermit crab-Paguroidea and other two are Galathoidea and Hippoidea. Later, other superfamilies have been included or families have been rearranged by various workers.

Even though there were lot of disagreements among carcinologists in the classification of this group, Forest (1987) restored the superfamily Coenobitidae (Dana, 1851) that was suppressed by McLaughlin (1983), who combined it with superfamily Paguroidea Laetrile, 1802. Forest (1987) and Forest *et al* (2000) information was based on unpublished records and it was not enough to convince Martin and Davis (2001), who in their updated classification once again suppressed Coenobitidae and brought all group of hermit crab under superfamily Paguroidea. Producing an updated classification is a huge task and bound to be out-dated by the time it is published. McLaughlin (1983) discussed that these hermit crabs were crevice dwelling animals that slowly lost their ability of calcification and tend to be attracted by the shelter. De Grave and his co-authors (2009) incorporated some updates and modified the higher level classification to the current phylogenetic understanding.

India has rich fauna of edible crustaceans, several of them supporting commercial fisheries since times immemorial (Dineshbabu *et al.,* 2011). Decapod crustaceans are commercially important. There are about 150 crustacean species forming a part of the faunistic record of Indian decapods, constituting as many as 117 species of shrimps and prawns.

There are a number of publications illustrating key for the identification of hermit crabs, including Alcock (1905), Provenzano (1959) and Ingle (1985). The advancement in the taxonomic study of hermit crab in India is mainly due to pioneering works of Henderson (1893, 1915), Alcock (1905), Southwell (1906), Sundara Raj (1927), Reddi (1935), Kamalaveni (1950) and Thomas (1977, 1974, and 1989).

In the Indian context, Alcock (1905) monograph is the old key but it is still use full for identification purposes. He divided Anomuran into four families including Pylochelidae, Paguridae, Coenobitidae and Lithodidae and reported the number of species found in India, which is around 90, one-fifth of world's hermit crab diversity. The absence of paired abdominal appendages except uropods has been used to differentiate them from their ancestors (Alcock, 1905). Henderson (1893) was the first worker to give his contribution towards Indian carcinological studies. He studied hermit crabs that occurred along the south-east coast of India.

Annandale and Kemp (1915) came across five species of hermit crabs during their survey of the Chilka Lake on Orissa coast. Of which, one species was new to the science (*Clibanarius olivaceus*) and the rest were already described by Alcock (1905). They described the characters of *C. olivaceus* in comparison with other congener species based upon the colour pattern of ambulatory legs. He also argued that colour remains same throughout the life span of representatives of genus *Clibanarius,* which is a reliable character for species differentiation (Henderson, 1915).

Chopra and Das (1940) described the characters of two hermit crabs (*Clibanarius nathi* and *C. signatus*) which were collected from Arabian Sea of India. Among the two species, first one was new to science and the other one was reported to occur as a rare animal in India. Bhatt (1959) recorded 68 species of arthropods including hermit crabs from Bombay during his research for Ph.D.

A detailed study of the anomuran fauna of Lawson's Bay, Waltair coast and Visakhapatnam harbour was conducted and 23 species belonging to Paguridae were collected (Sarojini and Nagabhushanam, 1972). Out of these, one species *P. indicus* happens to be new to science. Besides, *Clibanarius striolatus, C. humilis, C. eurysternus* and *P. anceps* were recorded for the first time from the Indian coast. They had also prepared an identification key for genera *Clibanarius* and *Diogene*.

Southwell (1906) reported the hermit crabs from Gulf of Mannar region. Sundara Raj (1927) dealt the pagurids of Krusadai Island. Reddi (1935) described hermit crabs from Porto Novo on the South-east coast of India while an account on the collection of the Indian Museum has been given by Kamalaveni (1950). Reddy and Ramakrishna (1972) listed 20 species of hermit crabs pertaining to Paguridae and Coenobitidae. Parulekar (1972) observed two sandy shores of Anjidiv Island to distinguish the species based on their distribution and exposure time. During the investigation, he recorded *Clibanarius padavensis, C. aequibilis* and *Diogene custos* in the sheltered zone of mid littoral and lower littoral zone. Hermit crabs found in different zones of Malvan coast were recorded (four on the sandy shore, one on mangrove area, two on rock pool and gravel bed) by Parulekar, (1981).

Thomas (1989) studied 27 species of hermit crabs, belonging to 8 genera *Paguropsis, Paguristes, Clibanarius, Dardanus, Diogenes, Trizopagurus, Calcinus* and *Triglopagrus* from the shallow littoral areas in the Palk Bay and the Gulf of Mannar. Besides this, he also collected samples of trawl catches from Pulicat Lake on the east coast and Cape Comerin to Mangalore on the west coast and from the deep sea of Cochin, Mandapam, Andaman and Laccadive Islands.

An identification key with selected diagnostic characters had been described for the seven families and 122 genera of the Anomura Superfamily Paguroidea by McLaughlin (2003)**.** Coastal and marine biodiversity inventory of India prepared by Venkataraman and Wafar (2005) summarises the diversity of commercially important species of fish, mollusc, etc. including 26 species of lobster, 162 species of the hermit crab and 705 species of brachyuran crabs. However, it is estimated that an excess of 800 species of hermit crab belonging to 86 genera in 6 families occurs worldwide (Gordan, 1956; Hazlett, 1981a).

Dineshbabu *et al* (2011) reported 14 species of hermit crabs belonging to two families from Karnataka waters of which one species *Clibanarius padavensis* was collected from estuaries and rest from marine waters. In addition, four more species were collected from the intertidal area and *C. aeqabilis* was collected from Devgadh Island. A study was undertaken along Saurashtra coastline to investigate the spatial and temporal variation in the population of *C. nathi* and *C. zebra by* Vaghela and kundu (2012)*.* They also opined that temporal and spatial variations in the populations were due to the nature of substratum or due to various degrees of wave action.

Mangroves are considered as breeding and feeding grounds of crustacean decapods. But as the destruction of mangroves continues due to many reasons, a need has been felt for generating the information about the status of organism and their diversity which would form the baseline for further studies and their conservation (Prabhakar, 2012; Varadharajan *et al*., 2013). A study by Prabhakar (2012) revealed that the hermit crab *Pagurus prideaux* is abundant at Sheva and Dharamtal creek of Uran. Varadharajan *et al* (2013) recorded a total of 79 individuals belonging to 21 families, of which 4 species belonged to family Diogenidae and 1 species to Paguridae (Varadharajan *et al*., 2013) reported the variation in abundance of hermit crabs from the coast.

The diogenid hermit crabs of genus *Diogenes* (Dana, 1851) are typically characterized by the possession of an intercalary rostriform process in the middle of ocular acicles, which is a unique feature for Paguroidea (Komai *et al*., 2013). Rounded or obsolete rostrum is also an identification trait (Reshmi and Bijukumar, 2011). *Diogene* genus is represented by 61 species (McLaughlin *et al.*, 2010; Komai *et al.*, 2013), out of which 19 species are available in Indian waters (Henderson, 1893; Alcock, 1905; Kamalaveni, 1950; Thomas, 1989; Siddiqui *et al.,* 2004; McLaughlin, 2005; Reshmi and Bijukumar, 2011).

Investigation around Kerala state by komai *et al* (2013) resulted in a discovery of new species or first record of many species of hermit crabs in India. Noteworthy work was done by these authors in recent times a new record of two species belonging to genus *Coenobita* was added the list of species under this genus occurring in India (Reshmi and Bijukumar, 2010). *Calcinus morgani* and *Diogene klassi* have been also added to the record by Reshmi and Bijukumar, (2011). A new species belonging to the genus *Ciliopagurus* (komai *et al.*, 2012) and other species belonging to *Diogene* genus were described with proper illustrations by Komai *et al* (2013). Siddiqui *et al* (2004) compared various type materials and clarified the problems in the identification of hermit crabs available in Pakistan waters under genus *Diogene*. They provided identification key for twelve species of *Diogene* with illustration.

The relationship between the various families and animals within the groups of Anomurans has become the subject of interest to many workers both at molecular and morphological level (Ahyong *et al*., 2009; Lemaitre and McLaughlin, 2009). Before 1997, the literature was related to evolutionary history based on morphological characters only (Ritcher and Scholtz, 1994; Scholtz and Ritcher, 1995; McLaughlin and Lemaitre, 1997). Mac Donald *et al.,* (1957) established an evolutionary relationship among the hermit crabs based on larval characters thereby dividing two groups as Coenobitoidea (Coenobitidae, Diogenidae, Lomisidae and Pylochelidae) and Paguroidea (Lithodidae, Paguridae and Parapaguridae).

McLaughlin (1983a) was the pioneer worker to use cladistics analysis to establish the evolutionary relationship among the hermit crabs by using 30 morphological characters. She abandoned Coenobitoidea and restored six families under Superfamily Paguroidea (Coenobitidae, Diogenidae, Pylochelidae, Lithodidae, Paguridae and Parapaguridae).

Cunningham *et al* (1992) proposed that symmetrical king crab was evolved from asymmetrical hermit crabs by using cladogram based on DNA sequences. In response to that McLaughlin and Lemaitre (1997) separated the asymmetrical crabs (Coenobitidae, Diogenidae, Paguridae and Parapaguridae) from Lithodids using 37 morphological characters of 57 species. Tudge (1997) on the other way, used spermatozoal characters to infer the relationship among the group. Dixon *et al.* (2003) analysed decapod based on the external morphology of 60 taxa including 14 representatives from anomuran groups. They opined that Anomuran and Brachyurans were monophyletic sister clades. With a renewed interest, McLaughlin *et al* (2007) upgraded the analysis made by McLaughlin *et al* (1983a) with 79 characters and concluded that Lithodids are separated from Paguroids and lead to new classification also.

Among decapods, carcinization (developmental body plan) exist in varying degree in anomurans. The term carcinization involves several transformations like flattening, broadening, sclerotization of the cephalothorax and reduction or unfolding of pleon (McLaughlin and Lemaitre, 1997). Carcinized paguroids have their origin from their ancestors that rely on speed rather than protection.

As such hermit crabs do not have any commercial importance however they form an essential link in the food chain of demersal fishes with few exceptions like coconut crab and some symmetrical crabs. *Birgus latro* is the largest land crab, found distributed in oceanic islands in Indian and Pacific Ocean. They are considered as an excellent diet as other decapods; in fact it is considered as a luxurious food item. Due to high exploitation rate, some conservative measure such as minimum legal size restriction have been followed along Gaum and Vanuata, and also the capture of the ovigerous female was strictly banned in this area. Investigation of their farming potential has also been done by Brown and Fielder (1991). A commercial Lithodid fishery was started since 1900 in Japan and from 1940 onwards in Pacific Ocean. *Paralithodes.* spp (red king crab) was the dominant contributor to Lithodid fishery. Until 1975, Lithodid landings were taken in tangle nets. Now pots are considered as less destructive gear.

3. MATERIALS & METHODS

3.1 Sample collection

The samples of hermit crabs were collected from intertidal and subtidal areas of selected station of Maharashtra coast viz. Aksha Beach, Bandstand of Mumbai & Alibaug and Srivardhan of Raigad (fig 3.1.1). These intertidal areas were extensively surveyed from August 2014 to April 2015 for the collection of hermit crabs. The sampling schedule was prepared for each month according to the lowest low tide, based on the tide table published by Naval Hydrographic Office, India. All specimens were collected by hand picking during low tide. Apart from the collection of samples from the intertidal area, samples were also procured from the subtidal areas (15 m depth) with the help of CIFE's research cum training vessel M. V. Narmada every fortnight. The collected specimens were identified and photographed followed by morphological measurements.

3.2 External morphological examination

Hermit crabs along with molluscan shells, in which they take shelter, were frozen, then gently pulled out from their shells by slowly twisting the crab against the direction of shell spiral, and in difficult cases a light hammer was used to crack the shell gently before pulling out the crab, after thawing (Teoh *et al.,* 2014). Position of their gonophores was used to determine the sex of hermit crab; the female has paired gonophores on the 5th pereiopods while male in 3th pereiopods (Elwood and Neil 1992). Besides, the female has biramous pleopod while the male has uniramous pleopods. The ovigerous female are seen carrying eggs on the pleopods.


Bandstand


Srivardhan


Alibaug


Versova

Fig 3.1.1 Sampling sites

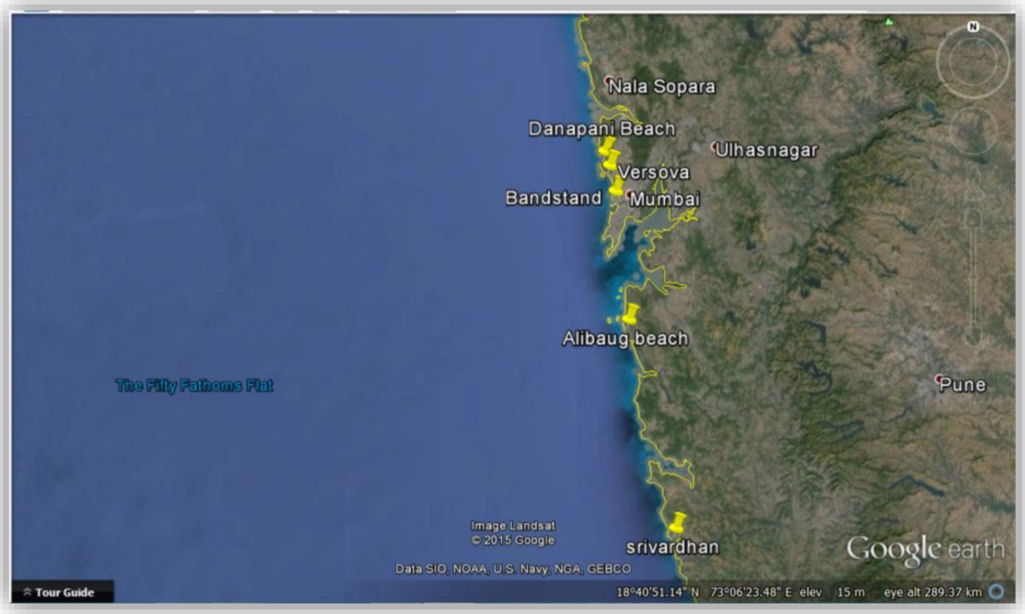


Fig 3.1.2 Location of sampling sites

3.3 Morphological measurements

A total of 16 morphometric traits were recorded from each specimen. The measurements were taken using Vernier calliper (all the measurements have been rounded to the nearest 0.1 mm). The measurements considered were:

1) Cephalic Shield length (SL) - The distance from the tip of the rostrum to the midpoint of the posterior margin of the shield.
2) Carapace Length (CL) – The distance from the tip of the rostrum, along the midline, to the posterior end of the carapace.
3) Carapace Width (CW) – The maximum width of carapace at any position.
4) Ocular Peduncle Length (EL) – The total length of an ultimate peduncular segment including cornea on the lateral face of peduncle.
5) Corneal Diameter (C) – The maximum width of the cornea measured on the dorsal surface.
6) Antennae Length (AL) – The distance from the ultimate segment to the tip of the antennal flagellum.
7) Antennular Peduncle Length (AP) – The distance from the base of antennae to an ultimate peduncular segment.
8) Total Length (TL) – The distance from the tip or rostrum to the tip of the telson.
9) Cheliped Propodus Length (CHL) – The distance from the tip of the propodus fixed finger to the base of propodus.
10) Cheliped Propodus Width (CHW) – The maximum width of propodus at any point.
11) Cheliped Dactylus Length (FL) – The distance from the tip of the dactylus movable finger to the case of dactylus.
12) Dactylus Length (DL) – The distance from the tip of left dactylus to the base of dactylus on the mesial surface.
13) Propodal Length (PR) – The distance from the tip of left propodus to the base of propodus on the mesial surface.
14) Carpus Length (CR) – The distance from the tip of the left carpus to the base on the mesial surface.

15) Merus Length (ML) – The distance from the tip of left merus to the base on the mesial surface.

16) Ischium Length (IL) – The distance from the tip of left ischia to the base on the mesial surface.

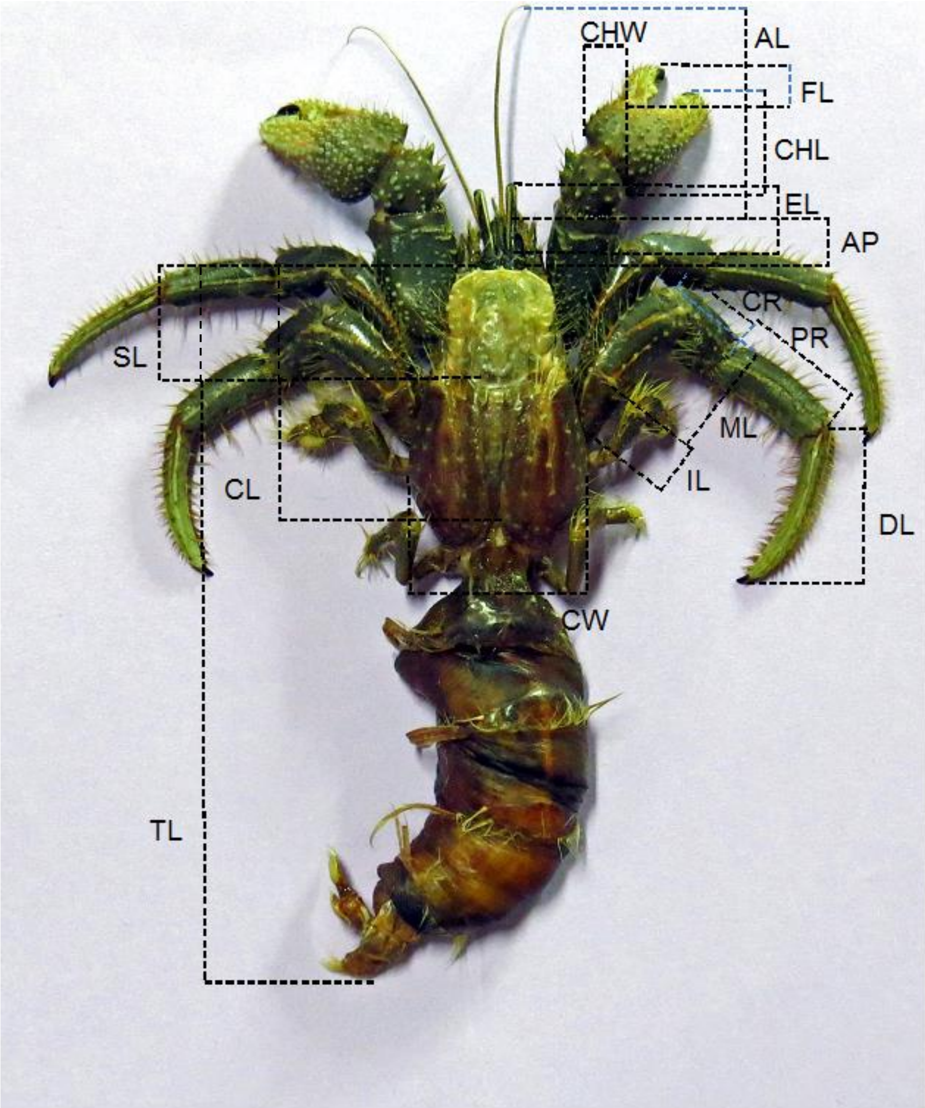


Fig: 3.3.1 Morphometric measurements of hermit crab

3.4 Meristic counts

The meristic characters including number of teeth in cutting edge of cheliped, the spines on the dorsal surface of the carpus and uropod in telson were recorded. Though one or two meristic characters are consistent throughout the families, remaining characters were considered for further analysis.

3.5 Analytical methods

3.5.1 Analysis of morphometric data

3.5.1.1 Descriptive statistics

Two morphometric characters scaled to cephalic shield length, two morphometric characters scaled to total length and fourteen morphometric characters scaled to carapace length of specimens of 8 species were subjected to descriptive analysis (mean, minimum, maximum, standard deviation and coefficient of variation). Mean plots of these scaled characters were also plotted to represent the dispersal of the variables graphically.

3.5.1.2 Correlation

Simple linear correlation between 18 scaled morphometric characters were established and presented in a matrix form.

3.5.1.3 Multivariate analysis of variance (MANOVA)

Multivariate analysis of variance was performed for 16 morphometric characters to test for the significant difference among different species.

3.5.1.4 Factor analysis

Factor analysis was performed for 16 morphometric characters, and the morphometric characters showing loading above the threshold value (0.6) are selected for forward stepwise discriminant analysis.

3.5.1.5 Stepwise discriminant analysis

A total of 12 morphometric characters, sorted after factor analysis, were used for forward stepwise discriminant analysis. Classification matrix and scatter plot were also generated.

3.5.2 Analysis of meristic data

Three meristic characters of the freshly collected specimen of 8 species were also subjected to descriptive analysis (median, mode, frequency of the mode, minimum and maximum). Variability plots similar to morphometric character were also plotted.

3.6 Cluster Analysis

Cladistic analysis is an efficient tool to differentiate the congener species based upon characters taken for analysis. Following McLaughlin (2007); Lemaitre *et al*., (2009), a total of 56 morphological characters were used to see the divergence among species and genera by Hierarchical Cluster analysis. The character states used for cluster analysis are:

1. Carapace shape:
    - sub-cylindrical (0)
    - sub-quadrate (1)
    - sub-ovate to ovate(2)
    - sub-triangular (3)
    - sub-globose (4)
2. Carapace regions (e.g., hepatic, gastric, cardiac, branchial)
    - absent (0)
    - not well defined (1)
    - weakly delineated (2)
    - distinctly delineated (3)
3. Carapace dorsal integument:
    - covering of spines or tubercles (0)
    - scattered spines, spinules or tubercles (1)

- distinct transverse grooves or furrows (2)
- smooth or nearly so (3)

4. Carapace margins:
   - armed with spines, tubercles, granules or protuberances (0)
   - unarmed (1)
5. Cervical groove:
   - clearly distinct (0)
   - weakly delineated (1)
   - obsolete or absent (2).
6. Shield width:
   - longer than broad (0)
   - width approximately equal to the length (1)
   - broader than long (2).
7. Shield length:
   - shorter than posterior carapace (0)
   - approximately equal to the posterior carapace (1)
   - longer than posterior carapace (2).
8. The anterior portion of the carapace:
   - well calcified through- out (0)
   - moderately or partially calcified (1).
9. The posterior portion of the carapace:
   - well calcified throughout (0)
   - weakly calcified or with areas of calcification (1)
   - chitinous or membranous (2).
10. Linea transversalis:
    - not apparent (0)
    - apparent, not contiguous with the cervical groove (1)
    - apparent, contiguous with the cervical groove at least centrally (2).
11. Rostrum:
    - well developed, without the subrostral spine (0)
    - well developed, with the subrostral spine (1)
    - somewhat to moderately well developed (2)
    - reduced or absent (3).

12. Ocular peduncles:
    - well developed (0)
    - reduced (1).
13. Ocular segmental bases:
    - widely separated (0)
    - contiguous or nearly so (1)
14. Antennal peduncle lengths:
    - overreaching distal margins of corneas (0)
    - not reaching to distal margins of corneas (1)
15. Antennal acicle:
    - moderate to short (0)
    - markedly reduced, vestigial or lost (1)
16. Ocular peduncular shape:
    - cylindrical (0)
    - dorso-ventrally flattened (1)
    - laterally compressed (2)
17. Corneal development:
    - large to moderate (0)
    - markedly reduced or absent (1)
18. Ocular acicles:
    - absent (0)
    - present (1)
19. Chelae:
    - not forming operculum (0)
    - forming operculum (1)
20. Chela shape:
    - sub rectangular (0)
    - sub-ovate to ovate (1)
    - subtriangular (2)
21. Chela dorsal surface:
    - generally flattened or smoothly convex (0)
    - with the ridge(s) or crests (1)
    - with granules, tubercles or spines (2)

22. Dactyl and fixed finger termination:
    - corneous claws (0)
    - calcified claws (1)
23. Palms of chelae with dorsomesial or upper margins:
    - with elevated entire or scutellated ridges (0)
    - with row(s) of tubercles (1)
    - row(s) of spines (2)
24. Chela dorsolateral or lower margin:
    - not delimited (0)
    - with elevated entire or scutellated ridge(s) or lobes (1)
    - with row(s) of tubercles (2)
    - row(s) of spines (3)
25. Chela setation:
    - with sparse setae (0)
    - with moderate to abundant setae (1)
26. Carpal antero-dorsal (dorsodistal) margin:
    - unarmed (0)
    - armed with granules, tubercles, spinules or spines (1)
27. Carpal stridulatory apparatus:
    - absent (0)
    - present (1)
28. Pereiopod symmetry:
    - second and third pereiopods similar in shape and/or armature [exclusive of stridulatory apparatus] (0)
    - second and third pereiopods dissimilar in shape and/or armature [exclusive of stridulatory apparatus] (1)
29. Propodi of second pereiopods:
    - unarmed (0)
    - with few to numerous protuberances, granules, tubercles or spinules (1)
    - with 1 prominent dorsodistal spine (2); with row of few to numerous spines (3)
30. Carpi of second pereiopods:

- unarmed or with only dorsodistal spine (0)
- with few numerous granules, tubercles or spinules (1)
- with few to numerous spines (2)

31. Propodi of third pereiopods:
    - unarmed or with small spine only at dorsodistal margin (0)
    - with few to numerous protuberances, granules, tubercles or spinules (1)
    - with few to numerous spines (2)
32. Carpi of third pereiopods:
    - unarmed or with spine only at dorsodistal margin (0)
    - with few to numerous protuberances, granules, tubercles or spinules (1)
    - with few to numerous spines (2)
33. Dactyl and propodal pereiopod setation:
    - lacking setae (0)
    - with sparse setae (1)
    - with moderate to abundant setae (2)
34. Pereiopods 1 (cheliped) termination:
    - simple (0)
    - sub- chelate (1)
    - chelate (2)
35. Pereiopods 1 symmetry:
    - equal or subequal (0)
    - left distinctly larger (1)
    - right distinctly larger (2)
36. The structure of pereiopods 1:
    - generally sub-cylindrical (0)
    - dorsoventrally flattened (1)
37. Armament of pereiopods 1:
    - similar (0)
    - dissimilar (1)
38. Pereiopod 1 dactylar orientation:
    - vertical (0)

- oblique (1)
- horizontal (2)

39. Dactyls of pereiopods 2-4:
    - generally sub-circular (0)
    - laterally compressed and dorsoventrally expanded (1)
40. Tips of dactyls of pereiopods 2-4:
    - with corneous claws (0)
    - without corneous claws (1)
41. Pereiopod 4:
    - developed as walking or digging leg (0)
    - reduced and not used for walking or digging (1)
42. Pereiopod 4 termination:
    - simple (0)
    - semi-chelate (1)
    - sub-chelate (2)
43. Pereiopod 5 carriage:
    - carried externally (0)
    - carried under the carapace (1)
    - carried horizontally (2)
    - carried dorsally or sub-dorsally (3)
44. Pereiopod 5 termination:
    - simple (1)
    - sub-chelate (1)
    - semi-chelate (2)
    - chelate (3)
45. Pereiopod 5 rasp:
    - absent (0)
    - well developed (1)
46. Fifth pereiopod development:
    - normal walking leg (0)
    - reduced (1)
47. Pleon symmetry:
    - pleomeres symmetrical (0)

- pleomeres asymmetrical (1)

48. Paired pleopod 1:
    - present and modified (0)
    - absent (1)
49. Pleopod 2:
    - paired and modified (0)
    - unpaired (1)
    - markedly reduced or absent (2)
50. Pleopods 3-5:
    - paired (0)
    - unpaired (1)
    - reduced (2)
    - vestigial or absent (3)
51. Uropod symmetry:
    - symmetrical, forming tail fan (0)
    - symmetrical, not forming tail fan (1)
    - asymmetrical (2)
52. Telson development:
    - elongate, triangular or subtriangular (0)
    - generally sub-quadrate or sub rectangular (1)
    - short, subtriangular to sub semicircular (2)
53. Telson shape:
    - longer than broad (0)
    - length approximately equal to the width (1)
    - broader than long (2)
54. Telson lateral margins:
    - entire (0)
    - with transverse indentations (1)
    - with transverse sutures (2).
55. Telson posterior lobes:
    - not delimited (0)
    - delimited, symmetrical or nearly so (1)
    - delimited, asymmetrical (2)

56. Telson terminal margin:

- entire or with slight median depression (0)
- with median concavity or cleft (1)

3.7 Software packages

Entry of data, editing and transformation were done in MS-Excel and all other statistical analyses were done using Statistica version 7.

4. RESULTS

During the present study, eight species of hermit crabs namely *Clibanarius infraspinatus, C. padavensis, C. longitarsus, C. arethusa, Pagurus kulkarnii, P. pitragsaleei, Diogene alias and D. dubius* were recorded form the selected intertidal and subtidal areas of Maharashtra. The species are described in detail in proceeding pages.

4.1 Description of species

Genus: *Clibanarius Dana, 1852*

Species: *Clibanarius infraspinatus* Hilgendrof, 1869

Common name: Orange striped hermit crab

Plate: 4.1.A. *Clibanarius infraspinatus* Hilgendrof, 1869

Synonyms: *Pagurus (Clibanarius) infraspinatus* Hilgendorf, 1869: 97; *Clibanarius vulgans* 1890, De Man, Notes Leyden Mus. XII., p. 112, *Clibanarius infraspinatus*-Yao-Chiongco, 1938: 19, 80 pl.2, fig. 4.

Materials examined: Collected from Bandstand and Danapani (Mumbai) & Srivardhan (Raigad); Number of specimens examined: 40, size of the specimens examined: 2.31 to 15.36 SL.

Remarks: This species is reported from Red Sea, Indian Ocean, India, north Australia, Indonesia, Singapore, Vietnam, Taiwan, Philippine Islands, Japan (McLaughlin *et al.,* 2007). This species was first reported in India by Alcock (1905).

Description: Shield 1.1 times longer than broad; anterior margin between rostrum and lateral projections slightly concave, smooth or bearing 1–2 tiny tubercles near each base of lateral projection; anterolateral margins sloping, 2-3 tubercles present; posterior margin roundly truncate; dorsal surface with some transverse spinulose ridges laterally. Rostrum prominent, triangular; lateral projections each with small submarginal spinule. Ocular peduncles equal in length, about 0.6 times as long as shield, long and slender, inflated at base; cornea not dilated, corneal width slightly less than 0.2 of peduncular length, subequal to basal width of ocular peduncle; ocular acicles with straight mesial margins, nearly convex anterolateral margin bearing 3-4 spinules or spines decreasing in size laterally and not extending to entire length of lateral margin. Antennular peduncles slightly longer than ocular peduncles: antennal peduncles short and reaching beyond 3/4th of ocular peduncles. Antennal article reaching beyond the proximal margin of ultimate peduncular segment, with about 6-8 spines in mesial margin.

Chelipeds slightly subequal, left slightly larger than right, similar in armament; Dactylus distinctly smaller than palm; upper margin with double row of small spiniform tubercles; outer surface usually with deep furrow medially with single row of small blunt calcareous teeth increasing in size distally; inner surface with median row of tiny tubercles, row of small tubercles adjacent to upper margin, and shallow sulcus proximally. Palm shorter than carpus; upper surface becoming wider distally, with scattered small spines or tubercles; outer surface covered with rounded granules, substantially sculptured with 1 blunt ridge on midline extending onto fixed finger and shallow depressions or furrows, in particular, lower one-third forming deep furrow extending onto fixed finger; longitudinal row of spines decreasing in size distally along upper one-third of outer surface, sometimes elevated in ridge; a few prominent spines present proximally; lower margin slightly upturned, irregular double or triple row of spines becoming smaller and single row distally, spines around proximo-lower angle particularly prominent; inner surface glabrous, with faint longitudinal sulcus proximal to dactylar articulation. Fixed finger slightly deflexed; cutting edge sinuous, with row of small, blunt, closely-set calcareous teeth.

Carpus slightly longer than wide, with single row of spines increasing in size distally on upper margin; outer surface convex, with scattered, numerous small spines or spine-like tubercles and tufts of short stiff setae on dorsal surface, dorsodistal margin denticulate; 3-4 strong spines on dorsomesial margin; ventrolateral distal angle with 1 or 2 small spines; inner (mesial) surface with cluster of small spines or tubercles adjacent to distomesial angle, otherwise nearly smooth; ventral surface with tiny, low tubercles. Merus distinctly longer than height; dorsal surface concave, bearing numerous spinules often arranged in short transverse rows and tufts of short stiff setae, dorsodistal margin with 3 spines mesially; lateral surface with short spinulose ridges; mesial surface with several tufts of moderately short setae dorsally and low tubercles ventrally, distomesial margin spinulose, ventromesial margin with prominent blunt spine proximally; ventral surface with scattered low tubercles and tufts of setae. Ischium with very low, blister-like protuberances on ventral surface, ventromesial margin minutely denticulate. Right cheliped moderately stout, with numerous tufts of long setae, particularly on dorsal side; broad hiatus between fingers.

Dactylus gently arched, about 2.5 times longer than palm; dorsal surface with irregular longitudinal row of spinules along midline in proximal half; mesial surface with several spinules or tubercles adjacent to dorsal margin; ventral surface unarmed; cutting edge with row of tiny calcareous denticles. Palm about half-length of carpus; dorsal surface with few minute tubercles mesially, dorsomesial margin with row of spinules; mesial surface with few spinules or short spinulose ridges dorsally, distal margin (base of dactylus) denticulate; ventral surface slightly convex. Fixed finger gently curved, with few spinules on dorsal surface; cutting edge with row of small, often acute, calcareous teeth. Carpus with row of spines increasing in size distally on dorsomesial margin, dorsodistal margin with 1 small spine mesially; dorsolateral surface with several spinules or minute tubercles arranged in 2 irregular longitudinal rows; mesial surface with several short setose ridges dorsally, distomesial margin denticulate ventrally. Merus with short, transverse spinulose ridges or row of spinules and tufts of long setae over entire length of dorsal margin, dorsodistal margin spinose; lateral surface with scattered minute spinules dorsally, ventrolateral margin only delimited in distal part and with 3 or 4 small spines; mesial surface nearly smooth, ventromesial margin with row of tiny spines; ventral surface with scattered very low protuberances and tufts of setae. Ischium with few blister-like protuberances on ventral surface and with row of minute denticles on ventromesial margin.

Ambulatory legs generally similar, but third pair slightly longer than second one. Dactyli about 1.4–1.5 times longer than propodi and 7.7– 8.3 times longer than wide; dorsal margins unarmed, and each with 2 rows of moderately long stiff setae (not merging in single row in distal half); lateral surfaces nearly flat, each with one row of tufts of moderately short stiff setae upto distal end near to dorsal margin and short row of setae extend upto midway to dactylus lateral side; mesial surfaces slightly convex, each with 2 rows of moderately long, stiff setae dorsally and ventrally; ventral margin of dactyls in ambulatory legs with 7-9 corneous spines in distal half, each with tufts of or individual stiff setae decreasing in length distally (second and right third) or with row of short bristle-like setae and row of short sparse setae distally (left third). Propodi nearly straight; dorsal surfaces unarmed, with tufts of long stiff setae; lateral and mesial surfaces each with rows of tufts of moderately short to long stiff setae adjacent to dorsal and ventral margins; ventral margin smooth, with sparse tufts of setae.

Carpi each with row of small spines in second pereiopods and third pereiopod with a dorsodistal spine along with some tufts of setae on dorsal margin; lateral surfaces unarmed, distal end without setae; mesial and ventral surfaces with few setae. Meri with dorsal and ventral tufts of setae; dorsal margins each with row of spinules; lateral surfaces unarmed or with few minute spinulose tubercles ventrally; mesial surfaces smooth; ventral surfaces each with row of spinules, ventrolateral distal margin with 1 minute spine. Ischia with small, blister-like protuberances on ventral surfaces; dorsal margins without armature.

Fourth pereiopods chelate. Dactyli reaching beyond the distal margins of propodi. Propodi each with distinctly produced dorsodistal margin sometimes bearing 1 or 2 small spines; rasp consisting of numerous corneous scales. Carpi each with 3 small dorsodistal spines and with long tuft of setae. Both male and female with pleopods unpaired (second to fifth), second pleopod longest. Telson with small median cleft; terminal margin largely acute on left, posterior lobes asymmetrical; with 5 to 7 corneous tipped spines.

Colour: Shield tan to brownish-orange, abdomen greyish-brown coloured, ocular peduncles dark brown with longitudinal reddish white strips, chelipeds brownish orange with lighter coloured tubercles. Ambulatory legs brownish orange, Carpi, Propodi, dactyli with two creamish tan stripes bordered with reddish brown and one median longitudinal brownish orange stripe on lateral face. Merus each with two longitudinal stripes laterally and one medial stripe.

Species: *Clibanarius padavensis* De Man, 1888

Plate: 4.1.B. *Clibanarius padavensis* De Man, 1888

Synonyms: *Clibanarius padavensis* de Man 1888, p. 242, pl. 16, fig. 1.

Materials examined: Collected from Danapani (Mumbai) and Alibaug (Raigad); Number of specimens examined: 60, size of the specimens examined: 3.8 to 8.3 SL.

Distribution: The distribution records of this species include Gulf of Oman, India, Maldives and Andaman Sea, Indonesia, Arafura Sea, Vietnam, Taiwan, Sri Lanka, Indonesia, Malaysia and Singapore (McLaughlin *et al*., 2007). This species was first reported from India by Alcock (1905). The specimens collected did not show any variation from the original description of the species.

Description: Shield 0.7 times longer than broad with tubercles on dorsal surface; anterior margin between rostrum and lateral projections slightly concave, bearing numerous tiny tubercles near each base of lateral projection; anterolateral margins sloping; posterior margin rounded; dorsal surface with some transverse spinulose ridges laterally. Rostrum prominent, triangular, reaching the base of the ocular acicles; lateral projections each with small submarginal blunt spinule. Ocular peduncles equal in length, about 0.6 times as long as shield, long and narrow, inflated at base; cornea slightly dilated, corneal width slightly less than 0.23 of peduncular length, subequal to basal width of ocular peduncle; ocular acicles with concave mesial margins, acute anterolateral margin bearing 1-3 spinules on terminal margin or moderately long tuft of setae increasing in size laterally and not extending to entire length of lateral margin. Antennal peduncle reaching upto the base of corneas; antennal acicle triangular with serrated margins, reaching base of ultimate peduncular joint.

Chelipeds spooned and of same size; Dactylus slightly smaller than palm; upper margin with double row of small tubercles or spines, inner margin with 2 calcareous teeth. Palm longer than carpus; upper surface wide, with scattered small tubercles; outer surface covered with small rounded granules. Fixed finger with row of small, blunt, widely-set calcareous teeth (2 teeth whose size increasing towards distal end). Carpus slightly wider than longer, with single prominent spines on upper margin; outer surface convex, with scattered, few small spines or spine-like tubercles and tufts of short stiff setae; ventrolateral distal angle with minute tubercles; inner (mesial) surface nearly smooth or some scattered tubercles; ventral surface with tiny, low tubercles. Merus distinctly longer than height; dorsal surface concave, dorsodistal margin with moderately long tufts of setae; lateral surface with short spinulose ridges (each bearing 2 spinules on distal end); mesial surface smooth, low tubercles dorsally, ventromesial margin with row of small spines or tubercles; ventral surface with scattered low tubercles and tufts of setae. Ischium ventromesial margin minutely denticulate.

Ambulatory legs generally similar, but third pair slightly longer than second one. Dactyli longer than propodi, 10-12 times longer than wide; dorsal margins unarmed, and each with 2 rows of moderately long stiff setae (not merging in single row in distal half); lateral surfaces nearly flat, each with one row of tufts of moderately short stiff setae whose size decreasing length towards distal end ; mesial surfaces each with a rows of moderately long, stiff setae dorsally merging at the junction of distal and proximal end; ventral margins each with 2 rows of tufts of individual stiff setae increasing in length proximally, 7-8 minute spinulose or spines present in between 2 rows of tufts of setae on ventral margin, with nearly sickle like curved end. Propodi nearly straight; dorsal surfaces unarmed, with tufts of moderately long stiff setae; lateral surface smooth without setae and mesial surfaces with 2 short rows of tufts of moderately short to long stiff setae adjacent to dorsal and ventral margins; ventral margin smooth, with one row of tufts of setae. Carpi each with a spine at dorsodistal end along with some tufts of small setae on dorsal margin; lateral surfaces unarmed, distal end with numerous moderately long setae; mesial region smooth and ventral surfaces with sparsely distributed small setae. Meri with moderately long tufts of setae on ventral; dorsal margins each with row of minute spinules; lateral surfaces unarmed and or with few minute setae with ridge on laterodistal end; mesial surfaces smooth; ventral surfaces each with row of spinules. Ischia with long tufts of setae on ventrodistal end, dorsal margins without armature; mesial surface smooth as in case of merus.

Fourth pereiopods chelate. Dactyli reaching beyond the distal margins of propodi. Propodi each with distinctly produced dorsodistal margin of numerous corneous scales. Carpi each with 1 small dorsodistal spines and with long tuft of setae, ventral margin of merus and ischia with long tufts of setae. Both male and female with pleopods unpaired (second to fifth). Telson slightly asymmetrical; left slightly larger than right; shallow median cleft separating asymmetrical posterior lobes, left terminal margin with 6-7 corneous tipped spines and right margin with 4-5 acute spines, whose size noticeably increasing towards laterally, both spine rows not extending onto lateral margin .

Colour: Carapace yellowish brown. Ocular peduncle yellowish with a reddish or brown stripe on dorsal and another stripe on the inner angle; Antennal and antennular peduncles yellowish with red or brown bands; flagellum yellow. Chelipeds and ambulatory legs yellowish with 2-3 longitudinal reddish or brown bands. Setae light yellow coloured.

Species: *Clibanarius arethusa* De Mann, 1888

Plate: 4.1.C. *Clibanarius arethusa* De Mann, 1888

Synonyms: *Clibanarius arethusa* De Man, 1888a: 252

Materials examined: Collected from Srivardhan (Raigad); Number of specimens examined: 3, size of the specimens examined: 5.8 to 9.2 SL.

Distribution: This species is available from East Indian Ocean from Kenya to Arabian Sea, Indonesia, Japan, Taiwan, Australia, Vietnam, Reunion, South China Sea, Philippine Islands, New Caledonia, French Polynesia and India (McLaughlin *et al*., 2007). This species was first reported in India by Alcock (1905).

Description: Shield 0.8 times longer than broad; anterior margin between rostrum and lateral projections slightly concave, bearing numerous tiny tubercles near each base of lateral projection; anterolateral margins sloping; posterior margin roundly truncate; dorsal surface with some transverse spinulose ridges lateral side. Rostrum triangular; lateral projections each with small submarginal spinule. Ocular peduncles equal in length, slightly shorter than shield, overreaching both antennal and antennular peduncles; about 0.6 times as long as shield, long and narrow, inflated at base; cornea not dilated, corneal width less than 0.15 of peduncular length, subequal to basal width of ocular peduncle; ocular acicles with straight mesial margins, anterolateral margin bearing 6-7 spinules or long tuft of setae decreasing in size laterally and extending to entire length of lateral margin. Ocular acicles sub-triangular with 3 terminal spines. Antennular peduncles nearly reaching base of corneas; antennal peduncles reaching beyond the midpoint of ocular peduncle. Antennal acicle reaching the distal margin of penultimate segment.

Cheliped subequal; similar in armature, right slightly longer and more robust; dactylus distinctly larger than palm; upper margin with double row of small tubercles or spines; outer surface usually with deep furrow medially with single row of small blunt calcareous teeth increasing in size distally; inner surface with median row of tubercles, row of small tubercles adjacent to upper margin. Palm longer than carpus; row of 4 or 5 small spines on the dorsomesial, margins upper surface becoming wider proximally, with scattered small tubercles; outer surface covered with rounded granules. Fixed finger with row of small blunt, widely-set calcareous teeth (2-3 teeth whose size increasing towards distal end). Carpus slightly wider than longer, with single row of spines increasing in size distally on upper margin; outer surface convex, with scattered, few small spines or spine-like tubercles and tufts of short stiff setae; ventrolateral distal angle with 1 or 2 small spines; inner (mesial) surface with cluster of small spines or tubercles adjacent to distomesial angle, otherwise nearly smooth; ventral surface with tiny, low tubercles. Merus distinctly longer than height; dorsal surface concave, bearing numerous spinules often arranged in short transverse rows, dorsodistal margin with moderately long tufts of setae; lateral surface with short spinulose ridges (each bearing 2spinules); mesial surface smooth, few tufts of moderately short setae dorsally and low tubercles ventrally, ventromesial margin with row of small spines or tubercles; ventral surface with scattered low tubercles and tufts of setae. Ischia ventromesial margin minutely denticulate.

Ambulatory legs generally similar, slightly robust; but third pair longer than second one. Dactyli of third pair is exactly same as propodi (in 2nd pair propodi is 0.9 times length of dactyli) and 6-7 times longer than wide; dorsal margins unarmed, and each with 2 rows of moderately long stiff setae (not merging in single row in distal half); lateral surfaces nearly flat, each with one row of tufts of moderately short stiff setae upto distal end near to dorsal margin; mesial surfaces each with 2 rows of moderately long, stiff setae dorsally merging at the junction of distal and proximal end; ventral margins each with 2 rows of tufts of individual stiff setae decreasing in length proximally, 4-6 spines present in between 2 rows of tufts of setae on ventral margin, with nearly sickle like curved end . Propodi nearly straight; dorsal surfaces unarmed, with tufts of long stiff setae; lateral and mesial surfaces each with rows of tufts of moderately short to long stiff setae adjacent to dorsal and ventral margins; ventral margin smooth, with one row of tufts of setae. Carpi each with a spine at dorsodistal end along with some tufts of moderately long setae on dorsal margin; lateral surfaces unarmed, distal end with long setae; mesial and ventral surfaces with sparsely distributed small setae. Meri with moderately long tufts of setae on ventral; dorsal margins each with row of minute spinules; lateral surfaces unarmed or with few minute setae with ridge on laterodistal end; mesial surfaces smooth; ventral surfaces each with row of spinules. Ischia with long tufts of setae on ventral surfaces; dorsal margins without armature; mesial surface smooth as in merus.

Fourth pereiopods chelate. Dactyli reaching beyond the distal margins of propodi. Propodi each with distinctly produced dorsodistal margin of numerous corneous scales. Carpi each with 1 small dorsodistal spines and with long setae, ventral margin of merus and ischia with long tufts of setae. Both male and female with pleopods unpaired (second to fifth), second pleopod longest. .Telson with shallow median cleft separating asymmetrical posterior lobes, left terminal margin with 5-6 corneous tipped spines noticeably increasing towards laterally, right margin with 2-4 spinules, both spine rows not extending onto lateral margin . Left uropod less than twice size of right uropod.

Colour: Shield light gray. Ocular and antennular peduncles brown. Antennular flagellum light brown. Antennal peduncle brown with light brown flagellum. Chelipeds and ambulatory legs reddish brown.

Species: *Clibanarius longitarsus* (De Haan, 1849)

Plate: 4.1.D. *Clibanarius longitarsus* (De Haan, 1849)

Synonyms: *Pagurus asper* H. Milne Edwards, 1848: 62; *Pagurus longitarsus* De Haan, 1849: 211, pl. 50, fig. 3; *Clibanarius longitarsis*- Dana, 1825b: 464: *Pagurus (Clibanarius) longitarsus*- Hilgendorf, 1869: 96; Clibanarius longitarsus- De Man, 1902: 741.

Materials examined: Collected from Srivardhan (Raigad); Number of specimens examined: 48, size of the specimens examined: 2.2 to 5.21 SL.

Remarks: Reported so far form Red Sea, Indian Ocean, North Australia, Thailand, Indonesia, Taiwan and Japan (McLaughlin et al., 2007). It was earlier reported from Nicobar Islands, Lakshadweep and Madras by Thomas (1989) and McLaughlin and Dworschak (2001).

Description: Shield longer than broad; rostrum triangular. Ocular peduncles slightly shorter than shield; ocular acicles with a simple spine terminally. Ocular peduncles slightly shorter overreached by antennular peduncles; antennal peduncles reaching at the base of corneas. Antennal acicle not reaching at the base of ultimate peduncular segment; mesial face with 3-4 spines and a terminal single spine.

Chelipeds subequal, robust; left slightly shorter than right, similar in armature; dorsal surface of palm with irregular row of corneous-tipped spines, dorsomesial margin with row of 55 spines; carpi with a prominent corneous-tipped spine distally at dorsomesial margins. Distal half of dactyls of ambulatory legs with 11-14 closely-spaced spinules at the ventral margin. Telson with asymmetrical posterior lobes and shallow median dark terminal margins with few small spinules and 2-3 larger, corneous tipped spines.

Colour: Shield and carapace greenish-brown with dark brown patches. Ocular peduncles yellowish green. Chelipeds greenish-brown with golden bristles. Second and third pereiopods bluish-green; propodus and dactyl with two longitudinal bluish-green stripes on lateral and ventro-lateral olivebrown stripes.

Genus: *Diogene* Dana, 1851

Species: *Diogene dubius Herbst, 1804*.

Plate: 4.1.E. *Diogene dubius Herbst, 1804*.

Synonyms: *Cancer dubius* Herbst 1804: 23, pl. 60, fig. 5; *Pagurus dubius*: Oliver 1811: 646; *Diogenes miles*: Heller 1865: 83 (in part); *Diogenes custos*: Henderson 1893: 414; *Diogenes dubius*: Alcock 1905b: 165

Materials examined: Collected from Versova; Number of specimens examined: 1, size of the specimens examined: 6.5 SL.

Distribution: Pakistan, Eastern coast of India, Nicobar Islands, Indonesia and South China Sea.

Description: Shield maximum width slightly exceeding medial length (1.1 times broader than long), with broadly rounded rostral lobe; anterior margin between rostrum and lateral projections slightly concave, bearing numerous tiny tubercles in between rostrum and lateral projection; anterolateral margins acutely angular with small apical process; posterior margin roundly truncate; dorsal surface with some transverse spinulose ridges lateral side bearing short setae. Rostrum well developed, reaching beyond the tips of ocular acicle with 4-6 pairs of spines on margins; lateral projections each with small submarginal spinule. Ocular acicle with row or small spinules on anterior margin, 1-2 larger spines on the inner margin. Ocular peduncles equal in length, about 0.4 times as long as shield, long and stout, inflated at base; corneal width less than 0.2 of peduncular length, subequal to basal width of ocular peduncle; ocular acicles with straight or slightly concave mesial margins, straight anterolateral margin bearing 6-7 spinules or long tuft of setae decreasing in size laterally and extending to entire length of lateral margin. Antennular peduncle nearly equal to antennal peduncle. Antennal acicle bifurcate, reaching at the distal joint of fourth peduncular segment. Inner branch reaching 0.5 length of fourth segment.

Chelipeds unequal; left larger than right. Dactyls with 2 rows of small tubercles on upper margin, outer face with closely packed tubercles; 2 rows of sub-acute tubercles on inner face. Outer face of fixed finger with numerous small tubercles, lower margin with closely packed conical tubercles. Upper surface of carpus with 2 rows of small conical spines, outer surface spinulose with strongest spines in ventral half. Dactylus of right cheliped with row of small spines on upper margin obscured by long setae. Irregular rows of small spines on outer face. Upper margin of carpus with rows of spines, outer face with prominent spines medially and small spines on dorsal surface; shallow longitudinal sulcus; proximal half with row of tiny spines; proximal half of ventro-mesial margin with row of small spines and long dense setae in distal half. Dorsal surface of propodus with 2-4 rows of small spines; lateral face with vertical rows of bifid tubercles; dorsal margin of carpi with row of small spines, lateral face with longitudinal row of bifid tubercles.

Ambulatory legs generally similar, but third pair longer than second one. Dactyli is larger than propodi (dactyli length is 1.5 times of propodi) and 10-11 times longer than wide; dorsal margins unarmed, with some small tubercles; lateral surfaces nearly flat; mesial surfaces each with 2 rows of moderately long, stiff setae dorsally merging at the junction of distal and proximal end; ventral margins each with 2 rows of tufts of individual stiff setae decreasing in length proximally. Propodi nearly straight; dorsal surfaces with 2 rows of acute spinules in 2^{nd} pair and in 3^{rd} pair one row of spine and one row of tubercles; lateral and mesial surfaces smooth, mesial surface with rows of tufts of moderately short to long stiff setae adjacent to ventral margins; ventral margin smooth having one row of tufts of setae. Carpi each with a row of spine at dorsal margin along with some tufts of moderately long setae on dorsal margin; lateral surfaces unarmed, distal end with short setae; mesial and ventral surfaces smooth. Meri dorsal margin with 7-8 pointed spines, moderately long tufts of setae on ventral; lateral surfaces unarmed or with few minute setae with ridge on laterodistal end; mesial surfaces smooth. Ischia with long tufts of setae on ventral surfaces; dorsal margins without armature; mesial surface smooth similar to merus.

Fourth pereiopods chelate. Dactyli reaching beyond the distal margins of propodi. Propodi each with distinctly produced dorsodistal margin of numerous corneous scales. Carpi each with 1 small dorsodistal spinulose and with long setae, ventral margin of merus and ischia with long tufts of setae. Pleopods unpaired in both male and female (second to fifth), all are of same size. Telson with indistinct median cleft separating asymmetrical posterior lobes is absent, left terminal margin with 5 corneous tipped spines noticeably increasing from lateral to posterior side, right margin with 1-2 spinules. Left uropod more than twice size of right uropod.

Colour: Light cream coloured body, Ocular peduncles, antennular and antennal peduncles with alternating cream and grey stripes. Rostrum and ocular acicles grey with red tinge. Chelipeds and ambulatory legs brown with brownish-grey patches.

Species: *Diogene alias McLaughlin* & Holthuis, 2001

Plate: 4.1.E. *Diogene alias* McLaughlin & Holthuis, 2001

Synonyms: *Pagurus diogenes*: Fabricius 1787: 327: *Cancer diogenes* 1791: 17, pl: 22, fig. 5, *Diogenes miles* 1865: 83 (in part), *Diogenes diogenes*. Henderson 1893: 412: *Diogenes alias* McLaughlin & Holthuis 2001: 256, Not *Pagurus Diogenes*: Fabricius 1775: 410; Not *Pagurus Diogenes*: De Hann 1849: 208; Not *Diogenes diogenes*: Naiyanetr 1980: 24

Materials examined: Collected from Versova; Number of specimens examined: 31, size of the specimens examined: 6.89 to 10.73 SL.

Distribution: This species is reported from Pakistan, Eastern coast of India, Nicobar Islands, Indonesia and South China Sea (Siddiqui *et al*., 2004). This species was first reported in India by Alcock (1905). *D. alias* was reported from Mangalore and Calicut (southwest coast of India) by Rahayu (2000).

Description: Shield maximum width slightly exceeding medial length (1.01-1.05 times broader than long), sub rectangular shaped; anterior margin between rostrum and lateral projections slightly concave, bearing numerous tiny tubercles on anterolateral projection; anterolateral margins rounded with small spinulose on lateral side; posterior margin roundly truncate; dorsal surface with some transverse spinulose ridges on lateral side bearing moderately long setae. Rostrum obtuse; lateral projections each with small submarginal spinule. Ocular peduncles equal in length, about 0.7 to 0.9 times as long as shield and stout, inflated at base, with row of small spines over entire length of antenna margin , 2 or 4 frequently more prominent at inner angle.; corneal width less than 0.23 of peduncular length, subequal to basal width of ocular peduncle; ocular acicles with straight mesial margins, anterolateral margin bearing numerous spinules or long tuft of setae decreasing in size laterally and extending to entire length of lateral margin. Intercalary rostral process usually reaching beyond anterior margins of ocular acicles, margins, most frequently, each with several prominent spines. Antennular peduncles when fully extended, overreaching corners by approximately half length of ultimate segments. Antennal acicles usually prominently bifurcate; outer branches reaching to or beyond the proximal margin of ultimate peduncular segment; inner margins each with several spines. Antennal flagella sparsely setose, every 2 or 3 articles with pair of moderate to long setae.

Chelipeds unequal, left cheliped larger and with row of slender , acute spines near upper outer margin of dactyli and usually 2 smaller spines centrally in proximal half of outer surface; upper margin with 2 rows of acute spines. Fixed finger with outer surface flattened, armed with row of prominent spines; lower margin with row of strong, acute spines, forming nearly straight line with lower, similarly armed margin of palm; convex outer surface of palm with 5 or 6 rows of acute, often slightly curved spines, irregular area devoid of spines or with only appreciably smaller, randomly set spines adjacent to upper margin and continuing proximately to articulation with carpus. Upper margin of palm with 2 or 3 irregular rows of smaller spines and tufts of moderately long setae. Carpus with row of moderate spines on the upper outer margin and adjacent to it on the upper margin row of strong spines, short row of spines is seen distally to the area devoid of spines or with very small spines proximally. Carpus with row of strong spines on upper margin , adjacent short row of spines distally, area devoid of spines or with only few small spinules or spinulose tubercles proximally; remainder of outer face with several rows of smaller spines and tufts of long setae. Right cheliped with 1 or 2 rows of acute spines on upper margin of dactyl, partially obscured by long setae. Palm with 1 or 2 rows of acute spines on upper surface, also partially obscured by long setae; outer face with armature varying from 2 or 3 very weak or practically indistinct rows of tubercles to rows of prominent spines, sometimes extending onto fixed finger, and all accompanied by long setae. Carpus with long setae and row of strong spine son upper margin, outer surface with 3 or 4 rows of low, sub-acute, bifid tubercles and long setae, lower margin tuberculate.

Ambulatory legs generally similar, but third pair longer than second one. Dactyli is longer than propodi and 8-9 times longer than wide; dorsal margins armed having one row of spines whose size increasing proximally, and each with one row of moderately long stiff setae (merging with row of spines in distal half); lateral surfaces nearly flat, 3rd pair with one row of tufts of moderately short stiff setae upto distal end near to dorsal margin, 2nd pair don’t have setae on lateral surface; mesial surfaces each with 2 rows of moderately long, stiff setae; ventral margins each with a row of tufts of individual stiff setae increasing in length proximally. Propodi with 3 longer prominent spine on dorsal surface, 2nd

rows of small blunt tubercles but 3rd with rows of strong tubercles; lateral and mesial surfaces each with minute tubercles and tufts of moderately short setae sparsely situated; ventral margin of 3rd pair smooth and of 2nd pair having row of long setae. Carpi each with a row of spine at upper margin along with some tufts of moderately long setae on dorsal margin; lateral surfaces with few rows of tiny tubercles, distal end with moderate setae; mesial and ventral surfaces with sparsely distributed small setae. Meri with moderately long tufts of setae on ventral; dorsal margins each with row of minute spinules; lateral surfaces unarmed or with few minute setae and 2 acute spine on laterodistal end in 2nd pair and on 3rd pair 3-4 spines; mesial surfaces smooth; ventral surfaces each with row of spinules and some tufts of setae. Ischia with long tufts of setae on lower mesial margin; dorsal margins with long setae; mesial surface smooth.

Fourth pereiopods chelate. Dactyli reaching beyond the distal margins of propodi. Propodi dorsodistal margin of numerous corneous scales. Carpi each with 1 small dorsodistal spines and with long setae, ventral margin of merus and ischia with scattered tubercles and long tufts of setae. Both male and female with pleopods unpaired (second to fifth), all are of same size. Median cleft separating asymmetrical posterior lobes is absent in telson, left terminal margin with 5-6 corneous tipped spines noticeably increasing towards posterior margin, right margin with 3-4 spinules, both spine rows extending onto lateral margin. Left uropod more than twice size of right uropod, distal parts of endopod and exopod with sub-acute pseudo-chelate.

Colour: Shield cream coloured with brownish tinge. Ocular peduncle with light brown longitudinal stripe. Chelipeds, ambulatory legs, antennae, antennules are all coloured with creamish-brown.

Genus: *Pagurus Fabricius, 1775*

Species: *Pagurus pitragsaleei* McLaughlin, 2002

Plate: 4.1.G. *Pagurus pitragsaleei* McLaughlin, 2002

Synonyms: *Pagurus cf. boriaustraliensis* – Rahayu & Komai, 2000: 30, figs. 4-8 (not *Pagurus boriaustraliensis* Morgan, 1990), *Pagurus pitragsaleei* McLaughlin, 2002: 444.

Materials examined: Collected from Alibaug (Raigad); Number of specimens examined: 3, size of the specimens examined: 2.9 to 5.8 SL.

Remarks: *Pagurus pitragsaleei* was recorded earlier from Phuket, Thailand and northeast Taiwan (McLaughlin *et al*., 2007). The present record of this species from southwest coast of India is second record next to Reshmi's work.

Description: Shield maximum width slightly exceeding medial length (1.1 times broader than long); anterior margin between rostrum and lateral projections slightly concave, bearing numerous tiny tubercles in between rostrum and lateral projection; anterolateral margins acutely angular with small apical process; posterior margin roundly truncate; dorsal surface with some transverse spinulose ridges lateral side bearing short setae. Rostrum moderately obtuse, broadly rounded rostrum; lateral projections each with small submarginal spinule. Ocular acicle terminating in a single submarginal spine. Ocular peduncles equal in length, about 0.6 times as long as shield, long and narrow, inflated at base; cornea not dilated, corneal width less than 0.15 of peduncular length, subequal to basal width of ocular peduncle; ocular acicles with straight mesial margins, anterolateral margin bearing 6-7 spinules or long tuft of setae decreasing in size laterally and extending to entire length of lateral margin.

Right cheliped larger not appreciably longer than left. Both with armature obscured long setae. Dactyl with longitudinal, tuberculate median ridge, a row of small closely spaced spines on the dorsomesial margin. Palm with protuberance proximally at dorsal midline separated by space from tuberculate and setose ridge. Dorsomesial region with a row of small spines. Carpus with scattered tubercles on dorsal surface, dorsolateral margin with row of small spines, dorsomesial region with row of prominent spines ventro-mesial margins with a wing like projections. Left cheliped slightly shorter than right, dorsal midline of palm with 1-2 tuberculate protuberance followed distally by small sub-acute tubercles forming a row. Dorsomesial region with 3-4 prominent spines, dorsolateral margin with row of spines. Carpus flattened dorsally, a row of three large prominent spines on dorsomesial margin, dorsolateral margin with 3-4 spines.

Ambulatory legs generally similar, but third pair longer than second one. Dactyli of third pair is exactly same as propodi (in 2nd pair propodi is 0.9 times length of dactyli) and 6-7 times longer than wide; dorsal margins unarmed, and each with 2 rows of moderately long stiff setae (not merging in single row in distal half); lateral surfaces nearly flat, each with one row of tufts of moderately short stiff setae upto distal end near to dorsal margin; mesial surfaces each with 2 rows of moderately long, stiff setae dorsally merging at the junction of distal and proximal end; ventral margins each with 2 rows of tufts of individual stiff setae decreasing in length proximally, 7- 8 minute spines present in between 2 rows of tufts of setae on ventral margin, with nearly sickle like curved end . Propodi nearly straight; dorsal surfaces unarmed, with tufts of long stiff setae; lateral and mesial surfaces each with rows of tufts of moderately short to long stiff setae adjacent to dorsal and ventral margins; ventral margin smooth, with one row of tufts of setae. Carpi each with a spine at dorsodistal end along with some tufts of moderately long setae on dorsal margin; lateral surfaces unarmed, distal end with long setae; mesial and ventral surfaces with sparsely distributed small setae. Meri with moderately long tufts of setae on ventral; dorsal margins each with row of minute spinules; lateral surfaces unarmed or with few minute setae with ridge on latero-distal end; mesial surfaces smooth; ventral surfaces each with row of spinules. Ischia with long tufts of setae on ventral surfaces; dorsal margins without armature; mesial surface smooth as in merus.

Fourth pereiopods chelate. Dactyli reaching beyond the distal margins of propodi. Propodi each with distinctly produced dorsodistal margin of numerous corneous scales. Carpi each with 1 small dorsodistal spines and with long setae, ventral margin of merus and ischia with long tufts of setae. Both male and female with pleopods unpaired (second to fifth), second pleopod longest. Telson with deep median cleft separating asymmetrical posterior lobes, left terminal margin with 5-7 corneous tipped spines noticeably increasing towards laterally, right margin with 5-6 spinules, both spine rows not extending onto lateral margin . Left uropod less than twice size of right uropod, distal parts of endopod and exopod with subacute pseudo-chaetae.

Colour: Carapace brownish grey, ocular peduncle grayish-white with short black stripes and lateral margin with continuous longitudinal stripe. Antennal peduncles light orange with black stripes. Antennal peduncles grayish-white with black stripes, flagella banded with grey and black. Chelipeds with palms mottled with grayish-white and black. Carpus and merus of cheliped with numerous short black stripes. Ambulatory legs grayish-white with short black stripes.

Species: *Pagurus Kulkarnii* Sankolli, 1962

Plate: 4.1.F. *Pagurus Kulkarnii* Sankolli, 1962

Synonyms: *Pagurus kulkarnii* Sankolli, 1962: 136 figs: 1, 2; Tirmizi & Siddiqui, 1982: 89, figs: 44, 45; *P. kulkarnii* – Morgan, 1987:182.

Materials examined: Collected from Srivardhan (Raigad); Number of specimens examined: 48, size of the specimens examined: 2.2 to 5.21 SL.

Remarks: This species showed a distribution range in intertidal areas of Kerala, Karachi and Gulf of Thailand (McLaughlin *et al*., 2007). They are found in the littoral and sub-littoral areas, commonly associated with soft silt, sand, rocks and coral reefs (Rahayu, 2000). The specimen collected from Maharashtra coast inhabited small shells which were found in the rocky patches covered with vegetation's.

Description: Shield slightly longer than broad with a rounded rostrum. Moderately elongate with small peduncles overreach both antennular and antennal peduncles; corneas not dilated. Ocular acicles each with terminal spinule. Antennal acicle long, curved and reaching beyond the proximal margin of ultimate peduncular segment. Shield with numerous granules.

Chelipeds unequal with right longer and stouter; upper surface of right cheliped with small tubercles. Palm with granular upper surface, row of small tubercles on the dorsomesial and dorsolateral margins. Carpus with few tubercles on the dorsal surface, row of spines on dorsomesial margin, dorsolateral margin generally spinulose. Ventro-mesial margin of carpus and merus and disto-mesial margin of merus produced into wing like projections. Left cheliped smaller than right with spinulose dorsomesial margin, dorsal surface of palm granular; carpus with a dorsodistal spine. Second and third ambulatory legs almost similar; dactyls shorter than propodi, with 5 or 6 corneous spines on ventral margins. Dorsal margin of propodi with transverse rows of minute ridges, 2-5 corneous spinules on ventro-distal margin; carpi each with dorsodistal spine. Telson asymmetrical with a moderately deep median cleft. Left lobe slightly larger than right. Each with irregularly sized blunt spines.

Colour: Shield light pinkish tan with few darker patches. Ocular peduncles orange proximally and distally separated by broad grey or light brown band. Ocular acicles reddish brown proximally. Antennal flagella banded with grey and reddish brown. General colour of chelipeds and ambulatory legs white to light brown or brownish rose with small longitudinal stripes.

4.2 Field Identification key

In present work, a total of 8 species were recorded under two families Paguridae and Diogenidae. Based on morphological features an identification key for 8 species is generated for field identification.

1. The left cheliped is larger than right
   -- Diogenidae
   The right cheliped larger than left---2
1. a. Basis and ischium of third maxilliped placed close to each other
   --3

3. a. Rostrum moderately to well developed and tips of pereiopods blackened
   --*Clibanarius*

- 3 strong spines on the outer margin of carpus of cheliped
  --*Clibanarius infraspinatus*.
- 2 strong spines on the outer margin of carpus of cheliped
  -- *Clibanarius longitarsus.*
- 1 strong spine on the outer margin of carpus of cheliped-----------------------4

4a. Rostrum acute and well developed

--*Clibanarius padavensis.*

4b. Four or five small spines present in dorsomesial region of cheliped-
---*Clibanarius arethusa.*

3. b. Rostrum replaced by intercalary rostriform process and tips of pereiopods blackened--*Diogene.*

- Cheliped with well-developed spines or ornamentation with abundant setae on both cheliped and walking legs
  -- *Diogene alias.*

- Cheliped with numerous tubercles with sparse setae on both cheliped and walking legs --- *Diogene dubius*.

2. The right cheliped is larger than left -- Paguridae

2. a. Basis and ischium of third maxilliped widely separated by each other --5

5. a. Antennal flagellum with alternate bands of red and white and dark black or brown stripes on ambulatory legs

 ---*Pagurus kulkarnii*

5. b. Antennal flagellum bluish white and have very elongate setae all over the pereiopods and well developed left uropods

 --- *Pagurus pitragsaleei*

4.3. Morphometric characters

4.3.1 Descriptive statistics of morphometric data

Descriptive statistics (minimum, maximum, mean, standard deviation, standard error and coefficient of variation) were obtained for 18 morphometric characters (2 scaled to SL, 2 scaled to TL and 14 scaled to carapace length) for 8 species collected during study period. Several morphometric variables obtained were found to be important in differentiating between the species. Even in very closely resembling species some variables were found to differ. The statistics are presented species wise (Tables: 4.3.1.1 to 4.3.1.8).

The mean proportion of eye peduncle to shield length (EL/SL) ranged from 0.475 (*P. kulkarnii*) to 0.586 (*C. padavensis*). *C. padavensis, C. infraspinatus*, *C. longitarsus, C. arethusa, D. alias, D. dubius and P. pitragsaleei* were having EL/SL values more than 0.5.

The mean proportion of Corneal diameter to shield length (C/SL) ranged from 0.079 (*P. pitragsaleei*) to 0.586 (*P. kulkarnii*). Values lower than 0.16 for C/SL were *recorded for C. padavensis, C. infraspinatus*, *C. longitarsus, C. arethusa, D. alias, D. dubius and P. pitragsaleei*.

The mean proportion of eye peduncle to carapace length (EL/CL) ranged from 0.227 (*D. alias*) to 0.331 (*P. pitragsaleei*). Values lower than 0.256 for EL/CL were *recorded for C. padavensis, C. infraspinatus*, *C. longitarsus, C. arethusa, D. alias, D. dubius and P. kulkarnii*.

The ratio of corneal diameter to carapace length (C/CL) has minimum (0.042) in *D. alias* and maximum (0.074) in *C. longitarsus*. Smaller value of less than 0.6 were observed in *C. infraspinatus*, *C. arethusa, D. alias, D. dubius and P. pitragsaleei.*

The mean proportion of shield length to carapace length (SL/CL) has its minimum and maximum values of 0.401 in *D. alias* and 0.566 in *P.*

pitragsaleei, respectively. Lower values of less than 0.5 were found to occur in *C. padavensis, C. infraspinatus, C. longitarsus*, *C. arethusa, D. alias* and *D. dubius.*

The mean ratio of antennal peduncle to carapace length (AP/CL) was lowest in case of *C. infraspinatus* with a value of 0.318. The highest value was recorded in case of *P. pitragsaleei* (0.423). Lower values (<0.4) were found in *C. padavensis, C. infraspinatus, C. longitarsus*, *C. arethusa, D. alias, D. dubius* and *P. kulkarnii.*

The mean proportion of carapace width to carapace length (CW/CL) ranged from 0.54 (*C. arethusa*) to 0.696 (*P. pitragsaleei*). Values lower than 0.6 for CW/CL were recorded for *C. padavensis*, *C. longitarsus, C. arethusa* and *P. kulkarnii*.

The ratio of cheliped length to carapace length (CHL/CL) has minimum value (0.469) in *P. pitragsaleei* and maximum value (0.798) in *D. dubius*. Higher value of more than 0.6 were observed in *C. padavensis, C. longitarsus, C. arethusa, D. alias, D. dubius* and *P. kulkarnii.*

The mean proportion of cheliped width to carapace length (CHW/CL) has its minimum and maximum values of 0.302 in *P. pitragsaleei* and 0.631 in *C. infraspinatus* respectively. Lower values of less than 0.6 were found to occur in *C. padavensis, C. longitarsus*, *C. arethusa, D. alias, P. kulkarnii, P. pitragsaleei* and *D. dubius.*

The mean ratio of finger length to carapace length (FL/CL) was lowest in case of *P. pitragsaleei* with a value of 0.335. The highest value was recorded in case of *D. alias* (0.469). Lower values (<0.4) were found in *C. padavensis, C. infraspinatus*, *C. arethusa, P. pitragsaleei,* and *P. kulkarnii.*

The palm length scaled to carapace length (P/CL) had its lowest mean value of 0.498 in case of *P. pitragsaleei* and highest value of 0.807 in *D. dubius.* The lowest and highest mean values of ratio of dactylus length to carapace length (DL/CL) were 0.464 in *P. pitragsaleei* and 0.78 in *P. kulkarnii.*

The proportion of propodus length to carapace length (PR/CL) was found to maximum in *D. dubius* (0.494) and minimum was recorded in *P. pitragsaleei* (0.438). The ratio of carpus length to carapace length (CR/CL) has minimum value (0.241) in *C. padavensis* and maximum value (0.351) in *C. infraspinatus*. Smaller value of less than 0.3 were observed in *C. longitarsus, C. padavensis, C. arethusa, P. kulkarnii* and *P. pitragsaleei.*

The mean proportion of merus length to carapace length (ML/CL) has its minimum and maximum values of 0.375 in *D. dubius* and 0.457 in *C. padavensis* respectively. Higher values above 0.4 were found to occur in *C. padavensis, C .infraspinatus, C. longitarsus*, *C. arethusa, P. kulkarnii, P. pitragsaleei* and *D. alias.*

The mean ratio of ischium length to carapace length (IL/CL) was lowest in case of *D. dubius* with a value of 0.165. The highest value was recorded in case of *C. padavensis* (0.266). Higher values (>0.2) were found in *C. padavensis, C. infraspinatus, C. longitarsus*, *C. arethusa, D. alias, P. pitragsaleei* and *P. kulkarnii.*

The mean proportion of carapace length to total length (CL/TL) ranged from 0.341 (*P. pitragsaleei*) to 0.416 (*D. alias*). Values lower than 0.4 for CL/TL were *recorded for C. infraspinatus, C. padavensis*, *C. longitarsus, C. arethusa, D. dubius, P. pitragsaleei* and *P. kulkarnii*.

The ratio of antennal length to total length (AL/TL) has minimum (0.215) in *P. pitragsaleei* and maximum (0.653) in *P. kulkarnii*. Lower values of less than 0.6 were observed in *C. padavensis, C. infraspinatus, C. longitarsus, C. arethusa, D. alias, D. dubius* and *P. pitragsaleei.*

High values of coefficient of variation (>15) were in recorded in CR/CL (16.67) for *C. padavensis*; in *C. arethusa* it is recorded in AL/CL (16.51), SL/CL (15.78) and *P. kulkarnii* with C/CL (19.19), CR/CL (16.41) and IL/CL (7.35). Very low value of coefficient of variation (<1) was recorded in ML/CL (0.39), P/CL (0.73) for *C. arethusa* and in *D. alias for* D/CL (0.98). Means plot of each character for different species were plotted to gives exact information about the dispersion of variables among the species. The median for each variable were also joined to visualise the differentiation among the species.

Table 4.3.1.1 Descriptive statistics of morphometric measurements of *C. infraspinatus*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	40	0.547002	0.531764	0.566538	0.010234	0.001618	1.870919
C/SL	40	0.125583	0.109057	0.139268	0.008997	0.001422	7.163842
EL/CL	40	0.237989	0.197329	0.267573	0.015555	0.002459	6.535968
C/CL	40	0.054671	0.039462	0.065295	0.005499	0.000869	10.058390
SL/CL	40	0.435198	0.356693	0.490155	0.029179	0.004614	6.704733
AP/CL	40	0.318625	0.300154	0.339845	0.010378	0.001641	3.257239
CW/CL	40	0.638058	0.601543	0.656842	0.013252	0.002095	2.077000
CHL/CL	40	0.529276	0.502198	0.556834	0.014805	0.002341	2.797178
CHW/CL	40	0.631411	0.601545	0.658457	0.014954	0.002364	2.368398
FL/CL	40	0.361528	0.313346	0.398567	0.021315	0.003370	5.895853
P/CL	40	0.66216	0.613587	0.699207	0.024118	0.003813	3.642262
DL/CL	40	0.765504	0.712723	0.799823	0.024246	0.003834	3.167374
PR/CL	40	0.461799	0.412365	0.498417	0.021045	0.003328	4.557229
CR/CL	40	0.351316	0.313460	0.391280	0.025221	0.003988	7.178910
ML/CL	40	0.454173	0.401190	0.499270	0.025076	0.003965	5.521336
IL/CL	40	0.25336	0.213365	0.298281	0.024203	0.003827	9.552660
CL/TL	40	0.38049	0.301075	0.451045	0.036705	0.005804	9.646702
AL/TL	40	0.472481	0.417912	0.498793	0.017942	0.002837	3.797414

Table 4.3.1.2 Descriptive statistics of morphometric measurements of *C.longitarsus*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	87	0.564028	0.525528	0.579442	0.009501	0.001019	1.68454
C/SL	87	0.163919	0.151455	0.175639	0.007127	0.000764	4.347609
EL/CL	87	0.256377	0.190961	0.359925	0.027264	0.002923	10.63439
C/CL	87	0.074557	0.053372	0.104685	0.008907	0.000955	11.94674
SL/CL	87	0.454765	0.339581	0.637681	0.050379	0.005401	11.0781
AP/CL	87	0.326357	0.308357	0.347838	0.007872	0.000844	2.411949
CW/CL	87	0.592538	0.581323	0.605787	0.007829	0.000839	1.321249
CHL/CL	87	0.652072	0.601738	0.699875	0.043269	0.004639	6.635569
CHW/CL	87	0.446028	0.425627	0.469223	0.009371	0.001005	2.100974
FL/CL	87	0.451226	0.432133	0.469384	0.01048	0.001124	2.322599
P/CL	87	0.645686	0.382822	0.669384	0.03042	0.003261	4.711206
DL/CL	87	0.744172	0.725922	0.759902	0.007457	0.0008	1.00212
PR/CL	87	0.45613	0.441204	0.475684	0.008789	0.000942	1.926805
CR/CL	87	0.275399	0.261452	0.293788	0.008063	0.000864	2.927915
ML/CL	87	0.447262	0.425627	0.467287	0.009865	0.001058	2.205626
IL/CL	87	0.26492	0.201355	0.297948	0.039347	0.004218	14.8526
CL/TL	87	0.369553	0.271889	0.53125	0.042418	0.004548	11.47821
AL/TL	87	0.5701	0.551523	0.586386	0.009153	0.000981	1.605587

Table 4.3.1.3 Descriptive statistics of morphometric measurements of *C.padavensis*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	60	0.586436	0.573421	0.598743	0.008264	0.001067	1.409272
C/SL	60	0.127676	0.110234	0.139871	0.008981	0.001159	7.0343
EL/CL	60	0.272794	0.2215	0.309688	0.024374	0.003147	8.934792
C/CL	60	0.060665	0.041726	0.076368	0.007766	0.001003	12.80172
SL/CL	60	0.449429	0.369942	0.497403	0.035404	0.004571	7.877541
AP/CL	60	0.335412	0.320405	0.349123	0.007686	0.000992	2.291507
CW/CL	60	0.544627	0.510541	0.569373	0.01656	0.002138	3.040532
CHL/CL	60	0.637602	0.613211	0.667489	0.01342	0.001733	2.104791
CHW/CL	60	0.440402	0.410967	0.465342	0.015416	0.00199	3.500367
FL/CL	60	0.364996	0.300025	0.398956	0.038623	0.004986	10.58168
P/CL	60	0.53997	0.502337	0.599992	0.037887	0.004891	7.01653
DL/CL	60	0.734338	0.720395	0.749874	0.008918	0.001151	1.214401
PR/CL	60	0.457276	0.440092	0.490288	0.010181	0.001314	2.226374
CR/CL	60	0.24113	0.201456	0.295454	0.04019	0.005189	16.6675
ML/CL	60	0.454912	0.40298	0.47569	0.011289	0.001457	2.481527
IL/CL	60	0.266238	0.250099	0.276905	0.008184	0.001057	3.073961
CL/TL	60	0.344964	0.246795	0.397357	0.033041	0.004266	9.578145
AL/TL	60	0.540022	0.500366	0.599994	0.040548	0.005235	7.508512

Table 4.3.1.4 Descriptive statistics of morphometric measurements of *C.arethusa*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	3	0.562761	0.5482375	0.582357	0.017616	0.010171	3.130319
C/SL	3	0.116174	0.101565	0.127676	0.01333	0.007696	11.47415
EL/CL	3	0.249437	0.2052408	0.2950267	0.044909	0.025928	18.00423
C/CL	3	0.051511	0.0438982	0.06468167	0.011453	0.006612	22.23366
SL/CL	3	0.44212	0.3680203	0.5066079	0.069842	0.040323	15.78861
AP/CL	3	0.338453	0.3347912	0.345156	0.005813	0.003356	1.717549
CW/CL	3	0.540388	0.5346541	0.5446273	0.005152	0.002974	0.9533717
CHL/CL	3	0.631201	0.6245137	0.6376018	0.006549	0.003781	1.037502
CHW/CL	3	0.451218	0.4404019	0.4615214	0.010561	0.006097	2.341398
FL/CL	3	0.358113	0.3445291	0.3649956	0.011765	0.006792	3.285194
P/CL	3	0.543042	0.5399695	0.5475123	0.003961	0.002287	0.7294464
DL/CL	3	0.737374	0.73157	0.746215	0.00778	0.004492	1.055131
PR/CL	3	0.450244	0.441725	0.4572758	0.007881	0.00455	1.750468
CR/CL	3	0.244703	0.2411299	0.2478154	0.003366	0.001944	1.375729
ML/CL	3	0.452859	0.4517822	0.4549117	0.001778	0.001027	0.3927003
IL/CL	3	0.261968	0.254881	0.2662383	0.00618	0.003568	2.359117
CL/TL	3	0.375889	0.3510804	0.3898669	0.021543	0.012438	5.731107
AL/TL	3	0.284454	0.2392515	0.3314727	0.046137	0.026637	16.21964

Table 4.3.1.5 Descriptive statistics of morphometric measurements of *D.alias*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	31	0.565010	0.534235	0.592733	0.011793	0.002118	2.087137
C/SL	31	0.104743	0.090274	0.119636	0.008796	0.001580	8.397541
EL/CL	31	0.226663	0.198730	0.271930	0.018490	0.003321	8.157490
C/CL	31	0.042056	0.034840	0.057720	0.005262	0.000945	12.511490
SL/CL	31	0.401124	0.351457	0.483487	0.030982	0.005565	7.723817
AP/CL	31	0.366572	0.351039	0.379577	0.008295	0.001490	2.262774
CW/CL	31	0.622814	0.610169	0.639578	0.009309	0.001672	1.494738
CHL/CL	31	0.671094	0.652988	0.689943	0.009373	0.001683	1.396676
CHW/CL	31	0.483873	0.472665	0.498709	0.007544	0.001355	1.558989
FL/CL	31	0.469597	0.446587	0.484648	0.008897	0.001598	1.894575
P/CL	31	0.675489	0.662544	0.698568	0.008223	0.001477	1.217376
DL/CL	31	0.775861	0.762453	0.789464	0.007587	0.001363	0.977943
PR/CL	31	0.484275	0.470981	0.498367	0.008587	0.001542	1.773122
CR/CL	31	0.344233	0.263178	0.359035	0.017337	0.003114	5.036445
ML/CL	31	0.445076	0.430894	0.459378	0.007834	0.001407	1.760232
IL/CL	31	0.203102	0.190132	0.217865	0.009015	0.001619	4.438668
CL/TL	31	0.416185	0.524735	0.559784	0.035778	0.006426	8.596597
AL/TL	31	0.540702	0.524735	0.559784	0.008828	0.001586	1.632655

Table 4.3.1.6 Descriptive statistics of morphometric measurements of *D.dubius*

Variable	Valid N	Mean	Minimum	Maximum
EL/SL	1	0.524460	0.524460	0.52446
C/SL	1	0.091565	0.091565	0.0915645
EL/CL	1	0.253457	0.253457	0.2534565
C/CL	1	0.044251	0.044251	0.0442505
SL/CL	1	0.483271	0.483271	0.4832714
AP/CL	1	0.344116	0.344116	0.3441162
CW/CL	1	0.670632	0.670632	0.670632
CHL/CL	1	0.798513	0.798513	0.798513
CHW/CL	1	0.590335	0.590335	0.5903346
FL/CL	1	0.452045	0.452045	0.4520446
P/CL	1	0.807435	0.807435	0.8074349
DL/CL	1	0.749442	0.749442	0.7494424
PR/CL	1	0.494424	0.494424	0.4944238
CR/CL	1	0.313755	0.313755	0.3137546
ML/CL	1	0.374721	0.3747212	0.3747212
IL/CL	1	0.165056	0.1650558	0.1650558
CL/TL	1	0.355069	0.3550686	0.3550686
AL/TL	1	0.296727	0.2967265	0.2967265

Table 4.3.1.7 Descriptive statistics of morphometric measurements of *P. kulkarnii*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	48	0.475096	0.44865	0.491429	0.011485	0.001658	2.417372
C/SL	48	0.58625	0.28	0.75	0.087071	0.012568	14.85222
EL/CL	48	0.248325	0.197222	0.296923	0.023034	0.003325	9.275893
C/CL	48	0.067213	0.017808	0.0875	0.012902	0.001862	19.19639
SL/CL	48	0.54969	0.5	0.71875	0.041858	0.006042	7.614767
AP/CL	48	0.345921	0.313678	0.39227	0.021321	0.003077	6.163422
CW/CL	48	0.560115	0.502674	0.596759	0.035984	0.005194	6.424347
CHL/CL	48	0.647194	0.632132	0.666756	0.009019	0.001302	1.393529
CHW/CL	48	0.466734	0.440402	0.485757	0.009495	0.001371	2.034447
FL/CL	48	0.367019	0.342482	0.379931	0.008361	0.001207	2.278026
P/CL	48	0.552387	0.534563	0.592679	0.011968	0.001727	2.16659
DL/CL	48	0.78035	0.734338	0.797739	0.010988	0.001586	1.408115
PR/CL	48	0.456194	0.440369	0.469478	0.00817	0.001179	1.790964
CR/CL	48	0.277793	0.205405	0.573579	0.045611	0.006583	16.41898
ML/CL	48	0.427653	0.39227	0.454912	0.010839	0.001565	2.534642
IL/CL	48	0.23938	0.201383	0.298241	0.041548	0.005997	17.35644
CL/TL	48	0.393368	0.303318	0.496703	0.049772	0.007184	12.65267
AL/TL	48	0.653293	0.398104	0.795918	0.056939	0.008218	8.715754

Table 4.3.1.8 Descriptive statistics of morphometric measurements of *P.pitragsaalei*

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev	Std.Err	Coef.Var
EL/SL	9	0.584491	0.5405405	0.6152125	0.02443	0.008143	4.179717
C/SL	9	0.07963	0.07317073	0.08448276	0.003577	0.001192	4.491463
EL/CL	9	0.331028	0.3062787	0.3525641	0.015944	0.005315	4.816632
C/CL	9	0.045081	0.04132231	0.0474359	0.001852	0.000617	4.108459
SL/CL	9	0.566511	0.5435801	0.610687	0.01993	0.006643	3.517942
AP/CL	9	0.423638	0.3842549	0.4790076	0.028176	0.009392	6.651035
CW/CL	9	0.696203	0.6246575	0.7435897	0.035556	0.011852	5.107073
CHL/CL	9	0.468912	0.41321	0.519084	0.040034	0.013345	8.53772
CHW/CL	9	0.301929	0.2671756	0.3474359	0.032755	0.010918	10.84854
FL/CL	9	0.335218	0.2999063	0.4198473	0.036172	0.012057	10.79053
P/CL	9	0.497995	0.4663677	0.610687	0.044007	0.014669	8.836858
DL/CL	9	0.463962	0.4189316	0.4961832	0.025404	0.008468	5.475365
PR/CL	9	0.438323	0.3751914	0.4858974	0.035652	0.011884	8.133842
CR/CL	9	0.289286	0.2480916	0.3032159	0.016146	0.005382	5.581426
ML/CL	9	0.418545	0.3746556	0.4855072	0.040109	0.01337	9.582948
IL/CL	9	0.241124	0.2202437	0.2564103	0.011817	0.003939	4.900883
CL/TL	9	0.340784	0.2971393	0.3852941	0.026858	0.008953	7.88124
AL/TL	9	0.215385	0.1765611	0.2955882	0.034619	0.01154	16.07305

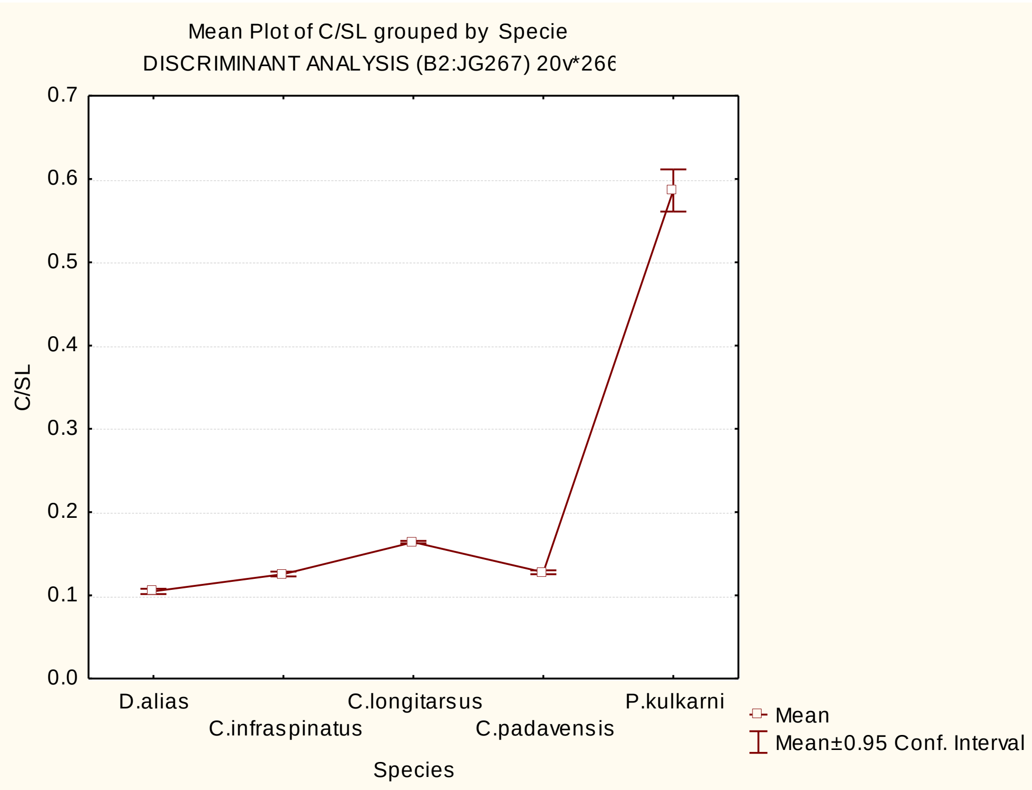
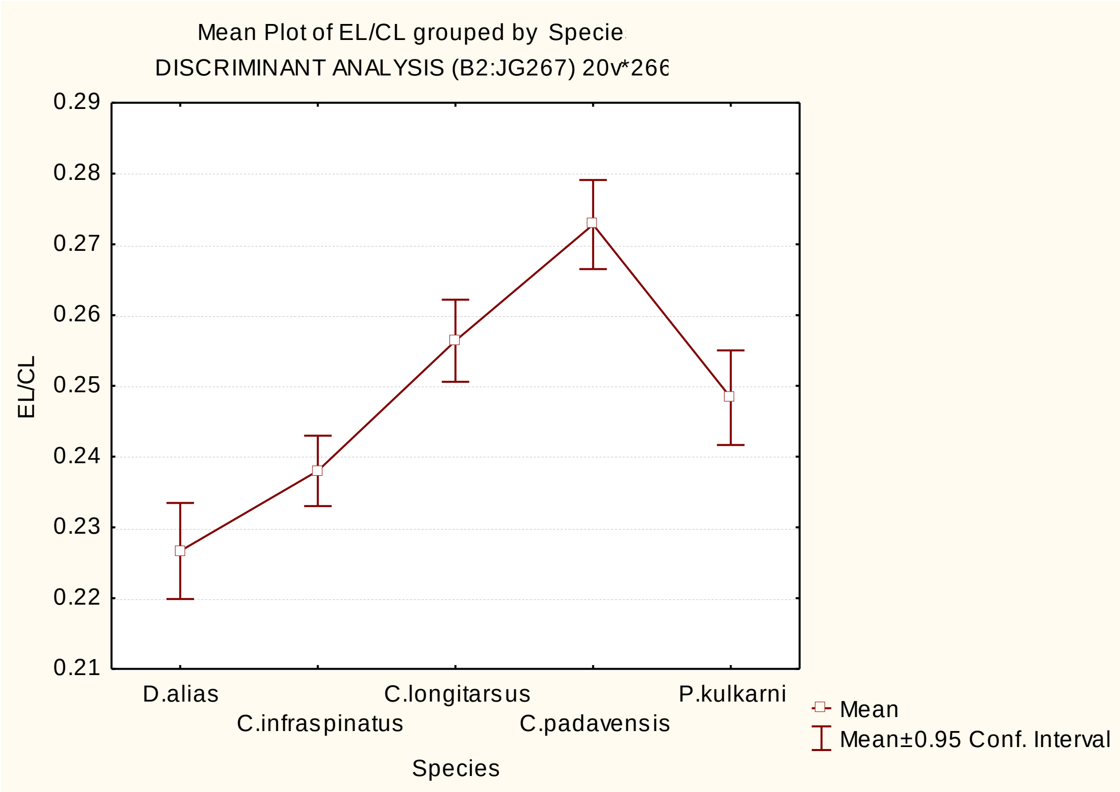


Fig: 4.3.1.1 Species wise mean plot of EL/SL and C/SL



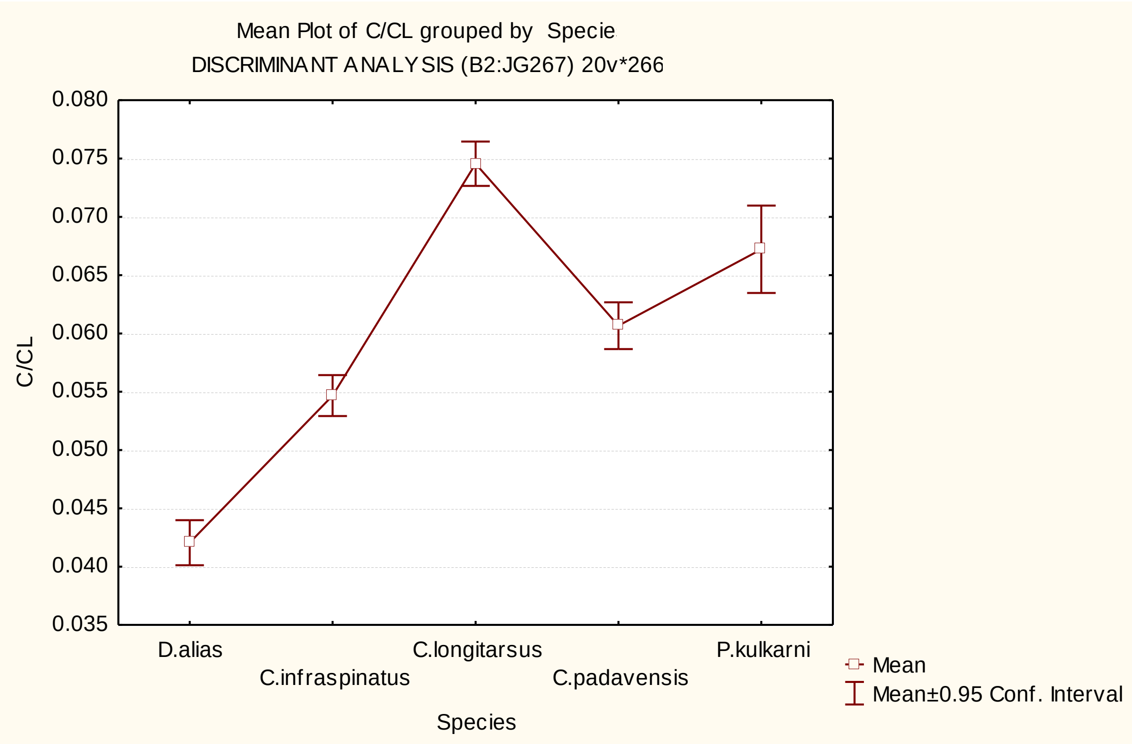
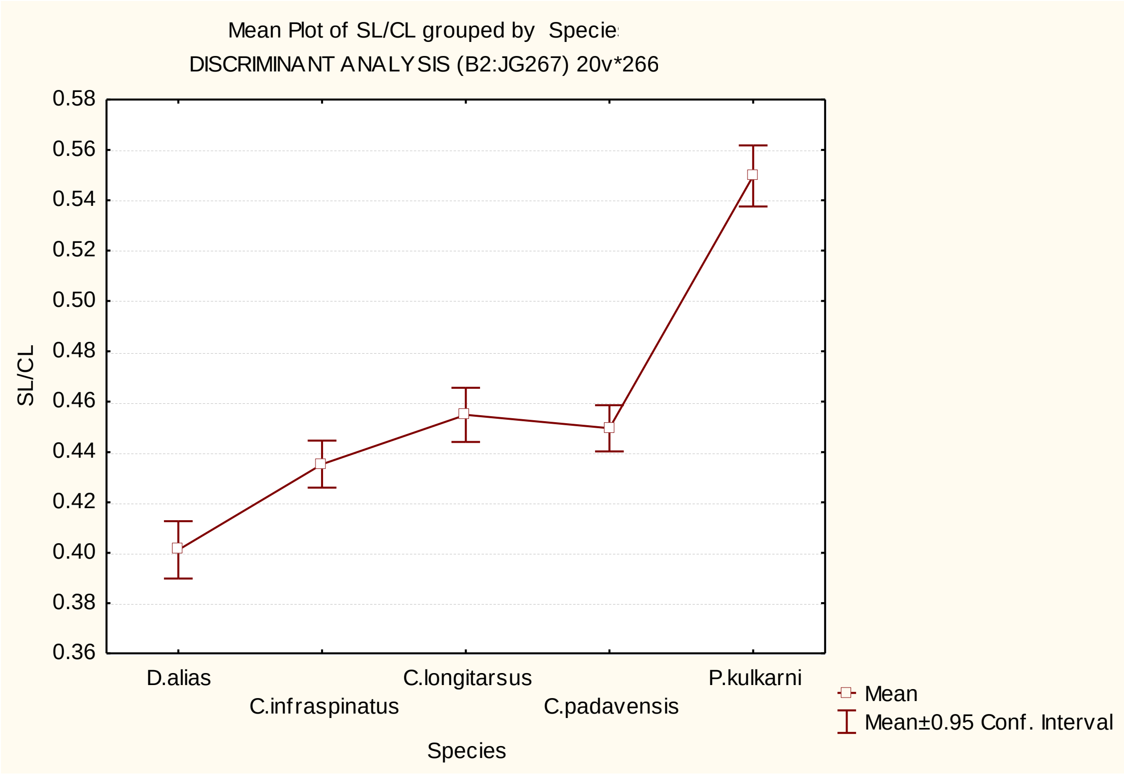


Fig: 4.3.1.2 Species wise mean plot of EL/CL and C/CL



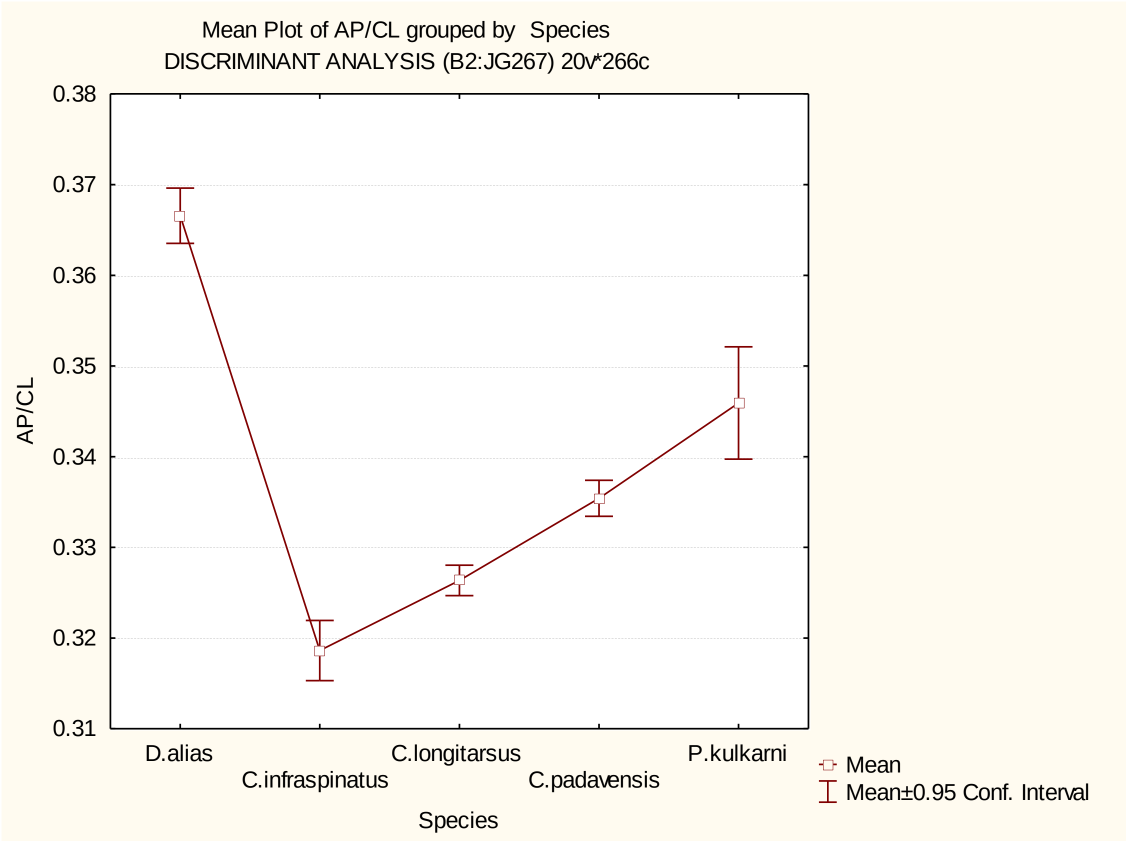
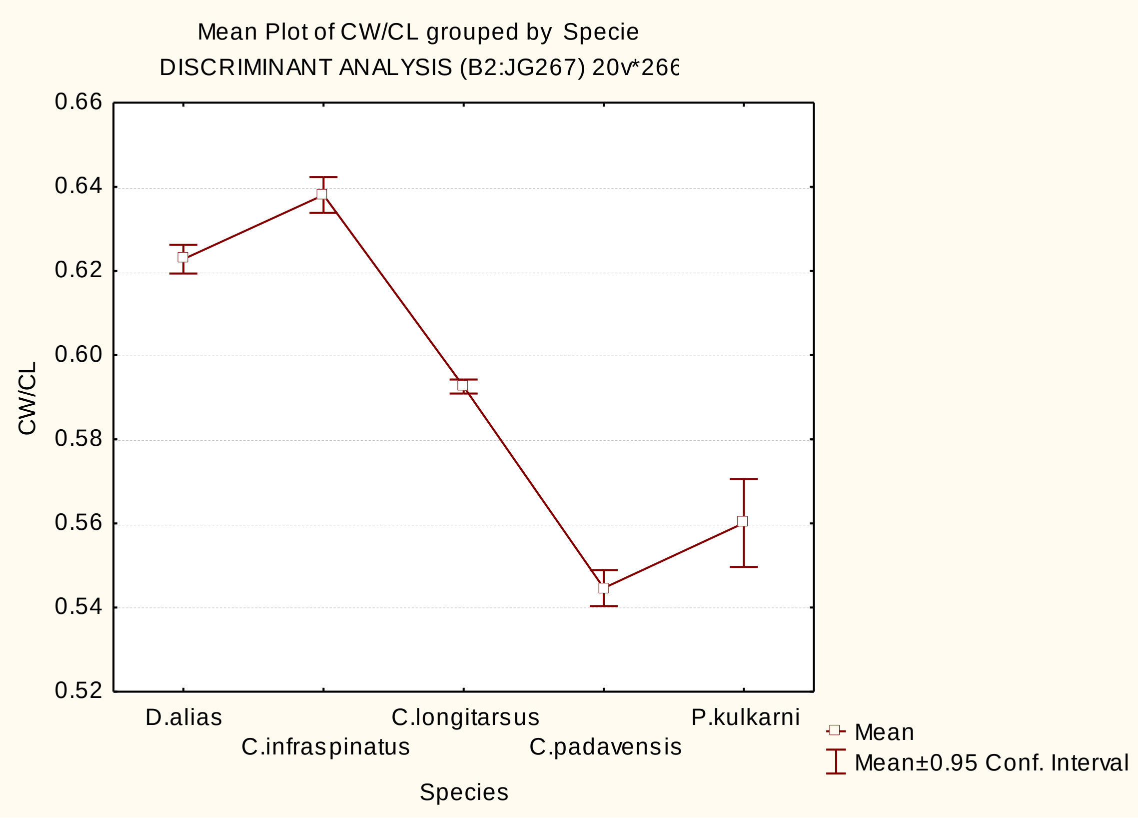


Fig: 4.3.1.3 Species wise mean plot of SL/CL and AP/CL



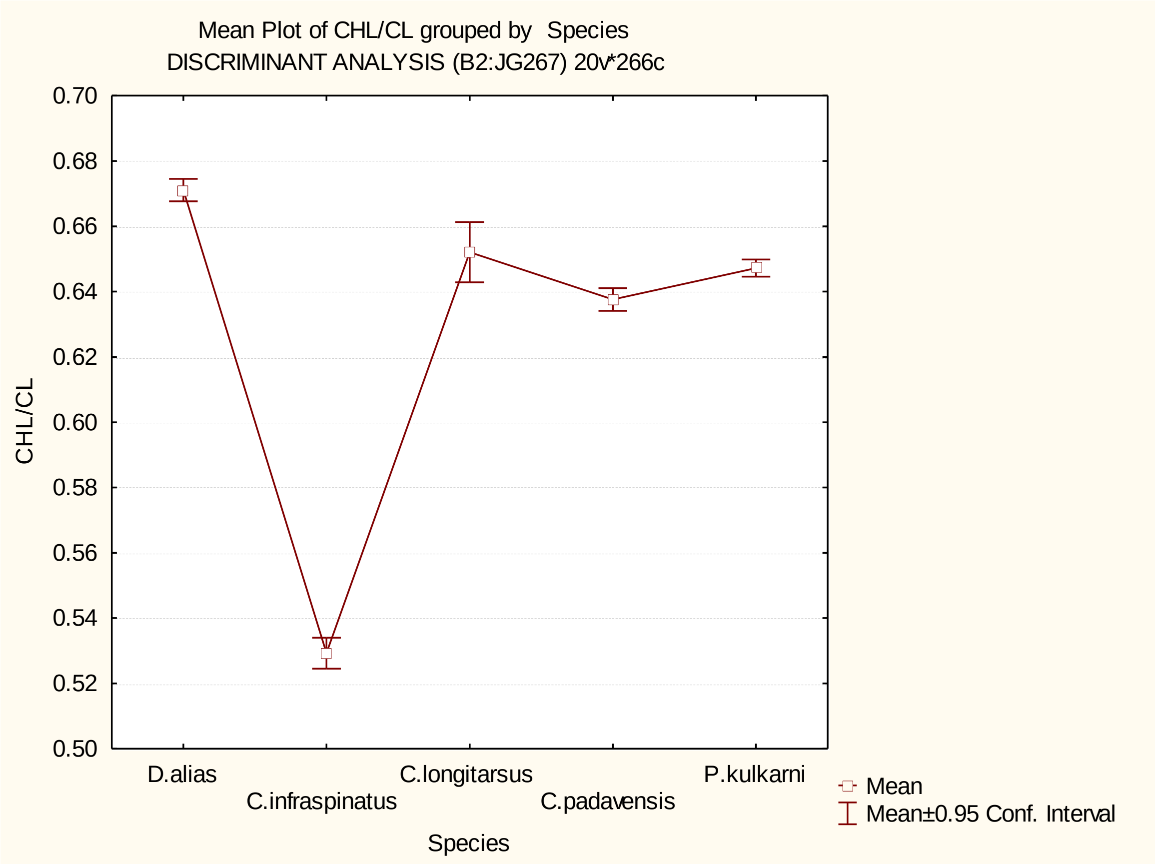
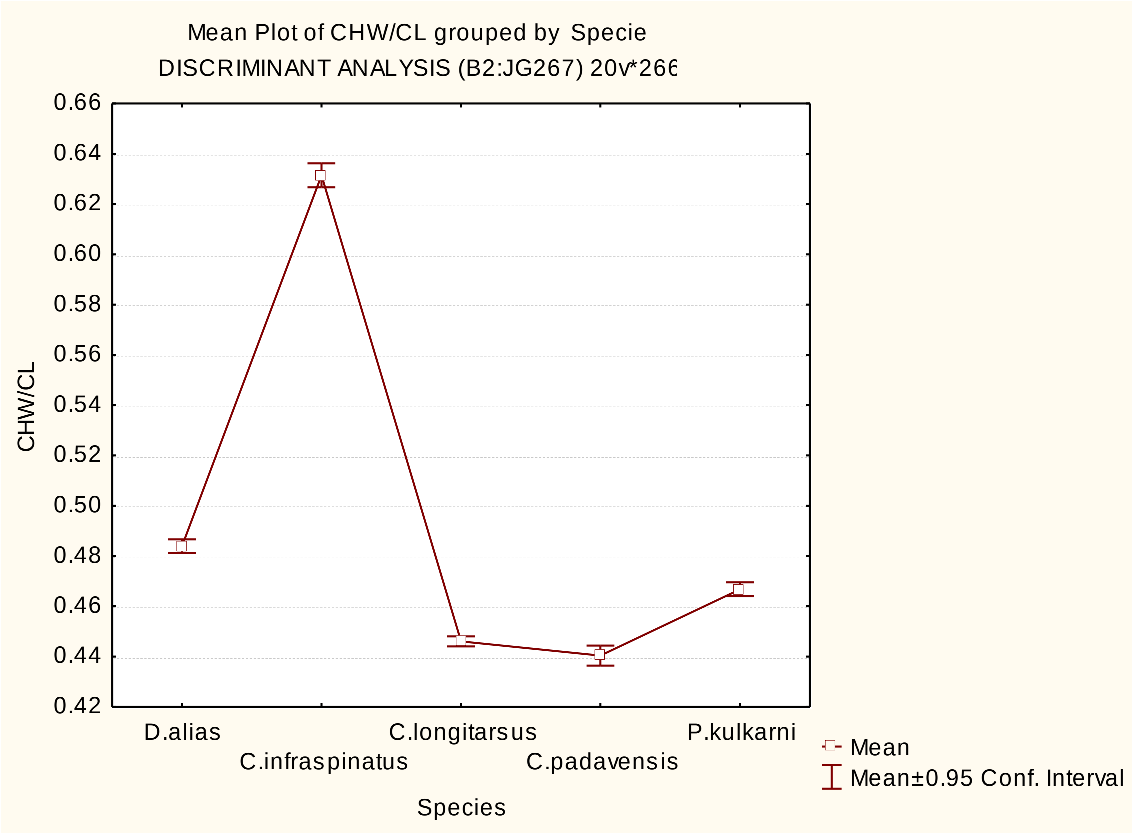


Fig: 4.3.1.4 Species wise mean plot of CW/CL and CHL/CL



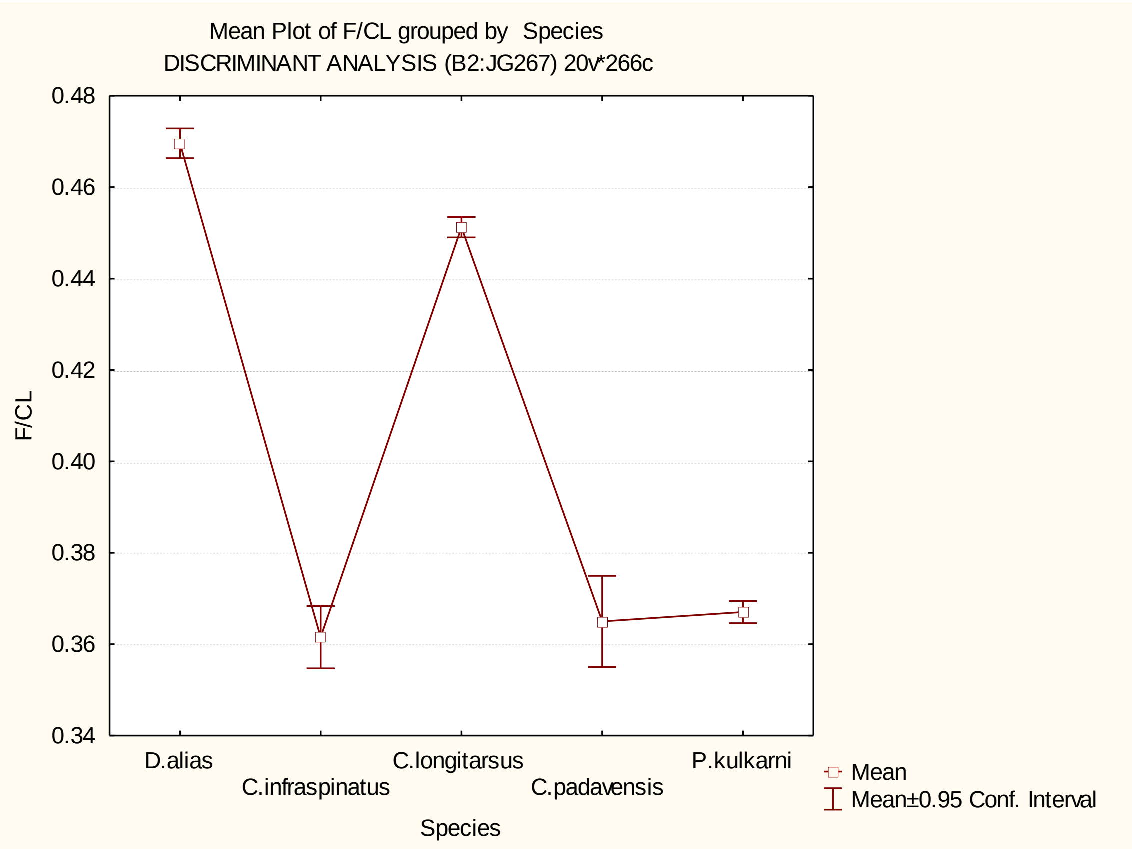
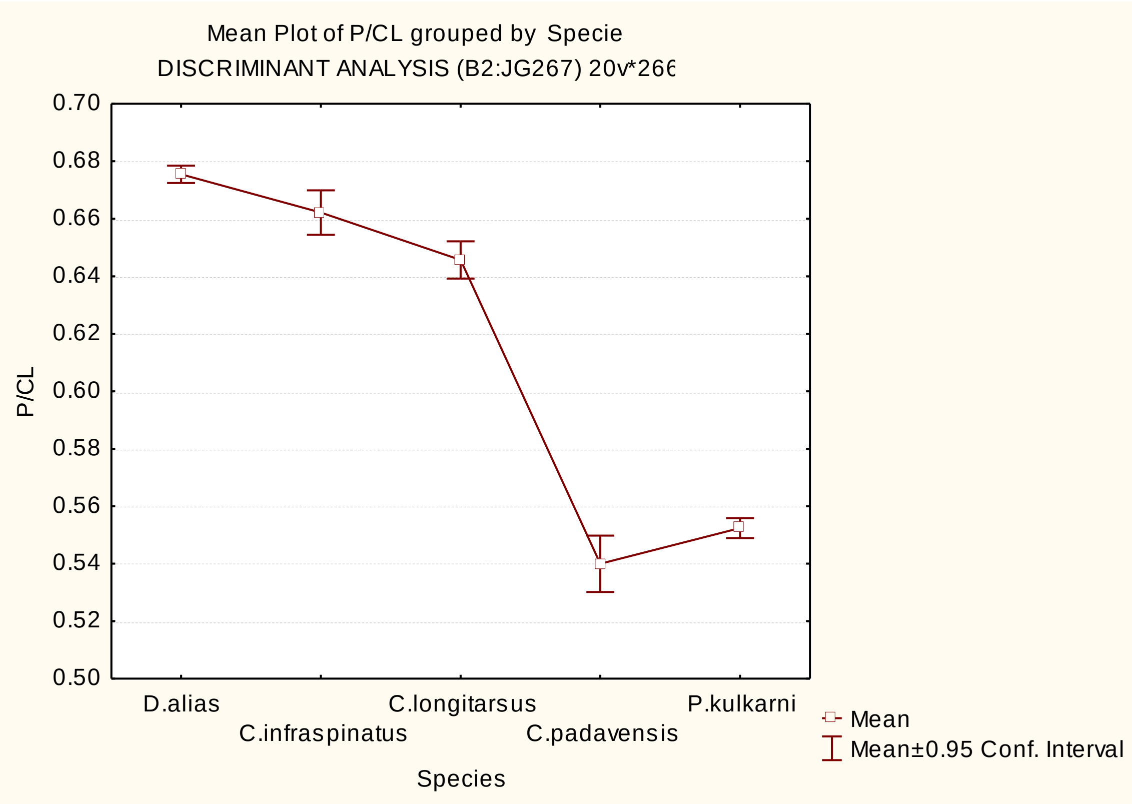


Fig: 4.3.1.5 Species wise mean plot of CHW/CL and FL/CL



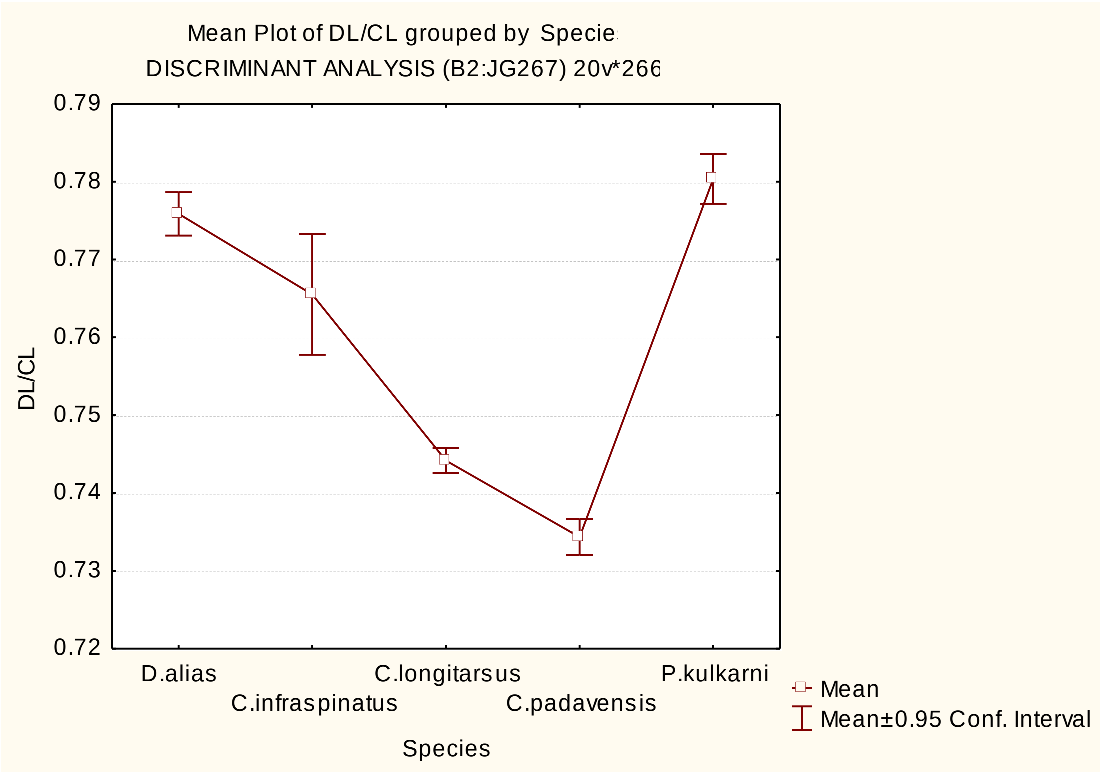
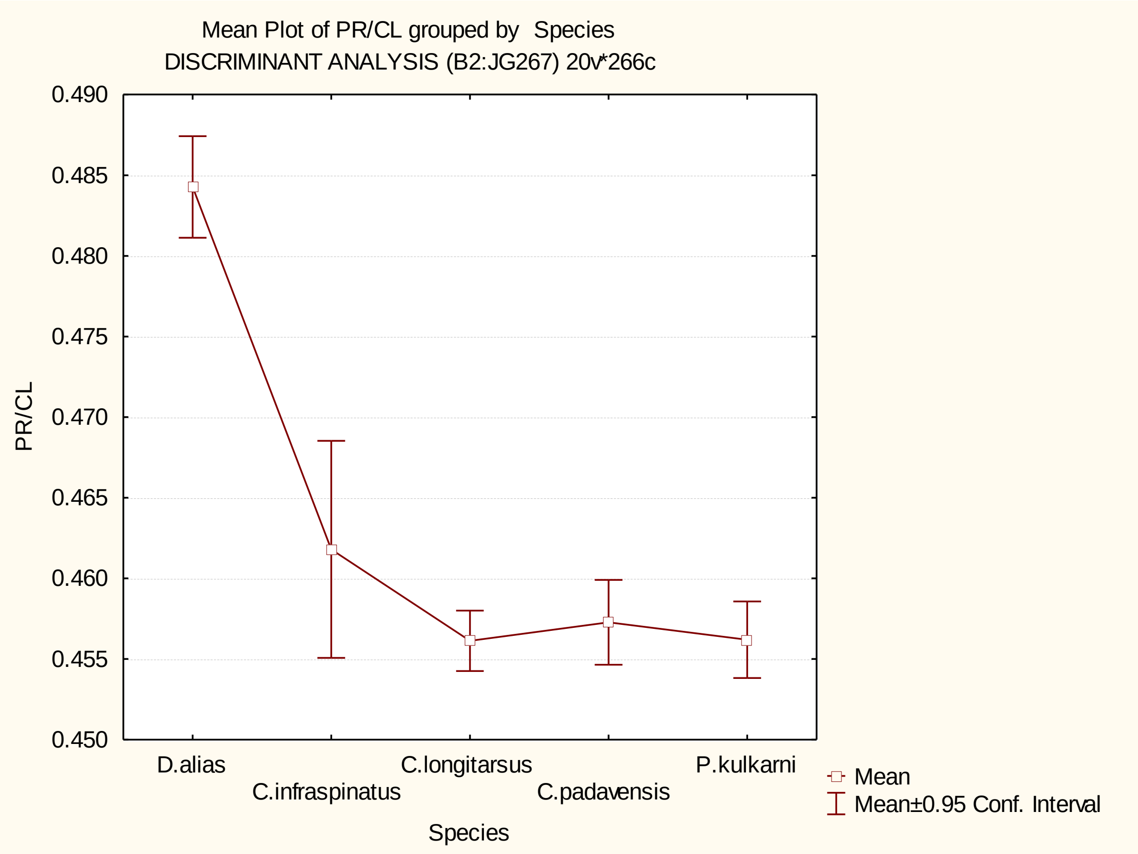


Fig: 4.3.1.6 Species wise mean plot of P/CL and DL/CL



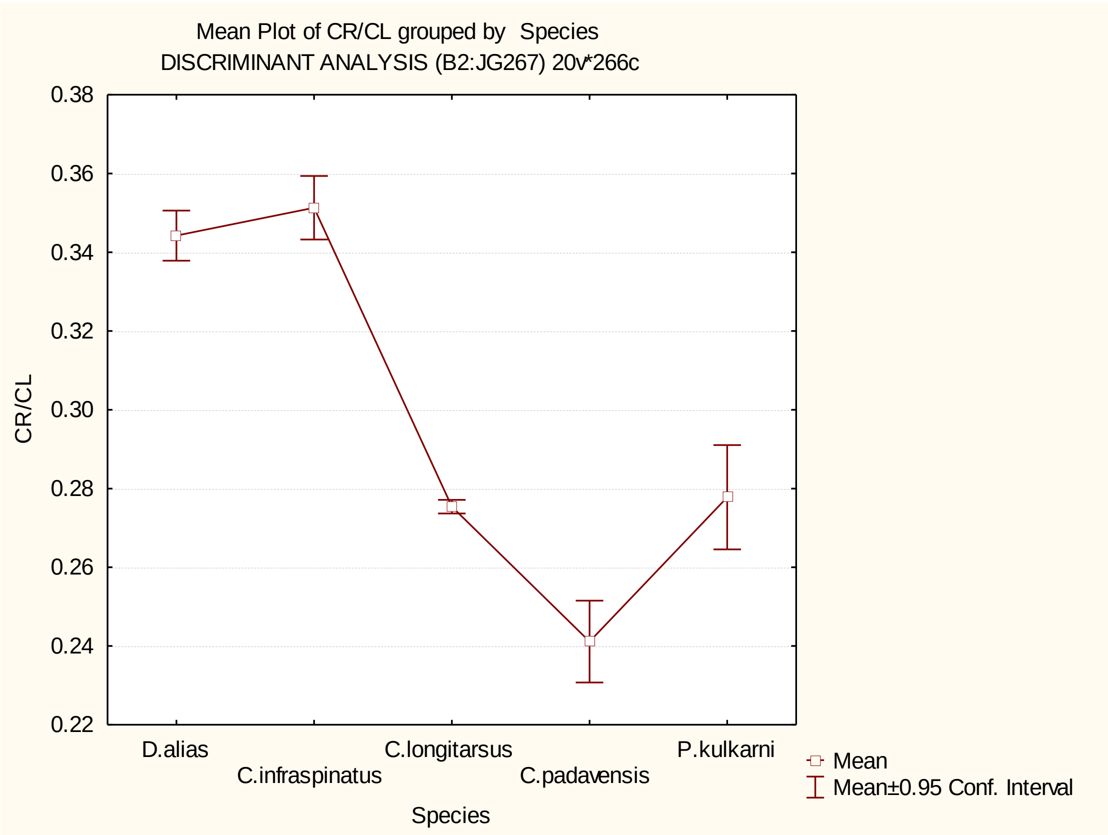
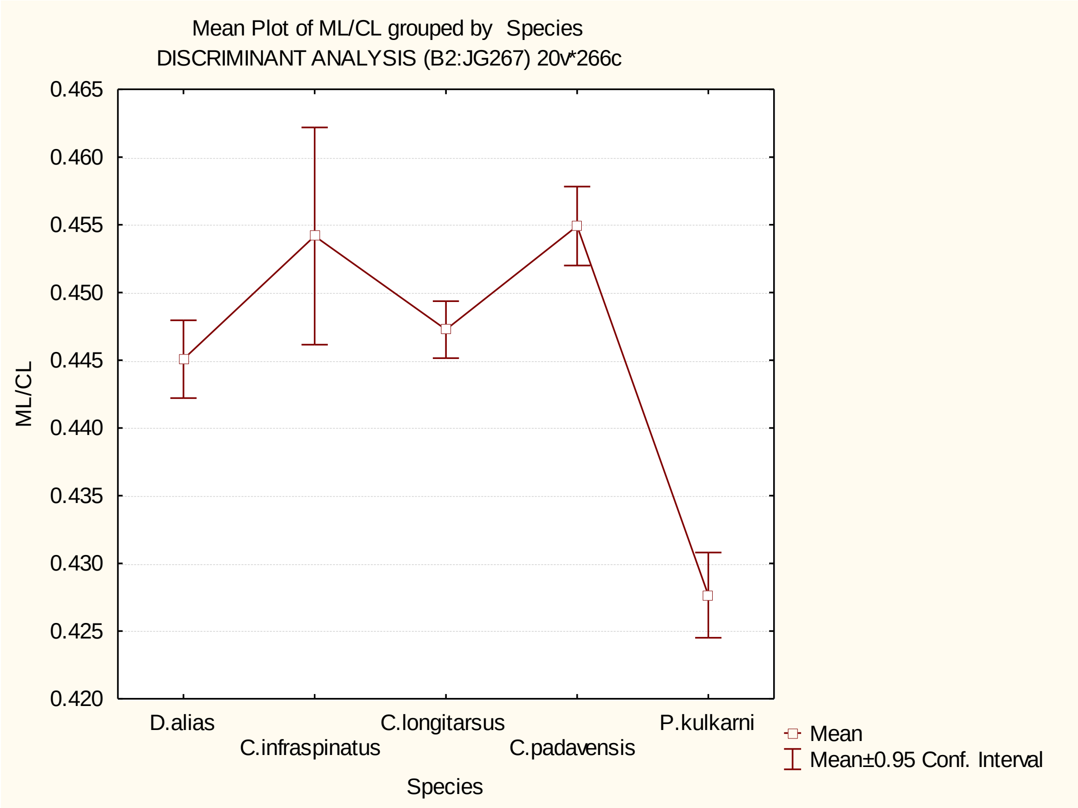


Fig: 4.3.1.7 Species wise mean plot of PR/CL and CR/CL



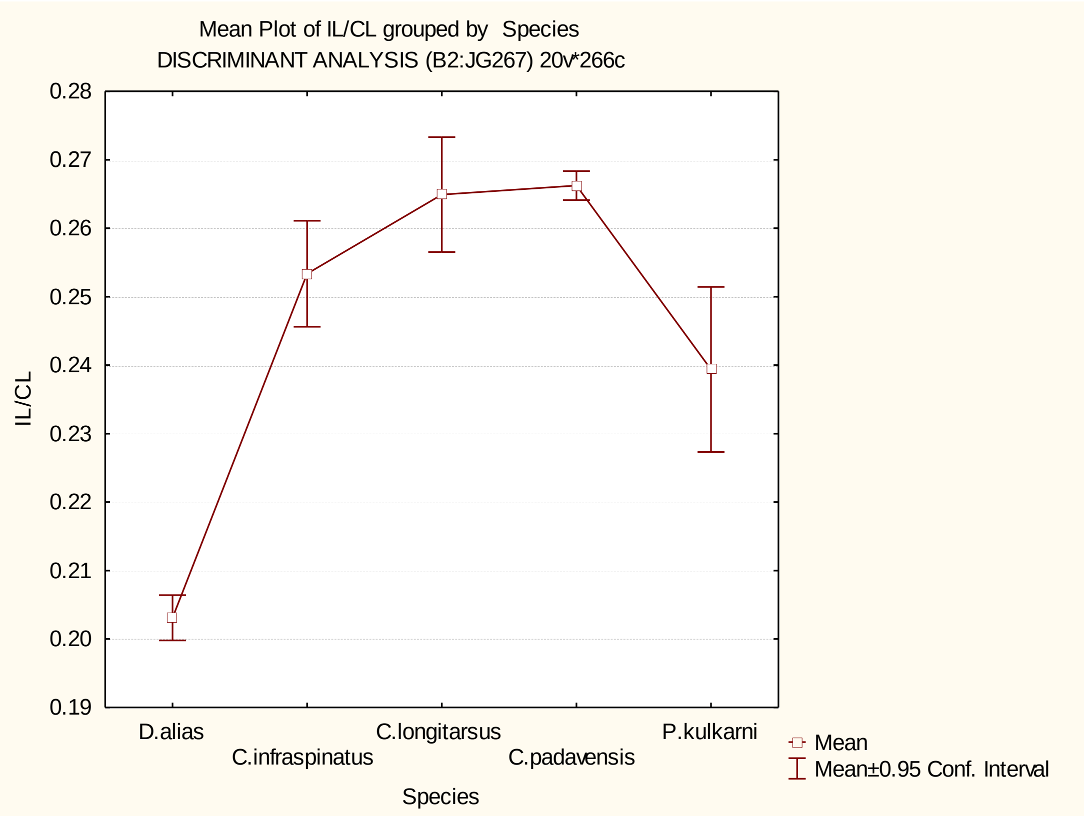
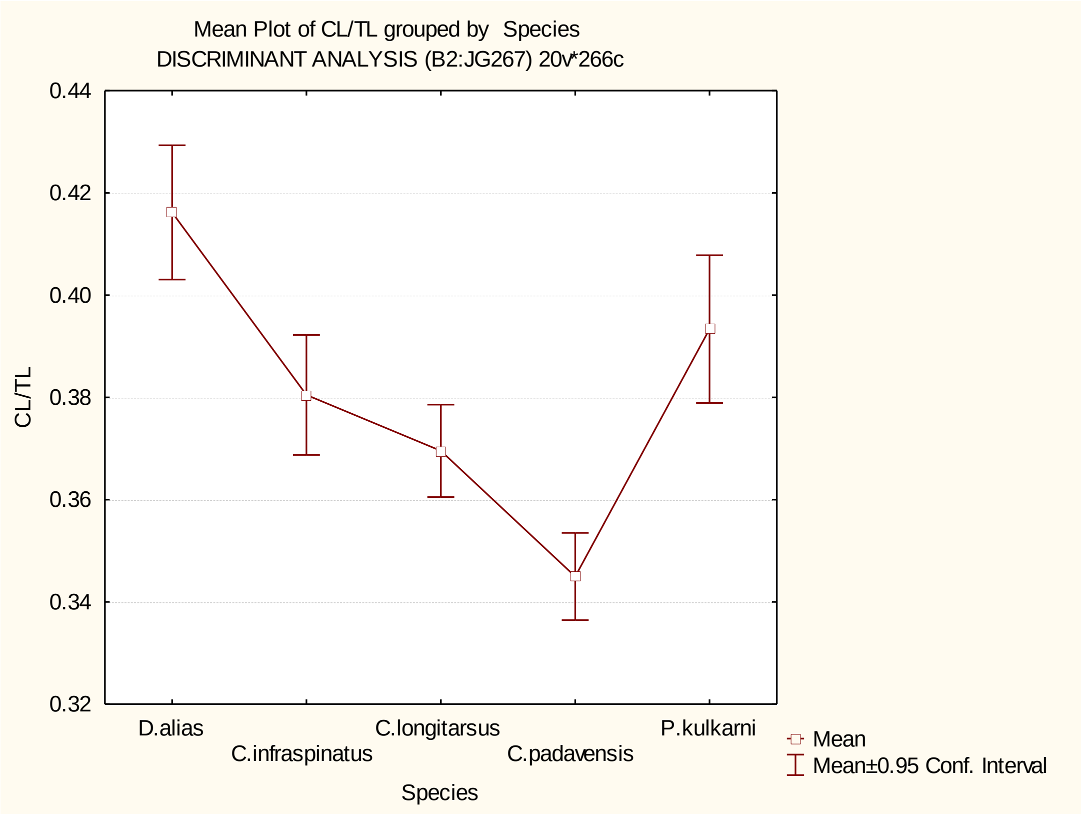


Fig: 4.3.1.8 Species wise mean plot of ML/CL and IL/CL



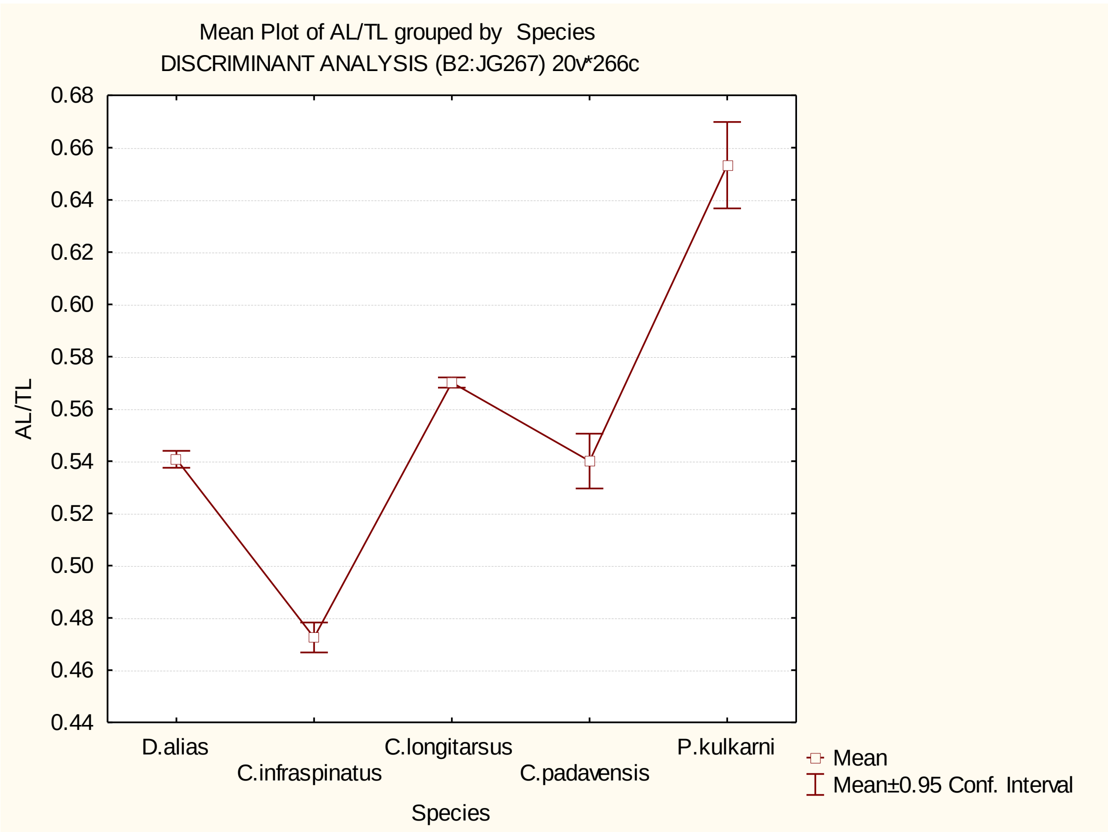


Fig: 4.3.1.9 Species wise mean plot of CL/TL and AL/TL

4.3.2. Correlation of morphometric traits

The correlation matrix of 17 morphometric measurements was generated (Table: 4.3.2.1). All morphometric characters showed prominent correlation ($r > 0.6$) with both cephalic shield length and carapace length. Correlation coefficient of more than 0.95 was observed for SL, AP, CW, CL, PL, DL, PR, CR and ML with carapace length. Correlation coefficients ranging from 0.90 to 0.95 were observed between CL and characters like EL, TL, FL and IL. For AL and CHW the correlation with CL generated coefficient (r) of 0.80 to 0.90. Relatively lower value of coefficients (<0.8) were observed for corneal diameter.

4.3.3. Multivariate analysis of variance (MANOVA)

Multivariate analysis of variance was carried out for the transformed morphometric variables of 8 species for the null hypothesis of no significant difference between the groups. The null hypothesis was rejected based on at 5% significance level based on the result of Wilks Lamda, Pillai's trace, Hotelling and Roy's test. In all above mentioned test the p value was less than 0.05 (Table: 4.3.3.1.).

Table: 4.3.2.1. Correlation matrix of morphometric characters of 8 species of hermit crabs

Variable	SL	EL	C	AP	AL	TL	CL	CW	CHL	CHW	FL	PL	DL	PR	CR	ML	IL
SL	1.000000	0.937318	0.802609	0.926585	0.838341	0.891196	0.958962	0.919864	0.887859	0.786828	0.860394	0.900683	0.911649	0.942240	0.926014	0.944578	0.881038
EL	0.937318	1.000000	0.725791	0.872616	0.822293	0.882128	0.911068	0.834049	0.798853	0.613868	0.751886	0.804699	0.819582	0.937428	0.867548	0.905640	0.876698
C	0.802609	0.725791	1.000000	0.724249	0.764085	0.724803	0.770758	0.733094	0.756708	0.725136	0.765956	0.784421	0.788110	0.727106	0.713520	0.770093	0.780050
AP	0.926585	0.872616	0.724249	1.000000	0.864130	0.893675	0.975608	0.953712	0.963588	0.825934	0.945429	0.956963	0.960906	0.960062	0.965542	0.971023	0.873547
AL	0.838341	0.822293	0.764085	0.864130	1.000000	0.908713	0.889821	0.798702	0.855356	0.685025	0.830500	0.845809	0.891692	0.902035	0.840217	0.890628	0.870972
TL	0.891196	0.882128	0.724803	0.893675	0.908713	1.000000	0.931704	0.863158	0.863084	0.730483	0.837568	0.874311	0.892819	0.924697	0.896131	0.928158	0.892451
CL	0.958962	0.911068	0.770758	0.975608	0.889821	0.931704	1.000000	0.961659	0.952501	0.832370	0.933025	0.960799	0.968517	0.980308	0.975264	0.992761	0.914764
CW	0.919864	0.834049	0.733094	0.953712	0.798702	0.863158	0.961659	1.000000	0.945690	0.897432	0.948297	0.968342	0.943992	0.912174	0.963043	0.955742	0.841458
CHL	0.887859	0.798853	0.756708	0.963588	0.855356	0.863084	0.952501	0.945690	1.000000	0.856812	0.980430	0.970469	0.967986	0.918082	0.940689	0.950053	0.840930
CHW	0.786828	0.613868	0.725136	0.825934	0.685025	0.730483	0.832370	0.897432	0.856812	1.000000	0.896338	0.927839	0.901080	0.748420	0.864364	0.831903	0.725085
FL	0.860394	0.751886	0.765956	0.945429	0.830500	0.837568	0.933025	0.948297	0.980430	0.896338	1.000000	0.979799	0.963776	0.880188	0.927014	0.931397	0.818216
PL	0.900683	0.804699	0.784421	0.956963	0.845809	0.874311	0.960799	0.968342	0.970469	0.927839	0.979799	1.000000	0.982165	0.917252	0.961796	0.960701	0.862362
DL	0.911649	0.819582	0.788110	0.960906	0.891692	0.892819	0.968517	0.943992	0.967986	0.901080	0.963776	0.982165	1.000000	0.939238	0.959489	0.968131	0.885360
PR	0.942240	0.937428	0.727106	0.960062	0.902035	0.924697	0.980308	0.912174	0.918082	0.748420	0.880188	0.917252	0.939238	1.000000	0.954293	0.978625	0.916849
CR	0.926014	0.867548	0.713520	0.965542	0.840217	0.896131	0.975264	0.963043	0.940689	0.864364	0.927014	0.961796	0.959489	0.954293	1.000000	0.974182	0.873747
ML	0.944578	0.905640	0.770093	0.971023	0.890628	0.928158	0.992761	0.955742	0.950053	0.831903	0.931397	0.960701	0.968131	0.978625	0.974182	1.000000	0.919589
IL	0.881038	0.876698	0.780050	0.873547	0.870972	0.892451	0.914764	0.841458	0.840930	0.725085	0.818216	0.862362	0.885360	0.916849	0.873747	0.919589	1.000000

Table: 4.3.3.1 Multivariate analysis of variance (MANOVA) for morphometric data of 8 species of hermit crabs

Effect	Test	Value	F	Effect df	Error df	p
Species	Wilks	0.00	247.4	72	961.8285	0.00
	Pillai's	3.68	158.0	72	988.0000	0.00
	Hotellng	101.95	343.4	72	970.0000	0.00
	Roy's	48.87	670.6	18	247.0000	0.00

4.3.4. Stepwise (forward) discriminant analysis

Selected variables (12) after factor analysis were subjected to stepwise discriminant analysis (SDFA). Discriminant analysis generated 4 functions (Table: 4.3.5.1) with first two explaining 92.15% of total variation. The means of canonical variables (4.3.5.2) shows that Root 1 successfully discriminates *P. kulkarnii* and *C.infraspinatus. P. kulkarnii, C.infraspinatus* and *C.padavensis* are clearly isolated by Root 2. Root 3 clearly isolated *D.alias, C.longitarsus* and *P. kulkarnii* and Root 4 successfully separated *D.alias.*

The factor matrix (Table 4.3.5.3) indicated cheliped width as main contributor to Root 1 comes from where as for Root 2, major contributor were eye peduncle length and corneal diameter. While major contributors for third root were carapace width and palm length and for fourth roots it is dactyl length.

Scattergram (Fig: 4.3.5.1) between Root 1 and Root 2 shows that most of the species can be separated based on characters like cheliped width, eye peduncle length, dactyl length, palm length, carapace width and corneal diameter. Table: 4.3.5.4 shows the summary of stepwise inclusion of morphometric variable and its respective significance level. A classification matrix (Table: 4.3.5.5) was also generated showing successful classification of 99.2481% with two instance of misclassification.

Table: 4.3.4.1 Standardised coefficients for canonical variables of 5 species of hermit crab in stepwise (forward) discriminant analysis

Variable	Root 1	Root 2	Root 3	Root 4
CHW/CL	-0.83881	0.38495	-0.269164	-0.21866
C/SL	0.39249	0.64741	-0.066108	-0.03012
P/CL	-0.25798	0.02405	0.702590	-0.01097
C/CL	0.03765	-0.22174	0.483183	-1.14379
EL/SL	-0.09722	-0.56054	-0.117504	0.03014
CW/CL	-0.26038	0.13985	0.421383	0.13643
DL/CL	-0.09509	0.19039	0.147028	0.46213
EL/CL	-0.00340	-0.00420	-0.510382	0.45204
AL/TL	0.27634	0.03771	0.128788	-0.04498
ML/CL	-0.11255	-0.08425	-0.202895	-0.04296
CR/CL	-0.05688	0.17342	0.058723	0.18455
SL/CL	0.00907	0.22256	-0.062485	0.14999
Eigenval	43.32244	36.27904	4.758651	2.01933
Cum.Prop	0.50154	0.92153	0.976623	1.00000

Table: 4.3.4.2. Means of canonical variables of 5 species of hermit crab in stepwise (forward) discriminant analysis

Group	Root 1	Root 2	Root 3	Root 4
D.alias	-3.1921	1.5016	-2.21827	3.51163
C.infraspinatus	-13.9232	-4.3953	1.10096	-0.75442
C.longitarsus	1.5844	3.3188	-2.17318	-1.15864
C.padavensis	2.8083	5.9433	3.21750	0.27577
P.kulkarni	7.2822	-10.7515	0.43218	0.11607

Table: 4.3.4.3. Factor structure matrix for 5 species of hermit crab in stepwise (forward) discriminant analysis (Pooled – within – groups correlations)

Variable	Root 1	Root 2	Root 3	Root 4
CHW/CL	-0.755798	0.390078	-0.335151	-0.233819
C/SL	0.395819	0.635622	-0.088537	-0.177759
P/CL	-0.202010	-0.034488	0.695898	0.033137
C/CL	0.094295	-0.009833	0.134932	-0.691759
EL/SL	-0.158079	-0.599470	-0.133569	0.093853
CW/CL	-0.225245	0.039121	0.429373	0.096022
DL/CL	-0.028841	0.209114	0.155669	0.437071
EL/CL	0.049515	-0.053394	-0.145395	-0.198411
AL/TL	0.222906	0.123994	0.158733	-0.016980
ML/CL	-0.060123	-0.090007	-0.090732	-0.060179
CR/CL	-0.160099	0.083504	0.214632	0.295526
SL/CL	0.104849	0.128977	-0.074140	-0.223068

Table: 4.3.4.4 Summary of Stepwise Discriminant Analysis

Variable Enter/Remove	Step	F to entr/rem	df 1	df 2	p-level	No. of vars. in	Lambda	F-value	df 1	df 2	p-level
CHW/CL-(E)	1	2017.025	4	261	0.000000	1.00000	0.031336	2017.025	4	261	0.00
C/SL-(E)	2	1376.202	4	260	0.000000	2.00000	0.001413	1664.011	8	520	0.00
P/CL-(E)	3	172.936	4	259	0.000000	3.00000	0.000385	1058.255	12	686	0.00
C/CL-(E)	4	67.210	4	258	0.000000	4.00000	0.000189	767.334	16	789	0.00
EL/SL-(E)	5	49.474	4	257	0.000000	5.00000	0.000107	630.091	20	853	0.00
CW/CL-(E)	6	26.195	4	256	0.000000	6.00000	0.000076	528.602	24	894	0.00
DL/CL-(E)	7	20.227	4	255	0.000000	7.00000	0.000057	460.670	28	921	0.00
EL/CL-(E)	8	19.205	4	254	0.000000	8.00000	0.000044	415.701	32	938	0.00
AL/TL-(E)	9	6.251	4	253	0.000082	9.00000	0.000040	366.860	36	950	0.00
ML/CL-(E)	10	4.048	4	252	0.003368	10.00000	0.000038	327.413	40	957	0.00
CR/CL-(E)	11	3.533	4	251	0.007946	11.00000	0.000036	296.120	44	962	0.00
SL/CL-(E)	12	1.535	4	250	0.192419	12.00000	0.000035	268.755	48	965	0.00

Table: 4.3.4.5. Classification matrix of 5 different species in stepwise (forward) discriminant analysis

Group	Percent Correct	D.alias p=.11654	C.infraspinatus p=.15038	C.longitarsus p=.32707	C.padavensis p=.22556	P.kulkarni p=.18045
D.alias	100.0000	31	0	0	0	0
C.infraspinatus	100.0000	0	40	0	0	0
C.longitarsus	98.8506	0	0	86	1	0
C.padavensis	98.3333	0	0	1	59	0
P.kulkarni	100.0000	0	0	0	0	48
Total	99.2481	31	40	87	60	48

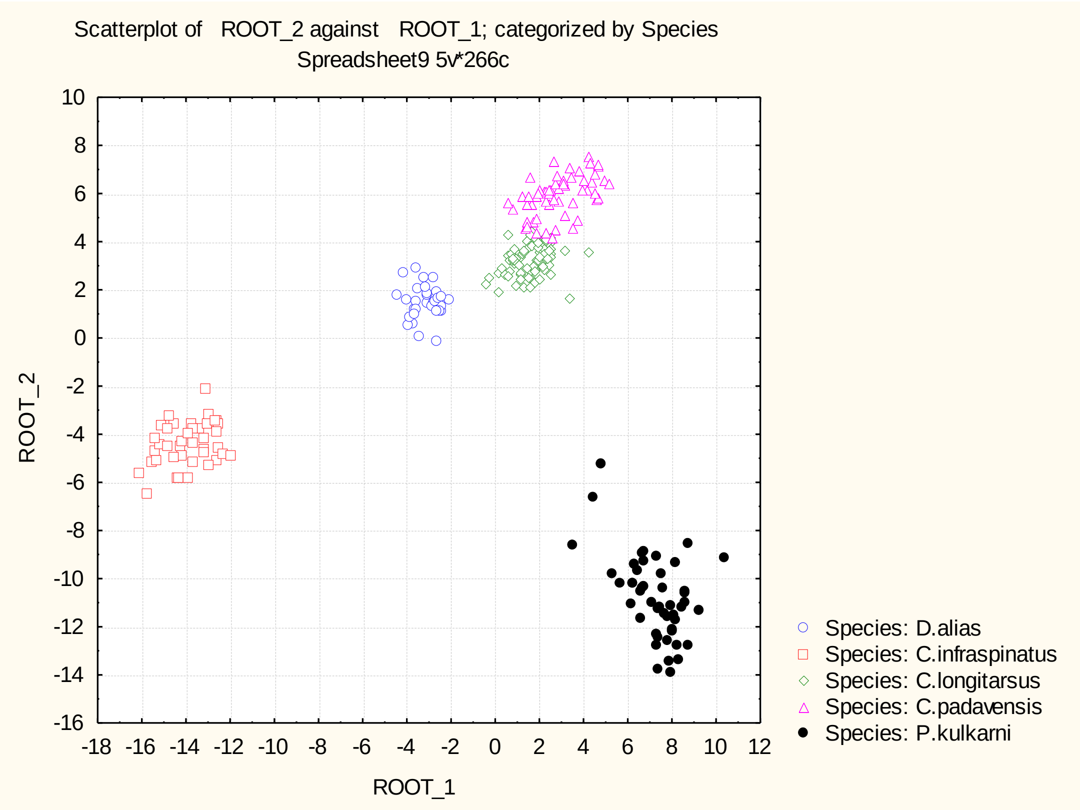


Fig: 4.3.4.1. Scatter plot of discriminant function for Root 1 and Root 2 of Morphometric variable

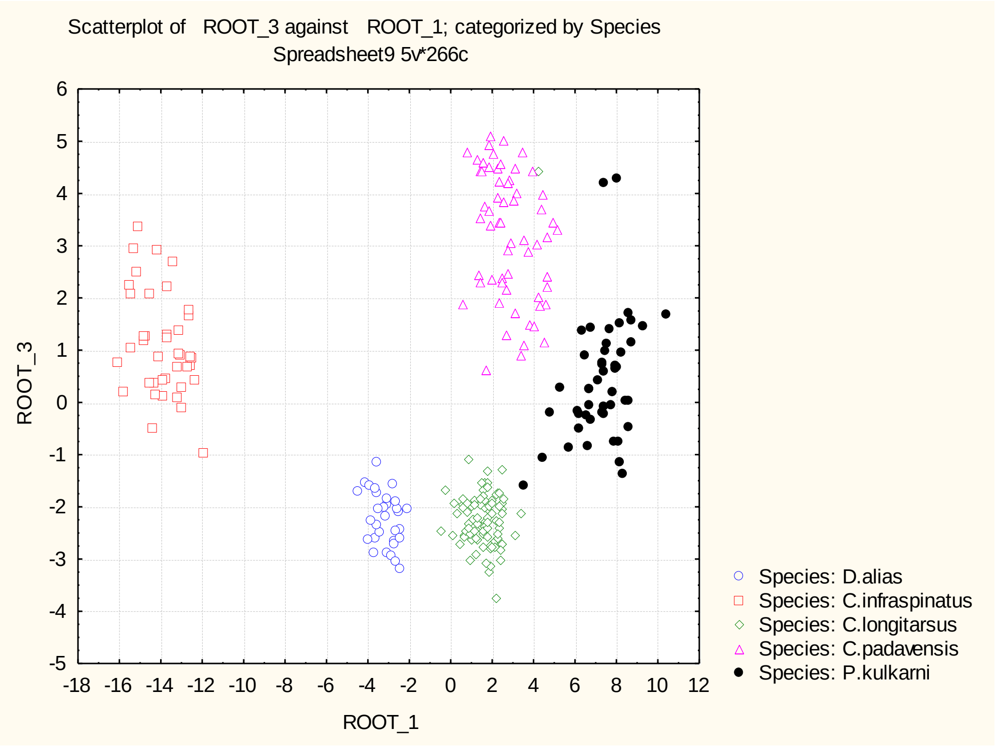


Fig: 4.3.4.2. Scatter plot of discriminant function for Root 1 and Root 3 of Morphometric variables

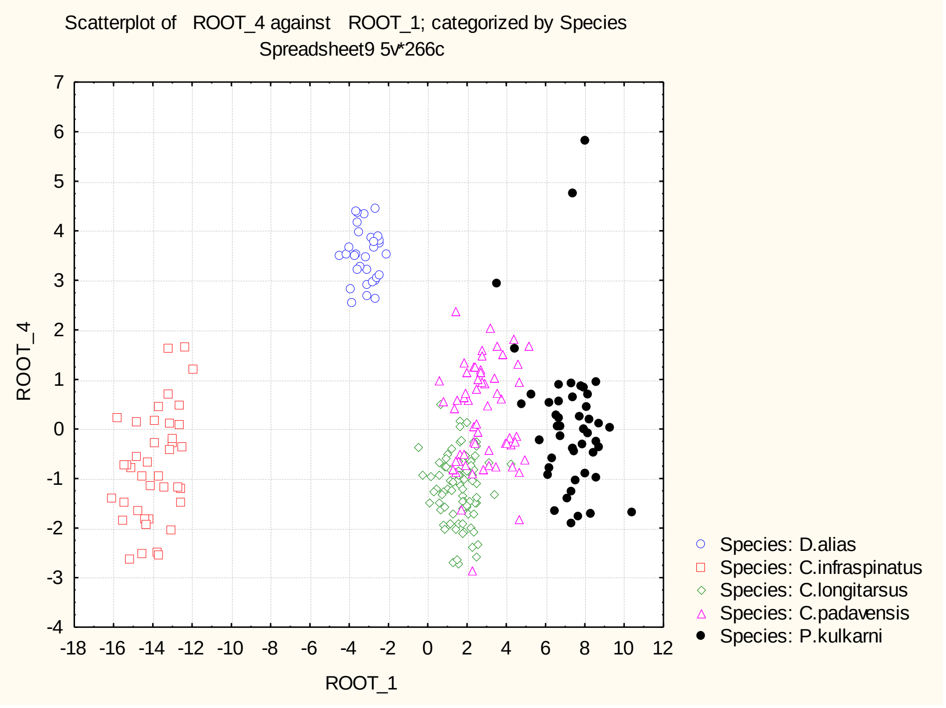


Fig: 4.3.4.3. Scatter plot of discriminant function for Root 1 and Root 4 of Morphometric variables

4.4. Meristic characters

Two meristic characters (number of teeth on dactylus and propodus of the cheliped) were analysed for median and modal value. Frequency of mode, maximum and minimum recorded counts were also tabulated (Table 4.4.1 to 4.4.8). Higher numbers of teeth in dactylus of cheliped were observed in *D. alias* and lower number in *C. infraspinatus, C. arethusa* and *P. kulkarnii.* Maximum numbers of teeth in propodus of cheliped were observed in *D. alias* and minimum number in *P. kulkarnii.* Variability plot (Fig: 4.4.1 and 4.4.2) reflected the dispersion of counts within each species.

Table: 4.4.1 Descriptive statistics of meristic characters of *C. infraspinatus*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	40	2.000000	2.000000	25	1.000000	2.000000
CPT	40	3.500000	Multiple	20	3.000000	4.000000

Table: 4.4.2 Descriptive statistics of meristic characters of *C. longitarsus*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	87	3.000000	3.000000	49	2.000000	3.000000
CPT	87	3.000000	3.000000	44	2.000000	3.000000

Table: 4.4.3 Descriptive statistics of meristic characters of *C. padavensis*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	60	3.000000	3.000000	32	2.000000	3.000000
CPT	60	3.000000	3.000000	35	2.000000	3.000000

Table: 4.4.4 Descriptive statistics of meristic characters of *C. arethusa*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	3	1.000000	1.000000	2	1.000000	2.000000
CPT	3	1.000000	1.000000	2	1.000000	2.000000

Table: 4.4.5 Descriptive statistics of meristic characters of *D. alias*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	31	4.000000	4.000000	16	4.000000	5.000000
CPT	31	5.000000	5.000000	16	5.000000	6.000000

Table: 4.4.6 Descriptive statistics of meristic characters of *D. dubius*

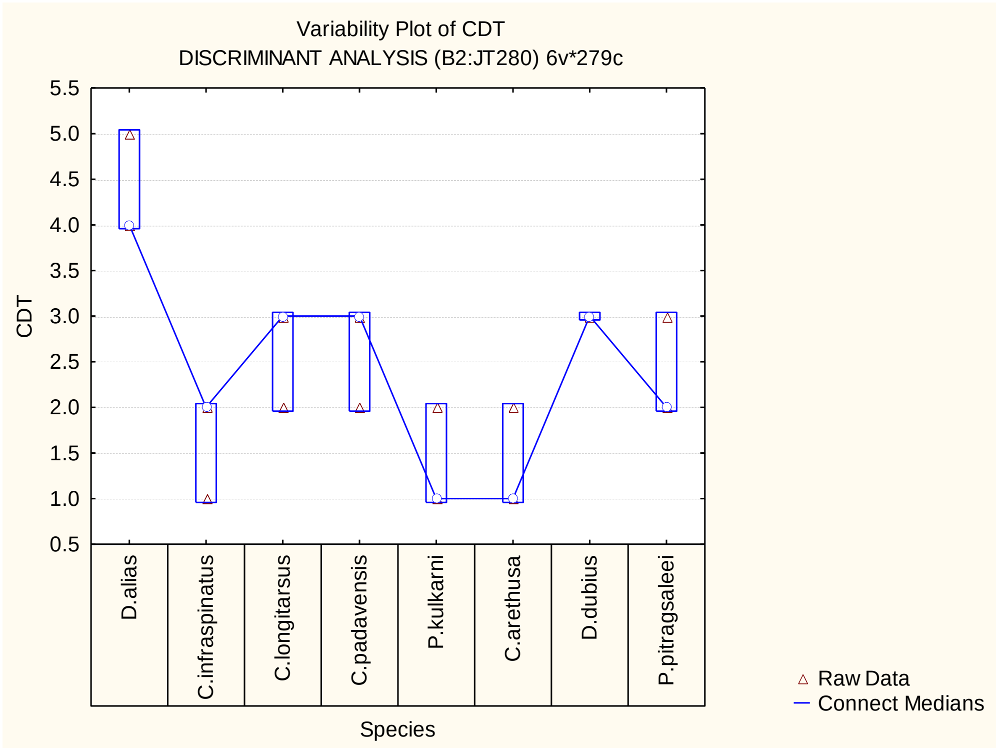
Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	1	3.000000	3.000000	1	3.000000	3.000000
CPT	1	4.000000	4.000000	1	4.000000	4.000000

Table: 4.4.7 Descriptive statistics of meristic characters of *P. pitragsaleei*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	9	2.000000	2.000000	5	2.000000	3.000000
CPT	9	4.000000	4.000000	5	3.000000	4.000000

Table: 4.4.8 Descriptive statistics of meristic characters of *P. kulkarnii*

Variable	Valid N	Median	Mode	Frequency of mode	Minimum	Maximum
CDT	48	1.000000	1.000000	34	1.000000	2.000000
CPT	48	1.000000	1.000000	48	1.000000	1.000000



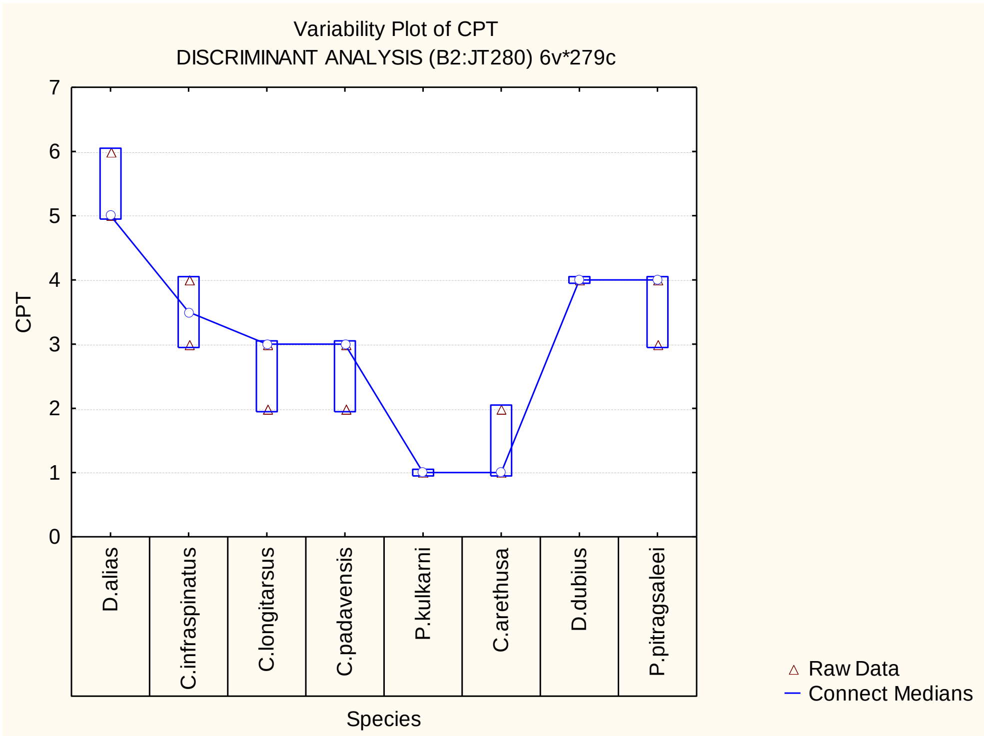


Fig: 4.4.1. Species wise variability plot of CDT and CPT

4.5. Hierarchical cluster analysis

A hierarchical cluster analysis was performed based on character matrix comprising of 56 characters from 8 species of hermit crabs (Table 4.5.1) based on Ward's method. The concerned species were divided into two groups A and B. Group A comprises of genera of *Clibanarius* and *Pagurus*. Group B included only one genus *Diogene* comprising two species (Fig 4.5.1).

Table: 4.5.1.a Character matrix of 8 hermit crabs for hierarchical cluster analysis

Species	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**	**C19**	**C20**	**C21**
C. infraspinatus	**3**	**2**	**1**	**0**	**0**	**1**	**0**	**0**	**2**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**2**
C. arethusa	**3**	**2**	**3**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**2**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**0**	**2**
C. padavensis	**0**	**2**	**3**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**2**
C. longitarsus	**3**	**2**	**3**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**2**
D. alias	**3**	**2**	**1**	**0**	**0**	**2**	**0**	**0**	**2**	**0**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**2**	**2**
D. dubius	**3**	**2**	**1**	**0**	**0**	**2**	**0**	**0**	**2**	**0**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**2**	**0**
P. kulkarnii	**3**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**2**
P. pitragsaleei	**1**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**2**	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**
Species	**C22**	**C23**	**C24**	**C25**	**C26**	**C27**	**C28**	**C29**	**C30**	**C31**	**C32**	**C33**	**C34**	**C35**	**C36**	**C37**	**C38**	**C39**	**C40**	**C41**	**C42**
C. infraspinatus	**0**	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**2**	**0**	**0**	**0**	**2**	**1**	**0**	**1**	**1**
C. arethusa	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**2**	**1**	**0**	**1**	**1**
C. padavensis	**0**	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**2**	**1**	**0**	**1**	**1**
C. longitarsus	**0**	**1**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**0**	**2**	**1**	**0**	**1**	**1**
D. alias	**0**	**2**	**2**	**1**	**1**	**0**	**0**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**2**	**1**	**0**	**1**	**1**
D. dubius	**0**	**2**	**2**	**0**	**1**	**0**	**0**	**3**	**2**	**2**	**2**	**1**	**2**	**1**	**1**	**1**	**2**	**1**	**0**	**1**	**1**
P. kulkarnii	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**2**	**2**	**1**	**2**	**1**	**0**	**1**	**1**
P. pitragsaleei	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**0**

Table: 4.5.1.b Character matrix of 8 hermit crabs for hierarchical cluster analysis

Species	C43	C44	C45	C46	C47	C48	C49	C50	C51	C52	C53	C54	C55	C56
C. infraspinatus	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**0**	**2**	**0**
C. arethusa	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**1**	**2**	**0**
C. padavensis	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**0**
C. longitarsus	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**1**	**2**	**0**
D. alias	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**0**	**2**	**0**
D. dubius	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**0**	**2**	**0**
P. kulkarnii	**3**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**2**	**0**
P. pitragsaleei	**3**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**2**	**0**

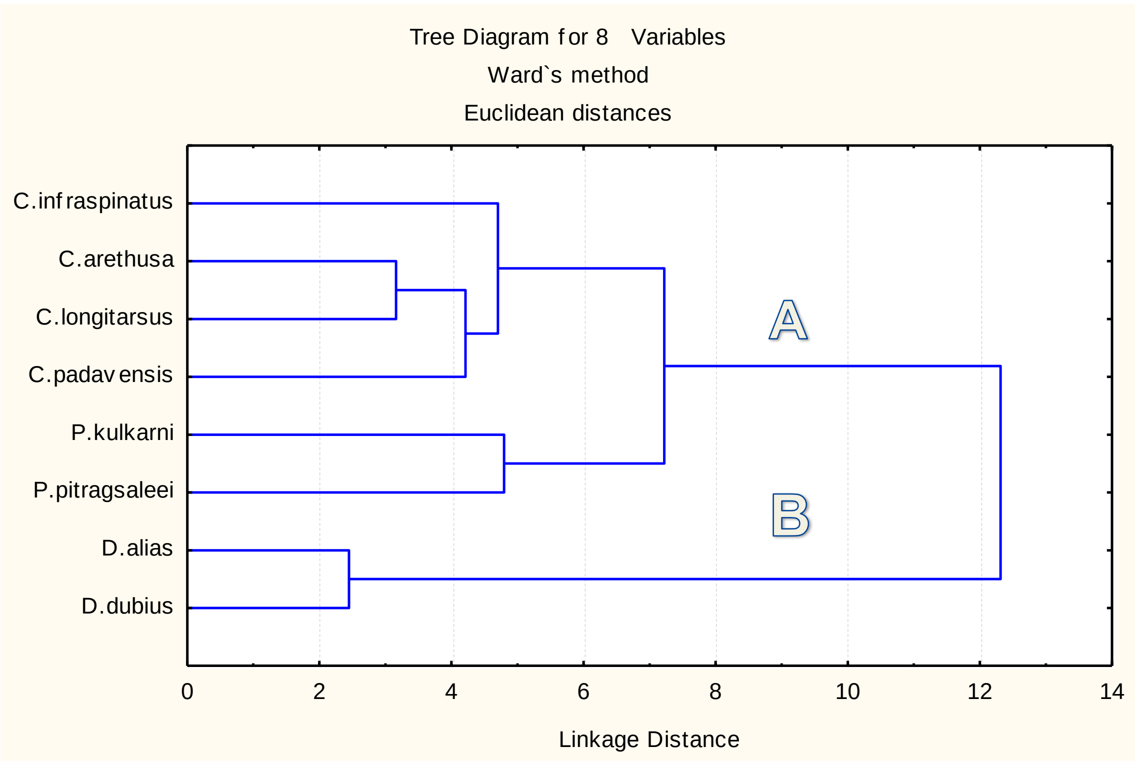


Fig: 4.5.1. Cladogram depicting linkage between 8 species of hermit crabs

5. DISCUSSION

5.1. Importance of hermit crabs

Decapod crustacean exhibit fourth largest diversity among the animal group. They form an important link in the food chain of the tropical marine ecosystem and indirectly contribute to the fishery production. Anomura are easily recognized by having naked, asymmetrical, unsegmented and soft spiral shaped abdomen which are concealed within empty gastropod shell. They are differentiated from Brachyura by antennae placed outside the eye and highly reduced fourth and fifth pereiopod. Though lot of anomalies still exit in their classification, widely accepted classification was Martin and Davis (2001). The hermit crabs belong to Coenobitidae, land hermit crabs; Diogenidae, left-handed hermit crabs; Paguridae, right-handed hermit crabs; Parapaguridae, deep-water hermit crabs and Pylochelidae, non- gastropod shelter using hermit crabs.

Hermit crabs do not have any commercial importance however they form an essential link in the food chain of demersal fishes with few exceptions like coconut crab and some symmetrical crabs. A commercial Lithodid fishery was started since 1900 in Japan and from 1940 onwards in Pacific Ocean. *Paralithodes. spp* (red king crab) was the dominant contributor to Lithodid fishery. Until 1975, Lithodid landings were taken in tangle nets. However, pots are considered as less destructive gear.

5.2. Gross morphology, morphometric and meristic characters

Hermit crabs are represented by approximately 2002 species worldwide (Appeltans *et al.,* 2012). In India, hermit crabs are represented by 162 species (Venkataraman and Wafar, 2005). Recently, Reshmi (2015) recorded 60 species of hermit crab from Kerala coast; of which 3 are new to science and 10 new records in India. Thus checklist of hermit crab in India has been extended to a number 175 species. In the present work, I could record a total of 8 species which comes under two families Diogenidae and Paguridae from Maharashtra waters. Probably, the reason for the collection and identification of 8 species only is that the study was conducted only for limited period of six months. Many ecosystems are still remains to explore.

The cheliped shape and their ornamentation are also considered as a one of the key character in distinguishing families of hermit crabs. Family Diogenidae are known to comprise of left handed hermit crabs with few exceptions of genus like *Paguristes* which has slightly larger right cheliped (Miyake, 1978) while Paguridae is comprised of right handed hermit crabs. In genus *Clibanarius,* usually chelipeds are similar, tips are spooned; eyestalks long and slender (Provenzano, 1959). In Paguridae, the antennular flagellum ends in a filament; third maxillipeds widely separated basally and second and third pereiopods cylindrical. Genus *Pagurus* of the family Paguridae possess chelipeds mostly right is always larger than left one (Provenzano, 1959) and in Diogene of Diogenidae possess opposite characters that left cheliped is always larger. Genus *Pagurus* is differentiated from genera *Clibanarius* and *Diogene* by third maxilliped where it is well separated in former and in latter cases it is closely situated (Alcock, 1905; Provenzano, 1959). Genera *Clibanarius* and *Pagurus* have a triangular to subtriangular shaped ocular acicle. Sandberg and McLaughlin (1998) and Forest *et al*. (2000) described that ocular acicle are nothing but a small calcified plate. It may be simple, bifid or multi-spinose (McLaughlin, 2003).

The hermit crabs of genus *Diogenes* Dana, 1851 possess an intercalary rostriform process flanked by ocular acicles, representing a unique feature for Paguroidea (komai *et al*., 2013); mostly available in subtidal areas. The shape of ocular acicle and the gap between them are also useful for taxonomic study (Ingle, 1993). Genus *Diogene* possesses a broad acicle with a serrated distal margin. This character was found to be very useful in present work to discriminate genus *Diogene* from others.

In Indian waters, genus Diogene is represented by nineteen species namely *D. alias* McLaughlin & Holthuis, 2001, *D. avarus* Heller, 1865, *D. bicristimanus* Alcock, 1905, *D. costatus* Henderson, 1893, *D. custos* Fabricius, 1798, *D. dubius* Herbst, 1804, *D. fasciatus* Rahayu & Forest, 1995, *D. investigatoris* Alcock, 1905, *D. karwarensis* Nayak & Neelakantan, 1989, *D.*

klaasi Rahayu & Forest, 1995, *D. lophochir* Morgan, 1987, *D. maclaughlinae* Nayak & Neelakantan, 1985, *D. manaarensis* Henderson, 1893, *D. miles* Fabricius, 1787, *D. persicus* Nobili, 1905, *D. planimanus* Henderson, 1893, *D. rectimanus* Miers, 1884, *D. tirmiziae* Siddiqui & McLaughlin, 2003, *D. violaceus* Henderson, 1893 and *D. waltairensis* Kamalaveni, 1950 (Henderson 1893; Alcock 1905; Kamalaveni 1950; Nayak & Neelakantan 1985, 1989; Thomas 1989; Siddiqui & McLaughlin 2003; Siddiqui *et al*. 2004; McLaughlin 2005; Reshmi & Bijukumar 2011; Komai *et al*. 2013). In the present study, *D. alias* McLaughlin & Holthuis, 2001 and *D. dubius* Herbst, 1804 belong to this family were recorded.

The selected morphometric traits were able to differentiate *D. dubius* and *D. alias*. SL/CL (0.48), CHL/CL (0.79), CHW/CL (0.59), P/CL (0.80), and ML/CL (0.37) were found to be higher in *D. dubius* than the respective values of 0.40, 0.67, 0.48, 0.67 and 0.44 in *D.alias*.

Usually, hermit crabs have a pair of longitudinal sulci on their shield. Even though, McLaughlin (1974) discussed that it is difficult to use them as a taxonomical feature to discriminate the species, Ingle (1993) used this as one character and opined that genus *Diogene* possess very indistinct sulci; in genus *Clibanarius* and *Pagurus* it is variously interrupted. The medial part of anterior region of shield is strongly convex in case of genus *Diogene* and in both *Clibanarius* and *Pagurus* it is acutely produced with a well-developed rostrum (Ingle, 1993). In *Pagurus*, rostrum is obsolete, roundly subtriangular with an intercalary rostral process which may be either well developed or reduced/vestigial (Provenzano, 1959; McLaughlin, 2003). The similar pattern was observed during present study. In the present study, under *Pagurus* genera *P. pitragsaleei* and *P. kulkarnii* was recorded. Some of the morphometric measurements showed significant difference between the two species. EL/SL (0.58), C/SL (0.07), EL/CL (0.33), CW/CL (0.69) were found to be higher in *P. pitragsaleei* than *P. kulkarnii*.

Paguroids pleon may be elongate, straight or flexed, bulbous or reduced. The anterior portion of abdomen having a columellar muscle extension called abdominal process which is used to hold the shell. Few species belongs to genus *Clibanarius* and *Diogene* having this proximal extension. The abdomen terminates in telson which has a medial cleft or suture with many processes at their terminal margin. It may or may not extend upto lateral margin. Terminal margin usually rounded, straight or oblique in Pagurus (McLaughlin, 2003). In present work genus *Clibanarius* have abdominal process which was prominent in case of *Clibanarius infraspinatus* compared to other species of *Clibanarius.* Almost all species recorded from Maharashtra waters in present work possess median cleft which may be either shallow or narrow and well developed and have bulbous abdomen. Terminal margin of species *Pagurus pitragsaleei* and *Clibanarius arethusa* in rounded shape and rest of species possess oblique or triangular shaped margin.

Based on colour pattern of cheliped and their walking legs bands, we can discriminate genus *Clibanarius* from others. The colour pattern as a reliable character for identification of genus *Clibanarius* was emphasized by Henderson (1915). The species *C. infraspinatus* having yellowish stripes on their walking legs; *C. arethusa* with reddish brown colour over walking legs and shield portion; *C. padavensis* having yellowish with red or brown bands and *C. longitarsus* having greenish brown with golden bristles. The species *Clibanarius infraspinatus* was differentiated from other based on a strong tooth available on the merus of cheliped on ventral margin. This tooth is a distinguishing feature of this particular species among genera *Clibanarius*. This character is also considered as a valuable one by Alcock (1905). In the present work, the species *Clibanarius infraspinatus* have some variable which distinguish it from other three species of same genera. CW/CL (0.63), CHL/CL (0.52), CHW/CL (0.63), P/CL (0.66) and CR/CL (0.35) were found to be differ from other species of genera *Clibanarius* (0.54-0.59, 0.63-0.65, 0.44-0.45, 0.54-0.64 and 0.24-0.27). *Clibanarius longitarsus* can be distinguished from other by few characters such as corneal diameter, finger length and palm length. *Clibanarius arethusa* possess short antennal length than other species of genus *Clibanarius.*

The presence and absence of pleopods and their number also involved in this taxonomic work. In case of Diogenidae family, some exception were also exist that in genus *Paguristes*, first two pleopods are paired and the remaining were unpaired in male and in female from 2-5 pleopods are unpaired (Miyake, 1978). In Paguridae, male having 3-4 unpaired pleopods and female have 4 or 5 unpaired pleopods. Unpaired pleopods 2-5 are present in the both sexes of *Diogene, Clibanarius* and *Pagurus* (Ingle, 1993). In *Pagurus kulkarni,* there is difference exist between male and female specimen based on presence of pleopod. This result is in compliance with the works by Tirmizi and Siddiqui (1982) and McLaughlin (2002).

5.2. Stepwise discriminant analysis

MANOVA of 18 morphometric variables for 5 species of hermit crab showed significant difference between them. The same variables were subjected to factor analysis. The two principal factor or components were generated along with the factor loadings of different variables. 12 variables showed factor loading of more than 0.6 on at least one of the two factors showing their prominent contribution to the explained variation. The sorted 12 morphometric variables were used for stepwise discriminant analysis which successfully discriminated (99.2481%) 5 species. The rankings or order of characters entered in to analysis were also generated showing the relative importance of the variable in discrimination. Cheliped width, eye peduncle length, dactyl length, palm length, carapace width and corneal diameter are important morphometric character in distinguishing the species. The root1 vs. root 2 scatterplot show close morphometric resemblance between *C. padavensis and C. longitarsus.* The three other species of genus *Pagurus, Clibanarius* and *Diogene* are clearly separated in plot showing marked morphometric difference. The root 1 vs., root 3 scatterplot show clear discrimination between *C. padavensis and C. longitarsus* based on some important characters in consideration.

5.3. Hierarchical cluster analysis

Phylogenetic analysis is the basis for all evolution related work. This analysis helps us to resolve problems in their evolutionary status. In general, two type of cladistic analysis are followed: rooted and un-rooted tree. In case of un-rooted one, ancestor of that particular is not known and the rooted one is having ancestor which is well established. The study attempted to resolve the complex phylogeny of hermit crab using morphological characters. Based on 56 morphometric characters, hierarchical cluster analysis revealed that species were broadly grouped into two categories or lineage, one comprising of the genus *Diogene* and the other comprising of *Clibanarius* and *Pagurus. Clibanarius* showed greater affinity towards genus *Pagurus.* Similarly among *Clibanarius* genus *C. arethusa* and *C. longitarsus* were closely related to *C. padavensis*. Though genus *Clibanarius* belong to another family, it shows greater affinity towards genus *Pagurus* rather than genus *Diogene.* This is probably due to the reason that *Pagurus* is a sister group related to diogenid. Similar results were also obtained by Tudge (1997) in phylogeny work based on spermatozoal morphology. By the result from present research is not enough to propose the doubt that Pagurus genus should be included in Diogenids. This has to be further investigated based upon various anatomical and molecular characters.

6. SUMMARY

Hermit crabs form an essential link in the food chain of demersal fishes thereby gaining ecological importance. But some Lithodid crabs have some commercial importance in some geographical regions like Japan and they contribute significantly to annual landings. Hermit crabs are represented by 162 valid species from Indian waters out of 2002 recorded species worldwide. Although several attempts were made on phylogenetic and systematic aspect of the family, the outcome seems to be tentative and open for investigations. To differentiate the species of the hermit crab, samples were obtained from different intertidal areas including Aksha, Bandstand and Versova of Mumbai and Alibaug and Srivardhan of Raigad districts in Maharashtra.

Generally, characters like cheliped shape and their ornamentation, shield pattern, telson shape, presence of pleopod; number of gills were used in past for species differentiation. In the present study also the cheliped shape and their ornamentation, telson shape, presence of pleopods, spine on the carpus of cheliped, spine on terminal margin of telson and morphometric measurements were considered in differentiating the species of crabs. Eight species were identified and differentiated in the study.

High correlation coefficients (> 0.6) were obtained for all the combination of morphometric measurements. Very high correlation coefficients were obtained for total length, eye peduncle length, finger length and ischium length with carapace length. Descriptive statistics of different morphometric variable, scaled either to SL or CL show reasonable discriminating power between species belonging to same genus.

The morphometric variables were analysed for significant variation between species using MANOVA. Significant morphological differences were observed between species. The morphometric variables were subjected to factor analysis. A total of 12 variable were found to have higher loadings (>0.6) on either first or second factor. The above mentioned 12 variables were subjected to

Stepwise Discriminant Function Analysis. The first two discriminant functions were found to explain 92.5% of variation. The cheliped width, eye peduncle length, corneal diameter, carapace width, palm length and dactyl length were among the major contributors to the discriminant functions. Means of canonical variables shows the sufficiency of first two roots in discrimination of most of the considered species which can be clearly observed in scattergram of Root 1 vs. Root 2. The generated classification matrix shows correct classification of 99.2481%.

The hierarchical cluster analysis using ward method based on character matrix of 8 species and 56 characters shows the two broad grouping. One group comprised of two genera namely *Clibanarius* and *Pagurus*. *Diogene* was categorised in other group. The species belonging to particular genus were found to be closer than to the members of other genera which affirm the natural generic assignment to the species.

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