

G18652

**SYSTEMATICS, FISHERY, RESOURCE  
CHARACTERISTICS AND BIONOMICS OF DEEP  
SEA PRAWNS OFF KERALA**

THESIS SUBMITTED TO THE  
**COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY**  
IN PARTIAL FULFILMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
**DOCTOR OF PHILOSOPHY**

BY

**S.R. RADHIKA RAJASREE**

SCHOOL OF INDUSTRIAL FISHERIES  
**COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY**  
COCHIN – 682 016

**2004**

## DECLARATION

I, S. R. Radhika Rajasree, do hereby declare that the thesis entitled “ **Systematics, Fishery, Resource Characteristics and Bionomics of Deep Sea Prawns Off Kerala**” is a genuine record of research work done by me under the supervision of **Dr. B.Madhusoodana Kurup**, Professor (Fisheries), School of Industrial Fisheries, Cochin University of Science and Technology and has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any university or institution .

Cochin-682016

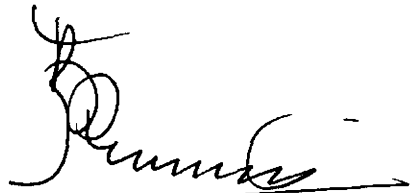
July - 2004



**S. R. Radhika Rajasree**

## CERTIFICATE

This is to certify that this thesis is an authentic record of research work carried out by Smt. **S. R. Radhika Rajasree**, under my supervision and guidance in the **School of Industrial Fisheries, Cochin University of Science and Technology** in partial fulfilment of the requirements for the degree of Doctor of Philosophy and no part thereof has been submitted for any other degree.



---

**Dr. B. Madhusoodana Kurup**  
(Supervising Teacher)

Cochin-16  
July 2004

Dr. B. Madhusoodana Kurup  
Professor  
School of Industrial Fisheries  
Cochin University of Science and Technology  
Cochin – 682 016

## **ACKNOWLEDGEMENTS**

I wish to express my sincere thanks and deep sense of gratitude to my guide Dr. B.Madhusoodana Kurup, Professor, School of Industrial Fisheries, Cochin University of Science and Technology for his valuable guidance, critical assessment and constant encouragement through out the course of my work.

I am also grateful to Prof. (Dr.) Ramakrishnan Korakandy , Director , School of Industrial Fisheries , Cochin University of Science and Technology for providing me the necessary facilities to carry out this work successfully.

I am thankful to Dr. M. Harikrishnan , Lecturer , St. Alberts College, Ernakulam for his valuable assistance in statistical analysis of the data and offering valuable suggestions.

The encouragement and assistance extended by my teachers, other faculty members, members of office staff and my fellow researchers in the school of Industrial Fisheries are gratefully acknowledged. I am also indebted to the research scholars of School of Marine Sciences for their timely help.

I am deeply indebted to the fishermen, auctioneers and deep sea boat owners in Munambum and Cochin Fisheries harbours for their help during fishery data collection.

My special appreciation goes to my husband and my sister for putting up with me and patiently bearing all inconveniences during the days of difficulties and enthusiastically helping in my work.

I would like to place on record my sincere gratitude to Fisheries Resource Management Society, Department of Fisheries, and Government of Kerala and Dept. of Ocean Development for granting me an opportunity to work as a Research Fellow and making use of part of the data of the above projects for the preparation of the thesis.

Radhika Rajasree ,S.R.



# CONTENTS

---

|   | PAGE NO. |
|---|----------|
| <b>Section 1.</b>   |          |
| Chapter 1. General Introduction   | 1        |
| <b>Section 2. Systematics and bio diversity assessment of<br/>Deep sea prawns</b>                   |          |
| Chapter 2. Systematics  | 20       |
| Chapter 3. Bio Diversity Assessment   | 76       |
| <b>Section 3. Exploratory surveys and quantification of exploited<br/>Deep sea prawns</b>           |          |
| Chapter 4. Assessment of deep sea prawn resources off Kerala<br>on the basis of Exploratory Surveys | 93       |
| Chapter 5. Deep sea prawn fishery off Kerala  | 112      |
| Chapter 6. Resource Characteristics   | 141      |
| <b>Section 4. Bionomics of deep sea prawns</b>  |          |
| Chapter 7. Food and Feeding habits of <i>Heterocarpus gibbosus</i><br>and <i>H. woodmasoni</i>      | 168      |
| Chapter 8. Reproductive Biology   | 188      |
| Chapter 9. Carotenoid Estimation and Proximate Analysis   | 217      |
| Chapter 10. Age and Growth  | 243      |
| Chapter 11. Population Dynamics   | 262      |
| Chapter 12. Summary and Recommendations   | 282      |
| References  | 299      |
| Publications  |          |

## List of Abbreviations

|                 |   |   |
|-----------------|---|---|
| BB              | — | Black Berry                             |
| C/hr            | — | Catch per hour                          |
| CPU             | — | Catch Per Unit                          |
| EEZ             | — | Exclusive Economic Zone                 |
| GB              | — | Grey Berry                              |
| Hr.             | — | Head roe                                |
| HSI             | — | Hepato Somatic Index                    |
| IQF             | — | Individually Quick Frozen               |
| Lat.            | — | Latitude                                |
| L <sub>OA</sub> | — | Overall Length                          |
| Long.           | — | Longitude                               |
| N               | — | North                                   |
| NFE             | — | Nitrogen Free Extract                   |
| OB              | — | Orange Berry                            |
| t               | — | Tonnes                                  |
| TL              | — | Total Length                            |
| TW              | — | Total Weight                            |
| µm              | — | Micro meter                             |
| ELEFAN          | — | Electronic Length Frequency<br>Analysis |

## **SECTION 1**

Chapter 1

**GENERAL INTRODUCTION**

## 1.1 INTRODUCTION

Fisheries in India, of late have grown as a major industry with an annual turnover of Rs. 220 billion which account for 1.4% of the GDP of the country (Ayyappan and Biradar, 2000), and providing employment, directly and indirectly to about 10 million people. Among the Asian countries, India ranks second in fish production through aquaculture and third in capture fisheries. The water spread available for fish production in the country is so vast with 2.02 million Km<sup>2</sup> of EEZ for marine capture fisheries and 1.2 million ha for coastal aquaculture. The present total fish production of the country is 5.6 million tonnes with a per capita fish availability of 8 kg per annum against the ideal consumption rate of 11 kg as recommended by WHO (Sugunan and Sinha, 2001). Realizing the importance of fisheries in national development, the Government of India has identified fisheries as a priority sector in the national five-year plans. The annual budget allocation for the fisheries sector as a percentage of the agricultural sector has been steadily increasing continuously from 0.26% in the First Plan to 0.52% in the Fourth Plan. This shows the greater importance and priority being accorded to the fisheries sub sector. As a result, the marine fish production of the country has increased from 0.53 million tonnes (mt) in 1951 to the present yield of 2.64 mt in 2002 (CMFRI, 2003). India with a coastline of about 8,129 km and continental shelf area of about 0.5 million km<sup>2</sup> possesses rich and diverse marine

finfish and shellfish resources. Due to the complex problems related to the multi-species, multi – gear character of the Indian fisheries sector, and the changing climatic and oceanographic conditions, it is a challenge to manage the fishery resources effectively. The country's marine production rose from an average of 0.8million tonnes in 60's to the current production of 2.64 million tonnes in 2003. Of this, pelagic resources contributed to 53% while demersal fishes, crustacean and molluscan resources contributed to 26%, 17% and 4% respectively. Among the crustacean resources, the penaeid and non-penaeid prawns contributed to 48% and 32% respectively (CMFRI, 2003).

The estimated annual fishery resource potential of the Indian EEZ has been estimated to be 3.9 million mt, comprising of 2.2 million mt from 0-50m depth zone and 1.7 million mt from beyond this region (Sudarsan, 1992). However, the Indian marine fisheries are currently confronted with serious problems of diminishing yields from the inshore waters and there exist an ever-increasing conflict in sharing the resources. This situation warrants proper management of the resources (Devaraj and Vivekanandan, 1999). Currently marine fish production of India stands at 2.64 mt and exploitation of resources from the inshore waters have already reached the catchable potential (2.2 million mt) by 1997, and therefore scope for further increase in production is very limited (Vivekanandan, 2001). It is, therefore, imperative that further exploitation

of the resources should take place only from the outer continental shelf and deep seas by extending the fishing effort to these regions.

Investigations on the offshore and deep sea fishery resources received greater impetus since the past decade when it was realized that the increasing fishing effort on certain inshore resources in certain centers along the coasts would bring about decline in the catch rates, and to meet the increasing demand for fish and fishery products by the growing population it has become necessary to search vigorously for new fishing grounds and resources. Lack of adequate information on the deep sea resources was often posed as one of the constraints for the development of deep sea fishing. However, the extensive synoptic and exploratory surveys and studies carried out along the Indian EEZ by various Governmental agencies have thrown some light on this aspect. These surveys could bring out the quantitative and qualitative availability and abundance of unexploited and under exploited fishery resources along the outer continental self and slope of the Indian waters.

In India, scientific investigations on the existence of several species of deep sea prawns are available from the surveys of the Royal Indian Marine Survey Steamer "Investigator" during the years 1884-1925. The results of the expedition that took place in the Indian Ocean in subsequent years have augmented our knowledge of the deep sea prawns. The exploratory surveys by the research vessels R.V.CONCH,

R.V.KALAVA and R.V.VARUNA during 1958-1965 have unraveled the occurrence of commercially exploitable deep sea prawn stock in trawlable concentration along the shelf edge and the upper continual slope off south west coast of India. Indo – Norwegian vessels M.V.KLAUS SUNNANA, M.V.TUNA and M.V.VELAMEEN (1967-1968) unfolded valuable information on the deep sea finfish and shellfish resources (Mohamed and Suseelan, 1973; Suseelan, 1974) off Kerala coast, and strongly suggested the possibility of their commercial level exploitation. Exploratory surveys carried out by FORV Sagar Sampada since 1980's (Suseelan *et al.*, 1989 a, b) also showed the availability, depth and distribution pattern of deep sea resources off South West coast of India. The revelation of commercially exploitable deep sea prawn wealth beyond the continental shelf by these surveys in the recent past had strongly asserted the view that there exists immense scope for the exploitation of deep sea crustaceans off Kerala coast.

The prawns occupy a prominent position in the economy of Kerala on account of its high export value among the marine fishery resources of the state. The stupendous development that has taken place in the fisheries sector of the state during the last four decades was mainly due to the growing demand for shrimps in the overseas markets. The average production of coastal prawns was 74,000 t during 1973-75 while during 1976-78 and 1978-80, it fluctuated between 38,000t and 43,000t and reached about 72, 000t in 1994, thus showing wide fluctuations over the



years with an increase in the incidence of unmarketable or small- size species thus showing signs of over fishing (Vijayan *et al.*, 2000). Till recently, deep sea crustacean resources were considered a close preserve of larger factory vessels and were believed to be beyond the reach of medium trawlers operating along the coastal waters. Increasing fishing effort exerted on the crustacean resources along the Kerala coast has resulted in the decline of catch rates and this coupled with rapid blooming of the prawn processing and export industry followed by the great upsurge in the operational cost, called for a vigorous search for new fishing grounds and new resources. The pioneer commercial exploitation of deep sea prawns off Kerala coast had started in 1999 by the local trawl boats and thus deep sea prawn fishing by the locally constructed trawl units became a reality in the history of marine fisheries of the country. Landings by large trawlers were focused mostly in three fisheries harbours of Kerala and comprised of a wide assemblage of deep sea prawn species represented by both pandalid and penaeid prawns, and thus accounted for a substantial percentage in the total marine fisheries of Kerala. For rational exploitation and management of these resources on scientific basis, reliable data on the exploited stock of this new resource, their biological and ecological characteristics together with information on the nature and extent of deep sea prawn resources in the depth zone of 150 – 600 m are essential prerequisites.

The deep sea prawns are an assemblage of a wide array of prawn species represented by the families Pandalidae, Aristeidae, Solenoceridae, Penaeidae and Oplophoridae which are abundant in relatively high concentration on the Quilon Bank between latitudes 8°30'N and 9°10'N and longitudes 75° 30'E and 76° E between the depth zones 250-450m. The average annual yield of deep sea prawns during the first year of commercial exploitation was 23,426t during 1999-2000 (Rajan and Nandakumar, 2001), which increased to 48,675t (Rajasree and Kurup, 2004) during 2000-01, thus contributed to 9.35% of the total marine fish production of Kerala (Kurup, 2001). The total catch reported during 2001-02 was 17,888t from Quilon Bank (CMFRI, 2003).

Several studies on fishery and biology of various species of deep sea prawns are available from many parts of the world (Details are provided under review of literature and also in the respective chapters). However, investigations on these resources from Indian waters are very few and fragmentary. In addition, investigations on the systematics, proximate composition, carotenoid content, age and growth characteristics and population dynamics of the deep sea prawns have not been forthcoming from any part of the Indian coast. Further, the stock of deep sea prawns has diminished over a short span of four years since the commencement of their commercial exploitation in 1999 and it would be worth examining the factors that caused to this decline. Realizing the lacuna, the present study was undertaken on the fishery, biological

characteristics and population dynamics of deep sea prawns from the Kerala coast encompassing the 6 major and 4 minor harbours with a view to evolve appropriate management strategies for the judicious exploitation and conservation deep sea prawn resources.

## 1.2 REVIEW OF LITERATURE

The relevant literature on taxonomy, biology and stock assessment are reviewed elaborately in the respective chapters. Though several studies have been carried out on the fishery aspects of deep sea prawns from various countries, information on the biology and population characteristics of the resources are scanty.

The classical works on taxonomy and distribution of deep sea prawns, in a global context, are those of Dana (1852,1855), Bate (1881,1888), Milne-Edwards (1881, 1883), Alcock and Anderson (1894), Alcock (1901, 1906), De Man (1911, 1920) Calman (1909,1923,1925) and Allen (1967). Morphometric studies on commercial important deep-water shrimps were carried out only in temperate waters by a few researchers, notably by Arana (1970), Sardá *et al.* (1995) and Bas & Sardá (1998). In the Indian context, valuable contribution on taxonomy and distribution of deep sea crustaceans are those of Alcock (1901) and Suseelan (1985). George and Rao (1967) made notes on some deep-

water decapod crustaceans from the south west coast of India while Thomas (1979) reported deep sea decapod crustaceans from Gulf of Mannar. No studies on morphometrics of deep sea prawns were hitherto attempted.

Information on the commercial exploitation and potential fishing grounds of deep sea prawns had been reported by Massuti, (1959), Maurin (1965), Monod (1966), Williams (1968), Alvarez (1968), Longhurst (1970), Crosnier and Forest (1973), Holthuis (1980) and Berenboim (1989) while Oren Sanz *et al.* (1998) reported on the multi faceted decline of shrimp fisheries in the Greater Gulf of Alaska.

Literature regarding the structure of decapod crustacean assemblages in different geographic regions and their correlation with environmental and oceanographic conditions viz., depth, bottom type and characteristics of the water masses were studied notably by Lagardere (1973,1977), Wenner and Boesh, (1979), Gonza'lez and Olaso (1987) and Abelló, *et al.* (1988) while Wu (1982), Bianchi (1992) and Setubal (1992) correlated the species diversity as well as richness of crustaceans community to sediment granulometry , character of bottom substratum , fishing disturbances , flow of various water bodies , salinity and oil spills.

The species assemblage of deep sea crustaceans in the Indian Ocean region was reported by a few workers notably Hida and Pereyra (1966), Gulland (1971) while Holthuis (1980) compiled similar information

from the upper continental slope of Mozambique, Pakistan, Sumatra, North Western Malaysia and Burma. Along the Indian EEZ, the depth wise variation in the distribution and abundance of deep sea prawns were studied on the basis of exploratory fishing surveys notably by John and Kurien (1959), Kurien (1964,1965), George (1966), George and Rao (1966), Rao and Suseelan (1967), Mohamed and Sueelan (1968), Silas (1969), Mohamed and Suseelan (1973) and Suseelan (1974, 1985).

The food and feeding on the pandalid prawn *Pandalus borealis* was studied in detail by Allen (1959), Turpaeva (1948,1953), Butler (1964,1968), Berenboim (1981,1992) and Weinberg (1980). Burukovsky (1992) reported the feeding habits of shrimps from western Africa while Mary and Ioannis (1999) made a comparative study on the food and feeding habits of *Plesionika ensis*, *Polycheles typhlops*, *Parapenaeus longirostris* and *Plesionika heterocarpus*. Cartes (1993) observed the diets of deep-water pandalid shrimps *Plesionika edwardsi*, *P. martia* and *P. acanthonotus* of the western Mediterranean whereas Mistakidis (1957) and Allen (1963) examined the gut contents of *Pandalus montagui*. Kubo (1951) and Omori (1971) studied the feeding habit of *Pandalus kessleri* and *Plesionika izumiae*. Notable contribution on the food and feeding habits of the Royal red shrimp *Hymenopenaeus robustus* were made by Bullis (1956), Bullis and Rathjen (1959), Bullis and Thompson (1959), Thompson (1967), Klima (1969) and Anderson and Lindner (1971). Suseelan (1985) made a preliminary study on the gut contents of

*Heterocarpus gibbous* and *H.woodmasoni* collected during the exploratory fishery surveys off the south west coast of India.

Reproductive biology of several pandalid species have been subjected to detailed investigation notably by Hjort and Ruud (1938), Rasmussen (1953), Allen (1959), Hoglund (1962), Dow (1966), Squires (1968), Horsted and Smidt (1956) and Butler (1964, 1968). Larval development of pandalid shrimps have been investigated by Modin and Cox (1967), Wickins (1972), Haynes (1976,1978, 1979), Rothlisberg (1980), Weinberg (1982), Mikulich and Ivanov (1983), Needler (1938), Lebour (1940) and Hiroshi (1978). The biology of *P.montagui* Leach was investigated by Mistakidis (1957), Allen (1963) and Stevenson and Pierce (1985). The life history traits of commercial important pandalid shrimps of North America viz. *Pandalus platyceros* Brandt, *P.danae* Stimpson, *P.goniurus* Stimpson, *P.stenolepis* Rathbun, *P.hypsinotus* Brandt have been studied by Berkeley (1929), Tegelberg and Smith (1957), Butler (1964, 1970) and Dahlstrom (1970) while Company and Sardá (1997) gave a comprehensive account on the comparative reproductive biology of 5 deep water pandalid shrimps *Plesionika heterocarpus*, *P.edwardsii*, *P.gigliolii*, *P.martia* and *P.acanthonotus*. Moffit (1983), King (1984) and King and Butler (1985) studied the reproductive biology of the Genus *Heterocarpus laevigatus*. Menon (1972) reported the larval development in this genus collected during International Indian Ocean Expedition surveys.

A review of literature showed that no concerted attempt has so far been made to evaluate biochemical as well as carotenoid variation commensurate with the change in phases of reproduction in deep sea prawns, however, the carotenoid composition and distribution in decapods were reported by Tsukuda (1963), Larry and Salwin (1966), Ishikawa *et al.* (1966), Czerpak and Czeczuga (1969) and Katayama *et al.* (1972).

Age and growth of deep water prawns inhabiting Mediterranean waters were also subjected to serious studies, notably by Mauchline (1972), Gage and Tyler (1991), Orsi and Relini (1985), Sardá and Demestre (1987) and Demestre (1990). Company and Sardá (2000) assessed the growth patterns of 17 deep-water decapod crustaceans from the Northwestern Mediterranean Sea. Ohtomi and Irieda (1995) studied the growth structure of *Solenocera melantho* while Ohtomi (1997) assessed the growth of pandalid shrimp *Plesionika semilaevis* from Kagoshima Bay. Roa and Ernst (1996) studied the age structure of *Hetrocarpus reedi* from Central Chile where as Dailey and Ralston (1986) assessed the reproductive biology, growth and mortality of *H.laevigatus* in Hawaii. In Indian waters, no published information on the age and growth of pandalid shrimps is hitherto available.

The available studies on the population dynamics of deep sea prawns are very limited and notably by Yahiaou *et al.* (1986), Orsi and

Relini (1988), Demestre and Martin (1993), Yahiaoui (1994), Ragonese and Bianchini (1995), Ragonese *et al.* (1994), Spedicato *et al.* (1994) and Donghia *et al.* (1998) on *Pandalus borealis*. Dailey and Ralston (1986) reported the population dynamics of *Heterocarpus laevigatus* while Cessay (2000) assessed the mortality of *P. borealis*.

### 1.3 DESCRIPTION OF THE STUDY AREA

Kerala with a total terrestrial area of 38863 km<sup>2</sup> has a 590 km long coastline and is a frontline state in marine fisheries development. The state is situated between latitudes 8°18'N to 12° 48'N and longitudes 74°52'E to 72° 22' E and lies in the extreme south west part of the peninsular India, bordered by Western Ghats on the eastern side and the Arabian sea on the western side. The inshore sea area falling within the territorial limit of the state is about 13,000 km<sup>2</sup>. The continental shelf area of the sea adjoining the state is 39139 km, which is almost on par with the territorial extent of Kerala, and this part of the sea is considered the most productive zone as far as fishing is concerned. Forty one rivers originating from the Western Ghats open into the Arabian Sea in this state, rendering the inshore waters of Kerala very fertile and highly productive among the world oceans.



The population of the fisher folk in Kerala is estimated at about 10.85 lakhs, live in 222 fishing villages while the number of fishermen actively engaged in sea fishing is estimated at 2.20 lakhs. Fisheries contribute about 3% of the economy of the state (Vijayan *et al.*, 2000).

The major fishing harbours surveyed is Sakthikulangara, Neendakara, Cochin, Munambam, Beypore and Puthiyappa while the minor harbours are Thotapally, Murikkumpadam, Ponnani and Mopla Bay (Fig.1.1). More than 90% of the state's marine fish catches are landed in the above six major harbours (Scaria *et al.*, 1999).

#### **1.4 SCOPE OF THE STUDY**

For rational exploitation of deep sea prawn resources on scientific basis, reliable data on this emerging new resource such as detailed life history traits, influence of ecological parameters contributing to their distribution and abundance, stock recruitment, regeneration capacity, important groups sustaining the stock etc. are essentially required. While scanning the scientific literature on the deep sea prawn resources both at national and global levels, it is evident that, no concerted attempts had so far been made to bring out a holistic account on the deep sea prawn wealth of the country giving emphasis to quantifying the extent of organic diversity existing among the group, bionomics, biodiversity, resource

characteristics and stock size. Most importantly, virtually no information is also available on the population dynamics and stock recruitment relationships of this peculiar group of animals, which inhabit mostly beyond 300m on the continental slope. Hence, there exists considerable lacuna in our knowledge on various aspects of the biology of deep-sea prawns from Indian waters. Against this background, the present study was conceptualized with a view to bridge the existing gap on this important marine living resources off Kerala coast as this information is indispensable and vital for their sustainable exploitation and for imposition of various conservation and management measures for the preservation of the stock. A better understanding of the biological characteristics of the species, and the information gathered on population parameters will be useful in evolving suitable strategies for future management of the deep sea prawn resources in Indian waters in general and off Kerala coast in particular.

Detailed investigations on the systematics, fishery, bionomics and stock assessment of deep sea prawns, is therefore, undertaken on the basis of data gathered from the exploratory and commercial fishing operations. The objectives of the study are thus outlined as follows:

1. To investigate the organic diversity existing among the different deep sea prawns off Kerala and to prepare a key for their easy identification, together with the quantification of the morphometric

variability existing among these species. Also to establish allometric relationship between the various morphometric characters with a view to establish species-specific ratios as well as relationships.

2. To calculate relative bio diversity indices of deep sea prawns off Kerala to examine the change in community structure based on the taxonomic relatedness and also to assess the depth wise, year wise species abundance, richness and evenness of deep sea prawns off Kerala.
3. To bring out information relevant for the exploitation of deep sea prawns such as catch and effort, demarcation of important fishing ground showing the abundance of commercial important species based on exploratory trawling operations and to quantify the exploited stock of deep sea prawns landed at various harbours of Kerala.
4. To establish variations if any, in length-weight relationships of deep sea prawns with a view to assess how various species maintain their body dimensional equality and depth of occurrence in relation to their life habits. Also to investigate resource characteristics such as relative condition factor, sex ratio, modal class representing fishery and percentage of berried prawns and study some aspects of bionomics viz. reproductive biology and food and feeding habits

of males and females of *Heterocarpus gibbosus* and *H.woodmasoni*.

5. To evaluate the proximate composition in the muscle tissue and hepatopancreas of *H.gibbosus* and *H.woodmasoni* and to delineate variations, if any, sex wise and maturity stage wise. In addition, effort was made to assess the distribution and mobilization pattern of total carotenoids in various tissues of *H.gibbosus* during different stages of gonad maturation and to elucidate the depth linked variation in total carotenoids among important species of deep sea prawns.
6. Quantify the dynamic forces acting on the male and female populations such as growth, exploitation and mortality in *H.gibbosus* and *H.woodmasoni*.

## 1.5 PRESENTATION OF RESULTS

The results of the present study are presented in 12 chapters, which are organized under four sections. Section 1 deals with the general introduction and a brief review of the literature, also highlighting the scope of the present study and presenting a brief description of the study area, which is encompassed under **Chapter 1**.

The second section deals with the systematics and biodiversity assessment of deep sea prawns and comprised of two chapters. While **Chapter 2** gives an account of the systematics of deep sea prawns and depicts the results of morphometric analysis whereas **Chapter 3** accommodates the results of the biodiversity assessment of deep sea prawns at various depth zones off Kerala coast.

Results of the exploratory and exploited deep sea prawn fishery off Kerala coast and resource characteristics of important species of deep sea prawns are presented in the third section which are described in the next three chapters. Assessment of deep sea prawn resources off Kerala coast on the basis of exploratory surveys is provided in **Chapter 4** whereas details of commercial deep sea prawn fishery off Kerala coast is given in **Chapter 5** which include information on fishing area, depth, annual catch trends and seasonal fluctuations from the 10 fisheries harbours.

In **Chapter 6**, the results of analysis of resource characteristics of commercially exploited deep sea prawns viz. length weight relationship, relative condition factor, sex ratio, length frequency and percentage of berried females to the total female population are presented.

Fourth section deals with the bionomics of the two most commercially important deep sea prawns viz., *H.gibbosus* and *H.woodmasoni* and consists of five chapters.

**Chapter 7** explains the seasonal, sex wise and maturity stage wise variations in the food and feeding habits of *H.gibbosus* and *H.woodmasoni* while **Chapter 8** gives a detailed account of the maturation and spawning of the above two species giving emphasis to maturity stages of males and females, size at first maturity, gonadosomatic index, histo- somatic index and fecundity.

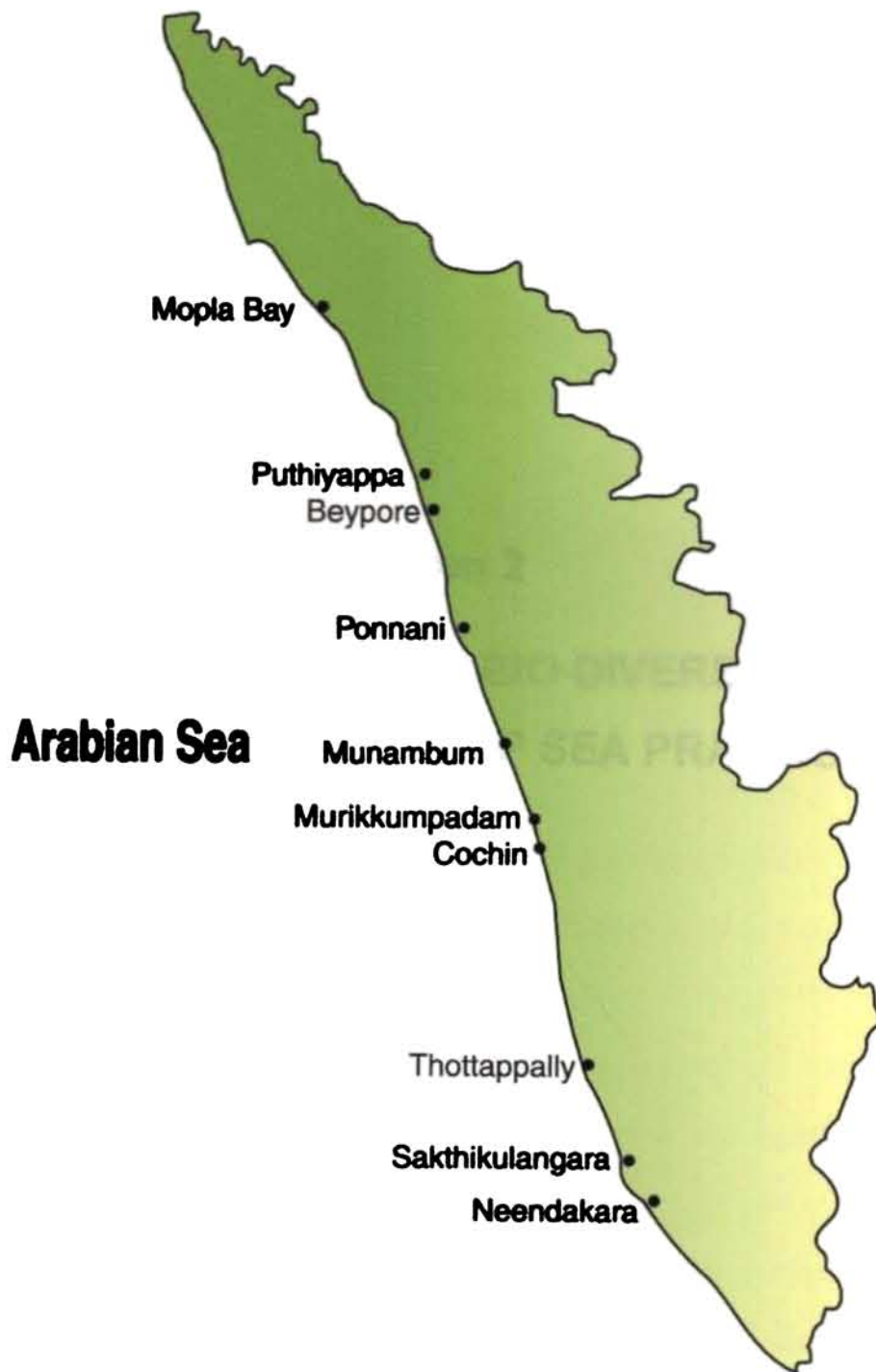
**Chapter 9** embodies the results of sex wise and maturity stage wise proximate composition analysis of *H.gibbosus* and *H.woodmasoni* besides the estimation of carotenoid concentration in different tissues of deep sea prawns.

The results of age and growth estimated separately for males and females in *H.gibbosus* and *H.woodmasoni* are presented in **Chapter 10** while results of the population dynamics of the above two species covering the stock assessment and the factors governing, such as mortality, exploitation rate, exploitation ratio and relative yield per recruit of the male and female population of *H.gibbosus* and *H.woodmasoni* are presented in **Chapter 11**. This is followed by **Chapter 12**, wherein the summary and recommendations of the study are given, which is followed by the list of references consulted.

Each chapter is organized with an introduction, which includes detailed review of the relevant literature followed by materials and

methods and results and discussion. The results of the study are also presented in the form of tables and graphs at the appropriate places.

**Fig 1.1**  
**Harbours of Kerala Selected for Study**





## **Section 2**

# **SYSTEMATICS AND BIO DIVERSITY ASSESSMENT OF DEEP SEA PRAWNS**

Chapter 2  
**SYSTEMATICS**

## 2.1 INTRODUCTION

Deep sea decapod crustaceans constitute one of the dominant high price groups of invertebrates in the marine fishery sector of Kerala although the structure and organization of their community are not well known as that of coastal penaeid prawns. In view of the increasingly prominent role played by deep sea prawns and prawn products in the economy of the country, the taxonomic identity of various species exploited from the deep sea fishing grounds off Kerala is an essential prerequisite for the sustainable development and management of deep sea prawn wealth of Kerala.

The deep sea prawns landed at various harbours of Kerala is an assemblage of wide array of species representing various families, the prominent being families Pandalidae, Aristeidae, Solenoceridae and Penaeidae while family Oplophoridae contributes to only a minor portion of the deep sea trawl catches in Kerala. There exist taxonomic ambiguities among various species of deep sea prawns harvested off Kerala coast due to their close resemblance in general appearance, thus dissecting out their morphometric characteristics becomes so imperative for sorting out taxonomic ambiguities and easy separation of various species. As the exploited stock comprised of an assemblage of both penaeideans and carideans, a delineation of variations associated with

the body parts such as rostral length, carination, length of podomeres, etc., are important as these characters are of great significance in the taxonomy of deep sea prawns. Hence, detailed knowledge on various morphometric and morphological parts are essential pre-requisites for the better understanding of the taxonomy of deep sea prawns.

According to George (1969), the morphological variation shown by a species are basically used as taxonomic tool in the crustacean systematics and the characters generally often given due importance are nature of rostrum and its spines, carapace, carinae and sulcii, carination of abdomen, telson and appendages. Johnson (1973) expressed the view that changes in the shape and armature of 2<sup>nd</sup> cheliped due to simple allometric growth process may serve as a unique character in differentiation of closely related species.

The taxonomy of deep sea prawns had been studied by a series of workers, among them, pioneering contributions are those of Dana (1852, 1855), Bate (1881, 1888), Milne-Edwards (1881,1883), Smith (1882, 1884), Ortmann (1890) Alcock (1901) De Man (1920) from Atlantic and Pacific Oceans. Some of the important works that succeeded were by Faxon (1896), Kemp (1906,1909), Milne-Edwards and Bouvier (1900, 1909), Sund (1920), Springer and Bullis (1956), Sivertsen and Holthuis (1956) from Atlantic waters, Calman (1909,1923,1925), Coutiere (1905, 1906, 1938), Riggio (1900,1905), Pesta (1913), Maurin (1961, 1963) and

Alvarez (1968) from Mediterranean waters, Monod (1933), Holthuis (1951) and Crosnier and Forest (1973) from African coasts, Allen (1967) from British waters, De Man (1911,1920) , Schmitt ( 1926) and King (1984) from south west Pacific , Faxon (1893,1895) , Chace (1936), Rathbun ( 1906), Bullis and Rathjen (1959) , Anderson and Lindner (1971) and Bullis (1956) and Chace (1992) from American and Mexican waters .

From the Indian waters, the earliest and most significant contributions on the taxonomy of deep sea prawns were made by Woodmason (1891, 1892) , Alcock (1899,1901,1906) , Alcock and Anderson (1899) and Lloyd (1907) from the pioneer exploratory surveys of R.I.M.S.S. INVESTIGATOR (1884-1925) . Balss (1925) from VALDIVIA (1898-1899), Ramadan (1938), Calman (1939) and Tirmizi (1960) from JOHN MURRAY (1933-1934) have also contributed to the knowledge on the occurrence of various species of deep sea prawns in the Indian Ocean region. John and Kurian (1959), Kurian (1964), George (1966), George and Rao (1966), Silas (1969) and Mohamed and Suseelan (1973) reported on the distribution and abundance of deep sea prawns based on the data collected by the exploratory research vessels CONCH, KALAVA, VARUNA, KLAUS SUNNANA, TUNA and VELAMEEN from south west coast of India. Later, Suseelan (1985) made detailed study on the taxonomy of deep sea prawns of south west coast of India based on the above exploratory surveys.

The linear measurement and function of different body parts, sexual dimorphism, sexual maturity, fecundity and changes in the weight-length relationship etc. are a few of the processes that are studied through morphometric analysis (Hartnoll, 1985). Both conceptual and empirical aspects on various linear body measurements in crustaceans have been studied by a number of workers notably by Hartnoll (1974,1978), Finney and Abele (1981), Huber (1985) and Blackstone (1986). Morphometric studies on the commercially important deep water shrimps are restricted to temperate waters by a few researchers based on very few number of morphometric characters of *H.reedi* and *A.antennatus* (Arana, 1970; Sardá *et al.*, 1995; Bas & Sardá, 1998). Whereas, no published information on the morphometric analysis of deep sea prawns have been made so far from tropical waters.

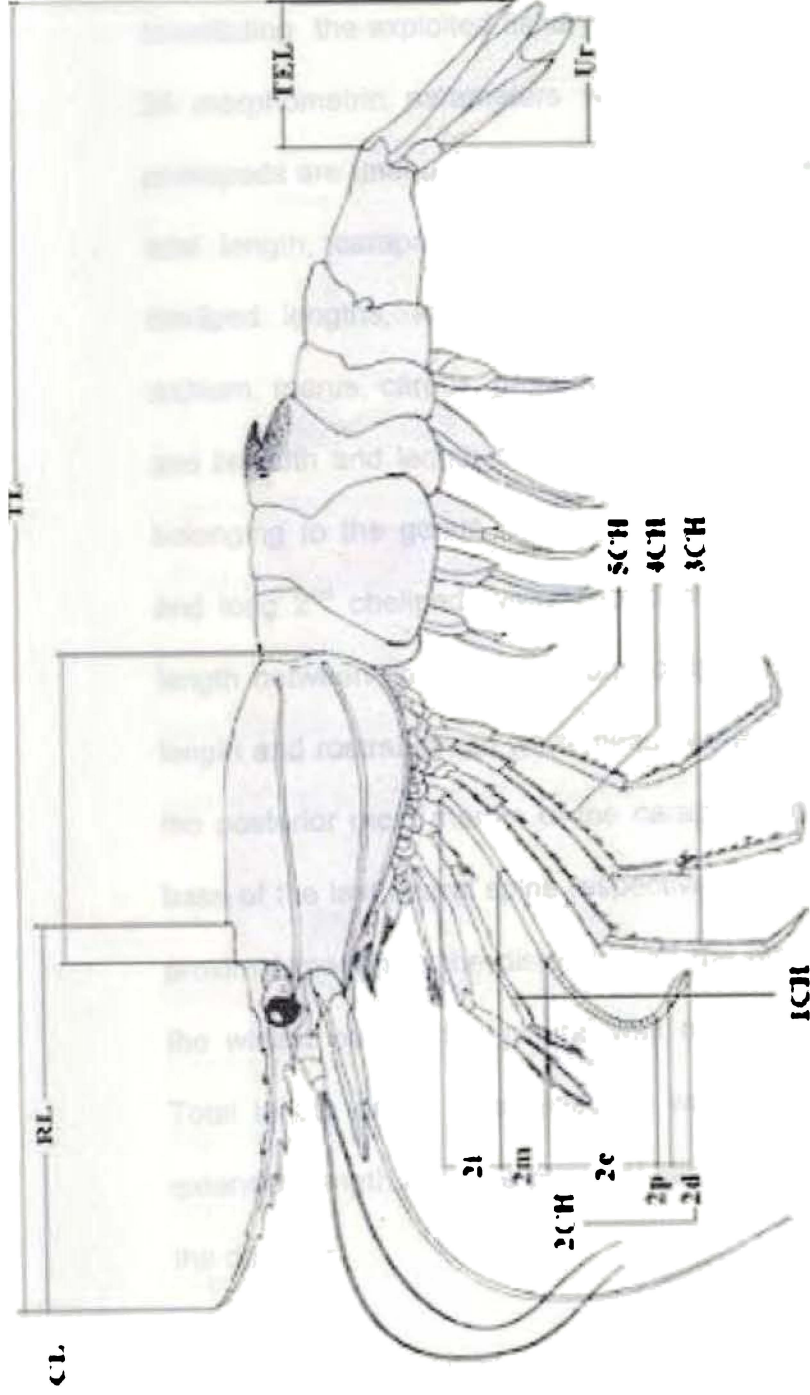
The exploited stock of deep sea prawns landed at various harbours of Kerala since 1999, is an assemblage of wide variety of species belong to families Penaeidae, Pandalidae, Aristeidae, Solenoceridae, Oplophoridae, etc., which are very new to the fishery and the individual species often poses much difficulty for their easy identification. Therefore, correct identification of deep sea prawns landed at various harbours based on easily measurable or identifiable characters are found imperative. So the present study is carried out with the following objectives:

1. To investigate the organic diversity exists among the different deep sea prawns off Kerala and to prepare a key for their easy identification.
2. To quantify the morphometric variability among the deep sea prawns of Kerala.
3. To establish allometric relationship between various morphometric characters with a view to bring out species-specific ratios as well as relationships.

## 2.2 MATERIAL AND METHODS

Specimens for the study were collected from the commercial deep sea prawn landings at Sakthikulangara, Cochin, Munambum and Murikkumpadam harbours of Kerala by the deep sea trawlers operated at a depth of 150-600m depth off Kerala coast during September 2000 to April 2003. Species level identification of the deep sea prawns were done following Alcock (1901) and Suseelan (1985).

Deep sea prawn species excluding the genus *Heterocarpus* of Pandalidae family, the morphometric measurements were made on nineteen characters, with a view to establish the extent of morphometric



TL- Total length

CL- Carapace length

RL- Rostral length

TEL- Telson length

Ur- Uropod length

2i- Ischium of 2nd cheliped

2m - Merus of 2nd cheliped

2c - Carpus of 2nd cheliped

2p - Propodus of 2nd cheliped

2d - Dactylus of 2nd cheliped

1CH- Length of 1st cheliped

2 CH- Length of 2nd cheliped

3CH- Length of 3rd cheliped

4CH- Length of 4th cheliped

5 CH- Length of 5th cheliped

2ai - Short ischium of 2nd cheliped\*

2am - Short merus of 2nd cheliped\*

2acd - Short carpus of 2nd cheliped\*

2asp - Short propodus of 2nd cheliped\*

2ad - Short dactylus of 2nd cheliped\*

\* For *Heterocarpus* species

**Fig. 2.1 Schematic diagram showing various morphometric measurements recorded in deep-sea prawns**



variations that exist among the species coming under these groups in order to elucidate the taxonomic peculiarity of different species constituting the exploited fishery. Whereas in the genus *Heterocarpus*, 24 morphometric parameters were observed since the 2<sup>nd</sup> pair of pereopods are unequal in total length. The parameters so examined are total length, carapace length, rostral length, 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> cheliped lengths, length of podomeres in the second cheliped viz. ischium, merus, carpus, propodus and dactylus, 2<sup>nd</sup> pleural length, depth and breadth and length of telson and Uropod (Fig 2.1). For the species belonging to the genus *Heterocarpus*, the measurements of both short and long 2<sup>nd</sup> chelipeds were recorded. Total length was taken as the length between tip of the rostrum to tip of the telson whereas carapace length and rostral length were measured from posterior margin of orbit to the posterior most margin of the carapace and tip of the rostrum to the base of the last rostral spine respectively. Telson was measured from its proximal margin to the distal tip and the pleural width was measured at the widest part of the pleural wall of the second abdominal segment. Total length of the chelipeds and walking legs were taken along their extended length from the proximal base of the ischium to the distal end of the dactylus.

32 males and 29 females of *H.gibbosus*, 25 males and 23 females of *H.woodmasoni*, 5 males and 10 females of *H.laevigatus*, 20 males and 21 females of *P.spinipes*, 20males 29 females of *P.martia*, 20males and

21 females of *P. ensis*, 40 males 35 females of *Aristeus alcocki*, 30 males 32 females of *Parapenaeus investigatoris*, 30 males and 40 females of *Penaeopsis jerry*, 40 males 42 females of *Metapenaeopsis andamanensis*, 30 males and 40 females of *AcanthePHYRA sanguinea*, 30 males and 30 females of *Oplophorus typus*, 16 males and 18 females of *Plesionika alcocki*, 20 males and 20 females of *AcanthePHYRA armata* were used for the morphometric analysis.

Ratios between the above listed morphometric measurements with reference to total length, carapace length, lengths of carpus and merus of 2<sup>nd</sup> cheliped were worked out, and compared using ANOVA (Snedecor and Cochran, 1967). The ratios, which were found statistically significant, were further subjected to t-test (Snedecor and Cochran, 1967) for establishing species wise variation.

To establish the allometric relationship between various body parts, method of least squares (Snedecor and Cochran, 1967) was employed by applying the equation  $y = a + b x$  where a and b are regression parameters. From the results of regression analysis of 19 morphometric characters, 7 characters such as total length, carapace length, rostral length and lengths of podomeres of 2<sup>nd</sup> pair of pereopods (ischium, merus, carpus and propodus), which are invariably used for taxonomic purposes, were selected for Analysis of Covariance (ANACOVA) and further by t-test (Snedecor and Cochran, 1967).

## 2.3 RESULTS

Fifteen species of deep sea prawns coming under three super families, 5 families and 10 genera were identified from the exploited stock of deep sea prawns landed in Kerala. Detailed description of 15 species together with complete synonymy and regional distribution are also presented.

### 2.3.1. Classification of deep sea prawns

#### Infra order Penaeidea

Super family *Penaeoidea* Rafinsque

##### Family : Penaeidae Rafinsque

Genus *Parapenaeus* Smith

1. *Parapenaeus investigatoris* Alcock and Anderson  
(1899)

Genus *Penaeopsis* Bate

2. *Penaeopsis jerryi* Perez Farfante (1979)

Genus *Metapenaeopsis* Bouvier

3. *Metapenaeopsis andamanensis* Wood-Mason  
(1891)

##### Family: Aristaeidae Wood-Mason

Genus *Aristeus* Duvernoy

4. *Aristeus alcocki* Ramadan (1938)

**Family: Solenoceridae Wood-Mason**Genus *Solenocera* Lucas

5. *Solenocera hextii* Wood-Mason (1891)

**Infra order Caridea**Super family *Pandaloidea* Haworth**Family Pandalidae Haworth**Genus *Heterocarpus* A. Milne-Edwards

6. *Heterocarpus gibbosus* Bate, 1888
7. *Heterocarpus woodmasoni* Alcock, 1901
8. *Heterocarpus laevigatus* Bate, 1899

Genus *Parapandalus* Borradaile

9. *Parapandalus spinipes* (Bate, 1888)

Genus *Plesionika* Bate

10. *Plesionika martia* A. Milne-Edwards, 1883
11. *Plesionika ensis* de Man, 1920
12. *Plesionika alcocki* (Anderson)

Super family *Oplophoroidea* Dana**Family Oplophoridae Dana**Genus *Acanthephyra* A. Milne-Edwards

13. *Acanthephyra sanguinea* Wood-Mason, 1892
14. *Acanthephyra armata* A. Milne-Edwards, 1881

Genus *Oplophorus* H.Milne-Edwards

15. *Oplophorus typus* H.Milne-Edwards , 1837

### 2.3.1.1. Key to the shrimp families of commercially important deep sea prawns

1. Pleurae of second abdominal somite overlapping the first and third segments; 3rd pereopod with out chela.....  
 .....Superfamily Pandaloidea...2  
 Pleurae of 2<sup>nd</sup> abdominal somite not overlapping the first segment, 3<sup>rd</sup> pereopod with chela.....  
 .....Superfamily Penaeoidea ...4
2. Carpus of the second pair of pereopods divided in to numerous segments.....3  
 Carpus of the second pair of pereopod un segmented .....  
 .....Superfamily Oplophoroidea
3. Chelae of the second pair of pereopods very minute and slender ..... Family Pandalidae  
 Chelae of the 2<sup>nd</sup> pair of pereopods well developed and stout.....  
 .....Family Oplophoridae.
4. Cervical sulcus reaching <2/3 the distance from the hepatic spine to the top of the carapace; post orbital spine lacking ; 4<sup>th</sup> leg lacks epipod.....5

- Cervical sulcus reaching the top of the carapace; post orbital spine present ;4<sup>th</sup> leg with an epipod .....Family Solenoceridae
5. Exopods present on 2<sup>nd</sup> and 3<sup>rd</sup> maxillipeds ; antennular flagella subequal and originate distally on the 3<sup>rd</sup> segment ; 5<sup>th</sup> leg lacks epipod .....Family Penaeidae
- Exopod absent on the 2<sup>nd</sup> and 3<sup>rd</sup> maxillipeds; upper antennular flagellum much shorter than lower and originate near base of the 3<sup>rd</sup> segment; epipod present on 5<sup>th</sup> leg.....Family Aristaeidae

### 2.3.1.2. Key to the commercially important deep sea prawns of the super family Penaeoidea

1. Inner border of the antennular peduncle with a setose scale;podo-branchiae absent .....2
- No setose scale on the inner border of the antennular peduncle ; podobranchiae present ;pleurobranchia on 10-13 segments reduced to mere papillae.....*Aristeus alcocki*
2. Exopodite of the external maxillipeds large , absence of a branchio-cardiac sulcus in the branchio stegal region.....3
- Exopodite of the external maxillipeds rudimentary presence of 'L' shaped branchio-cardiac sulcus in the branchiostegal region .....

- ..... *Solenocera hextii*
3. Symmetrical petasma; no basal spine at 3<sup>rd</sup> maxilliped  
 .....4
- Presence of a jointed asymmetrical petasma ; 3<sup>rd</sup> maxilliped and 1<sup>st</sup>  
 pereopods with a basal spine.....
- ..... *Metapenaeopsis andamanensis*
4. A long fissure on either side of the carapace through out the entire  
 length; rostrum not glabrous and less than 1/3<sup>rd</sup> the length of  
 carapace .....*Parapenaeus investigatoris*
- No fissure on carapaceal wall; rostrum glabrous, as long as  
 carapace.....*Penaeopsis jerryi*

### 2.3.1.3. Key to the commercially important deep sea prawns of the super family Pandaloidea

1. Carapace hard and rigid with longitudinal carinae ; 2<sup>nd</sup> pair of  
 pereopods unequal.....*Heterocarpus*...3
- Carapace smooth without a longitudinal carinae ; 2<sup>nd</sup> pair of  
 pereopods equal .....2
2. Epipodites present in first and second pair of pereopods  
 .....*Plesionika* .....5

Epipodites absent in all the pereopods ; telson longer than exopodite of uropod .....*Parapandalus spinipes*

3. 3<sup>rd</sup> abdominal tergum with out spines, 6<sup>th</sup> abdominal segment less than 5<sup>th</sup> .....4

3<sup>rd</sup> abdominal tergum ends in a sharp spine dorsally ; 6<sup>th</sup> segment more than doubles the length of 5<sup>th</sup> .....  
.....*Heterocarpus woodmasoni*

4. Only one tooth present anterior to orbit ; dorsal carapaceal ridge not prominent ..... *Heterocarpus laevigatus*

More than two teeth anterior to orbit; dorsal carapaceal ridge very prominent ..... *Heterocarpus gibbosus*

5. Rostrum armed with a series of closely packed spines ventrally; distinct ocellus .....6

Rostrum armed with distantly placed spines; ocellus absent.....*Plesionika alcocki*

6. 3<sup>rd</sup> abdominal tergum posteriorly protrudes as a sharp dorsal spine .....*Plesionika ensis*

3<sup>rd</sup> abdominal tergum with out spines but protrudes as a wavy margin.....*Plesionika martia*



### 2.3.1.4. Key to the commercially important deep sea prawns of the super family Oplophoroidea

1. Antennal scale smooth with out any serrations; expopods of 1<sup>st</sup> pair of pereopods not foliaceous .....*Acanthephyra* ...2

Antennal scale sharply serrated ; expopods of 1<sup>st</sup> pair of pereopods foliaceous .....*Oplophorus typus*

2. Post antennal spine well developed , telson shorter than exopod of Uropod ; a single large tooth on ventral .....*Acanthephyra armata*

Post antennal spine minute; telson longer than exopod of uropod ; 5-6 teeth on ventral .....*Acanthephyra sanguinea*

### 2.3.2. Species Description

#### 2.3.2.1. *Parapenaeus investigatoris* Alcock and Anderson, 1899

Plate: 2.1 A

**Synonymy:** *Parapenaeus investigatoris* Alcock and Anderson ,1899 ; de Man ,1911 ; Ramadan, 1938 ; Kubo ,1949 ; Barnard ,1947 ; George , 1966 ; 1979 ; Silas , 1969 ; Starobogatov , 1972 ; Mohamed and Suseelan , 1973 ; Ivanov and Hassan ,

1976; Kurian and Sebastian, 1976 ; Holthuis, 1980 ;  
Suseelan , 1985.

*Parapeneus fissures* Alcock and Anderson ,1894 .

*Peneus (Parapeneus) investigatoris* Alcock 1901 .

*Parapeneus investigatoris* Alcock 1906.

*Parapeneus murrayi* Ramadan 1938 .

**Vernacular name:** Chuvanna Pullan

**Diagnosis:** Up tilted convexes rostrum, 6<sup>th</sup> abdominal tergum very long.

**Distinctive characters:**

Rostrum very short, slightly tilted upwards and convexed dorsally above the orbital region. Dorsally rostrum armed with 6-7 teeth in addition to the epigastric tooth placed at the middle of rostral carina. Rostrum runs backwards as post rostral carina that ends at posterior margin of carapace. Hepatic and branchio stegal spines very prominent. A clearly distinguishable groove starts from antennal spine, runs along entire carapace and terminates at posterior border. Body compressed, 4<sup>th</sup> to 6<sup>th</sup> abdominal terga sharply carinated and each of tergum ending in a spine. 5<sup>th</sup> abdominal tergum less than half the length of 6<sup>th</sup>. Telson smaller than endopod of uropod and carries a pair of immovable spine at base of terminal spines. Eyes brownish red and moderate in size. Antennular flagella almost equal in size in both male and female, <sup>3</sup>/<sub>4</sub><sup>th</sup> the length of carapace. Ischium and basis of 1<sup>st</sup> pereopod bears very prominent spines; 2<sup>nd</sup> pereopod exceeding antennular peduncle while 3<sup>rd</sup>

and 4<sup>th</sup> pereopods are as long as peduncle. Petasma large leaf like, one-third the length of carapace. Thelycum trilobed and semicircular in shape.

**Colour:** Light pink through out the body.

**Distribution & economic importance:** South west coast of India (Suseelan, 1985), Andaman sea, Bay of Bengal, Gulf of Mannar, Japan and Malay Archipelago (Alcock, 1901). Due to the short body and low meat content it is of only minor economic importance in the commercial deep sea prawn fishery of Kerala.

### **2.3.2.2. *Penaeopsis jerryi* Perez Farfante , 1979**

**Plate:** 2.1 B

**Synonymy:** *Metapeneus rectacutus* Wood – mason, 1891.

*Peneus (Parapeneus) rectacutus* Alcock, 1901; Alcock and McArdle , 1901.

*Parapeneus rectacutus* Alcock, 1902 ; 1905 ; 1906 ; Kemp and Sewell , 1912 .

*Penaeopsis rectacutus* Ramadan ,1938; Sewell , 1955 ; Kurian , 1964 ; Silas, 1969 .

*Penaeopsis rectacuta* Holthuis and Rosa, 1965; George, 1966, 1979; Longhurst, 1971; Starobogatov, 1972; Crosnier and Jouannic, 1973; Mohamed and suseelan, 1973; Ivanov and Hassan, 1976; Thomas, 1979; Holthuis, 1980.

*Penaeopsis jerryi* Perez Farfante, 1979, 1980; Miquel 1984.

**Vernacular name:** Chuvanna pullan

**Diagnosis:** very long antennal flagellum, glabrous body, very long telson.

**Distinctive characters:**

Rostrum long, straight with a very slight double curve distally; armed with 12-13 teeth dorsally in addition to the epigastric tooth. Glabrous cephalothorax and abdomen, rostrum runs backwards as adrostral carina which fades at the half of the carapace. Cervical groove very prominent. Hepatic spine and antennal spine located at the same level. 6<sup>th</sup> abdominal somite less than double the length of 5<sup>th</sup>; telson longer than endopodite of caudal swimmeret, laterally armed with 3 pairs of spines. Abdominal carination starts from end of 3<sup>rd</sup> tergum, very prominent in 4<sup>th</sup> to 6<sup>th</sup> terga and ends in a spine. Inner antennular flagellum in male very much shorter than outer while in female they are equal in length and surpasses the distal end of antennular peduncle. Scaphocerite as long as the rostrum. Antennal flagellum very long, more than twice the length of the body. 1<sup>st</sup> pereopod reaching as long as carapocerite, while 2<sup>nd</sup> surpassing carapocerite. 4<sup>th</sup> and 5<sup>th</sup> pereopods reaching middle and distal extremity of antennular scale.

Thelycum trilobed and sub elliptical in structure. Petasma of the 1st pleopod formed by the union of endopodites, which fused to form a median canal.

**Colour:** pinkish red.

**Distribution & economic importance:** Andaman Sea, Southwest coast of India (Suseelan, 1985), Bay of Bengal, off Mozambique and Madagascar (Starobogatov, 1972). Moderate economic importance due to the bigger size in comparison to pandalids.

**2.3.2.3. *Metapenaeopsis andamanensis* Wood-Mason  
(1891)**

**Plate: 2 .2 A**

**Synonymy:** *Metapenaeopsis philippinensis* var. *andamanensis* Wood-Mason , 1891.

*Peneus (Metapeneus) coniger* var. *andamanensis* Alcock ,1901.

*Metapeneus coniger* var. *andamanensis* Alcock ,1906.

*Penaeopsis coniger* var. *andamanensis* de Man , 1911;  
Kemp and Sewell, 1912.

*Penaeopsis philippii* Calman, 1923 .

*Metapenaeopsis coniger* Kubo, 1949 .

*Metapenaeopsis andamanensis* Hall, 1961, 1962; George, 1966; Starobogatov, 1972; Champion, 1973; Mohamed and Suseelan, 1973; Ivanov and Hassan, 1976; Kurian and Sebastian, 1976; Thomas, 1979; Holthuis, 1980.

**Vernacular name** : Vella chemmen .

**Diagnosis:** 3-6<sup>th</sup> abdominal terga sharply carinated.

**Distinctive characters:**

Rostrum straight and ascended upwardly, dorsally armed with 7 teeth in addition to epigastric tooth. In female, free end of the rostrum surpassing antennular peduncle while in male its free tip hardly reaches 2<sup>nd</sup> segment of the antennular peduncle. Rostrum runs backwards as adrostral carina, which runs half of the carapace. Cervical and hepatic grooves are indistinct. Hepatic, pterygostomian, antennal and hepatic spines are well defined. Abdomen laterally compressed and moderately fleshy. 3-6 abdominal terga sharply carinated, posteriorly, 6th tergum ends as a sharp spine and laterally also ventro lateral angles ending to spine like processes. Subcarinae on either side of median carinae of 4<sup>th</sup> and 6<sup>th</sup> segment vaguely marked. 6<sup>th</sup> segment very strongly compressed and double the length of 5<sup>th</sup> segment. Telson shorter than endopod of uropod ends as a pointed sharp spine, armed with 3 pairs of movable spines arranged dorso lateral angle, antennular flagella unequal. Scaphocerite armed with short lateral spine; 3<sup>rd</sup> maxilliped with a well developed basal spine. 2<sup>nd</sup> pereopod equal with a basal spine, extending to more than half of scaphocerite while 4<sup>th</sup> and 5<sup>th</sup> pereopods reaching half length of scaphocerite.

Petasma half the length of carapace; its distoventral flap concentrically coiled. Appendix masculina covered with small setae along its outer margin. Thelycum deeply undermined; the middle lobe broad and recurved at its free end.

**Colour:** Yellowish orange through out.

**Distribution and economic importance:** Andaman Sea, Southwest coast of India (Alcock, 1901) Bay of Bengal, Malacca Strait, Kei islands, Japan (Holthuis, 1980). *M.andamanensis* has only minor economic importance in the deep-sea prawn fishery.

#### **2.3.2.4. *Aristeus alcocki* Ramadan, 1938**

**Plate:** 2 .2 B

**Synonymy:** *Aristeus semidentatus* Wood-mason, 1891; Alcock, 1901(*nec Aristeus semidentatus* Bate, 1881); Alcock and Mc Ardle, 1901; Kemp and Sewell, 1912; George 1966,1979; Mohamed and Suseelan, 1968, 1973; Silas, 1969; Thomas, 1979.

*Aristeus alcocki* Ramadan,1938; George,1966,1979; Silas 1969; Mohamed and Suseelan ,1973; Kurian and Sebastian ,1976; Holthuis, 1980.

**Vernacular name** : Red Ring.

**Diagnosis:** Bright red colour, very long rostral spine in females and glabrous body.

**Distinctive characters:**

Very prominent sharp rostrum with teeth present only on the dorsal side. Polished and shiny carapace. In female, rostrum very longer than carapace, more than double the length of antennal scale and curved

upwards in front of the orbit. Two spines prominent and located above carapace while epigastric spine very minute and located above cervical groove. In males, rostrum short, nearly straight and reaches only up to the distal end of antennular peduncle, end of which is slightly tilted upwards. Post rostral carina runs backwards and ends beyond gastric region. Postorbital spine very minute and sharp while branchio-stegal spine comparatively larger. Cervical groove appears as a very faint wavy margin while postorbital crest indistinct. 1-3 abdominal tergum smooth with out any distinct carination. Posterior 1/3<sup>rd</sup> of 4<sup>th</sup> abdominal tergum carinated which ends in to a sharp spine followed by 5<sup>th</sup> and 6<sup>th</sup> terga which also carinated and ends posteriorly as spines. 6<sup>th</sup> abdominal segment more than double the length of 5<sup>th</sup>. Telson very short, less than half the length of exopod of uropod, armed with 3 minute spines. Antennal scale very large supported by a sharp spine on either side. External maxillipeds are same length in males and antero-lateral angle of propodite prolonged beyond articulation of dactylus. 1st pereopod hardly surpasses scaphocerite. 4<sup>th</sup> and 5<sup>th</sup> pereopods long slender of which 5<sup>th</sup> pair of legs longest reaches about half a dactylus beyond tip of antennal scale. Petasma thin and leaf like, distal margin bluntly pointed and bent, while proximal border provided with a papilla like projection. Thelycum is a shield like plate located in between the 4<sup>th</sup> and 5<sup>th</sup> pereopods, distal end of which is pointed; sternal plate highly depressed and bordered by a oblique ridge on either side.



**Colour:** Abdomen bright pink in colour edged with reddish bands nearer posterior border of segments, cephalothorax, maxillipeds, pereopods, pleopods and caudal swimmerets are dark red in colour.

**Distribution and economic importance:** Arabian Sea, Gulf of Aden, Cape Comorin, Bay of Bengal (Alcock, 1901). The Arabian Red Shrimp (Holthuis 1980) locally known as the 'Red ring', is the most valuable deep sea prawn and forms the most sought after species for export.

#### **2.3.2.5. *Solenocera hextii* Wood-Mason, 1891**

**Plate: 2.3 A**

**Synonymy** *Solenocera hextii* Wood-Mason, 1891; Alcock and Anderson, 1894 ; Alcock ,1901 ; de Man, 1911; Ramadan, 1938; Anderson and Linder, 1945; George, 1966, 1979; Muthu ,1968 ; Silas, 1969 ; Starobogatov, 1972; Mohamed and Suseelan, 1973; Tirmizi and Bashir, 1973; Kurian and Sebastian ,1976; Thomas, 1979; Holthuis, 1980; Miquel, 1984.

**Vernacular name** : Mulaku chemmeen.

**Diagnosis:** Glabrous body, an 'L' shaped marking on the brachio-cardiac zone of carapace.

**Distinctive characters:**

Polished, glabrous and stout segment, rostrum ascendant straight upwardly, armed dorsally with 7 well-defined teeth and runs backwards as

a clearly defined carina till the posterior border of carapace. Anteriorly, rostrum reaches distal end of basal joint of antennular peduncle. A deep cut in the rostral carina at the level of cervical groove; antennal post orbital and hepatic spines prominent, a well defined supra hepatic spine on cervical carina present. A very prominent 'L' shaped branchio-cardiac sulcus present on either side of branchio stegal region. Its posterior limb almost parallel with adrostral carina. Abdominal terga sharply carinated, runs from the posterior end of 3<sup>rd</sup> somite to 6th segment and ends as a sharp spine. Similar spines present on postero-ventral corners also. Telson trifurcate, as long as exopod of uropod; distal margin of exopod of uropod bears a distinct spine.

Eyes large. Antennular flagella 3/4<sup>th</sup> the length of carapace, upper flagellum longer than lower and deeply channelled to form a tube like structure. Scaphocerite longer than the distal end of the antennular peduncle. Exopodite of 2<sup>nd</sup> maxillipeds is small and filamentous. External maxillipeds slightly surpassing antennular peduncle; 5<sup>th</sup> pereopod longer and relatively slender than other pereopods, over reaching antennular peduncle by length of its dactylus.

Petasma in 1<sup>st</sup> pleopod having a ventromedian tubule, armed with antero-laterally with very minute spinules. Appendix masculina elongate with narrow rounded apex; having closely set setae, while appendix interna very short, scale like covered with minute setae on lateral

margins. Thelycum with glabrous elevated sternal plates located between 5th pereopods, is quadrangular in appearance.

**Colour:** Colour of the specimen is light pink. Rostral carina and abdominal terga tinged with bright red border. Uropod deep red and antennular flagella banded with red and white.

**Distribution and economic importance:** Arabian Sea, Southwest coast of India, Bay of Bengal, (Alcock, 1901). One of the important commercial species, off Kerala coast at 100-200m.

#### **2.3.2.6. *Heterocarpus gibbosus* Bate, 1888**

**Plate: 2.3. B**

**Synonymy:** *Heterocarpus gibbosus* Bate, 1888; Wood-mason ,1892; Alcock , 1901; Kemp and Sewell, 1912; de Man ,1920; Balss,1925; George and Rao ,1966; Silas ,1969; Mohammed and Suseelan, 1973; Suseelan ,1974; Kurian and Sebastian,1976; Thomas, 1979; Holthuis, 1980; King, 1984.

**Vernacular name:** Thakkali Chemmeen.

**Diagnosis:** A striking dorsal thickening on the third abdominal tergum.

**Distinctive characters:**

Rostrum in adults short, stout and recurved upwards in front of the eyes. In young ones, rostrum very long and prominent. Rostrum armed with 6-7 teeth in carapace and 3-4 teeth in anterior dorsal side and 13-15 teeth on the ventral side. Numerous thin hairs appear between the sharp teeth on carapace. Rostrum runs backwards as very strong compressed and highly elevated carina, which ends nearer to the posterior border of carapace. Width of carina crest in front of the eye, 4-5mm in thickness. Two lateral carinae present on carapaceal wall. Post ocular carina very well differentiated from post antennal carina and starts behind middle of ocular peduncle and runs backwards to a shallow depression in middle, thereafter elevated and ends in posterior border of carapace parallel to rostral carina. Maximum depth between lowest portion of post ocular carina and rostral crest 10mm. Post-antennular carina also prominent, runs backwards as a straight elevation and ends in posterior three fourth of carapace in branchial region. Branchio-stegal spine projected sideways, not very sharp as postorbital spine, reaches at the base of antennal scale. Antennal scale broad in middle tapering towards proximal end. Inner margin of which is arranged with a tuft of setose hair while a feeble and flat spine supports outer side. Two spine like processes cover outer border of antennal scale. First maxillipeds are very stouter than first pair of pereopod, reaches in front of antennal scale. First pair of pereopod very thin, long occupies 27.85% of total length. Second pair of pereopod

slightly thicker than rest of the walking legs and unequal in size and length. Shortest one 79% in the carapace length while longer one 97.3% in carapace length. The ischium of second shorter pereopod flat while carpus very longer than merus provided with seven rings like constrictions at its middle portion. Chela very prominent and well articulated.

Other pair of second pereopod, slender and tapering towards the end, which finally extends more than antennal scale. Ischium slightly flattened and lined with minute hairs on inner side. 7-9 constrictions present in merus while 14-20 constrictions present in carpus. Carpus very long and ends in small chela. In the rest of the three pair of pereopods, dactylus is microscopic. Third pair the longest, reaches beyond antennal scale; about 10-15 minute spines arranged on posterior border of merus and in rest of pereopodal segments, the inner side of merus lined with minute spinules while the rest of the joints lined with microscopic spinelets.

The abdomen thick, fleshy and smooth. Sternal plate on either side of second abdominal segment very broad in female. Third tergal plate slightly thickened and elevated into a prominent hump, but not carinated. Thereafter the shape of the body slopes down sharply up to the fifth segment. Sternal plates from four to sixth segment ends on either side into pointed spines. In addition to this, another pair is located at posterior border of sixth segment on either side of the origin of telson. Telson 13%

in total length, middle portion of which is flattened and the sides bent down wards. 4 pairs of movable spines arranged on the dorso-lateral angles on either side. At the distal end, another 3 pairs of minute sharp spines are arranged of which the outer one is largest. Uropod arranged with smaller cilia on its outer margin. In females the theylical space between 4<sup>th</sup> and 5<sup>th</sup> pereopod very broad with no clearly demarcated projection at the junction between coxipodite of 5<sup>th</sup> pereopod and sternal plate.

**Colour:** Body bright pinkish orange in colour. Anterior half of rostrum whitish. Tip of maxillipeds dark red while rest of pereopods marked with white and pink.

**Distribution and economic importance:** Southern coasts of India, Andaman sea, Bay of Bengal, Pacific Islands (King, 1984), off Tablas Island, Bali Sea and Kei Islands. Second commercially important species, available in good quantities off Kerala.

### **2.3.2.7. *Heterocarpus woodmasoni* Alcock, 1901**

**Plate:** 2.4 A

**Synonymy:** *Heterocarpus woodmasoni* Alcock, 1901; Alcock and McArdle, 1901; de Man, 1920; Balss, 1925; Calman, 1939; George and Rao, 1966; Silas, 1969; Mohamed and Suseelan, 1973; Suseelan, 1974; Kurian and Sebastian, 1976; Holthuis, 1980; Suseelan, 1985.

**Vernacular name:** Mulaku Chemmeen.

**Diagnosis:** Presence of a sharp curved spine on the 3<sup>rd</sup> abdominal tergum.

**Distinctive characters:**

Integument hard and rigid, cephalothorax large. Rostrum more than half the length of carapace, long and slender towards the edge, armed with 9-10 teeth dorsally and 6-8 teeth on ventral margin. Dorsally 2-3 spines located behind orbits and continued backwards as post rostral carina and end near posterior margin of carapace. On ventral side spines very minute, start from origin of antennular peduncle and armed with very small setose hairs. In juveniles, rostrum very long and recurved upwards. Post antennular carina projects anterior as a sharp spine at the base of ocular peduncle and runs backwards as an elevation, which ends, at posterior end of carapace. Post antennal carina also projected as branchio stegal spine that runs parallel to post antennular carina and stops at the extreme posterior border of carapace.

Abdominal terga smooth and polished. 3<sup>rd</sup> tergum armed with a projection that ends in middle as a spine like processes. Posterior half of 3<sup>rd</sup> to 5<sup>th</sup> terga weakly carinated. While in the 6<sup>th</sup>, tergum bent inwardly in the middle. 6<sup>th</sup> segment slender and more than double the length of 5<sup>th</sup>.

Telson very long almost surpasses distal end of endopodite of uropod, armed with 5 pairs of movable minute spines located at dorso-lateral angle, which starts from middle, also a pair of very minute tooth

present at its distal end. Eyes large and brownish black. Antennal peduncle surrounded with minute hairs. Scaphocerite thin, leaf like, supported by a flat feeble spine. 3<sup>rd</sup> maxilliped very stout and prominent, armed distally with very minute spinules; its exopod well developed. 1<sup>st</sup> pair of pereopod short and slender, reaching two third of scaphocerite . 2<sup>nd</sup> pair of pereopod unequal, left leg is long and slender, surpassing scaphocerite . 3<sup>rd</sup> pair of pereopod over reaching scaphocerite , while 4<sup>th</sup> and 5<sup>th</sup> feeble and slender .

**Colour:** Colour of the specimen pale pinkish through out the body. Uropod and pleopods dark red in colour.

**Distribution and economic importance:** South west coast of India, Andaman sea, Bay of Bengal, Indo – pacific, East Africa to Kei Islands. Commercially very important, its landing is very good and well preferred for export.

### **2.3.2.8. *Heterocarpus laevigatus* Bate, 1899**

**Plate:** 2.4 B

**Synonymy:** *Heterocarpus laevigatus* Spence Bate, 1899: Anderson, 1896.

**Vernacular name:** Mulaku Chemmeen

**Diagnosis:** A single tooth in front of the carapace.

**Distinctive characters:**



Rostrum three fourths length of carapace, strongly recurved , very much similar to *H. gibbosus*. 10-16 serrations ventrally; while a single tooth present dorsally in front of eye, beyond which rostrum very smooth. Adrostral crest armed with 5 serrations. 3<sup>rd</sup> abdominal tergum projected as a prominent hump like process as that of *H.gibbosus* . Branchio stegal spine large and projects beyond orbital spine. Antennular scale sharp and extend beyond the 2<sup>nd</sup> segment of the antennular peduncle. 3<sup>rd</sup> pair of pereopod is longer than other walking legs. Other body structures are same as that of *H.gibbosus* .

**Colour:** Pinkish orange.

**Distribution and economic importance:** Arabian Sea (Alcock, 1901), Hawaii (Struhsaker & Aasted, 1974;Clarke, 1972), Guam (Wilder, 1974), New Caledonia (Intes, 1978), Madagascar (Crosnier and Jouannic, 1973) Reunion (Gueze, 1976). Available only in small numbers and do not support a fishery .

### **2.3.2.9. *Parapandalus spinipes* (Bate, 1888)**

**Plate:** 2.5 A

**Synonymy:** *Plesionika spinipes* Bate, 1888 .

*Pandalus (Parapandalus ) spinipes* Alcock ,1901; Chilton, 1911.

*Plesionika spinipes grandis* Doflein ,1902 .

*Plesionika spinipes grandis* Balss ,1914 .

*Parapandalus spinipes* de Man, 1920; Calman, 1939; George and Rao, 1966; Silas, 1969; Mohamed and Suseelan, 1973 ; Suseelan , 1974; Thomas, 1979 ; Holthuis ,1980; Suseelan , 1985.

**Vernacular name:** Chuvanna Pullan.

**Diagnosis:** Rostrum armed with series of serrations both dorsally and ventrally.

**Distinctive characters :**

Rostrum very long and slightly ascended beyond antennular peduncle, evenly and closely packed with serrations throughout margin with 42-45 teeth on dorsal and 30-38 teeth on ventral. Post rostral crest hardly reaches middle of the carapace. Carapaceal and abdominal wall smooth. Posterior border of 3<sup>rd</sup> abdominal tergum slightly convex, but not produced in to a spine. 6<sup>th</sup> somite longer than 5th segment but shorter than telson. Telson a little longer than the endopodite of uropod armed with three pairs of short movable spines on dorso lateral angle and three pairs on distal extremity. Scaphocerite long and acute, disto lateral spine prominent and sharp. External maxillipeds surpassing scaphocerite by their terminal joint. First pair of pereopod slender, slightly longer than 3<sup>rd</sup> maxilliped and ends in a microscopic chela, which is hidden in a tuft of setae. Legs of 2<sup>nd</sup> pair are equal and slender, reach just beyond the terminal joint of 3<sup>rd</sup> maxillipeds. 3<sup>rd</sup> to 5<sup>th</sup> pereopods are very long and

thin, 5<sup>th</sup> pair longest surpassing the rostrum. Merus of last pereopods posteriorly armed with slender distant spines.

**Colour:** Pale pink through out the body.

**Distribution and economic importance:** Cape Comorin, South west coast of India, Gulf of India, Malay Archipelago, Gulf of Mannar, Japan, Zanzibar, Gulf of Aden, Red Sea, Kei Islands, African Coast. Appeared as the most dominant species among the deep sea prawn landed in Kerala . Very good fishery prevails during December to March. Great demand for export market.

#### **2.3.2.10. *Plesionika alcocki* (Anderson, 1896)**

**Plate:** 2.5. B.

**Synonymy** *Pandalus alcocki* Anderson ,1896.

*Pandalus (Plesionika) alcocki* Alcock, 1901; Alcock and McArdle, 1901.

*Plesionika alcocki* de Man 1920; Calman, 1939; Mohamed and Suseelan, 1973; Holthuis, 1980.

**Vernacular name** Pullan Chemmeen

**Diagnosis** : Ventral border of the rostrum armed with 4-5 teeth arranged equidistantly.

**Distinctive characters:**

Laterally compressed body. Very long, slender rostrum, more than double length of carapace, curved upwardly from middle, arranged with 4-

5 teeth on dorsal side. Three of the teeth very minute and closely packed on gastric crest, while the other two are larger ones, isolated and located above the orbit. Ventrally rostrum armed with 5-6 teeth, which are placed beyond antennular peduncle. Carapace very smooth and shiny without any ridge. A lightly marked post antennal ridge abruptly ends in front of the gastric region. 6<sup>th</sup> abdominal segment not as twice the length of 5<sup>th</sup> somite. Telson very long, slender and armed with three pairs of movable spines on dorso lateral angles and another 3 pairs on the distal end. 1<sup>st</sup> pereopod very thin and as long as 3<sup>rd</sup> maxilliped, 2nd pair extending to the tip of scaphocerite, rest of pereopods surpassing scaphocerite. Their dactylus is covered with a tuft of cilia in the inner margin.

**Colour:** Light reddish through out the body.

**Distribution and economic importance:** South west coast of India, Arabian Sea, Bay of Bengal, Andaman Sea, Gulf of Aden, Maldives, East Africa. Found in small numbers and it is only having minor economic importance in the deep sea prawn fishery of Kerala.

#### **2.3.2.11. *Plesionika martia* (A.Milne-Edwards,1883)**

**Plate:** 2.6 A

**Synonymy:** *Pandalus martius* A.Milne – Edwards, 1883; Wood-Mason, 1892; Adensamer, 1898; Senna, 1902; Coutiere, 1905; Riggio, 1905; Rathbun, 1906; Brian, 1931.

*Plesionika uniproucta* Bate, 1888; Moreira, 1901.

*Plesionika cottei* Kotte ,1903.

*Plesionika(Pandalus) sicheri* Riggio, 1900.

*Pandalus (Plesionika) martius* Alcock ,1901; Lloyd, 1907;  
Mc Culloch ,1907; Kemp and Sewell, 1912.

*Plesionika martia* Kemp, 1906,1910;Stebbing, 1910; Balss ,  
1914 , 1925; de Man, 1920; Calman ,1925, 1939; Schmitt  
,1926; Vilela, 1936; Chace ,1940; Alvarez ,1946; 1968;  
Barnard ,1950; Holthuis, 1951; 1952; 1955;1980; Massuti  
,1953;1967; Dieuzeide, 1955; 1960; Sivertsen and Holthuis ,  
1956; Springer and Bullis, 1956 ; Yaldwyn ,1957; Yasuda ,  
1957;Maurin ,1961 , 1965,1968 ; Forest , 1964;Bullis and  
Thomson , 1965 Audouin ,1965 ; Monod ,1966 ; George  
and Rao ,1966; Rice, 1967 ; Allen ,1967 ; Crosnier and De  
Bondy , 1968; Crosnier and Forest ,1968 , 1973 ; Kensley  
,1969; Silas , 1969 ; Lagardere ,1970 , 1972 ; Longhurst  
,1970 ; Pequegnat , 1970 ; Omori , 1971; Crosnier and  
Jouannic , 1973; Suseelan ,1974 ; Kurian and Sebastian,  
1976; King ,1984; Mytilineou, 2001.

*Plesionika martia semilaevis* de Man ,1920; Zarenkov  
,1971.

**Vernacular name** : Chuvanna Pullan

**Diagnosis:** Rostrum plain except 3-4 closely packed spines above the orbital margin. 3<sup>rd</sup> abdominal tergum slightly protruded posteriorly but not as a spine.

**Distinctive characters:**

Rostrum long and slender, its basal portion arched upwardly above antennular peduncle and in curvature dorsally armed with 7-8 teeth of which those at the origin are small but increases in size while coming forwards, anterior two are isolated and large in size. Beyond which rostrum is smooth and straight. Ventrally it armed with 46-50 closely packed serrations. Rostrum runs back wards as post rostral carina, which ends beyond middle of carapace. Antennal and pterygostomial spines are present. Pleuron of the 3<sup>rd</sup> abdominal tergum convex and not produced into a spine. 6<sup>th</sup> abdominal tergum doubles the length of 5<sup>th</sup>. Telson very long having the length of 6<sup>th</sup> somite, armed with 3 pairs of teeth arranged on the dorso lateral angle, and two pairs at distal end.

Antennal scale is narrow and tapering, tip is truncated. 1<sup>st</sup> pereopod shorter and less than length of 3<sup>rd</sup> maxilliped, having a minute and a tuft of cilia covers the microscopic chela borne at the end of it. 2<sup>nd</sup> pair of pereopod equal in length, surpassing 3<sup>rd</sup> maxilliped, carpus of which surrounded by setose hairs, while dactylus carry a minute chela covered with setae. In 3<sup>rd</sup> to 5<sup>th</sup> pereopods, merus and carpus very long and slender.

**Colour:** Pinkish red. Newly hatched eggs is turquoise blue.

**Distribution and economic importance:** Eastern central Mediterranean Sea, Canary Islands, Western Atlantic, Eastern Atlantic, South west Africa (Cape of Good Hope), South west Africa, Madagascar, Gulf of Aden, Bay of Bengal, Andaman Sea, South west coast of India. , Australia, Hawaii, Japan, Fiji, Bermuda to South of Carolina, Gulf of Mexico, South west Ireland, Bay of Biscay, Gulf of Guinea, Gulf of Biscay , Sumatra and N.W. Malaysia and New Zealand . Available only in stray numbers and do not support a fishery in Kerala .

#### **2.3.2.12. *Plesionika ensis* (A.Milne-Edwards, 1881)**

**Plate: 2.6 B**

**Synonymy:** *Acanthephyra ensis* A. Milne-Edwards, 1881; Young, 1900.

*Pandalus ensis* A. Milne-Edwards, 1883; Faxon ,1896; Alcock and Anderson ,1899; Couteiere,1905; Rathbun , 1906.

*Plesionika uniproducta* Spence bate, 1888; Moreira, 1901; de Man ,1920.

*Pandalus Semilaevis* Spence Bate ,1888.

*Pandalus (Plesionika) ensis* Alcock ,1901.

*Pandalus ensis* de Man, 1920 ; Holthuis , 1951; 1952; Holthuis and Maurin ,1952 ; Springer and Bullis, 1956; Rossignol ,1962 ; Maurin, 1963; 1968 ; Forest ,1964 ; Bullis and Thompson ,1965 8 ; Monod ,1966; Crosnier and Forest,

1968 , 1973; Le Loeuff and Intes, 1968; Alvarez ,1968; Suseelan and Mohamed ,1968; George,1969; Silas,1969; Ribeiro ,1970; Pequegnat ,1970; Omori , 1971; Mohammed and Suseelan, 1973 ; Suseelan, 1974; Kurian and Sebastian ,1976 ; King ,1984.

**Vernacular name:** Chuvanna Pullan

**Diagnosis:** Presence of a postero-dorsal spine on the tergum of 3<sup>rd</sup> segment.

**Distinctive characters :**

Compressed body, rostrum slender, very long, curved down wards in front of antennal peduncle but runs straight there after. Rostrum armed dorsally with 5-6 spines in orbit- rostral angle in which half of them are minute and closely packed while anterior ones are slightly large and widely placed in front of the orbit. Beyond the antennular peduncle, rostrum is straight and slightly turned upward at the tip and quite smooth with out spines. Ventrally rostrum is closely and finely serrated with 35 - 40 teeth, which becomes very minute towards distal end. Carapace is smooth with distinct pterygostomian and antennal spines. Third abdominal tergum is acutely produced in to a sharp spine in its posterior end. Sixth abdominal segment is more than double the length of 5<sup>th</sup>. Antennal scale long and tapering towards the end. 1<sup>st</sup> pereopod reaches as far as antennal scale while 2<sup>nd</sup> pereopod a little shorter. External maxillipeds slightly larger than 1st pereopod. 2<sup>nd</sup> pair of pereopod equal in



length and stouter, carpus of which is constricted in to 15-16 constrictions. Telson long and slender armed with 3 pairs of small spines arranged on dorso-lateral angle, while another 3 numbers are present at terminal end. Those at the distal end are larger than inner ones. Endopod of the uropod is equal to that of telson.

**Colour:** Bright pink in colour through out the body, maxillipeds and telson are bright red in colour. Appendages are pinkish in colour. Tip of the rostrum usually reddish.

**Distribution and economic importance:** Arabian Sea (Suseelan and Mohamed ,1968), Andaman Sea; Pacific Ocean, Eastern and Western Atlantic, Bay of Bengal, Fiji, Hawaiian Archipelago (Alcock,1901). Among the pandalids occurring along the south west coast of India, *Plesionika ensis* is very rarely distributed and in the commercial catches, this species rarely coexist with *P. spinipes*.

### **2.3.2.13. *Oplophorus typus* H.Milne-Edwards ,1837**

**Plate: 2.7 A**

**Synonymy:** *Oplophorus typus* H. Milne –Edwards ,1837; Bate, 1888; Chace, 1936.

*Oplophorus gracilirostris* A. Milne –Edwards, 1881; Chace, 1936; George and Rao ,1966; Mohammed and Suseelan, 1973.

*Oplophorus brevirostris* Bate ,1888.

*Oplophorus longirostris* Bate, 1888.

*Hoplophorus smithii* Wood –Mason, 1891.

*Hoplophorus gracilirostris* Wood –Mason, 1891.

*Hoplophorus typus* de Man ,1920;Balss ,1925;

Calman,1939.

**Diagnosis:** 3<sup>rd</sup> to 5<sup>th</sup> abdominal terga protrudes posteriorly in to sharp spines .

**Distinctive characters :**

Rostrum very slender and tapering towards distal end, armed dorsally with 9-13 teeth (usually 10-11) and 8-9 teeth on the ventral border. Rostrum 93% in carapace length and 22.9% in total length. Slightly upturned after first four serrations, which appears as buds on curvature of rostrum. From the base, on either side of the rostrum buttressed by a sharp carina, which extends up to the middle portion of gastric region. Anterior basal edge of carapace slightly protrudes away from base to form a sharp spine on either edge. Eye stalks moderately depressed and short. Eyes prominent, almost reddish pink in colour, located at the base of rostral ridge. Antennal scale thin, slender, long, triangle shaped tapering towards anterior border and ends as spine. Outer edge of which is evenly serrated, usually ranged between 12-14 serrations while inner side is ciliated. At the base of antennal scale a strong tooth of 2mm long originated from outer border, which acts as a

support by hanging antennal scale. Posterior border of carapace articulated with abdomen on either side as blunt tooth like processes, which held inside by a small projection located at antero-lateral angle of 1<sup>st</sup> abdominal tergum. Lower base of abdominal ridge slightly blunt inwardly. Abdominal terga strongly carinated. 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> abdominal terga protruded backwards as long spines. 3<sup>rd</sup> spine is more than double the length of 1<sup>st</sup> and 2<sup>nd</sup> and fixed parallel to the body. While the other two curved downwards. Antennular peduncle short, antennal flagella are more than 1/3<sup>rd</sup> length of rostrum.

Anterior lower lobe of 1<sup>st</sup> abdominal pleura in female intact and 2<sup>nd</sup> abdominal tergum very broad usually accommodating large but few eggs. In males anterior middle portion bulged while lower part deeply excised at the edge. Posterior half of abdomen more or less tapering towards centre.

External maxillipeds of thoracic appendages are stout and they reach beyond the end of antennal peduncle. Ischium and merus of external maxillipeds strongly curved outwards as an expanded 'v' shape. 3<sup>rd</sup> pair of pereopod longest and reaches beyond the tip of 1<sup>st</sup> pair while 4<sup>th</sup> and 5<sup>th</sup> pair of pereopod almost equal. Telson and uropod is almost equal in length. Uropod is thin, long and covered with setae. Eggs large of 1 to 2mm in size.

**Distribution and economic importance:** Arabian Sea, Bay of Bengal, Andaman Sea , Gulf of Aden , New guinea ,Zanzibar , West Indies ,

Malayan Archipelago ,Fiji Islands. Stray catches. Do not support fishery due to their smaller size and sparse availability.

#### **2.3.2.14. *Acanthephyra sanguinea* Wood-Mason , 1892**

**Plate: 2.7 B**

**Synonymy:** *Acanthephyra sanguinea* Wood-Mason ,1892; Alcock ,1901; Kemp, 1906; Chace, 1936 ; Calman ,1939; George and Rao, 1966; Mohamed and Suseelan ,1973 .

**Vernacular name** : Mulaku Chemmeen

**Diagnosis:** 2<sup>nd</sup> to 6<sup>th</sup> abdominal terga sharply carinated, 3<sup>rd</sup> to 6<sup>th</sup> terga ending in to sharp spines.

**Distinctive characters :**

Rostrum slender and long armed with 8-9 teeth arranged equidistantly throughout upwardly directed rostrum, 5-6 teeth on ventral. Rostrum runs backwards as faint post rostral carina towards posterior border of carapace. Cervical groove is obsolete, hepatic groove indistinct; anteriorly carapace smooth with out any ridge. Post antennal spine very minute and smaller than post antennular spine and not buttressed by any carina. Abdominal terga from 2<sup>nd</sup> to 6<sup>th</sup> segment sharply carinated; the carination of 2<sup>nd</sup> tergum is low while that of 3<sup>rd</sup> is largest, fully overlapping of 4<sup>th</sup> tergum. 3<sup>rd</sup> to 6<sup>th</sup> terga terminating posteriorly in to sharp spines. Telson is slightly longer than exopod of the uropod armed with 4 pairs of spines arranged dorso- laterally besides 3 pairs of spines at terminal end.

Antennal scale very large, more than half of carapace, narrow and ends terminally into a sharp spine. 1<sup>st</sup> pereopod is shorter than others. Ischium and merus of 3<sup>rd</sup> and 4<sup>th</sup> pereopods armed with a row of minute spines on posterior margin. 5<sup>th</sup> pair of pereopods are longer than other pereopods.

**Colour :** Deep crimson through out the body.

**Distribution and economic importance :** Arabian sea , Bay of Bengal , Indian ocean , Andaman Sea , Gulf of Aden , Sumatra. Usually landed along with *A.alcocki* in small numbers and it is of moderate economic importance owing to higher size and attractive colour.

### **2.3.2.15. *AcanthePHYra armata* A. Milne-Edwards ,1881**

**Plate:** 2.8 A

**Synonymy:** *AcanthePHYra armata* A.Milne-Edwards ,1881.

**Vernacular name :** Mulaku Chemmeen

**Diagnosis:** a single tooth on ventral side of rostrum .

**Distinctive characters:**

Rostrum slender and very long, runs forward as shallow horizontal line and titled upward abruptly in front of the scaphocerite and run backwards as a feeble carina which fades after anterior two third of carapace. In front of carapace, dorsally rostrum bears 3-4 very small teeth followed by a single slightly large tooth above antennal peduncle. Rest of rostrum is very smooth. Ventrally a single large tooth present at

middle of the rostrum, which act as a junction from where rostrum ascended. Above eyes, a tuft of ciliae present in junction of carapace and rostrum. A very prominent antennal spine is present which runs backwards as post antennal carina to half of the carapace and is very sharp which supports hepatic groove. Hepatic groove is very sharp and ends at distal part of post antennal carina. A gastric crest appears as a feeble arch just above distal end of post antennal carina and fade in front of posterior border of carapace.

Abdominal terga from 2<sup>nd</sup> - 6<sup>th</sup> somite are sharply carinated of which 3<sup>rd</sup> to 6<sup>th</sup> terga produced in to a sharp spine. Tergum of 2<sup>nd</sup> segment intact as a sharp keel without any spine. Spine of 3<sup>rd</sup> tergum very prominent and protrudes outwardly while the other three spines curved downwards. Sternal plate of 2<sup>nd</sup> segment is very broad and marked with 2 vertical bars of which anterior one slightly curved while the posterior one more or less straight ; both reaches full length of sternal plate. Sternal plate of 4<sup>th</sup> and 5<sup>th</sup> segment in the mid ventral side produced into a small notch. 6<sup>th</sup> segment twice the length of 5<sup>th</sup>. Telson almost equal in size that of endopodite and smooth with out spines, dorsal side of which produced in to a blunt carina.

Eyes are brownish black in colour. Antennular peduncle reaches anterior 1/3<sup>rd</sup> of scaphocerite. Scaphocerite thin and very long, ends as a pointed blade, reaching anterior two third of rostrum. A long spine

borders outer margin of scaphocerite. Inner border fringed with small setose hairs. Thoracic legs covered with setose hairs.

**Colour:** The body deep crimson throughout. Berries also having the same coloration.

**Distribution and economic importance:** Arabian Sea, Bay of Bengal and Andaman Sea obtained in stray catches only. Moderate economic importance due to bigger size of the specimens represented in the commercial catches and attractive colouration.

### **2.3.3. Morphometric analysis**

Details of various morphometric measurements in respect of males and females of 15 species of deep sea prawns collected and identified from the exploited stock are presented in Table 2.1.1 to 2.1.15. Among the various species under the super family Penaeoidea, females of *A.alcocki* showed the largest total length and fall in higher size groups with a mean of 129.5mm while the lowest length range was observed in males of *P.investigatoris*. In the super family Pandaloidae, largest total length was registered in females of *H.woodmasoni* as evidenced from higher mean values.

Range and mean of various ratios worked out in males and females of deep sea prawns are presented in Table 2.2.1 to 2.2.6. Among them, the most distinct morphometric features were further used for

species wise comparison under the three super families viz., Penaeoidea , Pandaloidea and Oplophoroidea . Like coloration and morphological and meristic features, morphometric ratios also showed glaring differences among various species. Among various species under the super family Penaeoidea , *S.hextii* can easily be identified by the possession of very high carapace (0.34) to total length ratio whereas *A.alcocki* stands apart in possessing high rostral length (0.26) and propodus (0.09) of second cheliped in relation to total length indicating the distinctiveness of these species . In addition, the ratios of first and second chelipeds in relation to carpus length were on a higher side in *A.alcocki* when compared to other species which showed significant variation at 5 % level and these parameters are useful for the easy identification of this species in the exploited stock. In *P. investigatoris* , the ratio of rostral length in total length was found to be lower than that of other species studied under the Penaeoid super family (Table 2.5.1) .

In the two closely similar species , *P.jerryi* and *M.andamanensis* , the ratio of 2<sup>nd</sup> cheliped in relation to total length was 0.19 in the former and 0.28 in the latter and these ratios can be used for their easy identification (Table 2.5.1). Two more non overlapping ratios could be delineated in *P.jerryi* and *M.andamanensis* viz. , rostral length to carapace length (0.85 ; 0.62) and carapace length to merus length (1.49 and 4.73) showed significant variation ( $P < 0.05$ ) and therefore be useful for their easy differentiation ( Table 2.5.1) .



Under the super family Pandaloidea, *P.spinipes* stands out due to the possession of very high ratio of 1<sup>st</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> cheliped length in relation to total length and carapace length which are found unique to this species. In the remaining species, the cheliped to carapace length and total length were found to be very low (Table 2.5.2). Similarly, in *P.alcocki*, the ratios of rostral and 2<sup>nd</sup> merus length in relation to total length were found to be higher than those of other species and showed significant difference at 5% level ( $P < 0.05$ ). For distinguishing the two closely related species of the genus *Plesionika* viz., *P.martia* and *P.ensis*, three non overlapping ratios viz. fifth cheliped to total length and 2<sup>nd</sup> cheliped and rostral length to second merus length were found and these characters can reliably be used for differentiating them (Table 2.5.2).

In order to differentiate the three closely related species of the genus *Heterocarpus* viz. *H.gibbosus*, *H.laevigatus* and *H.woodmasoni*, a non overlapping ratio of 4<sup>th</sup> cheliped to carapace length was established which would be helpful for their easy separation other than the morphological and meristic characters. In *H.laevigatus*, the ratios of carapace to total length and rostral length and 2<sup>nd</sup> propodus length to 2<sup>nd</sup> merus length were very high when compared other species while the species stands out by possessing a low 2<sup>nd</sup> merus and carpus length to carapace length. In order to differentiate *H.woodmasoni* and *H.gibbosus*, the non overlapping ratios of 2<sup>nd</sup> ischial length and 2<sup>nd</sup> short cheliped length to carapace length were found useful (Table 2.5.2).

Under the super family Ophoroidea, three species were identified, among them *A.sanguinea* is distinct in possessing a number of unique characters which are useful for establishing the taxonomic identity of the species. In *A. sanguinea* , first cheliped and telson length were high , on the other hand , the ratio of first cheliped to total length was very low in *O.typos* which possess a very high second cheliped to carpus ratio(Table 2.5.3). In *A.sanguinea* and *A.armata*, the non overlapping ratios of rostral length and 2<sup>nd</sup> merus length in relation to carapce length and length of telson in relation to carapace length and 2<sup>nd</sup> carpus showed significant difference (  $P<0.05$ ) and this can be reliably be used as the characters for differentiating the two species(Table 2.5.3).

Various morphometric characters recorded from 15 species were regressed each other and regression coefficients so obtained are presented in Table 2.3.1 to 2.3.15. In females of *A.alcocki*, all the relationships in respect of total length and carapace length were found to be linear by obtaining significant 'r' values (Table 2.3.1) whereas in males of *A.alcocki*, almost all morphometric characters showed non-linear relationships while the relationship of carapace length with respect to 2<sup>nd</sup> podomers and 1<sup>st</sup> to 5<sup>th</sup> walking legs showed a very good correlation due to the high r values arrived at.

In females of *P.investigatoris* , the relationship between total length to podomers of 2<sup>nd</sup> cheliped length and walking legs were found to

be linear while in males the relationship between total length and rostral length, 2<sup>nd</sup> cheliped and uropod lengths showed linearity as evidenced by high regression coefficient values (Table 2.3.15). In females, the correlation of carapace length to all morphometric parameters showed a linear relationship in contrast to the non-linear relationship observed in males (Table 2.3.15). In *P.jerryi* and *M.andamanensis* also, all the regression relationships were found to be linear (Table 2.3.2 & 2.3.3). However, in females of *M.andamanensis*, the correlation of dactylus of 2<sup>nd</sup> cheliped and of 3<sup>rd</sup> walking leg with other morphometric parameters resulted in low 'r' values ranging from 0.01 to 0.204 which would suggest that the relationship is non linear in females, while in males such disparity could not be seen.

In females of *S.hextii*, the relationship between the podomeres of 2<sup>nd</sup> cheliped, carapace length and rostral length with other morphometric parameters showed a non-linear relationship as evident by very low 'r' values in males and females (Table 2. 3.4). On the contrary, the length of podomeres of 2<sup>nd</sup> cheliped, carapace length and rostral length showed a linear relationship with total length in both the sexes.

In *H.gibbosus* and *H.woodmasoni*, almost all the relationships were found to be non-linear (Table 2.3.5 & 2.3.6). In the former species, the relationship between total length to carapace length and length of rostrum and 2<sup>nd</sup> long cheliped showed a linear relationship in both the

sexes while in the latter species, linear relationships were observed between total length with carapace length, 3<sup>rd</sup> to 5<sup>th</sup> walking legs and propodus and 2<sup>nd</sup> cheliped length.

In *H.laevigatus*, podomeres of 2<sup>nd</sup> cheliped to total length, carapace and rostral length showed a highly linear relationship in both males and females as evident by very high 'r' values (Table 2.3.7). In *P.spinipes*, all the relationships were found to be non linear, however, it was significant for a few number of morphometric parameters (Table 2.3.8). In females, regression coefficient of total length to carapace length, 1<sup>st</sup> cheliped and pleural breadth, carpus length to 2<sup>nd</sup> cheliped length and 4<sup>th</sup> pereopod to 5<sup>th</sup> pereopods showed a linear relationship whereas in males, the relationship between rostral to 2<sup>nd</sup> cheliped and 4<sup>th</sup> cheliped to 5<sup>th</sup> cheliped were found to be linear. On the contrary, in *P.martia*, almost all the relationships were found to be linear. However, in males, the correlation of total length to carapace length and rostral length to podomeres of 2<sup>nd</sup> cheliped were found to be highly non linear while in females such disparity was not observed (Table 2.3.9).

In *P.ensis*, only very few linear relationships were observed in females while in males the number of linear relationships were on a higher side (Table 2.3.10). In females, the relationship between total length to carapace length and 2<sup>nd</sup> ischium showed linearity as evident by high r values. In *P.alcocki*, the relationship between total length and

carapace length , rostral length , 1<sup>st</sup> cheliped length and podomeres of 2<sup>nd</sup> cheliped showed linear relationships both in females and males (Table 2.3.11) . In *O.typus* , *A.sanguinea* and *A.armata* , all the relationships were found to be linear as manifested by significant 'r' values (Table 2. 3.12 to 2.3.14) .

Regression coefficients of total length - carapace length relationship among *P.jerryi*, *A.alcocki*, *S.hextii*, *P.investigatoris* and *M.andamanensis* were compared using ANACOVA and the results showed there exist significant difference at 5% level (Table 2. 4.1). Results of t-test showed that significant variation in the total length – carapace relationship between *P.jerryi* , *A.alcocki* ( $P<0.01$ ) ,*S.hextii* ( $P<0.05$ ) ,*M.andamanensis* ( $P<0.05$ ) and *P.investigatoris* ( $P<0.05$ ) .

Regression coefficient of the total length to rostral length (  $F - 975.81, P<0.05$ ) 1<sup>st</sup> cheliped length (  $F - 3290.78, P<0.05$  ) propodus length ( $F - 267.21, P<0.05$ ) 2<sup>nd</sup> cheliped were also varied significantly ( Table 2.4.2) . Relationship between carapace length and rostral length of the species also found to vary significantly at 5%level (Table 2.4.7). Results of the t-test showed that the total length and rostral length varied significantly between the species. The growth of 1<sup>st</sup> cheliped , propodus , 2<sup>nd</sup> cheliped and merus length also showed deviation among most of the species studied (Table 2.4.3 to 2.4.6). Comparison of regression coefficient of total length to length of carapace , rostrum and 1<sup>st</sup> cheliped

of various species under the super family Pandaloidea showed significant difference at 5% level ( $F= 24.25, <p0.05$ ) (Table 2.4.8 to 2.4.10). The results of t-test showed significant species specific variations.

Regression coefficient of total length – rostral length relationship, total length – 2<sup>nd</sup> cheliped length and carapace length - rostral length were compared and the results showed that there exist significant difference among various species under the super family Oplophoroidea. The results of t-test also showed that significant variation exist in both relationships between *A.sanguinea* and *O.typus* ( $P<0.01$ ) and *O.typus* and *A.armata* ( $P<0.01$ ) (Table 2. 4.12 to 2. 4.14).

## 2.4 DISCUSSION

The deep sea prawns collected from the exploited stock landed at various harbours of Kerala were identified and classified with the help of available systematic keys and majority of them showed very much agreement with the descriptions by Alcock (1901,1906). Nomenclature changes effected both in respect of species and definitions of body characters, and therefore a full utility of Alcock (1901,1906) cannot be made. Though key of almost all the species are available, adequate descriptions are wanted for most of the species . Taxonomic changes have nullified many nomenclatures as obsolete as well. Therefore, the key developed in the present study based on easily measurable

characteristics will be having much practical utility for easy identification of the deep sea prawns inhabiting off Kerala waters.

In systematics where body proportions play an important role in delineation of species, investigation on relative growth parts in relation to the rest of the body or in relation to each other can throw more light for arriving at true taxonomic status (Misra , 1959). The results of the morphometric ratios revealed that like coloration, morphological and meristic features, the morphometric ratios can also exhibit meaningful understanding of species wise changes. When the morphometrics is applied individually to each of the 15 species with out taking in to account their generic affiliations, more than 50 non-overlapping ratios could be recognised for their easy identification. The results of the study showed that *S.hextii* can easily be identified by its large carapace length and very low uropod length in relation to total length while *A.alcocki* stands unique in the super family Penaeoidea in possessing a very long rostral length , and propodus length in relation to total length . *P.jerryi* and *M.andamanensis* usually do not easily lend themselves to field separation because of their close resemblance in morphology. The present results showed that three non overlapping ratios viz. 2<sup>nd</sup> cheliped to total length, rostral length to carapace length and carapace length to 2<sup>nd</sup> merus could be used for the easy identification of the two species. Similarly, the closely identical species *P.martia* and *P.ensis* can easily be distinguished from each other by observing the ratios 2<sup>nd</sup> and 4<sup>th</sup> cheliped to total length

and 3<sup>rd</sup> and 5<sup>th</sup> cheliped to carapace length. *Parapandalus spinipes* stands out unique among the pandalids of the exploited stock of Kerala due to its distinctly longer 1<sup>st</sup> and 5<sup>th</sup> cheliped in relation to total length and carapace length. This particular observation further corroborates the splitting up of this species from genus *Plesionika* to *Parapandalus*, which had been widely discussed by a number of workers (Calman , 1939; Holthuis , 1980). The ratio of 2<sup>nd</sup> cheliped to total length can be taken as a criteria for the differentiation of *H.laevigatus* and *H.gibbosus* , the former possesses a ratio of 0.30 while in the latter it was 0.42.

Growth of various body parts in *A.alcocki* with respect to total length , carapace length and 2<sup>nd</sup> cheliped length was found to be higher in females than males while the uropod length was high in males and this can very well correlated to the faster growth rate and larger size of females. Similarly, the difference in 1<sup>st</sup> and 2<sup>nd</sup> chelipeds between the sexes are also consistent with extent of sexual dimorphism seen in this species which strongly corroborates with the hypothesis that, maximum size of males is only about half the length of females (Sardá and Demestre , 1987) . Accordingly, the swimming ability of males can be expected to be better than that of females. Regression equations in *P.investigatoris* showed that the relationship of total length to length of carapace , rostrum and podomeres of 1<sup>st</sup> cheliped were observed to be higher than that of males . The regression analysis of *P.jerryi* and *M.andamanensis* were found to be nearly equal in both the sexes. In



*P.jerryi* positively allometric relationship could be discernible in females between total length and rostral length and this can very well be explained by the stoutness of females than males where as in *M.andamanensis*, a positive allometry could be discernible in the walking legs of both the sexes. These finding have been corroborated with Sardá *et al.* (1993) who observed a positive allometric relation in *A.antennatus* . Since the relationship between size and weight has been commonly reported to increase following a power series (Bas ,1966;Le Reste *et al.*,1978) and the ability for rapid locomotion decreases with size it is to certain extent reasonable to expect the walking legs to become longer as overall size increases. Carapace length, rostral length, podomeres of 2<sup>nd</sup> chelipeds and uropod showed higher regression coefficient in females of *S.hextii* which can be explained due to the possession of large size in female specimens.

The results of linear measurements in both the sexes of *H.gibbosus* was found to be similar except for certain characters which showed a high positive allometry in males than females. Similar results was observed in *H.woodmasoni* , where the difference in growth of carapace length in females showed a highly positive allometry. The relationship between total length and pereopods of males *H.woodmasoni* showed very high correlation by registering 'r' values of 0.92 ; however, in females 'r' value was only up to 0.85. In *H.laevigatus* , there is no significant difference in rostral length and 1<sup>st</sup> cheliped length between the

two sexes while the carapace length in males showed a negative correlation ( $r = -0.33$ ) in contrast to the very high correlation value seen in females (0.92). This might be due to the lesser number of male specimens observed in the present study. Comparison of regression coefficient of various relationship in *P.spinipes* showed that almost all the relationships were negatively correlated in both the sexes except for carapace length (0.75), 1<sup>st</sup> cheliped (0.75) and pleural breadth (0.70) of females. High correlation in these characters might be due to larger size of females and the pleural breadth can be explained on the basis of larger 2<sup>nd</sup> pleura, which act as brood pouch in berried females. In other egg bearing females examined during this period also showed high pleural breadth and depth in relation total length when compared to their male counter parts.

In *P.martia*, a positive correlation was seen in all the relationships showing higher 'r' values than males where as in *P.ensis*, males showed a high degree of correlation than females. All the three species under Oplophoridae showed very high degree of correlation with out wide disparity between sexes. The comparison of regression coefficients of various body parts with respect to total length, carapace length, rostral length, 1<sup>st</sup> cheliped length and podomeres of 2<sup>nd</sup> cheliped showed species specificity among the members of Penaeoidea, Pandaloidea and Oplophoroidea. This can be well explained based on variations noticed in

carapace length, rostral length and size of the podomeres of 2<sup>nd</sup> cheliped among various species.

**Table 2.1.1** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Aristeus alcocki*

| Sl.No. measurements(mm)   | Male |       |       |       | Female |       |        |       |
|---------------------------|------|-------|-------|-------|--------|-------|--------|-------|
|                           | Min  | Max   | Mean  | SD    | Min    | Max   | Mean   | SD    |
| 1 Total length            | 82   | 160   | 129.5 | 28.95 | 109    | 177   | 145.29 | 17.77 |
| 2 total weight            | 5.12 | 24.65 | 12.8  | 7.22  | 4.02   | 21.21 | 13.39  | 4.44  |
| 3 Carapace length         | 30   | 49    | 36.7  | 7.63  | 28     | 52    | 41.82  | 6.98  |
| 4 Rostral length          | 12   | 47    | 33.5  | 12.58 | 27     | 53    | 38.68  | 5.91  |
| 5 1st pereopod length     | 21   | 45    | 36.2  | 9.26  | 26     | 50    | 37.86  | 6.68  |
| 6 Length of 2nd ischium   | 4    | 12    | 6.7   | 3.08  | 2      | 47    | 7.5    | 8.04  |
| 7 Length of merus         | 6    | 15    | 10    | 3.52  | 9      | 19    | 12.93  | 2.24  |
| 8 Length of carpus        | 6    | 18    | 10.7  | 4.93  | 9      | 16    | 13.68  | 2.02  |
| 9 Length of propodus      | 8    | 17    | 11.7  | 3.39  | 4      | 16    | 12.18  | 4.11  |
| 10 Length of dactylus     | 4    | 10    | 6.2   | 2.32  | 4      | 16    | 7.57   | 2.23  |
| 11 2nd pereopod length    | 31   | 72    | 45.2  | 15.55 | 29     | 95    | 53.86  | 12.06 |
| 12 length of 3rd pereopod | 50   | 69    | 59.2  | 9.04  | 37     | 72    | 56.86  | 7.77  |
| 13 length of 4th pereopod | 32   | 50    | 42    | 7.62  | 38     | 70    | 53.4   | 9.3   |
| 14 length of 5th pereopod | 30   | 67    | 42    | 17.26 | 43     | 77    | 59.88  | 9.54  |
| 15 Telson length          | 12   | 16    | 13    | 1.55  | 9      | 19    | 15.57  | 2.54  |

**Table 2.1.2** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Parapenaeus investigatoris*

| Sl.No. measurements(mm)   | Male |      |       |       | Female |      |        |       |
|---------------------------|------|------|-------|-------|--------|------|--------|-------|
|                           | Min  | Max  | Mean  | SD    | Min    | Max  | Mean   | SD    |
| 1 Total length            | 57   | 73   | 64.83 | 7.27  | 57     | 88   | 71.625 | 11.96 |
| 2 total weight            | 1.01 | 1.88 | 1.44  | 0.49  | 1.05   | 3.16 | 1.9225 | 0.80  |
| 3 Carapace length         | 19   | 20   | 19.25 | 0.50  | 17     | 23   | 19.875 | 2.42  |
| 4 Rostral length          | 6    | 57   | 13.63 | 18.25 | 5      | 9    | 6.9    | 1.6   |
| 5 1st pereopod length     | 12   | 15   | 13.50 | 1.29  | 13     | 17   | 15.1   | 1.79  |
| 6 Length of 2nd ischium   | 2    | 3    | 2.75  | 0.5   | 3      | 4    | 3.2    | 0.42  |
| 7 Length of merus         | 5    | 6    | 5.33  | 0.47  | 4      | 7    | 5.2    | 1.14  |
| 8 Length of carpus        | 5    | 6    | 5.33  | 0.47  | 4      | 8    | 5.9    | 1.25  |
| 9 Length of propodus      | 2    | 4    | 2.67  | 0.94  | 2      | 4    | 2.625  | 0.92  |
| 10 Length of dactylus     | 1    | 2    | 1.5   | 0.5   | 1      | 2    | 1.375  | 0.52  |
| 11 2nd pereopod length    | 15   | 20   | 17.33 | 2.13  | 15     | 22   | 17.375 | 2.62  |
| 12 length of 3rd pereopod | 21   | 24   | 21.75 | 1.50  | 21     | 29   | 23.25  | 2.87  |
| 13 length of 4th pereopod | 20   | 26   | 22.50 | 2.65  | 20     | 32   | 23.75  | 4.03  |
| 14 length of 5th pereopod | 27   | 29   | 27.75 | 0.96  | 26     | 38   | 31.125 | 4.64  |
| 15 Telson length          | 6    | 10   | 8.25  | 1.71  | 6      | 11   | 8.75   | 1.83  |
| 16 Uropod length          | 9    | 14   | 11.50 | 2.38  | 9      | 15   | 12     | 2.39  |

**2.1.3** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Peneopsis jerryi*

| Sl.No. | measurements(mm)       | Male |     |      |    | Female |     |      |    |
|--------|------------------------|------|-----|------|----|--------|-----|------|----|
|        |                        | Min  | Max | Mean | SD | Min    | Max | Mean | SD |
| 1      | Total length           | 107  | 111 | 109  | 2  | 101    | 111 | 110  | 5  |
| 2      | total weight           | 6.2  | 7.9 | 7    | 1  | 6      | 8   | 7    | 1  |
| 3      | Carapace length        | 29   | 32  | 30   | 2  | 28     | 32  | 31   | 2  |
| 4      | Rostral length         | 26   | 28  | 27   | 1  | 21     | 28  | 25   | 3  |
| 5      | 1st pereopod length    | 15   | 25  | 20   | 5  | 16     | 19  | 17   | 1  |
| 6      | Length of 2nd ischium  | 3    | 4   | 4    | 1  | 3      | 5   | 4    | 1  |
| 7      | Length of merus        | 7    | 9   | 8    | 1  | 4      | 7   | 5    | 1  |
| 8      | Length of carpus       | 9    | 12  | 10   | 2  | 8      | 9   | 9    | 1  |
| 9      | Length of propodus     | 3    | 5   | 4    | 1  | 2      | 4   | 4    | 1  |
| 10     | Length of dactylus     | 2    | 2   | 2    | 0  | 1      | 2   | 2    | 1  |
| 11     | 2nd pereopod length    | 25   | 32  | 28   | 4  | 23     | 23  | 23   | 0  |
| 12     | length of 3rd pereopod | 37   | 39  | 38   | 1  | 32     | 39  | 39   | 4  |
| 13     | length of 4th pereopod | 42   | 45  | 43   | 2  | 40     | 45  | 44   | 2  |
| 14     | length of 5th pereopod | 42   | 44  | 43   | 1  | 42     | 46  | 43   | 2  |
| 15     | Telson length          | 16   | 19  | 18   | 2  | 16     | 19  | 17   | 1  |
| 16     | Uropod length          | 18   | 21  | 20   | 2  | 16     | 19  | 18   | 1  |

**2.1.4** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Metapeneopsis andamanensis*

| Sl.No. | measurements(mm)             | Male |      |      |      | Female |      |      |      |
|--------|------------------------------|------|------|------|------|--------|------|------|------|
|        |                              | Min  | Max  | Mean | SD   | Min    | Max  | Mean | SD   |
| 1      | Total length                 | 59   | 120  | 83   | 20   | 72     | 111  | 95   | 14   |
| 2      | total weight                 | 0.98 | 6.69 | 2.57 | 1.75 | 2.04   | 7.76 | 5.00 | 2.02 |
| 3      | Carapace length              | 16   | 32   | 22   | 6    | 21     | 31   | 26   | 3.5  |
| 4      | Rostral length               | 10   | 21   | 13   | 4    | 10     | 28   | 18   | 6    |
| 5      | 1st pereopod length          | 11   | 25   | 17   | 5    | 16     | 31   | 22   | 6    |
| 6      | Length of 2nd ischium        | 2    | 6    | 4    | 1    | 3      | 5    | 4    | 0.7  |
| 7      | Length of merus              | 5    | 8    | 6    | 1    | 5      | 9    | 7    | 1    |
| 8      | Length of carpus             | 5    | 12   | 8    | 2    | 4      | 13   | 10   | 3    |
| 9      | Length of propodus           | 2    | 5    | 4    | 1    | 2      | 5    | 4    | 1    |
| 10     | Length of dactylus           | 1    | 2    | 1    | 0    | 1      | 3    | 2    | 1    |
| 11     | Total length of 2nd pereopod | 16   | 33   | 24   | 5    | 16     | 35   | 27   | 7    |
| 12     | length of 3rd pereopod       | 18   | 42   | 29   | 8    | 18     | 44   | 34   | 9    |
| 13     | length of 4th pereopod       | 25   | 47   | 33   | 8    | 27     | 45   | 33   | 8    |
| 14     | length of 5th pereopod       | 21   | 48   | 33   | 9    | 30     | 46   | 37   | 6    |
| 15     | Telson length                | 6    | 19   | 11   | 4    | 8      | 17   | 14   | 3    |
| 16     | Uropod length                | 6    | 23   | 14   | 6    | 13     | 22   | 17   | 3    |

**Table 2.1.5** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Solenocera hextili*

| Sl.No. | measurements(mm)       | Male |     |      |    | Female |     |      |    |
|--------|------------------------|------|-----|------|----|--------|-----|------|----|
|        |                        | Min  | Max | Mean | SD | Min    | Max | Mean | SD |
| 1      | Total length           | 55   | 109 | 65   | 17 | 5      | 11  | 7    | 2  |
| 2      | total weight           | 1    | 9   | 2    | 2  | 1      | 13  | 3    | 4  |
| 3      | Carapace length        | 14   | 32  | 23   | 5  | 20     | 47  | 28   | 8  |
| 4      | Rostral length         | 9    | 18  | 10   | 3  | 9      | 21  | 13   | 5  |
| 5      | 1st pereopod length    | 9    | 28  | 14   | 4  | 8      | 42  | 13   | 9  |
| 6      | Length of 2nd ischium  | 2    | 10  | 4    | 3  | 2      | 11  | 5    | 3  |
| 7      | Length of merus        | 4    | 10  | 6    | 2  | 3      | 15  | 9    | 3  |
| 8      | Length of carpus       | 3    | 11  | 8    | 2  | 6      | 21  | 9    | 5  |
| 9      | Length of propodus     | 2    | 4   | 2    | 1  | 1      | 3   | 2    | 1  |
| 10     | Length of dactylus     | 1    | 2   | 1    | 1  | 1      | 4   | 1    | 1  |
| 11     | Length of 2nd pereopod | 14   | 35  | 22   | 6  | 14     | 48  | 25   | 10 |
| 12     | length of 3rd pereopod | 24   | 37  | 31   | 3  | 25     | 44  | 31   | 6  |
| 13     | length of 4th pereopod | 20   | 33  | 24   | 3  | 20     | 30  | 26   | 4  |
| 14     | length of 5th pereopod | 22   | 34  | 30   | 4  | 21     | 41  | 30   | 6  |
| 15     | Telson length          | 6    | 19  | 9    | 4  | 4      | 19  | 14   | 4  |
| 16     | Uropod length          | 7    | 14  | 9    | 2  | 8      | 19  | 11   | 4  |

**Table 2.1.6** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Heterocarpus gibbosus*

| Sl.No. | measurements(mm)              | Male |       |       |       | Female |      |        |       |
|--------|-------------------------------|------|-------|-------|-------|--------|------|--------|-------|
|        |                               | Min  | Max   | Mean  | SD    | Min    | Max  | Mean   | SD    |
| 1      | Total length                  | 83   | 119   | 98.68 | 10.66 | 89     | 133  | 111.05 | 12.21 |
| 2      | total weight                  | 1.84 | 13.85 | 6.47  | 3.2   | 3.11   | 20.6 | 11.81  | 4.96  |
| 3      | Carapace length               | 23   | 37    | 29.77 | 4.05  | 26     | 38   | 34.43  | 3.22  |
| 4      | Rostral length                | 32   | 44    | 37.73 | 3.76  | 30     | 46   | 39.67  | 3.89  |
| 5      | 1st pereopod length           | 24   | 44    | 32.14 | 10    | 28     | 46   | 35.76  | 5.12  |
| 6      | Length of 2nd long ischium    | 8    | 12    | 10    | 1.11  | 6      | 14   | 11.1   | 1.61  |
| 7      | Length of 2nd long merus      | 8    | 13    | 10.36 | 1.56  | 8      | 14   | 11.57  | 1.57  |
| 8      | Length of 2nd long carpus     | 13   | 22    | 18.14 | 2.25  | 13     | 25   | 21     | 3     |
| 9      | Length of 2nd long propodus   | 1    | 2     | 1.82  | 0.39  | 1      | 3    | 2.05   | 0.5   |
| 10     | Length of 2nd long dactylus   | 0.5  | 1     | 0.91  | 0.2   | 0.5    | 1    | 0.95   | 0.15  |
| 11     | TL of 2nd long pereopod       | 33.5 | 49    | 41.23 | 4.89  | 30     | 54   | 46.67  | 5.87  |
| 12     | Length of 2nd short ischium   | 4    | 11    | 8     | 1.38  | 6      | 12   | 9.24   | 1.51  |
| 13     | Length of 2nd short merus     | 4    | 8     | 6     | 0.98  | 4      | 8    | 6.48   | 1.29  |
| 14     | Length of 2nd short carpus    | 7    | 11    | 8.09  | 1.15  | 6      | 12   | 9.19   | 1.78  |
| 15     | Length of 2nd short propodus  | 3    | 6     | 4.05  | 0.95  | 3      | 8    | 5.52   | 1.78  |
| 16     | Length of 2nd short dactylus  | 2    | 3     | 2.27  | 0.46  | 2      | 3    | 2.62   | 0.5   |
| 17     | length of 2nd (s) pereopod    | 24   | 34    | 28.41 | 2.5   | 21     | 41   | 33.05  | 5.74  |
| 18     | length of 3rd pereopod        | 40   | 61    | 50.73 | 5.65  | 43     | 68   | 58.71  | 7.14  |
| 19     | length of 4th pereopod        | 47   | 84    | 54.68 | 7.82  | 45     | 68   | 58.71  | 7.66  |
| 20     | length of 5th pereopod        | 32   | 60    | 50.05 | 7.09  | 44     | 68   | 58.57  | 8.13  |
| 21     | length of 2nd abdominal depth | 6    | 10    | 7.57  | 1.33  | 5      | 15   | 9.95   | 3.06  |
| 22     | length of 2nd abdominal width | 6    | 10    | 7.82  | 1.24  | 5      | 15   | 9.81   | 2.44  |
| 23     | 2nd brood pouch length        | 26   | 38    | 33    | 4.18  | 28     | 48   | 39     | 6.18  |
| 24     | Telson length                 | 8    | 17    | 13    | 2.16  | 8.00   | 18   | 15.1   | 2.28  |
| 25     | Uropod length                 | 8    | 19    | 14.33 | 5.69  | 13     | 18   | 16     | 2.65  |

**Table 2.1.7** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Heterocarpus woodmasoni*

| Sl.No. | measurements(mm)              | Male |      |        |       | Female |      |        |      |
|--------|-------------------------------|------|------|--------|-------|--------|------|--------|------|
|        |                               | Min  | Max  | Mean   | SD    | Min    | Max  | Mean   | SD   |
| 1      | Total length                  | 77   | 118  | 101.38 | 10.86 | 87     | 122  | 105.18 | 9.16 |
| 2      | total weight                  | 1.54 | 9.11 | 4.55   | 2.17  | 2.65   | 9.95 | 5.77   | 1.91 |
| 3      | Carapace length               | 19   | 39   | 28.94  | 5.92  | 15     | 34   | 27.55  | 4.49 |
| 4      | Rostral length                | 26   | 37   | 30.44  | 3.20  | 23     | 36   | 29.05  | 3.11 |
| 5      | 1st pereopod length           | 17   | 29   | 21.80  | 3.26  | 19     | 27   | 22.86  | 2.15 |
| 6      | Length of 2nd long ischium    | 3    | 7    | 5.80   | 1.14  | 5      | 8    | 6.45   | 0.74 |
| 7      | Length of 2nd long merus      | 4    | 9    | 6.94   | 1.29  | 6      | 9    | 7.45   | 0.8  |
| 8      | Length of 2nd long carpus     | 6    | 18   | 11.19  | 3.08  | 10     | 15   | 12.5   | 1.44 |
| 9      | Length of 2nd long propodus   | 1    | 2    | 1.50   | 0.52  | 1      | 2    | 1.59   | 0.5  |
| 10     | Length of 2nd long dactylus   | 0.5  | 1    | 0.69   | 0.25  | 0.5    | 1    | 1.8    | 0.25 |
| 11     | TL of 2nd long pereopod       | 14.5 | 37   | 26.00  | 5.55  | 23.5   | 33   | 28.8   | 2.72 |
| 12     | Length of 2nd short ischium   | 4    | 7    | 5.27   | 0.88  | 3      | 7    | 5.36   | 0.95 |
| 13     | Length of 2nd short merus     | 3    | 6    | 4.27   | 0.88  | 3      | 6    | 4.5    | 0.91 |
| 14     | Length of 2nd short carpus    | 4    | 7    | 5.67   | 0.72  | 2      | 8    | 5.86   | 1.08 |
| 15     | Length of 2nd short propodus  | 0.52 | 2    | 1.34   | 0.75  | 2      | 7    | 4.41   | 1.1  |
| 16     | Length of 2nd short dactylus  | 0.25 | 1    | 0.65   | 0.38  | 1.5    | 3    | 2.09   | 0.4  |
| 17     | length of 2nd (s)pereopod     | 17   | 28   | 21.60  | 2.90  | 14.5   | 31   | 22.23  | 3.31 |
| 18     | length of 3rd pereopod        | 26   | 43   | 33.30  | 4.42  | 28     | 42   | 34.7   | 3.7  |
| 19     | length of 4th pereopod        | 25   | 43   | 33.13  | 4.92  | 29     | 41   | 35.14  | 3.29 |
| 20     | length of 5th pereopod        | 23   | 40   | 2.93   | 4.83  | 27     | 38   | 33.15  | 3.44 |
| 21     | 2nd abdominal breadth         | 6    | 12   | 7.87   | 1.55  | 7      | 13   | 9.59   | 1.74 |
| 22     | length of 2nd abdominal depth | 6    | 9    | 7.00   | 0.97  | 4      | 12   | 7.55   | 2.09 |
| 23     | length of 2nd abdominal width | 4    | 10   | 7.13   | 1.51  | 5      | 11   | 7.59   | 1.84 |
| 24     | 2nd brood pouch length        | 13   | 40   | 27.45  | 7.01  | 25     | 37   | 31.05  | 3    |
| 25     | Telson length                 | 10   | 19   | 16.00  | 2.42  | 11     | 19   | 15.54  | 2.03 |
| 26     | Uropod length                 | 10   | 14   | 12.43  | 1.27  | 12     | 18   | 14.9   | 1.84 |

**Table 2.1.8** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Heterocarpus laevigatus*

| Sl.No. | measurements(mm)             | Male |     |      |     | Female |     |      |     |
|--------|------------------------------|------|-----|------|-----|--------|-----|------|-----|
|        |                              | Min  | Max | Mean | SD  | Min    | Max | Mean | SD  |
| 1      | Total length                 | 100  | 104 | 102  | 1.8 | 98     | 105 | 102  | 3.5 |
| 2      | total weight                 | 6    | 6.5 | 6.2  | 0.2 | 4.8    | 7   | 6    | 1.1 |
| 3      | Carapace length              | 35   | 39  | 37   | 1.8 | 35     | 38  | 36   | 2   |
| 4      | Rostral length               | 33   | 35  | 34   | 1   | 28     | 36  | 32   | 4   |
| 5      | 1st pereopod length          | 31   | 33  | 32   | 0.9 | 29     | 34  | 31   | 2.5 |
| 6      | Length of 2nd ischium        | 9    | 9   | 9    | 0   | 6      | 9   | 7    | 2   |
| 7      | Length of merus              | 5    | 6   | 6    | 0   | 5      | 7   | 6    | 1   |
| 8      | Length of carpus             | 9    | 10  | 9    | 1   | 9      | 10  | 9    | 1   |
| 9      | Length of propodus           | 5    | 5   | 5    | 0   | 4      | 5   | 4    | 1   |
| 10     | Length of dactylus           | 3    | 3   | 3    | 0   | 2      | 2   | 2    | 1   |
| 11     | Total length of 2nd pereopod | 31   | 33  | 32   | 1   | 23     | 33  | 30   | 3   |
| 12     | length of 3rd pereopod       | 41   | 49  | 46   | 3   | 43     | 49  | 46   | 3   |
| 13     | length of 4th pereopod       | 49   | 50  | 50   | 1   | 49     | 50  | 49   | 1   |
| 14     | length of 5th pereopod       | 44   | 49  | 47   | 1   | 45     | 47  | 46   | 1   |
| 15     | Telson length                | 14   | 15  | 14   | 1   | 11     | 16  | 14   | 2.5 |
| 16     | Uropod length                | 12   | 13  | 13   | 1   | 12     | 13  | 13   | 1   |

**Table 2.1.9** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Parapandalus spinipes*

| Sl.No. | measurements(mm)             | Male |     |      |      | Female |     |       |      |
|--------|------------------------------|------|-----|------|------|--------|-----|-------|------|
|        |                              | Min  | Max | Mean | SD   | Min    | Max | Mean  | SD   |
| 1      | Total length                 | 72   | 97  | 93   | 8.05 | 90     | 111 | 98    | 6    |
| 2      | total weight                 | 1.28 | 4.2 | 2.75 | 0.84 | 2.74   | 6.3 | 4.2   | 1.07 |
| 3      | Carapace length              | 17   | 27  | 21   | 2.8  | 21     | 28  | 24    | 2    |
| 4      | Rostral length               | 23   | 36  | 29   | 4.18 | 26     | 37  | 30    | 3    |
| 5      | 1st pereopod length          | 30   | 37  | 35   | 2.6  | 30     | 47  | 37    | 5    |
| 6      | Length of 2nd ischium        | 6    | 8   | 7    | 1    | 6      | 9   | 8     | 1    |
| 7      | Length of merus              | 7    | 10  | 8    | 1    | 7      | 10  | 8.8   | 1    |
| 8      | Length of carpus             | 10   | 14  | 12   | 1    | 13     | 18  | 15    | 1.5  |
| 9      | Length of propodus           | 1    | 2   | 2    | 1    | 1      | 2   | 2     | 0.3  |
| 10     | Length of dactylus           | 1    | 1   | 1    | 0    | 1      | 1   | 1     | 0    |
| 11     | Total length of 2nd pereopod | 27   | 34  | 30   | 2    | 31     | 40  | 34    | 2.45 |
| 12     | length of 3rd pereopod       | 60   | 87  | 84   | 8    | 69     | 103 | 86.6  | 9.48 |
| 13     | length of 4th pereopod       | 70   | 94  | 90   | 9    | 50     | 98  | 76.7  | 13.5 |
| 14     | length of 5th pereopod       | 79   | 100 | 93   | 7    | 63     | 98  | 82    | 10   |
| 15     | Telson length                | 8    | 14  | 12   | 2    | 10     | 15  | 13.04 | 1.34 |

**Table 2.1.10** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Plesionika martia*

| Sl.No. | measurements(mm)             | Male |     |      |      | Female |     |       |      |
|--------|------------------------------|------|-----|------|------|--------|-----|-------|------|
|        |                              | Min  | Max | Mean | SD   | Min    | Max | Mean  | SD   |
| 1      | Total length                 | 0    | 115 | 99   | 11   | 86     | 97  | 91.85 | 4.18 |
| 2      | total weight                 | 1.28 | 4   | 3    | 1    | 1.8    | 2.6 | 2     | 0.2  |
| 3      | Carapace length              | 4.2  | 25  | 21   | 3    | 18     | 20  | 19    | 1    |
| 4      | Rostral length               | 2.75 | 42  | 31   | 6    | 32     | 34  | 33    | 1    |
| 5      | 1st pereopod length          | 0.84 | 34  | 26   | 5    | 23     | 28  | 26    | 2    |
| 6      | Length of 2nd ischium        | 2.74 | 7   | 6    | 1    | 6      | 7   | 6     | 0    |
| 7      | Length of merus              | 6.3  | 8   | 6    | 1    | 6      | 7   | 7     | 0    |
| 8      | Length of carpus             | 4.2  | 13  | 10   | 2    | 9      | 10  | 10    | 0    |
| 9      | Length of propodus           | 1    | 2   | 1    | 1    | 1      | 2   | 1     | 0    |
| 10     | Length of dactylus           | 1    | 1   | 1    | 0.5  | 1      | 1   | 1     | 0    |
| 11     | Total length of 2nd pereopod | 22   | 31  | 23   | 3.6  | 23     | 27  | 25    | 2    |
| 12     | length of 3rd pereopod       | 26   | 32  | 28   | 2.46 | 26     | 28  | 27    | 1    |
| 13     | length of 4th pereopod       | 30   | 39  | 32   | 3.7  | 31     | 34  | 32    | 1    |
| 14     | length of 5th pereopod       | 27   | 30  | 37   | 3    | 26     | 29  | 28    | 1    |
| 15     | Telson length                | 9    | 15  | 11   | 2    | 9      | 10  | 9     | 1    |



**Table 2.1.11** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Plesionika ensis*

| Sl.No. | measurements(mm)       | Male |     |      |    | Female |     |      |     |
|--------|------------------------|------|-----|------|----|--------|-----|------|-----|
|        |                        | Min  | Max | Mean | SD | Min    | Max | Mean | SD  |
| 1      | Total length           | 92   | 116 | 99   | 8  | 96     | 113 | 103  | 9   |
| 2      | total weight           | 2.64 | 9   | 4    | 2  | 3      | 4   | 3    | 0   |
| 3      | Carapace length        | 21   | 39  | 26   | 6  | 21     | 28  | 24   | 3   |
| 4      | Rostral length         | 26   | 33  | 30   | 3  | 26     | 35  | 30   | 1   |
| 5      | 1st pereopod length    | 20   | 49  | 31   | 9  | 21     | 30  | 26   | 4   |
| 6      | Length of 2nd ischium  | 7    | 10  | 8    | 1  | 7      | 8   | 8    | 0.5 |
| 7      | Length of merus        | 6    | 10  | 8    | 1  | 6      | 9   | 8    | 1   |
| 8      | Length of carpus       | 10   | 14  | 12   | 2  | 10     | 12  | 11   | 1   |
| 9      | Length of propodus     | 2    | 3   | 2    | 0  | 2      | 2   | 2    | 0   |
| 10     | Length of dactylus     | 1    | 1   | 1    | 1  | 1      | 1   | 1    | 0   |
| 11     | TL of 2nd pereopod     | 20   | 28  | 23   | 3  | 21     | 23  | 22   | 1   |
| 12     | length of 3rd pereopod | 29   | 34  | 31   | 2  | 30     | 35  | 32   | 2   |
| 13     | length of 4th pereopod | 27   | 34  | 32   | 2  | 25     | 30  | 28   | 2   |
| 14     | length of 5th pereopod | 30   | 36  | 32   | 2  | 30     | 32  | 31   | 1   |
| 15     | Telson length          | 10   | 13  | 11   | 1  | 8      | 9   | 9    | 1   |

**Table 2.1.12** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Plesionika alcocki*

| Sl.No. | measurements(mm)       | Male |     |      |    | Female |     |      |    |
|--------|------------------------|------|-----|------|----|--------|-----|------|----|
|        |                        | Min  | Max | Mean | SD | Min    | Max | Mean | SD |
| 1      | Total length           | 56   | 60  | 58   | 2  | 57     | 69  | 62   | 6  |
| 2      | total weight           | 1    | 1   | 1    | 0  | 1      | 3   | 2    | 1  |
| 3      | Carapace length        | 12   | 14  | 13   | 1  | 12     | 16  | 14   | 2  |
| 4      | Rostral length         | 21   | 25  | 23   | 2  | 21     | 28  | 24   | 3  |
| 5      | 1st pereopod length    | 12   | 13  | 12   | 0  | 10     | 13  | 12   | 1  |
| 6      | Length of 2nd ischium  | 4    | 5   | 5    | 0  | 6      | 8   | 7    | 1  |
| 7      | Length of merus        | 6    | 7   | 7    | 0  | 6      | 9   | 7    | 1  |
| 8      | Length of carpus       | 8    | 12  | 10   | 2  | 7      | 12  | 9    | 2  |
| 9      | Length of propodus     | 2    | 2   | 2    | 1  | 2      | 3   | 2    | 1  |
| 10     | Length of dactylus     | 1    | 1   | 1    | 0  | 1      | 2   | 1    | 0  |
| 11     | TL of 2nd pereopod     | 16   | 16  | 16   | 0  | 16     | 16  | 16   | 0  |
| 12     | length of 3rd pereopod | 20   | 22  | 21   | 1  | 20     | 21  | 22   | 2  |
| 13     | length of 4th pereopod | 18   | 19  | 19   | 0  | 16     | 16  | 18   | 1  |
| 14     | length of 5th pereopod | 17   | 18  | 18   | 0  | 15     | 18  | 17   | 1  |
| 15     | Telson length          | 7    | 8   | 8    | 0  | 7      | 8   | 7    | 0  |
| 16     | Uropod                 | 7    | 8   | 7    | 0  | 8      | 9   | 8    | 0  |

21.13 Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Ophiophorus typus*

| Sl.No. measurements(mm)         | Male |     |      |     | Female |     |      |     |
|---------------------------------|------|-----|------|-----|--------|-----|------|-----|
|                                 | Min  | Max | Mean | SD  | Min    | Max | Mean | SD  |
| 1 Total length                  | 57   | 64  | 61   | 2.9 | 58     | 63  | 60   | 2.2 |
| 2 total weight                  | 1    | 1   | 1    | 0   | 1      | 1   | 1    | 0   |
| 3 Carapace length               | 12   | 15  | 14   | 1   | 12     | 14  | 13   | 1   |
| 4 Rostral length                | 16   | 19  | 18   | 1   | 15     | 18  | 16   | 1   |
| 5 1st pereopod length           | 9    | 13  | 11   | 2   | 8      | 13  | 10   | 2   |
| 6 Length of 2nd ischium         | 1    | 3   | 2    | 1   | 2      | 3   | 2    | 0   |
| 7 Length of merus               | 2    | 4   | 3    | 1   | 2      | 3   | 3    | 0   |
| 8 Length of carpus              | 1    | 4   | 3    | 1   | 1      | 3   | 2    | 1   |
| 9 Length of propodus            | 1    | 2   | 1    | 0   | 1      | 2   | 1    | 0   |
| 10 Length of dactylus           | 1    | 2   | 1    | 1   | 1      | 2   | 1    | 0   |
| 11 Total length of 2nd pereopod | 6    | 15  | 10   | 4   | 7      | 13  | 9    | 3   |
| 12 length of 3rd pereopod       | 9    | 15  | 12   | 3   | 10     | 16  | 13   | 3   |
| 13 length of 4th pereopod       | 10   | 16  | 13   | 3   | 11     | 17  | 14   | 3   |
| 14 length of 5th pereopod       | 9    | 13  | 11   | 2   | 11     | 15  | 13   | 2   |
| 15 Telson length                | 6    | 8   | 7    | 1   | 6      | 8   | 7    | 1   |
| 16 Uropod                       | 8    | 9   | 9    | 1   | 5      | 9   | 7    | 2   |

21.14 Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Acanthephyra sanguinea*

| Sl.No. measurements(mm)   | Male |     |      |    | Female |     |      |    |
|---------------------------|------|-----|------|----|--------|-----|------|----|
|                           | Min  | Max | Mean | SD | Min    | Max | Mean | SD |
| 1 Total length            | 87   | 101 | 96   | 8  | 96     | 100 | 98   | 2  |
| 2 total weight            | 5    | 87  | 16   | 29 | 5      | 7   | 6    | 1  |
| 3 Carapace length         | 16   | 20  | 18   | 2  | 17     | 22  | 19   | 3  |
| 4 Rostral length          | 24   | 27  | 26   | 2  | 23     | 26  | 25   | 2  |
| 5 1st pereopod length     | 25   | 28  | 27   | 2  | 24     | 26  | 25   | 1  |
| 6 Length of 2nd ischium   | 3    | 5   | 4    | 1  | 4      | 5   | 5    | 0  |
| 7 Length of merus         | 5    | 7   | 6    | 1  | 5      | 7   | 6    | 1  |
| 8 Length of carpus        | 3    | 6   | 5    | 1  | 5      | 6   | 6    | 0  |
| 9 Length of propodus      | 2    | 3   | 3    | 0  | 2      | 3   | 3    | 0  |
| 10 Length of dactylus     | 1    | 2   | 2    | 1  | 1      | 2   | 2    | 0  |
| 11 TL of 2nd pereopod     | 14   | 23  | 19   | 4  | 17     | 23  | 20   | 3  |
| 12 length of 3rd pereopod | 24   | 29  | 27   | 2  | 23     | 28  | 26   | 2  |
| 13 length of 4th pereopod | 28   | 31  | 29   | 1  | 25     | 31  | 28   | 3  |
| 14 length of 5th pereopod | 26   | 29  | 27   | 1  | 26     | 30  | 28   | 2  |
| 15 Telson length          | 13   | 17  | 15   | 2  | 16     | 18  | 17   | 1  |
| 16 Uropod                 | 12   | 15  | 14   | 2  | 14     | 16  | 15   | 1  |

**Table 2.1.15** Minimum ,maximum,mean and standard deviation of various morphometric measurements recorded in males and females of *Acanthephyra armata*

| Sl.No. | measurements(mm)             | Male |     |      |    | Female |     |      |    |
|--------|------------------------------|------|-----|------|----|--------|-----|------|----|
|        |                              | Min  | Max | Mean | SD | Min    | Max | Mean | SD |
| 1      | Total length                 | 108  | 153 | 135  | 24 | 85     | 103 | 95   | 9  |
| 2      | total weight                 | 4    | 18  | 12   | 6  | 2      | 4   | 3    | 1  |
| 3      | Carapace length              | 25   | 46  | 35   | 8  | 9      | 31  | 19   | 12 |
| 4      | Rostral length               | 30   | 35  | 33   | 2  | 9      | 31  | 19   | 12 |
| 5      | 1st pereopod length          | 28   | 31  | 30   | 1  | 16     | 26  | 21   | 5  |
| 6      | Length of 2nd ischium        | 4    | 10  | 7    | 3  | 2      | 4   | 3    | 1  |
| 7      | Length of merus              | 5    | 11  | 8    | 3  | 3      | 5   | 4    | 1  |
| 8      | Length of carpus             | 7    | 9   | 8    | 1  | 5      | 8   | 6    | 2  |
| 9      | Length of propodus           | 4    | 6   | 5    | 1  | 2      | 4   | 3    | 1  |
| 10     | Length of dactylus           | 1    | 3   | 2    | 1  | 1      | 2   | 1    | 1  |
| 11     | Total length of 2nd pereopod | 21   | 39  | 29   | 8  | 13     | 22  | 17   | 5  |
| 12     | length of 3rd pereopod       | 45   | 48  | 47   | 1  | 25     | 45  | 34   | 10 |
| 13     | length of 4th pereopod       | 40   | 46  | 43   | 3  | 20     | 39  | 29   | 10 |
| 14     | length of 5th pereopod       | 36   | 40  | 38   | 2  | 23     | 42  | 31   | 10 |
| 15     | Telson length                | 14   | 19  | 17   | 2  | 5      | 13  | 9    | 4  |
| 16     | Uropod                       | 17   | 25  | 24   | 4  | 8      | 16  | 12   | 4  |

**Table 2.3.1** Values of intercept (a) , regression coefficient (b), correlation coefficient(r) of different morphometric measurements of *Aristeus alcocki*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -1.184                  | 1.296                      | 0.880                     | 0.182                   | 0.654                      | 0.586                     |
| TL x RL       | -0.584                  | 1.004                      | 0.690                     | -2.806                  | 2.042                      | 0.917                     |
| TL x 1chl     | -0.913                  | 1.151                      | 0.696                     | -0.890                  | 1.158                      | 0.851                     |
| TL x 2 c      | -1.074                  | 1.020                      | 0.651                     | -1.825                  | 1.339                      | 0.476                     |
| TL x 2 p      | -1.818                  | 1.325                      | 0.164                     | -1.131                  | 1.038                      | 0.734                     |
| TL x 2 d      | -2.670                  | 1.638                      | 0.471                     | -1.823                  | 1.232                      | 0.688                     |
| TL x 2 CH     | -1.136                  | 1.324                      | 0.484                     | -0.690                  | 1.106                      | 0.654                     |
| TL x 3wl      | -1.160                  | 1.336                      | 0.753                     | 1.425                   | 0.164                      | 0.077                     |
| TL x 5wl      | -0.797                  | 1.179                      | 0.577                     | 0.321                   | 0.593                      | 0.201                     |
| TL x Ur       | 0.915                   | 0.178                      | 0.009                     | -0.171                  | 0.707                      | 0.380                     |
| CL x RL       | 0.533                   | 0.651                      | 0.553                     | -0.888                  | 1.526                      | 0.374                     |
| CL x 1chl     | 0.379                   | 0.739                      | 0.547                     | -0.025                  | 1.008                      | 0.470                     |
| CL x 2 i      | -2.119                  | 1.810                      | 0.277                     | -0.662                  | 0.932                      | 0.183                     |
| CL x 2 m      | 0.193                   | 0.566                      | 0.317                     | -1.627                  | 1.672                      | 0.858                     |
| CL x 2 c      | -0.120                  | 0.774                      | 0.715                     | -2.488                  | 2.234                      | 0.968                     |
| CL x 2 p      | -0.838                  | 1.166                      | 0.242                     | -1.071                  | 1.364                      | 0.924                     |
| CL x 2 d      | -1.127                  | 1.235                      | 0.511                     | -1.769                  | 1.629                      | 0.879                     |
| CL x 2CH      | 0.047                   | 1.038                      | 0.567                     | -0.841                  | 1.591                      | 0.989                     |
| CL x 3wl      | 0.201                   | 0.944                      | 0.717                     | 1.081                   | 0.443                      | 0.406                     |
| CL x 4wl      | 0.298                   | 0.860                      | 0.543                     | 1.242                   | 0.252                      | 0.099                     |
| CL x 5wl      | 0.451                   | 0.804                      | 0.512                     | -0.285                  | 1.190                      | 0.592                     |
| CL x Tel      | 0.200                   | 0.808                      | 0.342                     | 0.958                   | 0.099                      | 0.031                     |
| CL x Ur       | 0.873                   | 0.264                      | 0.037                     | -0.698                  | 1.293                      | 0.927                     |
| RL x 1chl     | 0.313                   | 0.795                      | 0.485                     | 0.811                   | 0.493                      | 0.702                     |
| RL x 2 i      | -2.112                  | 1.841                      | 0.219                     | -0.096                  | 0.594                      | 0.465                     |
| RL x 2 m      | -0.054                  | 0.733                      | 0.407                     | 0.633                   | 0.231                      | 0.102                     |
| RL x 2 c      | -0.093                  | 0.771                      | 0.544                     | 0.302                   | 0.463                      | 0.259                     |
| RL x 2 p      | 0.025                   | 0.643                      | 0.056                     | 0.450                   | 0.405                      | 0.508                     |
| RL x 2 d      | -1.072                  | 1.224                      | 0.384                     | -0.023                  | 0.531                      | 0.581                     |
| RL x 3wl      | 0.220                   | 0.948                      | 0.363                     | 0.994                   | 0.431                      | 0.452                     |
| RL x 4wl      | 0.409                   | 0.830                      | 0.425                     | 1.655                   | 0.077                      | 0.078                     |
| RL x 5wl      | 0.448                   | 0.781                      | 0.343                     | 1.516                   | 0.079                      | 0.061                     |
| RL x Tel      | -0.027                  | 0.764                      | 0.413                     | 0.967                   | 0.097                      | 0.190                     |
| RL x Ur       | 1.263                   | 0.023                      | 0.000                     | 0.963                   | 0.237                      | 0.194                     |
| 1chl x 2 i    | -0.754                  | 0.990                      | 0.083                     | 0.028                   | 0.492                      | 0.111                     |
| 1chl x 2 m    | 0.025                   | 0.688                      | 0.468                     | -0.023                  | 0.648                      | 0.278                     |
| 1chl x 2 c    | 0.168                   | 0.611                      | 0.445                     | -0.548                  | 0.996                      | 0.415                     |
| 1chl x 2 p    | -0.200                  | 0.791                      | 0.111                     | -0.208                  | 0.816                      | 0.714                     |
| 1chl x 2 d    | -0.802                  | 1.061                      | 0.376                     | -0.574                  | 0.869                      | 0.539                     |
| 1chl x 2 CH   | 0.595                   | 0.717                      | 0.270                     | 0.413                   | 0.792                      | 0.528                     |
| 1chl x 3wl    | 0.388                   | 0.850                      | 0.580                     | 1.725                   | 0.029                      | 0.004                     |
| 1chl x 4wl    | 0.485                   | 0.763                      | 0.428                     | 1.697                   | -0.041                     | 0.006                     |
| 1chl x 5wl    | 0.586                   | 0.740                      | 0.433                     | 1.005                   | 0.364                      | 0.120                     |
| 1chl x Tel    | 0.225                   | 0.609                      | 0.342                     | 0.876                   | 0.153                      | 0.162                     |
| 1chl x Ur     | 1.230                   | 0.043                      | 0.001                     | 0.467                   | 0.549                      | 0.361                     |
| 2i x 2 m      | 1.046                   | 0.075                      | 0.067                     | 0.901                   | 0.096                      | 0.013                     |
| 2 i x 2 c     | 1.005                   | 0.153                      | 0.331                     | 0.772                   | 0.276                      | 0.070                     |
| 2 i x 2 p     | 0.738                   | 0.381                      | 0.305                     | 0.822                   | 0.292                      | 0.200                     |
| 2i x 2 d      | 0.642                   | 0.279                      | 0.307                     | 0.381                   | 0.490                      | 0.375                     |
| 2i x 2CH      | 1.443                   | 0.347                      | 0.752                     | 1.343                   | 0.371                      | 0.255                     |

Table 2.3.1 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2i x 3wl      | 1.599                   | 0.155                      | 0.228                     | 1.665                   | 0.132                      | 0.173                     |
| 2i x 4wl      | 1.565                   | 0.149                      | 0.193                     | 1.475                   | 0.202                      | 0.301                     |
| 2i x 5wl      | 1.675                   | 0.090                      | 0.076                     | 1.255                   | 0.397                      | 0.312                     |
| 2i x Tel      | 1.080                   | 0.126                      | 0.174                     | 1.135                   | -0.029                     | 0.013                     |
| 2 m x 2 c     | 0.546                   | 0.526                      | 0.334                     | -0.194                  | 1.212                      | 0.929                     |
| 2m x 2 p      | 0.421                   | 0.562                      | 0.057                     | 0.399                   | 0.668                      | 0.724                     |
| 2m x 2 d      | -0.280                  | 1.035                      | 0.363                     | 0.067                   | 0.716                      | 0.554                     |
| 2m x 2 CH     | 0.939                   | 0.707                      | 0.266                     | 0.867                   | 0.786                      | 0.787                     |
| 2m x 3wl      | 0.926                   | 0.720                      | 0.422                     | 1.574                   | 0.200                      | 0.272                     |
| 2m x 4wl      | 0.942                   | 0.671                      | 0.334                     | 1.595                   | 0.040                      | 0.008                     |
| 2m x 5wl      | 1.002                   | 0.674                      | 0.364                     | 0.941                   | 0.642                      | 0.561                     |
| 2m x Tel      | 0.603                   | 0.523                      | 0.256                     | 1.101                   | 0.011                      | 0.001                     |
| 2m x Ur       | 1.367                   | -0.062                     | 0.002                     | 0.632                   | 0.700                      | 0.884                     |
| 2c x 2 p      | -0.702                  | 1.548                      | 0.357                     | 0.477                   | 0.581                      | 0.865                     |
| 2c x 2 d      | -0.741                  | 1.424                      | 0.569                     | 0.096                   | 0.678                      | 0.784                     |
| 2c x 2 CH     | 0.320                   | 1.243                      | 0.681                     | 0.965                   | 0.677                      | 0.924                     |
| 2c x 3wl      | 0.714                   | 0.895                      | 0.539                     | 1.578                   | 0.194                      | 0.404                     |
| 2c x 4wl      | 0.818                   | 0.768                      | 0.363                     | 1.541                   | 0.094                      | 0.071                     |
| 2c x 5wl      | 1.071                   | 0.600                      | 0.239                     | 1.092                   | 0.481                      | 0.498                     |
| 2c x Tel      | 0.338                   | 0.748                      | 0.433                     | 1.057                   | 0.056                      | 0.051                     |
| 2c x Ur       | 1.078                   | 0.196                      | 0.017                     | 0.739                   | 0.582                      | 0.969                     |
| 2p x 2 d      | 0.414                   | 0.432                      | 0.352                     | -0.443                  | 1.150                      | 0.882                     |
| 2p x 2 CH     | 1.252                   | 0.449                      | 0.598                     | 0.477                   | 1.101                      | 0.953                     |
| 2p x 3wl      | 1.437                   | 0.273                      | 0.338                     | 1.530                   | 0.228                      | 0.218                     |
| 2p x 4wl      | 1.469                   | 0.206                      | 0.175                     | 1.511                   | 0.117                      | 0.043                     |
| 2p x 5wl      | 1.585                   | 0.155                      | 0.107                     | 0.745                   | 0.782                      | 0.515                     |
| 2p x Tel      | 1.004                   | 0.170                      | 0.150                     | 1.021                   | 0.086                      | 0.048                     |
| 2p x Ur       | 0.989                   | 0.297                      | 0.260                     | 0.406                   | 0.864                      | 0.833                     |
| 2d x 2 CH     | 1.168                   | 0.639                      | 0.642                     | 0.958                   | 0.883                      | 0.920                     |
| 2d x 3wl      | 1.284                   | 0.507                      | 0.617                     | 1.558                   | 0.276                      | 0.479                     |
| 2d x 4wl      | 1.270                   | 0.479                      | 0.503                     | 1.450                   | 0.240                      | 0.270                     |
| 2d x 5wl      | 1.418                   | 0.380                      | 0.342                     | 1.117                   | 0.588                      | 0.436                     |
| 2d x Tel      | 1.015                   | 0.192                      | 0.102                     | 1.029                   | 0.108                      | 0.113                     |
| 2d x Ur       | 1.066                   | 0.269                      | 0.113                     | 0.790                   | 0.685                      | 0.786                     |
| 2CH x 3wl     | 0.675                   | 0.608                      | 0.566                     | 1.334                   | 0.266                      | 0.378                     |
| 2CH x 4wl     | 0.760                   | 0.537                      | 0.402                     | 1.365                   | 0.165                      | 0.108                     |
| 2CH x 5wl     | 1.076                   | 0.390                      | 0.229                     | 0.335                   | 0.754                      | 0.608                     |
| 2CH x Tel     | 0.483                   | 0.408                      | 0.290                     | 1.014                   | 0.060                      | 0.029                     |
| 2CH x Ur      | 0.670                   | 0.365                      | 0.133                     | 0.024                   | 0.790                      | 0.885                     |
| 3wl x 4wl     | 0.280                   | 0.815                      | 0.607                     | -0.134                  | 0.999                      | 0.746                     |
| 3wl x 5wl     | 0.601                   | 0.665                      | 0.436                     | -0.043                  | 0.910                      | 0.166                     |
| 3wl x Tel     | 0.380                   | 0.465                      | 0.248                     | 0.638                   | 0.268                      | 0.111                     |
| 3wl x Ur      | 0.752                   | 0.317                      | 0.066                     | -0.997                  | 1.307                      | 0.454                     |
| 4wl x 5wl     | 0.660                   | 0.646                      | 0.449                     | 1.011                   | 0.341                      | 0.031                     |
| 4wl x Tel     | 0.514                   | 0.396                      | 0.198                     | 0.720                   | 0.240                      | 0.119                     |
| 4wl x Ur      | 0.940                   | 0.213                      | 0.032                     | 0.360                   | 0.585                      | 0.122                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

Table 2.3.2

Values of intercept (a) , regression coefficient (b), correlation coefficient(r) of different morphometric measurements of *Panopais jerryi*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -1.103                  | 1.273                      | 0.903                     | -3.290                  | 2.341                      | 0.801                     |
| TL x RL       | -3.982                  | 2.645                      | 0.904                     | 0.537                   | 0.438                      | 0.051                     |
| TL x 1chl     | -1.180                  | 1.191                      | 0.508                     | -6.299                  | 3.719                      | 0.077                     |
| TL x 2 i      | 0.451                   | 0.070                      | 0.000                     | 5.534                   | -2.440                     | 0.079                     |
| TL x 2 m      | -7.489                  | 4.041                      | 0.558                     | -1.799                  | 1.324                      | 0.041                     |
| TL x 2 c      | 2.058                   | -0.552                     | 0.179                     | -11.237                 | 6.000                      | 0.477                     |
| TL x 2 p      | 9.445                   | -4.405                     | 0.329                     | -26.103                 | 13.094                     | 0.956                     |
| TL x 2 d      | 6.797                   | -3.249                     | 0.179                     | 0.301                   | 0.000                      | 1.000                     |
| TL x 2 CH     | 1.362                   | 0.000                      | 1.000                     | -6.712                  | 3.996                      | 0.332                     |
| TL x 3wl      | -2.872                  | 2.184                      | 0.992                     | -1.120                  | 1.324                      | 0.925                     |
| TL x 4wl      | -0.718                  | 1.158                      | 0.930                     | 0.110                   | 0.749                      | 0.167                     |
| TL x 5wl      | 0.471                   | 0.576                      | 0.404                     | -0.171                  | 0.885                      | 0.530                     |
| TL x Tel      | -1.556                  | 1.376                      | 0.676                     | -9.025                  | 5.042                      | 0.944                     |
| TL x Ur       | -1.909                  | 1.554                      | 0.849                     | -7.920                  | 4.522                      | 0.944                     |
| CL x RL       | -1.095                  | 1.677                      | 0.652                     | 0.732                   | 0.472                      | 0.406                     |
| CL x 1chl     | -0.419                  | 1.118                      | 0.801                     | -3.847                  | 3.463                      | 0.459                     |
| CL x 2 i      | 2.212                   | -1.093                     | 0.089                     | -0.310                  | 0.587                      | 0.031                     |
| CL x 2 m      | -4.770                  | 3.703                      | 0.841                     | -1.399                  | 1.552                      | 0.381                     |
| CL x 2 c      | 1.925                   | -0.667                     | 0.468                     | -3.634                  | 3.125                      | 0.885                     |
| CL x 2 p      | 2.964                   | -1.663                     | 0.084                     | -6.757                  | 4.961                      | 0.939                     |
| CL x 2 d      | 6.012                   | -3.924                     | 0.468                     | 0.301                   | 0.000                      | 1.000                     |
| CL x 2CH      | 1.362                   | 0.000                      | 1.000                     | -2.021                  | 2.335                      | 0.775                     |
| CL x 3wl      | -0.799                  | 1.594                      | 0.948                     | 0.813                   | 0.517                      | 0.966                     |
| CL x 4wl      | 0.307                   | 0.895                      | 0.998                     | 0.834                   | 0.542                      | 0.597                     |
| CL x 5wl      | 0.793                   | 0.571                      | 0.713                     | 1.395                   | 0.161                      | 0.119                     |
| CL x Tel      | 0.119                   | 0.755                      | 0.366                     | -0.992                  | 1.516                      | 0.584                     |
| CL x Ur       | -0.813                  | 1.255                      | 0.993                     | -0.714                  | 1.360                      | 0.584                     |
| RL x 1chl     | 0.854                   | 0.276                      | 0.211                     | -8.575                  | 6.889                      | 0.997                     |
| RL x 2 i      | -0.200                  | 0.571                      | 0.104                     | -5.029                  | 3.905                      | 0.759                     |
| RL x 2 m      | -0.848                  | 0.981                      | 0.255                     | -3.954                  | 3.392                      | 0.999                     |
| RL x 2 c      | 1.018                   | -0.057                     | 0.015                     | -4.525                  | 3.858                      | 0.741                     |
| RL x 2 p      | 3.566                   | -2.206                     | 0.638                     | -3.621                  | 2.944                      | 0.181                     |
| RL x 2CH      | 1.362                   | 0.000                      | 1.000                     | -3.307                  | 3.317                      | 0.858                     |
| RL x 3wl      | 0.555                   | 0.725                      | 0.847                     | 1.088                   | 0.344                      | 0.234                     |
| RL x 4wl      | 1.132                   | 0.360                      | 0.697                     | 0.307                   | 0.929                      | 0.964                     |
| RL x 5wl      | 1.475                   | 0.119                      | 0.133                     | 2.086                   | -0.316                     | 0.253                     |
| RL x Tel      | 0.437                   | 0.576                      | 0.918                     | 1.295                   | -0.029                     | 0.000                     |
| RL x Ur       | 0.610                   | 0.458                      | 0.571                     | 1.337                   | -0.026                     | 0.000                     |
| 1chl x 2 i    | 3.111                   | -2.034                     | 0.479                     | -0.144                  | 0.548                      | 0.712                     |
| 1chl x 2 m    | -3.280                  | 3.228                      | 0.997                     | 0.271                   | 0.490                      | 0.994                     |
| 1chl x 2 c    | 1.843                   | -0.732                     | 0.879                     | 0.256                   | 0.576                      | 0.786                     |
| 1chl x 2 p    | -0.451                  | 0.770                      | 0.028                     | -0.017                  | 0.475                      | 0.225                     |
| 1chl x 2 CH   | 5.529                   | -4.305                     | 0.879                     | 0.809                   | 0.491                      | 0.894                     |
| 1chl x 3wl    | 0.314                   | 1.009                      | 0.593                     | 1.510                   | 0.055                      | 0.281                     |
| 1chl x 4wl    | 0.858                   | 0.626                      | 0.781                     | 1.462                   | 0.136                      | 0.981                     |
| 1chl x 5wl    | 0.973                   | 0.539                      | 0.989                     | 1.687                   | -0.042                     | 0.208                     |
| 1chl x Tel    | 1.008                   | 0.186                      | 0.034                     | 1.232                   | 0.017                      | 0.002                     |
| 1chl x Ur     | 0.067                   | 0.937                      | 0.863                     | 1.281                   | 0.015                      | 0.002                     |

Table 2.3.2 Continued.....

| Relationships | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r |
|---------------|----------------------------|-------------------------------|------------------------------|----------------------------|-------------------------------|------------------------------|
| 2 m x 2 c     | 1.096                      | -0.222                        | 0.843                        | -0.012                     | 1.119                         | 0.718                        |
| 2m x 2 p      | 0.384                      | 0.165                         | 0.013                        | -0.146                     | 0.820                         | 0.162                        |
| 2m x 2 CH     | 1.362                      | 0.000                         | 1.000                        | 0.568                      | 0.967                         | 0.840                        |
| 2m x 3wl      | 1.330                      | 0.325                         | 0.643                        | 1.493                      | 0.097                         | 0.213                        |
| 2m x 4wl      | 1.491                      | 0.199                         | 0.803                        | 1.391                      | 0.272                         | 0.953                        |
| 2m x 5wl      | 1.521                      | 0.166                         | 0.976                        | 1.721                      | -0.097                        | 0.276                        |
| 2m x Tel      | 1.185                      | 0.073                         | 0.056                        | 1.280                      | -0.029                        | 0.001                        |
| 2m x Ur       | 1.035                      | 0.295                         | 0.897                        | 1.323                      | -0.026                        | 0.001                        |
| 2c x 2 p      | 3.259                      | -2.942                        | 0.250                        | -0.678                     | 1.276                         | 0.685                        |
| 2c x 2 CH     | 1.362                      | 0.000                         | 1.000                        | 0.653                      | 0.790                         | 0.978                        |
| 2c x 3wl      | 2.349                      | -0.840                        | 0.250                        | 1.444                      | 0.137                         | 0.743                        |
| 2c x 4wl      | 2.191                      | -0.595                        | 0.419                        | 1.439                      | 0.199                         | 0.887                        |
| 2c x 5wl      | 2.270                      | -0.672                        | 0.938                        | 1.632                      | 0.001                         | 0.000                        |
| 2c x Tel      | 1.036                      | 0.215                         | 0.028                        | 0.956                      | 0.299                         | 0.250                        |
| 2c x Ur       | 2.145                      | -0.959                        | 0.551                        | 1.033                      | 0.268                         | 0.250                        |
| 3wl x 4wl     | 0.791                      | 0.539                         | 0.968                        | 0.285                      | 0.856                         | 0.413                        |
| 3wl x 5wl     | 1.188                      | 0.289                         | 0.490                        | 0.918                      | 0.453                         | 0.262                        |
| 3wl x Tel     | 0.320                      | 0.588                         | 0.593                        | -3.925                     | 3.279                         | 0.757                        |
| 3wl x Ur      | 0.102                      | 0.732                         | 0.905                        | -3.346                     | 2.941                         | 0.757                        |
| 4wl x 5 wl    | 0.633                      | 0.617                         | 0.667                        | 1.991                      | -0.218                        | 0.108                        |
| 4wl x Tel     | -0.225                     | 0.896                         | 0.413                        | 0.418                      | 0.511                         | 0.033                        |
| 4wl x Ur      | -1.029                     | 1.393                         | 0.983                        | 0.550                      | 0.458                         | 0.033                        |
| 5wl x Tel     | 0.986                      | 0.154                         | 0.007                        | -4.803                     | 3.708                         | 0.756                        |
| 5wl x Ur      | -1.457                     | 1.648                         | 0.785                        | -4.133                     | 3.326                         | 0.756                        |
| Tel x Ur      | 0.577                      | 0.541                         | 0.288                        | 0.175                      | 0.897                         | 1.000                        |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

**Table 2.3.3** Values of Intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Metapenseopeis andamanensis*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -0.242                  | 0.838                      | 0.888                     | -0.606                  | 1.016                      | 0.939                     |
| TL x RL       | -2.284                  | 1.768                      | 0.755                     | -0.901                  | 1.052                      | 0.856                     |
| TL x 1chl     | -0.320                  | 0.832                      | 0.227                     | -0.796                  | 1.050                      | 0.895                     |
| TL x 2 c      | -3.449                  | 2.232                      | 0.656                     | -1.186                  | 1.091                      | 0.812                     |
| TL x 2 p      | -3.455                  | 2.054                      | 0.869                     | -2.380                  | 1.528                      | 0.867                     |
| TL x 2 d      | -2.159                  | 1.158                      | 0.134                     | -2.261                  | 1.258                      | 0.534                     |
| TL x 2 CH     | -1.527                  | 1.488                      | 0.752                     | -0.440                  | 0.946                      | 0.955                     |
| TL x 3wl      | -0.195                  | 0.865                      | 0.165                     | -0.405                  | 0.976                      | 0.603                     |
| TL x 4wl      | -1.013                  | 1.271                      | 0.588                     | -0.098                  | 0.842                      | 0.668                     |
| TL x 5wl      | -0.157                  | 0.864                      | 0.579                     | -0.273                  | 0.934                      | 0.779                     |
| TL x Tel      | -2.366                  | 1.774                      | 0.928                     | -1.753                  | 1.443                      | 0.764                     |
| TL x Ur       | -0.609                  | 0.926                      | 0.614                     | -1.830                  | 1.547                      | 0.698                     |
| CL x RL       | -1.683                  | 2.045                      | 0.800                     | -0.202                  | 0.981                      | 0.819                     |
| CL x 1chl     | -0.063                  | 0.981                      | 0.249                     | -0.149                  | 1.017                      | 0.924                     |
| CL x 2 i      | -0.292                  | 0.636                      | 0.248                     | -0.432                  | 0.782                      | 0.277                     |
| CL x 2 m      | -0.967                  | 1.278                      | 0.683                     | 0.216                   | 0.427                      | 0.630                     |
| CL x 2 c      | -2.725                  | 2.606                      | 0.708                     | -0.522                  | 1.063                      | 0.848                     |
| CL x 2 p      | -2.407                  | 2.129                      | 0.739                     | -1.354                  | 1.418                      | 0.821                     |
| CL x 2 d      | -2.062                  | 1.549                      | 0.189                     | -1.331                  | 1.102                      | 0.451                     |
| CL x 2CH      | -1.032                  | 1.728                      | 0.804                     | 0.207                   | 0.868                      | 0.885                     |
| CL x 3wl      | -0.441                  | 1.381                      | 0.333                     | 0.110                   | 1.010                      | 0.711                     |
| CL x 4wl      | -0.100                  | 1.132                      | 0.369                     | 0.519                   | 0.742                      | 0.571                     |
| CL x 5wl      | 0.356                   | 0.845                      | 0.438                     | 0.337                   | 0.879                      | 0.758                     |
| CL x Tel      | -1.412                  | 1.804                      | 0.759                     | -0.751                  | 1.314                      | 0.697                     |
| CL x Ur       | -0.112                  | 0.943                      | 0.503                     | -0.917                  | 1.530                      | 0.750                     |
| RL x 1chl     | 0.918                   | 0.337                      | 0.154                     | 0.316                   | 0.804                      | 0.678                     |
| RL x 2 i      | 0.328                   | 0.232                      | 0.173                     | -0.172                  | 0.707                      | 0.266                     |
| RL x 2 m      | 0.152                   | 0.570                      | 0.710                     | 0.337                   | 0.405                      | 0.666                     |
| RL x 2 c      | -0.275                  | 1.022                      | 0.570                     | -0.047                  | 0.851                      | 0.639                     |
| RL x 2 p      | -0.468                  | 0.887                      | 0.671                     | -0.762                  | 1.171                      | 0.658                     |
| RL x 2CH      | 0.550                   | 0.714                      | 0.717                     | 0.547                   | 0.737                      | 0.751                     |
| RL x 3wl      | 0.890                   | 0.515                      | 0.242                     | 0.481                   | 0.881                      | 0.636                     |
| RL x 4wl      | 0.983                   | 0.428                      | 0.276                     | 0.732                   | 0.701                      | 0.599                     |
| RL x 5wl      | 1.150                   | 0.332                      | 0.355                     | 0.595                   | 0.826                      | 0.787                     |
| RL x Tel      | 0.225                   | 0.757                      | 0.899                     | -0.178                  | 1.064                      | 0.538                     |
| RL x Ur       | 0.851                   | 0.307                      | 0.279                     | -0.207                  | 1.200                      | 0.543                     |
| 1chl x 2 i    | 0.322                   | 0.217                      | 0.112                     | -0.488                  | 0.911                      | 0.420                     |
| 1chl x 2 m    | 0.048                   | 0.601                      | 0.582                     | 0.249                   | 0.444                      | 0.763                     |
| 1chl x 2 c    | -0.509                  | 1.114                      | 0.500                     | -0.264                  | 0.960                      | 0.776                     |
| 1chl x 2 p    | -0.288                  | 0.678                      | 0.290                     | -0.966                  | 1.244                      | 0.707                     |
| 1chl x 2 d    | -1.683                  | 1.369                      | 0.570                     | -1.079                  | 1.009                      | 0.423                     |
| 1chl x 2 CH   | 0.426                   | 0.748                      | 0.581                     | 0.357                   | 0.834                      | 0.915                     |
| 1chl x 3wl    | 1.565                   | -0.035                     | 0.001                     | 0.457                   | 0.828                      | 0.534                     |
| 1chl x 4wl    | 1.408                   | 0.073                      | 0.006                     | 0.697                   | 0.672                      | 0.524                     |
| 1chl x 5wl    | 1.457                   | 0.073                      | 0.013                     | 0.639                   | 0.720                      | 0.570                     |
| 1chl x Tel    | 0.627                   | 0.391                      | 0.138                     | -0.593                  | 1.320                      | 0.788                     |
| 1chl x Ur     | 1.259                   | -0.026                     | 0.001                     | -0.476                  | 1.323                      | 0.629                     |
| 2i x 2 m      | 0.655                   | 0.312                      | 0.066                     | 0.616                   | 0.276                      | 0.582                     |
| 2i x 2 c      | 0.689                   | 0.461                      | 0.036                     | 0.709                   | 0.299                      | 0.148                     |
| 2i x 2 p      | 0.287                   | 0.534                      | 0.076                     | 0.195                   | 0.550                      | 0.273                     |
| 2i x 2CH      | 1.089                   | 0.540                      | 0.128                     | 1.082                   | 0.459                      | 0.546                     |



Table 2.3.3 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| Zi x 3wl      | 1.181                   | 0.551                      | 0.086                     | 1.299                   | 0.253                      | 0.099                     |
| Zi x 4wl      | 0.991                   | 0.841                      | 0.332                     | 1.296                   | 0.344                      | 0.271                     |
| Zi x 5wl      | 1.209                   | 0.565                      | 0.319                     | 1.390                   | 0.189                      | 0.077                     |
| Zi x Tel      | 0.778                   | 0.602                      | 0.138                     | 0.695                   | 0.493                      | 0.217                     |
| 2m x 2c       | -0.492                  | 1.729                      | 0.746                     | -0.285                  | 1.500                      | 0.489                     |
| 2m x 2p       | -0.496                  | 1.311                      | 0.670                     | -0.893                  | 1.815                      | 0.389                     |
| 2m x 2d       | -1.300                  | 1.696                      | 0.543                     | -1.006                  | 1.455                      | 0.227                     |
| 2m x 2CH      | 0.426                   | 1.174                      | 0.887                     | 0.196                   | 1.485                      | 0.750                     |
| 2m x 3wl      | 0.993                   | 0.621                      | 0.161                     | 0.420                   | 1.318                      | 0.350                     |
| 2m x 4wl      | 1.186                   | 0.377                      | 0.098                     | 0.583                   | 1.177                      | 0.416                     |
| 2m x 5wl      | 1.264                   | 0.343                      | 0.173                     | 0.585                   | 1.174                      | 0.392                     |
| 2m x Tel      | 0.343                   | 0.950                      | 0.504                     | -0.911                  | 2.433                      | 0.692                     |
| 2m x Ur       | 1.012                   | 0.252                      | 0.086                     | -0.331                  | 1.845                      | 0.316                     |
| 2c x 2p       | -0.066                  | 0.700                      | 0.767                     | -0.499                  | 1.155                      | 0.726                     |
| 2c x 2CH      | 0.835                   | 0.602                      | 0.934                     | 0.736                   | 0.701                      | 0.769                     |
| 2c x 3wl      | 1.413                   | 0.108                      | 0.020                     | 0.630                   | 0.924                      | 0.792                     |
| 2c x 4wl      | 1.317                   | 0.194                      | 0.104                     | 0.885                   | 0.696                      | 0.668                     |
| 2c x 5wl      | 1.419                   | 0.140                      | 0.115                     | 0.863                   | 0.720                      | 0.678                     |
| 2c x Tel      | 0.648                   | 0.514                      | 0.591                     | -0.062                  | 1.186                      | 0.756                     |
| 2c x Ur       | 1.024                   | 0.208                      | 0.234                     | -0.155                  | 1.426                      | 0.868                     |
| 2p x 2d       | -0.172                  | 0.501                      | 0.121                     | -0.289                  | 0.799                      | 0.581                     |
| 2p x 2CH      | 0.992                   | 0.697                      | 0.802                     | 1.074                   | 0.540                      | 0.839                     |
| 2p x 3wl      | 1.347                   | 0.278                      | 0.083                     | 1.154                   | 0.563                      | 0.541                     |
| 2p x 4wl      | 1.188                   | 0.516                      | 0.470                     | 1.253                   | 0.476                      | 0.575                     |
| 2p x 5wl      | 1.337                   | 0.355                      | 0.475                     | 1.221                   | 0.535                      | 0.689                     |
| 2p x Tel      | 0.661                   | 0.792                      | 0.897                     | 0.594                   | 0.757                      | 0.567                     |
| 2p x Ur       | 0.992                   | 0.381                      | 0.505                     | 0.627                   | 0.923                      | 0.669                     |
| 2d x 2CH      | 1.371                   | 0.357                      | 0.435                     | 1.309                   | 0.379                      | 0.455                     |
| 2d x 4wl      | 1.512                   | -0.051                     | 0.009                     | 1.463                   | 0.313                      | 0.274                     |
| 2d x 5wl      | 1.555                   | -0.003                     | 0.000                     | 1.446                   | 0.436                      | 0.502                     |
| 2d x Tel      | 1.127                   | 0.142                      | 0.060                     | 0.922                   | 0.539                      | 0.315                     |
| 2d x Ur       | 1.239                   | -0.105                     | 0.079                     | 1.033                   | 0.612                      | 0.324                     |
| 2CH x 3wl     | 1.047                   | 0.332                      | 0.071                     | 0.148                   | 0.959                      | 0.545                     |
| 2CH x 4wl     | 0.937                   | 0.400                      | 0.172                     | 0.314                   | 0.876                      | 0.677                     |
| 2CH x 5wl     | 1.123                   | 0.304                      | 0.211                     | 0.348                   | 0.851                      | 0.605                     |
| 2CH x Tel     | -0.075                  | 0.880                      | 0.642                     | -0.999                  | 1.466                      | 0.739                     |
| 2CH x Ur      | 0.775                   | 0.317                      | 0.212                     | -0.845                  | 1.441                      | 0.567                     |
| 3wl x 4wl     | 0.994                   | 0.337                      | 0.187                     | 0.704                   | 0.551                      | 0.453                     |
| 3wl x 5wl     | 1.072                   | 0.318                      | 0.355                     | 0.542                   | 0.663                      | 0.619                     |
| 3wl x Tel     | 0.676                   | 0.310                      | 0.129                     | -0.197                  | 0.820                      | 0.390                     |
| 3wl x Ur      | 0.844                   | 0.251                      | 0.204                     | -0.579                  | 1.166                      | 0.626                     |
| 4wl x 5wl     | 0.554                   | 0.685                      | 0.943                     | 0.364                   | 0.758                      | 0.544                     |
| 4wl x Tel     | -0.115                  | 0.838                      | 0.569                     | -0.636                  | 1.083                      | 0.457                     |
| 4wl x Ur      | 0.327                   | 0.597                      | 0.700                     | -0.658                  | 1.178                      | 0.429                     |
| 5wl x Tel     | -0.687                  | 1.180                      | 0.529                     | -0.611                  | 1.067                      | 0.468                     |
| 5wl x Ur      | -0.053                  | 0.822                      | 0.624                     | -1.099                  | 1.471                      | 0.707                     |
| Tel x Ur      | 0.631                   | 0.519                      | 0.653                     | 0.160                   | 0.960                      | 0.732                     |

1L- Total length

CL- Carapace length

RL- Rostral length

TEL- Telson length

Ur- uropod length

Zi - ischium of 2nd cheiped

2m - merus of 2nd cheiped

2c - carpus of 2nd cheiped

2p - propodus of 2nd cheiped

2d - dactylus of 2nd cheiped

1CH- Length of 1st cheiped

2CH- Length of 2nd cheiped

3CH- Length of 3rd cheiped

4CH- Length of 4th cheipe

5CH- Length of 5th cheipe

**Table 2.3.4 Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *S.harti***

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | 0.011                   | 0.746                      | 0.633                     | 1.629                   | -0.148                     | 0.021                     |
| TL x RL       | -0.744                  | 0.974                      | 0.649                     | -0.267                  | 0.703                      | 0.533                     |
| TL x 1chl     | -0.040                  | 0.625                      | 0.156                     | 1.825                   | -0.381                     | 0.090                     |
| TL x 2 i      | -2.874                  | 1.848                      | 0.734                     | -2.787                  | 1.854                      | 0.696                     |
| TL x 2 m      | -2.227                  | 1.607                      | 0.797                     | -0.889                  | 0.913                      | 0.590                     |
| TL x 2 c      | -1.240                  | 1.149                      | 0.643                     | -1.028                  | 1.019                      | 0.465                     |
| TL x 2 p      | -0.156                  | 0.257                      | 0.060                     | 1.249                   | -0.450                     | 0.106                     |
| TL x 2 d      | -1.681                  | 0.946                      | 0.253                     | 0.442                   | -0.175                     | 0.013                     |
| TL x 2 CH     | -1.188                  | 1.350                      | 0.889                     | -0.290                  | 0.890                      | 0.673                     |
| TL x 3wl      | 0.853                   | 0.440                      | 0.474                     | 1.267                   | 0.117                      | 0.053                     |
| TL x 4wl      | 0.939                   | 0.241                      | 0.202                     | 1.182                   | 0.107                      | 0.033                     |
| TL x 5wl      | 1.202                   | 0.145                      | 0.041                     | 1.827                   | -0.197                     | 0.128                     |
| TL x Tel      | -1.497                  | 1.340                      | 0.715                     | -1.821                  | 1.524                      | 0.801                     |
| TL x Ur       | -0.544                  | 0.842                      | 0.511                     | 1.470                   | -0.260                     | 0.057                     |
| CL x RL       | -0.295                  | 0.985                      | 0.584                     | 0.660                   | 0.278                      | 0.089                     |
| CL x 1chl     | -0.622                  | 1.236                      | 0.538                     | -0.036                  | 0.851                      | 0.475                     |
| CL x 2 i      | -1.109                  | 1.233                      | 0.287                     | 1.581                   | -0.684                     | 0.101                     |
| CL x 2 m      | -0.890                  | 1.211                      | 0.397                     | 0.985                   | -0.133                     | 0.013                     |
| CL x 2 c      | -0.825                  | 1.241                      | 0.659                     | 0.783                   | 0.059                      | 0.002                     |
| CL x 2 p      | -0.576                  | 0.635                      | 0.320                     | -0.462                  | 0.646                      | 0.232                     |
| CL x 2 d      | -1.865                  | 1.387                      | 0.478                     | -0.981                  | 0.810                      | 0.298                     |
| CL x 2CH      | -0.335                  | 1.205                      | 0.823                     | 1.432                   | -0.051                     | 0.002                     |
| CL x 3wl      | 0.799                   | 0.484                      | 0.504                     | 1.510                   | -0.019                     | 0.002                     |
| CL x 4wl      | 0.878                   | 0.363                      | 0.404                     | 0.994                   | 0.285                      | 0.248                     |
| CL x 5wl      | 0.986                   | 0.344                      | 0.203                     | 1.242                   | 0.162                      | 0.092                     |
| CL x Tel      | -0.422                  | 1.036                      | 0.378                     | 1.741                   | -0.541                     | 0.107                     |
| CL x Ur       | -0.320                  | 0.966                      | 0.590                     | 0.294                   | 0.512                      | 0.236                     |
| RL x 1chl     | 0.388                   | 0.685                      | 0.275                     | 1.104                   | 0.012                      | 0.000                     |
| RL x 2 i      | -0.630                  | 1.153                      | 0.418                     | -0.386                  | 1.002                      | 0.188                     |
| RL x 2 m      | -0.216                  | 0.952                      | 0.408                     | 0.181                   | 0.601                      | 0.237                     |
| RL x 2 c      | 0.122                   | 0.748                      | 0.398                     | -0.071                  | 0.901                      | 0.337                     |
| RL x 2 p      | 0.159                   | 0.159                      | 0.033                     | 0.664                   | -0.241                     | 0.028                     |
| RL x 2 d      | -0.785                  | 0.816                      | 0.275                     | 0.019                   | 0.095                      | 0.004                     |
| RL x 2CH      | 0.432                   | 0.862                      | 0.530                     | 0.732                   | 0.607                      | 0.290                     |
| RL x 3wl      | 1.087                   | 0.363                      | 0.473                     | 1.386                   | 0.094                      | 0.032                     |
| RL x 4wl      | 1.250                   | 0.134                      | 0.091                     | 1.212                   | 0.162                      | 0.070                     |
| RL x 5wl      | 1.366                   | 0.102                      | 0.029                     | 1.456                   | 0.008                      | 0.000                     |
| RL x Tel      | 0.083                   | 0.878                      | 0.449                     | 0.040                   | 0.932                      | 0.278                     |
| RL x Ur       | 0.202                   | 0.772                      | 0.628                     | 1.034                   | -0.044                     | 0.002                     |
| 1chl x 2 i    | 0.711                   | -0.040                     | 0.001                     | 1.802                   | -1.027                     | 0.346                     |
| 1chl x 2 m    | 0.402                   | 0.389                      | 0.117                     | 0.977                   | -0.153                     | 0.027                     |
| 1chl x 2 c    | 0.266                   | 0.601                      | 0.440                     | 0.784                   | 0.071                      | 0.004                     |
| 1chl x 2 p    | -0.115                  | 0.391                      | 0.345                     | -0.312                  | 0.650                      | 0.357                     |
| 1chl x 2 d    | -1.034                  | 1.008                      | 0.718                     | -0.792                  | 0.813                      | 0.458                     |
| 1chl x 2 CH   | 0.907                   | 0.427                      | 0.222                     | 1.456                   | -0.084                     | 0.010                     |
| 1chl x 3wl    | 1.269                   | 0.195                      | 0.233                     | 1.431                   | 0.048                      | 0.014                     |
| 1chl x 4wl    | 1.240                   | 0.139                      | 0.168                     | 1.074                   | 0.274                      | 0.349                     |
| 1chl x 5wl    | 1.269                   | 0.183                      | 0.162                     | 1.407                   | 0.049                      | 0.013                     |
| 1chl x Tel    | 0.805                   | 0.228                      | 0.052                     | 1.854                   | -0.758                     | 0.321                     |
| 1chl x Ur     | 0.593                   | 0.412                      | 0.305                     | 0.218                   | 0.688                      | 0.652                     |
| 2i x 2 m      | 0.438                   | 0.622                      | 0.555                     | 0.537                   | 0.410                      | 0.587                     |
| 2i x 2CH      | 1.053                   | 0.522                      | 0.818                     | 1.102                   | 0.398                      | 0.665                     |

Table 2.3.4 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2i x Tel      | 0.680                   | 0.586                      | 0.635                     | 0.562                   | 0.680                      | 0.788                     |
| 2m x 2c       | 0.394                   | 0.665                      | 0.699                     | 0.203                   | 0.820                      | 0.425                     |
| 2m x 2CH      | 0.754                   | 0.759                      | 0.910                     | 0.721                   | 0.796                      | 0.760                     |
| 2m x 3wl      | 1.308                   | 0.219                      | 0.383                     | 1.400                   | 0.104                      | 0.059                     |
| 2m x Tel      | 0.420                   | 0.762                      | 0.750                     | 0.259                   | 0.930                      | 0.421                     |
| 2m x Ur       | 0.762                   | 0.360                      | 0.304                     | 1.091                   | -0.129                     | 0.020                     |
| 2c x 2d       | -0.850                  | 1.022                      | 0.606                     | 0.143                   | -0.030                     | 0.001                     |
| 2c x 2CH      | 0.521                   | 0.915                      | 0.838                     | 0.845                   | 0.599                      | 0.679                     |
| 2c x Tel      | 0.288                   | 0.813                      | 0.541                     | 0.618                   | 0.451                      | 0.157                     |
| 2c x Ur       | 0.635                   | 0.453                      | 0.303                     | 1.069                   | -0.094                     | 0.017                     |
| 2p x 2d       | -0.311                  | 1.312                      | 0.538                     | -0.254                  | 0.896                      | 0.655                     |
| 2p x 2CH      | 1.222                   | 0.530                      | 0.151                     | 1.368                   | -0.015                     | 0.000                     |
| 2p x 3wl      | 1.396                   | 0.284                      | 0.234                     | 1.446                   | 0.091                      | 0.062                     |
| 2p x 4wl      | 1.307                   | 0.276                      | 0.293                     | 1.328                   | 0.131                      | 0.093                     |
| 2p x 5wl      | 1.341                   | 0.414                      | 0.369                     | 1.414                   | 0.115                      | 0.084                     |
| 2p x Tel      | 1.018                   | 0.151                      | 0.010                     | 1.272                   | -0.638                     | 0.269                     |
| 2p x Ur       | 0.859                   | 0.625                      | 0.311                     | 0.798                   | 0.459                      | 0.342                     |
| 2d x 2CH      | 1.335                   | 0.500                      | 0.431                     | 1.352                   | 0.081                      | 0.013                     |
| 2d x 3wl      | 1.473                   | 0.166                      | 0.239                     | 1.472                   | 0.098                      | 0.088                     |
| 2d x 4wl      | 1.385                   | 0.115                      | 0.164                     | 1.360                   | 0.176                      | 0.209                     |
| 2d x 5wl      | 1.461                   | 0.145                      | 0.144                     | 1.449                   | 0.110                      | 0.094                     |
| 2d x Tel      | 1.030                   | 0.301                      | 0.128                     | 1.042                   | -0.291                     | 0.069                     |
| 2d x Ur       | 1.021                   | 0.369                      | 0.348                     | 0.929                   | 0.498                      | 0.494                     |
| 2CH x 3wl     | 1.053                   | 0.315                      | 0.500                     | 1.197                   | 0.211                      | 0.204                     |
| 2CH x 4wl     | 1.114                   | 0.205                      | 0.300                     | 1.079                   | 0.221                      | 0.165                     |
| 2CH x 5wl     | 1.260                   | 0.158                      | 0.099                     | 1.599                   | -0.101                     | 0.040                     |
| 2CH x Tel     | -0.261                  | 0.950                      | 0.737                     | -0.378                  | 1.016                      | 0.419                     |
| 2CH x Ur      | 0.298                   | 0.551                      | 0.448                     | 1.133                   | -0.107                     | 0.011                     |
| 3wl x 4wl     | 0.463                   | 0.627                      | 0.561                     | 1.435                   | -0.037                     | 0.001                     |
| 3wl x 5wl     | 0.267                   | 0.812                      | 0.525                     | 0.952                   | 0.344                      | 0.100                     |
| 3wl x Tel     | -1.076                  | 1.435                      | 0.335                     | 0.501                   | 0.342                      | 0.010                     |
| 3wl x Ur      | -0.763                  | 1.226                      | 0.442                     | 0.313                   | 0.454                      | 0.045                     |
| 4wl x 5wl     | -0.079                  | 1.114                      | 0.693                     | 1.308                   | 0.111                      | 0.014                     |
| 4wl x Tel     | -0.333                  | 1.001                      | 0.114                     | 1.393                   | -0.279                     | 0.009                     |
| 4wl x Ur      | 0.027                   | 0.745                      | 0.114                     | 0.121                   | 0.627                      | 0.117                     |
| 5wl x Tel     | 0.971                   | 0.066                      | 0.001                     | 2.570                   | -1.069                     | 0.120                     |
| 5wl x Ur      | 0.419                   | 0.439                      | 0.071                     | 0.907                   | 0.055                      | 0.001                     |
| Tel x Ur      | 0.661                   | 0.382                      | 0.264                     | 1.267                   | -0.277                     | 0.189                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd chelipe  
 3CH- Length of 3rd chelipe  
 4CH- Length of 4th chelipe  
 5 CH- Length of 5th chelipe

**Table 2.3.5** Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Heterocarpus gibbosus*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | 0.086                   | 0.709                      | 0.624                     | -0.963                  | 1.222                      | 0.892                     |
| TL x RL       | 0.070                   | 0.747                      | 0.654                     | -0.064                  | 0.823                      | 0.780                     |
| TL x Tel      | -1.325                  | 1.223                      | 0.594                     | -0.891                  | 1.004                      | 0.384                     |
| TL x 1chl     | -0.528                  | 1.017                      | 0.641                     | -1.252                  | 1.381                      | 0.572                     |
| TL x 2 Li     | -1.123                  | 1.059                      | 0.480                     | -0.583                  | 0.793                      | 0.586                     |
| TL x 2 L m    | -1.026                  | 1.021                      | 0.630                     | -1.253                  | 1.137                      | 0.680                     |
| TL x 2 L c    | -0.640                  | 0.958                      | 0.470                     | -0.358                  | 0.810                      | 0.475                     |
| TL x 2 L p    | -2.695                  | 1.465                      | 0.363                     | -2.163                  | 1.210                      | 0.224                     |
| TL x 2 L d    | -2.076                  | 1.002                      | 0.284                     | -2.464                  | 1.210                      | 0.224                     |
| TL x 2 LCH    | -0.380                  | 1.001                      | 0.652                     | -0.182                  | 0.901                      | 0.729                     |
| TL x 2 Si     | -0.519                  | 0.724                      | 0.217                     | 0.464                   | 0.217                      | 0.014                     |
| TL x 2 S m    | -0.776                  | 0.773                      | 0.159                     | -1.254                  | 1.017                      | 0.399                     |
| TL x 2 S c    | -0.815                  | 0.866                      | 0.219                     | 0.561                   | 0.172                      | 0.018                     |
| TL x 2 S p    | -1.216                  | 0.947                      | 0.099                     | 1.121                   | -0.263                     | 0.016                     |
| TL x 2 S d    | -0.724                  | 0.555                      | 0.093                     | -0.150                  | 0.251                      | 0.021                     |
| TL x 2 SCH    | -0.063                  | 0.771                      | 0.218                     | 0.809                   | 0.323                      | 0.157                     |
| TL x 3wl      | 0.132                   | 0.799                      | 0.476                     | 0.632                   | 0.537                      | 0.250                     |
| TL x 4wl      | 0.320                   | 0.707                      | 0.334                     | 1.425                   | 0.156                      | 0.017                     |
| TL x 5wl      | 0.563                   | 0.588                      | 0.200                     | 0.175                   | 0.763                      | 0.237                     |
| CL x RL       | 0.493                   | 0.719                      | 0.488                     | 0.655                   | 0.626                      | 0.756                     |
| CL x Tel      | -0.951                  | 1.384                      | 0.613                     | -0.145                  | 0.852                      | 0.463                     |
| CL x 1chl     | 0.409                   | 0.743                      | 0.275                     | 0.015                   | 1.010                      | 0.511                     |
| CL x 2 Li     | 0.230                   | 0.528                      | 0.096                     | 0.197                   | 0.544                      | 0.462                     |
| CL x 2 L m    | -0.285                  | 0.876                      | 0.374                     | -0.254                  | 0.861                      | 0.652                     |
| CL x 2 L c    | 0.647                   | 0.437                      | 0.079                     | 0.492                   | 0.520                      | 0.327                     |
| CL x 2 L p    | -2.159                  | 1.601                      | 0.349                     | -1.282                  | 1.039                      | 0.277                     |
| CL x 2 L d    | -2.053                  | 1.319                      | 0.396                     | -1.583                  | 1.039                      | 0.277                     |
| CL x 2 LCH    | 0.712                   | 0.621                      | 0.202                     | 0.679                   | 0.635                      | 0.605                     |
| CL x 2 Si     | -0.008                  | 0.629                      | 0.132                     | 0.615                   | 0.191                      | 0.018                     |
| CL x 2 S m    | 0.279                   | 0.341                      | 0.025                     | -0.162                  | 0.635                      | 0.260                     |
| CL x 2 S c    | -0.452                  | 0.917                      | 0.197                     | 0.667                   | 0.161                      | 0.027                     |
| CL x 2 S p    | -0.283                  | 0.653                      | 0.038                     | 1.139                   | -0.369                     | 0.053                     |
| CL x 2 S d    | -0.665                  | 0.700                      | 0.119                     | 0.385                   | -0.024                     | 0.000                     |
| CL x 2 SCH    | 0.526                   | 0.643                      | 0.122                     | 1.171                   | 0.191                      | 0.092                     |
| CL x 3wl      | 0.811                   | 0.622                      | 0.232                     | 1.050                   | 0.444                      | 0.286                     |
| CL x 4wl      | 0.637                   | 0.735                      | 0.290                     | 1.516                   | 0.148                      | 0.027                     |
| CL x 5wl      | 1.075                   | 0.449                      | 0.094                     | 0.842                   | 0.580                      | 0.229                     |
| RL x Tel      | -0.814                  | 1.245                      | 0.526                     | -0.699                  | 1.148                      | 0.435                     |
| RL x 1chl     | 0.395                   | 0.723                      | 0.276                     | -0.942                  | 1.550                      | 0.625                     |
| RL x 2 Li     | -0.323                  | 0.854                      | 0.267                     | 0.064                   | 0.593                      | 0.284                     |
| RL x 2 L m    | -0.077                  | 0.712                      | 0.262                     | -0.749                  | 1.118                      | 0.570                     |
| RL x 2 L c    | -0.083                  | 0.878                      | 0.337                     | 0.123                   | 0.719                      | 0.324                     |
| RL x 2 L p    | -1.844                  | 1.341                      | 0.260                     | -1.584                  | 1.162                      | 0.180                     |
| RL x 2 L d    | -1.677                  | 1.033                      | 0.257                     | -1.885                  | 1.162                      | 0.180                     |
| RL x 2 Si     | 0.333                   | 0.835                      | 0.387                     | 0.345                   | 0.805                      | 0.505                     |
| RL x 2 S m    | 0.528                   | 0.271                      | 0.026                     | 0.619                   | 0.176                      | 0.008                     |
| RL x 2 S c    | 0.155                   | 0.405                      | 0.037                     | -0.798                  | 0.997                      | 0.332                     |
| RL x 2 S p    | 0.123                   | 0.521                      | 0.068                     | 0.746                   | 0.100                      | 0.005                     |
| RL x 2 S d    | 0.293                   | 0.267                      | 0.007                     | 1.121                   | 0.210                      | 0.058                     |
| RL x 3wl      | 0.815                   | 0.596                      | 0.225                     | 0.876                   | 0.525                      | 0.207                     |
| RL x 4wl      | 1.030                   | 0.460                      | 0.121                     | 1.525                   | 0.133                      | 0.011                     |
| RL x 5wl      | 1.154                   | 0.382                      | 0.072                     | 0.321                   | 0.872                      | 0.268                     |

Table 2.3.5 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| Tel x 1chl    | 0.939                   | 0.521                      | 0.423                     | 0.975                   | 0.473                      | 0.176                     |
| Tel x 2 L i   | 0.522                   | 0.441                      | 0.210                     | 0.591                   | 0.367                      | 0.329                     |
| Tel x 2 L m   | 0.504                   | 0.474                      | 0.341                     | 0.476                   | 0.483                      | 0.322                     |
| Tel x 2 L c   | 0.845                   | 0.403                      | 0.209                     | 0.888                   | 0.331                      | 0.208                     |
| Tel x 2 L p   | -0.951                  | 1.064                      | 0.482                     | -0.575                  | 0.742                      | 0.221                     |
| Tel x 2 L d   | -0.928                  | 0.767                      | 0.418                     | -0.876                  | 0.742                      | 0.221                     |
| Tel x 2 S i   | 1.128                   | 0.458                      | 0.343                     | 0.704                   | 0.173                      | 0.023                     |
| Tel x 2 S m   | 0.503                   | 0.389                      | 0.158                     | 0.480                   | 0.264                      | 0.070                     |
| Tel x 2 S c   | 0.372                   | 0.497                      | 0.181                     | 0.750                   | 0.139                      | 0.031                     |
| Tel x 2 S p   | -0.186                  | 0.772                      | 0.165                     | 0.924                   | -0.295                     | 0.053                     |
| Tel x 2 S d   | -0.251                  | 0.564                      | 0.241                     | 0.491                   | -0.129                     | 0.015                     |
| Tel x 3wl     | 1.212                   | 0.471                      | 0.416                     | 1.460                   | 0.219                      | 0.109                     |
| Tel x 4wl     | 1.366                   | 0.340                      | 0.194                     | 1.616                   | 0.107                      | 0.022                     |
| Tel x 5wl     | 1.387                   | 0.321                      | 0.150                     | 1.322                   | 0.336                      | 0.121                     |
| 1chl x 2 L i  | -0.110                  | 0.742                      | 0.381                     | 0.622                   | 0.250                      | 0.194                     |
| 1chl x 2 L m  | -0.162                  | 0.789                      | 0.607                     | 0.216                   | 0.530                      | 0.493                     |
| 1chl x 2 L c  | 0.062                   | 0.811                      | 0.543                     | 0.840                   | 0.277                      | 0.185                     |
| 1chl x 2 L p  | -1.339                  | 1.056                      | 0.304                     | -0.065                  | 0.207                      | 0.022                     |
| 1chl x 2 L d  | -1.021                  | 0.640                      | 0.187                     | -0.366                  | 0.207                      | 0.022                     |
| 1chl x 2 LCH  | 0.447                   | 0.786                      | 0.649                     | 0.999                   | -0.069                     | 0.005                     |
| 1chl x 2 S i  | -0.040                  | 0.645                      | 0.278                     | 1.121                   | 0.328                      | 0.322                     |
| 1chl x 2 S m  | -0.354                  | 0.746                      | 0.239                     | 0.049                   | 0.482                      | 0.299                     |
| 1chl x 2 S c  | -0.389                  | 0.867                      | 0.354                     | 0.900                   | 0.003                      | 0.000                     |
| 1chl x 2 S p  | -1.812                  | 1.634                      | 0.476                     | 0.796                   | -0.133                     | 0.014                     |
| 1chl x 2 S d  | -0.946                  | 0.875                      | 0.373                     | 0.276                   | 0.049                      | 0.003                     |
| 1chl x 2 SCH  | 0.131                   | 0.892                      | 0.470                     | 1.336                   | 0.077                      | 0.030                     |
| 1chl x 3wl    | 0.863                   | 0.582                      | 0.407                     | 1.295                   | 0.272                      | 0.214                     |
| 1chl x 4wl    | 0.984                   | 0.504                      | 0.273                     | 1.714                   | 0.014                      | 0.000                     |
| 1chl x 5wl    | 0.798                   | 0.623                      | 0.362                     | 1.078                   | 0.411                      | 0.229                     |
| 2Li x 2 L m   | 0.437                   | 0.598                      | 0.505                     | 0.127                   | 0.886                      | 0.444                     |
| 2Li x 2 L c   | 0.634                   | 0.658                      | 0.517                     | 0.565                   | 0.692                      | 0.372                     |
| 2Li x 2 L p   | -0.013                  | 0.299                      | 0.035                     | -0.850                  | 1.099                      | 0.199                     |
| 2Li x 2 L d   | -0.139                  | 0.106                      | 0.007                     | -1.151                  | 1.099                      | 0.199                     |
| 2Li x 2 LCH   | 0.953                   | 0.685                      | 0.713                     | 0.784                   | 0.831                      | 0.665                     |
| 2Li x 2 S i   | 0.486                   | 0.455                      | 0.201                     | 0.966                   | -0.070                     | 0.002                     |
| 2Li x 2 S m   | 0.134                   | 0.642                      | 0.257                     | -0.064                  | 0.839                      | 0.291                     |
| 2Li x 2 S c   | 0.430                   | 0.505                      | 0.173                     | 0.524                   | 0.381                      | 0.095                     |
| 2Li x 2 S p   | 0.077                   | 0.619                      | 0.099                     | 0.766                   | -0.170                     | 0.007                     |
| 2Li x 2 S d   | 0.419                   | -0.009                     | 0.000                     | -0.096                  | 0.446                      | 0.072                     |
| 2Li x 2 SCH   | 1.017                   | 0.476                      | 0.194                     | 1.140                   | 0.313                      | 0.158                     |
| 2Li x 3wl     | 1.216                   | 0.529                      | 0.486                     | 1.281                   | 0.423                      | 0.166                     |
| 2Li x 4wl     | 1.352                   | 0.397                      | 0.245                     | 1.507                   | 0.228                      | 0.040                     |
| 2Li x 5wl     | 1.407                   | 0.343                      | 0.159                     | 1.180                   | 0.515                      | 0.116                     |
| 2Lm x 2 Lc    | 0.421                   | 0.846                      | 0.607                     | 0.717                   | 0.533                      | 0.390                     |
| 2Lm x 2 Lp    | -0.609                  | 0.855                      | 0.205                     | -0.571                  | 0.809                      | 0.191                     |
| 2Lm x 2 Ld    | -0.713                  | 0.646                      | 0.195                     | -0.872                  | 0.809                      | 0.191                     |
| 2Lm x 2 LCH   | 0.748                   | 0.866                      | 0.808                     | 0.955                   | 0.651                      | 0.722                     |
| 2Lm x 2 Si    | 0.427                   | 0.503                      | 0.174                     | 1.054                   | -0.156                     | 0.014                     |
| 2Lm x 2 S m   | 0.083                   | 0.679                      | 0.203                     | 0.084                   | 0.681                      | 0.339                     |
| 2Lm x 2 S c   | 0.270                   | 0.646                      | 0.201                     | 0.894                   | 0.010                      | 0.000                     |
| 2Lm x 2 S p   | -0.441                  | 1.095                      | 0.219                     | 0.722                   | -0.124                     | 0.007                     |

Table 2.3.5 Continued.....

| Relationships | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r |
|---------------|----------------------------|-------------------------------|------------------------------|----------------------------|-------------------------------|------------------------------|
| 2Lm x 2 S d   | -0.169                     | 0.546                         | 0.149                        | 0.190                      | 0.158                         | 0.016                        |
| 2Lm x 2 SCH   | 0.812                      | 0.661                         | 0.265                        | 1.328                      | 0.122                         | 0.043                        |
| 2Lm x 3wl     | 1.158                      | 0.573                         | 0.404                        | 1.427                      | 0.273                         | 0.123                        |
| 2Lm x 4wl     | 1.161                      | 0.570                         | 0.359                        | 1.626                      | 0.107                         | 0.016                        |
| 2Lm x 5wl     | 1.172                      | 0.559                         | 0.298                        | 1.245                      | 0.444                         | 0.153                        |
| 2Lc x 2 Lp    | -0.728                     | 0.779                         | 0.200                        | -1.211                     | 1.161                         | 0.286                        |
| 2Lc x 2 Ld    | -0.574                     | 0.414                         | 0.095                        | -1.512                     | 1.161                         | 0.286                        |
| 2Lc x 2 LCH   | 0.553                      | 0.844                         | 0.906                        | 0.592                      | 0.813                         | 0.820                        |
| 2Lc x 2 Si    | 0.474                      | 0.369                         | 0.110                        | 0.517                      | 0.302                         | 0.037                        |
| 2Lc x 2 S m   | -0.105                     | 0.689                         | 0.247                        | 0.062                      | 0.566                         | 0.170                        |
| 2Lc x 2 S c   | 0.442                      | 0.390                         | 0.086                        | 0.919                      | -0.012                        | 0.000                        |
| 2Lc x 2 S p   | -0.488                     | 0.902                         | 0.175                        | 0.683                      | -0.069                        | 0.002                        |
| 2Lc x 2 S d   | 0.103                      | 0.233                         | 0.032                        | -0.195                     | 0.434                         | 0.087                        |
| 2Lc x 2 SCH   | 0.850                      | 0.503                         | 0.181                        | 1.149                      | 0.242                         | 0.121                        |
| 2Lc x 3wl     | 1.153                      | 0.465                         | 0.314                        | 1.523                      | 0.143                         | 0.024                        |
| 2Lc x 4wl     | 1.364                      | 0.305                         | 0.121                        | 1.504                      | 0.184                         | 0.034                        |
| 2Lc x 5wl     | 1.190                      | 0.435                         | 0.213                        | 1.305                      | 0.310                         | 0.054                        |
| 2Lp x 2 L d   | -0.223                     | 0.654                         | 0.714                        | -0.301                     | 1.000                         | 1.000                        |
| 2Lp x 2 LCH   | 1.590                      | 0.254                         | 0.248                        | 1.547                      | 0.266                         | 0.415                        |
| 2Lp x 2 Si    | 0.902                      | 0.194                         | 0.092                        | 0.872                      | 0.097                         | 0.018                        |
| 2Lp x 2 S m   | 0.753                      | 0.167                         | 0.044                        | 0.714                      | 0.235                         | 0.139                        |
| 2Lp x 2 S c   | 0.888                      | 0.224                         | 0.087                        | 0.901                      | 0.011                         | 0.000                        |
| 2Lp x 2 S p   | 0.601                      | 0.401                         | 0.105                        | 0.571                      | 0.104                         | 0.016                        |
| 2Lp x 2 S d   | 0.300                      | 0.369                         | 0.243                        | 0.301                      | 0.195                         | 0.083                        |
| 2Lp x 2 SCH   | 1.440                      | 0.244                         | 0.129                        | 1.423                      | 0.119                         | 0.139                        |
| 2Lp x 3wl     | 1.722                      | 0.146                         | 0.094                        | 1.708                      | -0.024                        | 0.003                        |
| 2Lp x 4wl     | 1.744                      | 0.070                         | 0.019                        | 1.703                      | 0.128                         | 0.077                        |
| 2Lp x 5wl     | 1.706                      | 0.193                         | 0.127                        | 1.700                      | -0.023                        | 0.001                        |
| 2Ld x 2 LCH   | 1.673                      | 0.253                         | 0.147                        | 1.627                      | 0.266                         | 0.415                        |
| 2Ld x 2 Si    | 0.960                      | 0.020                         | 0.001                        | 0.901                      | 0.097                         | 0.018                        |
| 2Ld x 2 S m   | 0.805                      | 0.089                         | 0.007                        | 0.785                      | 0.235                         | 0.139                        |
| 2Ld x 2 S c   | 0.958                      | 0.097                         | 0.010                        | 0.905                      | 0.011                         | 0.000                        |
| 2Ld x 2 S p   | 0.732                      | 0.432                         | 0.073                        | 0.602                      | 0.104                         | 0.016                        |
| 2Ld x 2 S d   | 0.422                      | 0.400                         | 0.171                        | 0.360                      | 0.195                         | 0.083                        |
| 2Ld x 2 SCH   | 1.517                      | 0.157                         | 0.032                        | 1.458                      | 0.119                         | 0.139                        |
| 2Ld x 3wl     | 1.769                      | 0.115                         | 0.035                        | 1.701                      | -0.024                        | 0.003                        |
| 2Ld x 4wl     | 1.767                      | 0.071                         | 0.012                        | 1.741                      | 0.128                         | 0.077                        |
| 2Ld x 5wl     | 1.767                      | 0.134                         | 0.037                        | 1.693                      | -0.023                        | 0.001                        |
| 2LCH x 2 Si   | 0.057                      | 0.542                         | 0.187                        | 0.723                      | 0.107                         | 0.004                        |
| 2LCH x 2 S m  | -0.581                     | 0.831                         | 0.283                        | -0.642                     | 0.877                         | 0.330                        |
| 2LCH x 2 S c  | -0.074                     | 0.618                         | 0.171                        | 0.750                      | 0.096                         | 0.006                        |
| 2LCH x 2 S p  | -1.149                     | 1.122                         | 0.214                        | 0.753                      | -0.097                        | 0.002                        |
| 2LCH x 2 S d  | -0.189                     | 0.360                         | 0.060                        | -0.409                     | 0.470                         | 0.083                        |
| 2LCH x 2 SCH  | 0.375                      | 0.683                         | 0.263                        | 0.973                      | 0.297                         | 0.148                        |
| 2LCH x 3wl    | 0.712                      | 0.632                         | 0.457                        | 1.236                      | 0.290                         | 0.081                        |
| 2LCH x 4wl    | 0.971                      | 0.477                         | 0.233                        | 1.346                      | 0.241                         | 0.047                        |
| 2LCH x 5wl    | 0.834                      | 0.558                         | 0.277                        | 0.929                      | 0.474                         | 0.102                        |
| 2Si x 2 S m   | -0.102                     | 0.942                         | 0.570                        | 0.761                      | 0.012                         | 0.000                        |
| 2Si x 2 S c   | -0.021                     | 1.017                         | 0.726                        | 0.841                      | 0.070                         | 0.010                        |
| 2Si x 2 S p   | -0.171                     | 0.928                         | 0.229                        | 0.658                      | -0.069                        | 0.004                        |
| 2Si x 2 S d   | -0.087                     | 0.518                         | 0.195                        | 0.378                      | -0.032                        | 0.001                        |
| 2Si x 2 SCH   | 0.617                      | 0.933                         | 0.769                        | 1.224                      | 0.254                         | 0.330                        |
| 2Si x 3wl     | 1.280                      | 0.506                         | 0.459                        | 1.550                      | 0.170                         | 0.085                        |

Table 2.3.5 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2Si x 4wl     | 1.246                   | 0.541                      | 0.470                     | 1.635                   | 0.111                      | 0.030                     |
| 2Si x 5wl     | 1.172                   | 0.616                      | 0.528                     | 1.520                   | 0.194                      | 0.052                     |
| 2Sm x 2 Sc    | 0.427                   | 0.658                      | 0.473                     | 0.743                   | 0.209                      | 0.069                     |
| 2Sm x 2 Sp    | -0.011                  | 0.911                      | 0.344                     | 0.672                   | -0.098                     | 0.006                     |
| 2Sm x 2 Sd    | 0.202                   | 0.260                      | 0.076                     | 0.256                   | 0.121                      | 0.013                     |
| 2Sm x 2 SCH   | 0.936                   | 0.719                      | 0.710                     | 1.236                   | 0.280                      | 0.305                     |
| 2Sm x 3wl     | 1.457                   | 0.384                      | 0.412                     | 1.478                   | 0.291                      | 0.190                     |
| 2Sm x 4wl     | 1.453                   | 0.389                      | 0.379                     | 1.476                   | 0.335                      | 0.211                     |
| 2Sm x 5wl     | 1.313                   | 0.562                      | 0.684                     | 1.292                   | 0.520                      | 0.286                     |
| 2Sc x 2 Sp    | -0.262                  | 1.028                      | 0.400                     | 0.866                   | -0.299                     | 0.034                     |
| 2Sc x 2 Sd    | 0.002                   | 0.427                      | 0.189                     | 0.733                   | -0.424                     | 0.099                     |
| 2Sc x 2 SCH   | 0.734                   | 0.815                      | 0.836                     | 1.146                   | 0.338                      | 0.281                     |
| 2Sc x 3wl     | 1.371                   | 0.413                      | 0.436                     | 1.307                   | 0.437                      | 0.271                     |
| 2Sc x 4wl     | 1.300                   | 0.487                      | 0.543                     | 1.275                   | 0.509                      | 0.306                     |
| 2Sc x 5wl     | 1.205                   | 0.585                      | 0.679                     | 1.175                   | 0.574                      | 0.220                     |
| 2Sp x 2 Sd    | 0.124                   | 0.398                      | 0.433                     | 0.062                   | 0.481                      | 0.335                     |
| 2Sp x 2 SCH   | 1.192                   | 0.445                      | 0.657                     | 1.374                   | 0.130                      | 0.109                     |
| 2Sp x 3wl     | 1.615                   | 0.209                      | 0.295                     | 1.832                   | -0.217                     | 0.175                     |
| 2Sp x 4wl     | 1.662                   | 0.143                      | 0.123                     | 1.789                   | -0.092                     | 0.026                     |
| 2Sp x 5wl     | 1.541                   | 0.309                      | 0.499                     | 1.864                   | -0.286                     | 0.143                     |
| 2Sd x 2 SCH   | 1.290                   | 0.543                      | 0.358                     | 1.404                   | 0.138                      | 0.086                     |
| 2Sd x 3wl     | 1.680                   | 0.209                      | 0.108                     | 1.781                   | -0.225                     | 0.131                     |
| 2Sd x 4wl     | 1.699                   | 0.161                      | 0.057                     | 1.798                   | -0.183                     | 0.072                     |
| 2Sd x 5wl     | 1.627                   | 0.332                      | 0.211                     | 1.814                   | -0.343                     | 0.143                     |
| 2SCH x 3wl    | 1.010                   | 0.500                      | 0.507                     | 0.983                   | 0.496                      | 0.142                     |
| 2SCH x 4wl    | 1.008                   | 0.501                      | 0.456                     | 0.799                   | 0.644                      | 0.199                     |
| 2SCH x 5wl    | 0.691                   | 0.709                      | 0.793                     | 0.657                   | 0.714                      | 0.138                     |
| 3wl x 4wl     | 0.377                   | 0.786                      | 0.554                     | 0.960                   | 0.455                      | 0.173                     |
| 3wl x 5wl     | 0.472                   | 0.732                      | 0.416                     | -0.493                  | 1.284                      | 0.775                     |
| 4wl x 5wl     | 0.472                   | 0.731                      | 0.464                     | 0.228                   | 0.845                      | 0.403                     |

TL- Total length

CL- Carapace length

RL- Rostral length

TEL- Telson length

Ur- uropod length

2si - ischium of 2nd cheliped

2sm - merus of 2nd cheliped

2cd - carpus of 2nd cheliped

2sp - propodus of 2nd cheliped

2sd - dactylus of 2nd cheliped

2il - ischium of 2nd cheliped

2im - merus of 2nd cheliped

2cd - carpus of 2nd cheliped

2ip - propodus of 2nd cheliped

2id - dactylus of 2nd cheliped

1CH- Length of 1st cheliped

2sCH- Length of 2nd cheliped

3CH- Length of 3rd cheliped

4CH- Length of 4th cheliped

5CH- Length of 5th cheliped

2LCH- Length of 2nd cheliped

**Table 2.3.6** Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Heterocarpus woodmasoni*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -1.625                  | 1.514                      | 0.759                     | -1.328                  | 1.388                      | 0.559                     |
| TL x RL       | 0.441                   | 0.505                      | 0.193                     | -0.047                  | 0.763                      | 0.654                     |
| TL x Tel      | -0.284                  | 0.730                      | 0.236                     | -1.297                  | 1.246                      | 0.717                     |
| TL x PI       | -2.213                  | 1.578                      | 0.651                     | -1.078                  | 0.985                      | 0.356                     |
| TL x 1chl     | -0.254                  | 0.798                      | 0.650                     | -1.334                  | 1.336                      | 0.861                     |
| TL x 2 L i    | -0.694                  | 0.743                      | 0.349                     | -1.841                  | 1.291                      | 0.370                     |
| TL x 2 L m    | -0.701                  | 0.778                      | 0.428                     | -1.471                  | 1.150                      | 0.386                     |
| TL x 2 L c    | -0.708                  | 0.892                      | 0.532                     | -1.341                  | 1.184                      | 0.187                     |
| TL x 2 L p    | -0.058                  | 0.117                      | 0.001                     | -1.691                  | 0.919                      | 0.080                     |
| TL x 2 L d    | -0.359                  | 0.117                      | 0.001                     | -1.829                  | 0.819                      | 0.068                     |
| TL x 2 LCH    | -0.094                  | 0.768                      | 0.553                     | -0.951                  | 1.176                      | 0.306                     |
| TL x 2 S i    | -1.293                  | 0.997                      | 0.200                     | -0.514                  | 0.616                      | 0.403                     |
| TL x 2 S m    | -1.501                  | 1.062                      | 0.262                     | -1.675                  | 1.151                      | 0.594                     |
| TL x 2 S c    | -1.264                  | 1.001                      | 0.132                     | -1.632                  | 1.192                      | 0.926                     |
| TL x 2 S p    | -1.734                  | 1.171                      | 0.176                     | -2.665                  | 1.645                      | 0.721                     |
| TL x 2 S d    | -1.066                  | 0.683                      | 0.133                     | -1.618                  | 0.974                      | 0.432                     |
| TL x 2 SCH    | -0.672                  | 0.997                      | 0.376                     | -0.909                  | 1.122                      | 0.742                     |
| TL x 3wl      | -0.365                  | 0.940                      | 0.695                     | -0.749                  | 1.135                      | 0.853                     |
| TL x 4wl      | -0.225                  | 0.876                      | 0.755                     | -1.161                  | 1.340                      | 0.897                     |
| TL x 5wl      | -0.369                  | 0.931                      | 0.645                     | -1.301                  | 1.393                      | 0.902                     |
| CL x RL       | 1.175                   | 0.199                      | 0.120                     | 1.235                   | 0.169                      | 0.111                     |
| CL x Tel      | 0.906                   | 0.198                      | 0.263                     | 0.529                   | 0.461                      | 0.582                     |
| CL x PI       | 0.081                   | 0.624                      | 0.404                     | 0.309                   | 0.404                      | 0.455                     |
| CL x 1chl     | -4.140                  | 18.869                     | 0.521                     | -20.099                 | 29.146                     | 0.511                     |
| CL x 2 L i    | 0.551                   | 0.179                      | 0.080                     | -0.221                  | 0.665                      | 0.582                     |
| CL x 2 L m    | 0.278                   | 0.413                      | 0.479                     | -0.030                  | 0.594                      | 0.355                     |
| CL x 2 L c    | 0.531                   | 0.393                      | 0.411                     | -0.043                  | 0.739                      | 0.251                     |
| CL x 2 L p    | 0.275                   | -0.067                     | 0.001                     | -1.487                  | 1.127                      | 0.415                     |
| CL x 2 L d    | -0.026                  | -0.067                     | 0.001                     | -1.705                  | 1.044                      | 0.380                     |
| CL x 2 LCH    | 1.013                   | 0.310                      | 0.358                     | 0.374                   | 0.709                      | 0.385                     |
| CL x 2 S i    | 0.240                   | 0.336                      | 0.090                     | 0.180                   | 0.371                      | 0.203                     |
| CL x 2 S m    | -0.045                  | 0.481                      | 0.214                     | 0.017                   | 0.423                      | 0.164                     |
| CL x 2 S c    | 0.323                   | 0.303                      | 0.048                     | 0.024                   | 0.504                      | 0.528                     |
| CL x 2 S p    | 0.141                   | 0.342                      | 0.060                     | -0.240                  | 0.600                      | 0.330                     |
| CL x 2 S d    | -0.293                  | 0.423                      | 0.203                     | -0.198                  | 0.366                      | 0.211                     |
| CL x 2 SCH    | 0.796                   | 0.381                      | 0.218                     | 0.663                   | 0.465                      | 0.438                     |
| CL x 3wl      | 0.984                   | 0.384                      | 0.461                     | 0.734                   | 0.544                      | 0.677                     |
| CL x 4wl      | 1.055                   | 0.341                      | 0.456                     | 0.694                   | 0.571                      | 0.562                     |
| CL x 5wl      | 1.032                   | 0.336                      | 0.333                     | 0.575                   | 0.629                      | 0.635                     |
| RL x PI       | 0.117                   | 0.588                      | 0.119                     | -0.468                  | 0.921                      | 0.277                     |
| RL x 1chl     | 1.241                   | 0.080                      | 0.009                     | -0.403                  | 1.178                      | 0.596                     |
| RL x 2 L i    | 0.740                   | 0.046                      | 0.002                     | -0.646                  | 0.939                      | 0.174                     |
| RL x 2 L m    | 0.692                   | 0.122                      | 0.014                     | -0.491                  | 0.894                      | 0.208                     |
| RL x 2 L c    | 0.414                   | 0.465                      | 0.191                     | -0.008                  | 0.702                      | 0.058                     |
| RL x 2 L p    | 2.177                   | -1.369                     | 0.177                     | -0.081                  | 0.157                      | 0.002                     |
| RL x 2 S i    | -0.570                  | 0.884                      | 0.208                     | -0.279                  | 0.675                      | 0.173                     |
| RL x 2 S m    | 0.719                   | -0.050                     | 0.001                     | -1.144                  | 1.199                      | 0.341                     |
| RL x 2 S c    | -0.144                  | 0.617                      | 0.066                     | -0.667                  | 0.961                      | 0.495                     |
| RL x 2 S p    | -0.578                  | 0.828                      | 0.116                     | -1.893                  | 1.704                      | 0.688                     |
| RL x 2 S d    | -0.197                  | 0.350                      | 0.046                     | -1.155                  | 1.005                      | 0.409                     |
| RL x 3wl      | 1.088                   | 0.306                      | 0.097                     | 0.181                   | 0.908                      | 0.486                     |
| RL x 4wl      | 1.186                   | 0.246                      | 0.078                     | -0.190                  | 1.157                      | 0.596                     |
| RL x 5wl      | 1.149                   | 0.250                      | 0.061                     | -0.206                  | 1.145                      | 0.542                     |



Table 2.3.6Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| Tel x Pl      | 0.486                   | 0.411                      | 0.100                     | 0.255                   | 0.535                      | 0.228                     |
| Tel x 1chl    | 0.981                   | 0.317                      | 0.231                     | 0.507                   | 0.697                      | 0.508                     |
| Tel x 2 L i   | 0.293                   | 0.432                      | 0.266                     | -0.421                  | 0.972                      | 0.456                     |
| Tel x 2 L m   | 0.487                   | 0.321                      | 0.165                     | -0.182                  | 0.846                      | 0.454                     |
| Tel x 2 L c   | 0.845                   | 0.209                      | 0.066                     | -0.125                  | 0.964                      | 0.268                     |
| Tel x 2 L p   | 0.038                   | 0.117                      | 0.002                     | -0.235                  | 0.321                      | 0.021                     |
| Tel x 2 S i   | 0.602                   | 0.100                      | 0.005                     | 0.403                   | 0.264                      | 0.065                     |
| Tel x 2 S m   | -0.036                  | 0.572                      | 0.172                     | -0.084                  | 0.596                      | 0.205                     |
| Tel x 2 S c   | 0.999                   | -0.203                     | 0.012                     | -0.161                  | 0.765                      | 0.764                     |
| Tel x 2 S p   | 0.947                   | -0.266                     | 0.021                     | -0.383                  | 0.846                      | 0.413                     |
| Tel x 2 S d   | 0.254                   | 0.051                      | 0.002                     | -0.143                  | 0.398                      | 0.156                     |
| Tel x 3wl     | 1.061                   | 0.397                      | 0.280                     | 0.795                   | 0.609                      | 0.532                     |
| Tel x 4wl     | 1.134                   | 0.345                      | 0.264                     | 0.637                   | 0.739                      | 0.593                     |
| Tel x 5wl     | 1.026                   | 0.409                      | 0.281                     | 0.665                   | 0.688                      | 0.477                     |
| Pl x 1chl     | 0.958                   | 0.410                      | 0.658                     | 0.853                   | 0.546                      | 0.392                     |
| Pl x 2 L i    | 0.626                   | 0.186                      | 0.084                     | 0.391                   | 0.394                      | 0.094                     |
| Pl x 2 L m    | 0.422                   | 0.459                      | 0.571                     | 0.510                   | 0.361                      | 0.104                     |
| Pl x 2 L c    | 0.595                   | 0.511                      | 0.669                     | 0.950                   | 0.091                      | 0.003                     |
| Pl x 2 L p    | -0.129                  | 0.315                      | 0.027                     | -0.437                  | 0.656                      | 0.111                     |
| Pl x 2 L d    | -0.430                  | 0.315                      | 0.027                     | -0.456                  | 0.299                      | 0.025                     |
| Pl x 2 LCH    | 1.058                   | 0.410                      | 0.603                     | 1.166                   | 0.266                      | 0.043                     |
| Pl x 2 S i    | 0.355                   | 0.376                      | 0.109                     | 0.699                   | 0.023                      | 0.001                     |
| Pl x 2 S m    | 0.149                   | 0.509                      | 0.231                     | -0.151                  | 0.873                      | 0.553                     |
| Pl x 2 S c    | 0.421                   | 0.346                      | 0.060                     | 0.307                   | 0.501                      | 0.413                     |
| Pl x 2 S p    | 0.099                   | 0.546                      | 0.147                     | 0.045                   | 0.654                      | 0.311                     |
| Pl x 2 S d    | 0.048                   | 0.273                      | 0.081                     | 0.049                   | 0.318                      | 0.125                     |
| Pl x 2 SCH    | 0.923                   | 0.430                      | 0.267                     | 0.932                   | 0.454                      | 0.331                     |
| Pl x 3wl      | 1.177                   | 0.367                      | 0.405                     | 1.178                   | 0.388                      | 0.271                     |
| Pl x 4wl      | 1.168                   | 0.386                      | 0.562                     | 1.008                   | 0.575                      | 0.451                     |
| Pl x 5wl      | 1.202                   | 0.319                      | 0.290                     | 1.041                   | 0.500                      | 0.317                     |
| 1chl x 2 L i  | -0.041                  | 0.624                      | 0.241                     | -0.174                  | 0.684                      | 0.216                     |
| 1chl x 2 L m  | -0.430                  | 0.957                      | 0.634                     | -0.036                  | 0.648                      | 0.254                     |
| 1chl x 2 L c  | -0.018                  | 0.819                      | 0.439                     | 0.185                   | 0.630                      | 0.110                     |
| 1chl x 2 L p  | -1.281                  | 1.074                      | 0.081                     | -0.899                  | 0.782                      | 0.120                     |
| 1chl x 2 L d  | -1.582                  | 1.074                      | 0.081                     | -1.154                  | 0.720                      | 0.109                     |
| 1chl x 2 LCH  | 0.328                   | 0.831                      | 0.634                     | 0.528                   | 0.653                      | 0.196                     |
| 1chl x 2 S i  | -0.238                  | 0.707                      | 0.098                     | -0.125                  | 0.630                      | 0.351                     |
| 1chl x 2 S m  | -1.160                  | 1.329                      | 0.402                     | -0.387                  | 0.759                      | 0.318                     |
| 1chl x 2 S c  | 0.039                   | 0.529                      | 0.036                     | -0.268                  | 0.763                      | 0.728                     |
| 1chl x 2 S p  | -0.358                  | 0.728                      | 0.067                     | -0.964                  | 1.189                      | 0.780                     |
| 1chl x 2 S d  | -0.585                  | 0.661                      | 0.122                     | -0.760                  | 0.815                      | 0.626                     |
| 1chl x 2 SCH  | 0.218                   | 0.827                      | 0.253                     | 0.227                   | 0.828                      | 0.837                     |
| 1chl x 3wl    | 0.253                   | 0.943                      | 0.686                     | 0.428                   | 0.817                      | 0.916                     |
| 1chl x 4wl    | 0.398                   | 0.844                      | 0.686                     | 0.257                   | 0.944                      | 0.922                     |
| 1chl x 5wl    | 0.305                   | 0.889                      | 0.575                     | 0.180                   | 0.976                      | 0.917                     |
| 2Li x 2 L m   | 0.660                   | 0.260                      | 0.076                     | 0.241                   | 0.795                      | 0.830                     |
| 2Li x 2 L c   | 0.805                   | 0.358                      | 0.135                     | 0.295                   | 0.989                      | 0.585                     |
| 2Li x 2 LCH   | 1.043                   | 0.514                      | 0.391                     | 0.720                   | 0.919                      | 0.843                     |

Table 2.3.6 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2Lm x 2Lc     | 0.509                   | 0.673                      | 0.428                     | 0.072                   | 1.152                      | 0.604                     |
| 2Lm x 2Lp     | -0.532                  | 0.816                      | 0.067                     | -0.763                  | 1.096                      | 0.390                     |
| 2Lm x 2Ld     | 0.192                   | 0.189                      | 0.044                     | -0.928                  | 0.888                      | 0.273                     |
| 2Lm x 2LCH    | 1.162                   | 0.279                      | 0.127                     | 0.500                   | 1.086                      | 0.895                     |
| 2Lm x 2Sc     | -0.015                  | 0.888                      | 0.147                     | 0.425                   | 0.397                      | 0.325                     |
| 2Lm x 2SCH    | 0.717                   | 0.718                      | 0.276                     | 1.089                   | 0.299                      | 0.181                     |
| 2Lm x 3wl     | 1.311                   | 0.346                      | 0.406                     | 1.213                   | 0.375                      | 0.319                     |
| 2Lm x 4wl     | 1.405                   | 0.217                      | 0.198                     | 1.175                   | 0.418                      | 0.298                     |
| 2Lm x 5wl     | 1.327                   | 0.288                      | 0.265                     | 1.137                   | 0.423                      | 0.285                     |
| 2Lc x 2Lp     | -0.424                  | 0.550                      | 0.032                     | -0.304                  | 0.441                      | 0.139                     |
| 2Lc x 2Ld     | -0.725                  | 0.550                      | 0.032                     | -0.448                  | 0.252                      | 0.048                     |
| 2Lc x 2LCH    | 0.658                   | 0.730                      | 0.748                     | 0.664                   | 0.718                      | 0.859                     |
| 2Lc x 2Sc     | -0.179                  | 0.856                      | 0.145                     | 0.600                   | 0.151                      | 0.103                     |
| 2Lc x 2Sp     | -0.612                  | 1.136                      | 0.249                     | 0.422                   | 0.203                      | 0.082                     |
| 2Lc x 2Sd     | -0.421                  | 0.672                      | 0.193                     | 0.274                   | 0.058                      | 0.012                     |
| 2Lc x 2SCH    | 0.442                   | 0.822                      | 0.382                     | 1.217                   | 0.118                      | 0.061                     |
| 2Lc x 3wl     | 0.843                   | 0.632                      | 0.470                     | 1.322                   | 0.197                      | 0.193                     |
| 2Lc x 4wl     | 0.976                   | 0.520                      | 0.397                     | 1.334                   | 0.184                      | 0.127                     |
| 2Lc x 5wl     | 0.926                   | 0.537                      | 0.320                     | 1.279                   | 0.204                      | 0.146                     |
| 2Lp x 2Ld     | -0.301                  | 1.000                      | 1.000                     | -0.301                  | 0.750                      | 0.600                     |
| 2Lp x 2LCH    | 1.432                   | 0.144                      | 0.273                     | 1.347                   | 0.383                      | 0.343                     |
| 2Lp x 2Si     | 0.692                   | 0.164                      | 0.075                     | 0.704                   | 0.101                      | 0.046                     |
| 2Lp x 2Sc     | 0.721                   | 0.202                      | 0.075                     | 0.745                   | 0.073                      | 0.034                     |
| 2Lp x 2Sp     | 0.623                   | 0.046                      | 0.004                     | 0.615                   | 0.111                      | 0.035                     |
| 2Lp x 2Sd     | 0.307                   | 0.039                      | 0.006                     | 0.323                   | 0.073                      | 0.026                     |
| 2Lp x 2SCH    | 1.326                   | 0.089                      | 0.041                     | 1.327                   | 0.075                      | 0.035                     |
| 2Lp x 3wl     | 1.532                   | 0.015                      | 0.003                     | 1.502                   | 0.156                      | 0.170                     |
| 2Lp x 4wl     | 1.542                   | 0.017                      | 0.004                     | 1.498                   | 0.165                      | 0.144                     |
| 2Lp x 5wl     | 1.509                   | 0.024                      | 0.006                     | 1.464                   | 0.167                      | 0.136                     |
| 2Ld x 2LCH    | 1.475                   | 0.144                      | 0.273                     | 1.463                   | 0.309                      | 0.209                     |
| 2Ld x 2Si     | 0.742                   | 0.164                      | 0.075                     | 0.763                   | 0.230                      | 0.224                     |
| 2Ld x 2Sm     | 0.648                   | 0.023                      | 0.002                     | 0.627                   | -0.026                     | 0.002                     |
| 2Ld x 2Sc     | 0.782                   | 0.202                      | 0.075                     | 0.776                   | 0.108                      | 0.070                     |
| 2Ld x 2Sp     | 0.637                   | 0.046                      | 0.004                     | 0.648                   | 0.085                      | 0.019                     |
| 2Ld x 2Sd     | 0.319                   | 0.039                      | 0.006                     | 0.360                   | 0.136                      | 0.084                     |
| 2Ld x 2SCH    | 1.353                   | 0.089                      | 0.041                     | 1.359                   | 0.112                      | 0.073                     |
| 2Ld x 3wl     | 1.536                   | 0.015                      | 0.003                     | 1.555                   | 0.158                      | 0.164                     |
| 2Ld x 4wl     | 1.547                   | 0.017                      | 0.004                     | 1.547                   | 0.125                      | 0.078                     |
| 2Ld x 5wl     | 1.516                   | 0.024                      | 0.006                     | 1.520                   | 0.164                      | 0.124                     |
| 2LCH x 2Si    | -0.986                  | 1.172                      | 0.295                     | 0.494                   | 0.161                      | 0.050                     |
| 2LCH x 2Sm    | -0.487                  | 0.777                      | 0.150                     | 0.509                   | 0.087                      | 0.009                     |
| 2LCH x 2Sc    | -1.047                  | 1.238                      | 0.216                     | 0.357                   | 0.284                      | 0.219                     |
| 2LCH x 2Sp    | -1.063                  | 1.162                      | 0.186                     | 0.179                   | 0.322                      | 0.124                     |
| 2LCH x 2Sd    | -0.926                  | 0.851                      | 0.221                     | 0.190                   | 0.103                      | 0.022                     |
| 2LCH x 2SCH   | -0.153                  | 1.026                      | 0.425                     | 1.042                   | 0.211                      | 0.118                     |
| 2LCH x 3wl    | 0.358                   | 0.807                      | 0.547                     | 1.092                   | 0.308                      | 0.284                     |
| 2LCH x 4wl    | 0.493                   | 0.721                      | 0.546                     | 1.069                   | 0.324                      | 0.236                     |
| 2LCH x 5wl    | 0.405                   | 0.760                      | 0.459                     | 1.018                   | 0.336                      | 0.236                     |

Table 2.3.6 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2Si x 2 Sm    | 0.609                   | 0.050                      | 0.003                     | 0.439                   | 0.268                      | 0.045                     |
| 2Si x 2 Sc    | 0.096                   | 0.917                      | 0.551                     | 0.513                   | 0.337                      | 0.160                     |
| 2Si x 2 Sp    | 0.120                   | 0.708                      | 0.320                     | 0.109                   | 0.726                      | 0.328                     |
| 2Si x 2 Sd    | 0.056                   | 0.357                      | 0.181                     | -0.049                  | 0.532                      | 0.300                     |
| 2Si x 2 SCH   | 0.919                   | 0.586                      | 0.645                     | 0.910                   | 0.595                      | 0.488                     |
| 2Si x 3wl     | 1.335                   | 0.277                      | 0.299                     | 1.179                   | 0.481                      | 0.358                     |
| 2Si x 4wl     | 1.406                   | 0.191                      | 0.179                     | 1.244                   | 0.388                      | 0.176                     |
| 2Sm x 2 Sp    | 0.525                   | 0.164                      | 0.015                     | 0.182                   | 0.713                      | 0.508                     |
| 2Sm x 2 Sd    | 0.192                   | 0.189                      | 0.044                     | 0.215                   | 0.189                      | 0.061                     |
| 2Sm x 2 SCH   | 1.162                   | 0.279                      | 0.127                     | 1.022                   | 0.501                      | 0.556                     |
| 2Sm x 3wl     | 1.311                   | 0.346                      | 0.406                     | 1.344                   | 0.287                      | 0.205                     |
| 2Sm x 4wl     | 1.405                   | 0.217                      | 0.198                     | 1.269                   | 0.403                      | 0.305                     |
| 2Sm x 5wl     | 1.327                   | 0.288                      | 0.265                     | 1.252                   | 0.376                      | 0.247                     |
| 2Sc x 2 Sp    | 0.021                   | 0.806                      | 0.633                     | -0.244                  | 1.159                      | 0.593                     |
| 2Sc x 2 Sd    | -0.002                  | 0.417                      | 0.377                     | -0.136                  | 0.622                      | 0.291                     |
| 2Sc x 2 SCH   | 0.963                   | 0.501                      | 0.720                     | 0.688                   | 0.860                      | 0.723                     |
| 2Sc x 3wl     | 1.433                   | 0.133                      | 0.106                     | 0.925                   | 0.795                      | 0.694                     |
| 2Sc x 4wl     | 1.482                   | 0.082                      | 0.050                     | 0.808                   | 0.946                      | 0.742                     |
| 2Sc x 5wl     | 1.440                   | 0.097                      | 0.053                     | 0.763                   | 0.982                      | 0.713                     |
| 2Sp x 2 Sd    | 0.070                   | 0.386                      | 0.330                     | 0.023                   | 0.482                      | 0.413                     |
| 2Sp x 2 SCH   | 1.024                   | 0.504                      | 0.746                     | 0.937                   | 0.636                      | 0.895                     |
| 2Sp x 3wl     | 1.437                   | 0.154                      | 0.145                     | 1.203                   | 0.511                      | 0.648                     |
| 2Sp x 4wl     | 1.507                   | 0.060                      | 0.027                     | 1.153                   | 0.586                      | 0.646                     |
| 2Sp x 5wl     | 1.435                   | 0.125                      | 0.090                     | 1.095                   | 0.624                      | 0.681                     |
| 2Sd x 2 SCH   | 1.149                   | 0.617                      | 0.504                     | 1.136                   | 0.606                      | 0.475                     |
| 2Sd x 3wl     | 1.443                   | 0.292                      | 0.234                     | 1.305                   | 0.660                      | 0.634                     |
| 2Sd x 4wl     | 1.483                   | 0.197                      | 0.133                     | 1.290                   | 0.697                      | 0.534                     |
| 2Sd x 5wl     | 1.438                   | 0.240                      | 0.149                     | 1.227                   | 0.787                      | 0.633                     |
| 2SCH x 3wl    | 0.909                   | 0.466                      | 0.451                     | 0.441                   | 0.810                      | 0.738                     |
| 2SCH x 4wl    | 1.159                   | 0.287                      | 0.215                     | 0.315                   | 0.903                      | 0.692                     |
| 2SCH x 5wl    | 1.001                   | 0.382                      | 0.286                     | 0.221                   | 0.948                      | 0.709                     |
| 3wl x 4wl     | 0.378                   | 0.760                      | 0.723                     | -0.124                  | 1.080                      | 0.881                     |
| 3wl x 5wl     | 0.055                   | 0.950                      | 0.853                     | -0.265                  | 1.150                      | 0.929                     |
| 4wl x 5wl     | 0.001                   | 0.979                      | 0.725                     | -0.013                  | 0.986                      | 0.905                     |

|                               |                                 |                                |
|-------------------------------|---------------------------------|--------------------------------|
| TL- Total length              | 2acd - carpus of 2nd cheliped   | 2ld - dactylus of 2nd cheliped |
| CL- Carapace length           | 2asp - propodus of 2nd cheliped | 1CH- Length of 1st cheliped    |
| RL- Rostral length            | 2ad - dactylus of 2nd cheliped  | 2sCH- Length of 2nd cheliped   |
| TEL- Telson length            | 2li - ischium of 2nd cheliped   | 3CH- Length of 3rd cheliped    |
| Ur- uropod length             | 2lm - merus of 2nd cheliped     | 4CH- Length of 4th cheliped    |
| 2ai - ischium of 2nd cheliped | 2lci - carpus of 2nd cheliped   | 5CH- Length of 5th cheliped    |
| 2am - merus of 2nd cheliped   | 2lp - propodus of 2nd cheliped  | 2LCH- Length of 2nd cheliped   |

**Table 2.3.7** Values of intercept (a) , regression coefficient (b), correlation coefficient(r) of different morphometric measurements of *Heterocarpus laevigatus*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -3.563                  | 2.553                      | 0.929                     | 0.170                   | 0.693                      | 0.330                     |
| TL x RL       | -3.314                  | 2.197                      | 0.944                     | -5.770                  | 3.624                      | 0.997                     |
| TL x 1chl     | -1.711                  | 1.615                      | 0.944                     | -3.054                  | 2.266                      | 0.966                     |
| TL x 2 i      | -1.454                  | 1.472                      | 0.926                     | -11.078                 | 5.957                      | 0.979                     |
| TL x 2 m      | 0.954                   | 0.000                      | 1.000                     | -5.238                  | 2.996                      | 0.380                     |
| TL x 2 c      | -9.309                  | 5.005                      | 0.944                     | -1.908                  | 1.434                      | 0.667                     |
| TL x 2 p      | -4.829                  | 2.892                      | 0.944                     | -5.460                  | 3.036                      | 0.667                     |
| TL x 2 d      | 0.699                   | 0.000                      | 1.000                     | -10.713                 | 5.517                      | 0.667                     |
| TL x 2 CH     | 0.477                   | 0.000                      | 1.000                     | -5.480                  | 3.463                      | 0.999                     |
| TL x 3wl      | -1.940                  | 1.716                      | 0.944                     | 0.144                   | 0.756                      | 0.161                     |
| TL x 4wl      | -7.845                  | 4.730                      | 0.982                     | 1.141                   | 0.275                      | 0.667                     |
| TL x 5wl      | 0.581                   | 0.555                      | 0.944                     | 2.384                   | -0.359                     | 0.327                     |
| TL x Tel      | 4.755                   | -1.534                     | 0.301                     | -9.843                  | 5.467                      | 0.995                     |
| TL x Ur       | 0.055                   | 0.548                      | 0.079                     | -1.329                  | 1.212                      | 0.825                     |
| CL x RL       | 0.676                   | 0.549                      | 0.763                     | -1.402                  | 1.862                      | 0.383                     |
| CL x 1chl     | 0.599                   | 0.578                      | 1.000                     | -0.636                  | 1.366                      | 0.511                     |
| CL x 2 i      | 0.954                   | 0.000                      | 1.000                     | -2.620                  | 2.243                      | 0.202                     |
| CL x 2 m      | -1.913                  | 1.700                      | 0.763                     | 2.605                   | -1.173                     | 0.085                     |
| CL x 2 c      | -0.555                  | 0.982                      | 0.763                     | -1.168                  | 1.370                      | 0.886                     |
| CL x 2 p      | 0.699                   | 0.000                      | 1.000                     | -3.893                  | 2.902                      | 0.886                     |
| CL x 2 d      | 0.477                   | 0.000                      | 1.000                     | -7.867                  | 5.274                      | 0.886                     |
| CL x 2CH      | 0.596                   | 0.583                      | 0.763                     | -1.015                  | 1.593                      | 0.308                     |
| CL x 3wl      | -0.938                  | 1.658                      | 0.847                     | -0.728                  | 1.532                      | 0.961                     |
| CL x 4wl      | 1.401                   | 0.188                      | 0.763                     | 1.283                   | 0.263                      | 0.886                     |
| CL x 5wl      | 2.915                   | -0.793                     | 0.565                     | 1.384                   | 0.178                      | 0.118                     |
| CL x Tel      | 1.138                   | 0.011                      | 0.000                     | -2.509                  | 2.333                      | 0.264                     |
| CL x Ur       | -0.067                  | 0.746                      | 0.763                     | 0.794                   | 0.198                      | 0.032                     |
| RL x 1chl     | 0.275                   | 0.801                      | 0.758                     | 0.548                   | 0.630                      | 0.983                     |
| RL x 2 i      | -0.987                  | 1.360                      | 1.000                     | -1.564                  | 1.825                      | 0.960                     |
| RL x 2 m      | 0.954                   | 0.000                      | 1.000                     | -0.376                  | 0.765                      | 0.326                     |
| RL x 2 c      | -4.006                  | 3.099                      | 1.000                     | 0.353                   | 0.410                      | 0.718                     |
| RL x 2 p      | -1.765                  | 1.791                      | 1.000                     | -0.670                  | 0.868                      | 0.718                     |
| RL x 2 d      | 0.699                   | 0.000                      | 1.000                     | -2.011                  | 1.578                      | 0.718                     |
| RL x 2CH      | 0.477                   | 0.000                      | 1.000                     | 0.040                   | 0.951                      | 0.994                     |
| RL x 3wl      | -0.122                  | 1.063                      | 1.000                     | 1.310                   | 0.235                      | 0.204                     |
| RL x 4wl      | -2.721                  | 2.854                      | 0.989                     | 1.575                   | 0.079                      | 0.718                     |
| RL x 5wl      | 1.169                   | 0.343                      | 1.000                     | 1.799                   | -0.091                     | 0.276                     |
| RL x Tel      | 2.538                   | -0.564                     | 0.113                     | -1.121                  | 1.498                      | 0.984                     |
| RL x Ur       | 0.256                   | 0.586                      | 0.250                     | 0.614                   | 0.325                      | 0.781                     |
| 1chl x 2 i    | 0.954                   | 0.000                      | 1.000                     | -2.815                  | 2.470                      | 0.895                     |
| 1chl x 2 m    | -3.660                  | 2.931                      | 0.758                     | -0.679                  | 0.972                      | 0.212                     |
| 1chl x 2 c    | -1.565                  | 1.694                      | 0.758                     | -0.065                  | 0.692                      | 0.826                     |
| 1chl x 2 p    | 0.699                   | 0.000                      | 1.000                     | -3.622                  | 2.663                      | 0.826                     |
| 1chl x 2 CH   | -0.003                  | 1.005                      | 0.758                     | -0.727                  | 1.470                      | 0.957                     |
| 1chl x 3wl    | -2.646                  | 2.862                      | 0.842                     | 0.974                   | 0.460                      | 0.317                     |
| 1chl x 4wl    | 1.207                   | 0.325                      | 0.758                     | 1.495                   | 0.133                      | 0.826                     |
| 1chl x 5wl    | 3.750                   | -1.381                     | 0.571                     | 1.830                   | -0.112                     | 0.170                     |
| 1chl x Tel    | 1.139                   | 0.011                      | 0.000                     | -2.307                  | 2.299                      | 0.935                     |
| 1chl x Ur     | -0.834                  | 1.287                      | 0.758                     | 0.397                   | 0.472                      | 0.666                     |
| 2m x 2 c      | 0.550                   | 0.578                      | 1.000                     | 0.956                   | 0.017                      | 0.002                     |
| 2m x 2 p      | 0.699                   | 0.000                      | 1.000                     | 0.606                   | 0.037                      | 0.002                     |
| 2m x 2 CH     | 1.252                   | 0.343                      | 1.000                     | 1.120                   | 0.452                      | 0.402                     |
| 2m x 3wl      | 0.969                   | 0.921                      | 0.989                     | 1.805                   | -0.184                     | 0.225                     |
| 2m x 4wl      | 1.613                   | 0.111                      | 1.000                     | 1.691                   | 0.003                      | 0.002                     |

Table 2.3.7 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2m x 5wl      | 1.809                   | -0.182                     | 0.113                     | 1.762                   | -0.129                     | 0.997                     |
| 2m x Tel      | 1.014                   | 0.189                      | 0.250                     | 0.544                   | 0.757                      | 0.451                     |
| 2m x Ur       | 0.772                   | 0.439                      | 1.000                     | 0.914                   | 0.244                      | 0.791                     |
| 2c x 2 p      | 0.699                   | 0.000                      | 1.000                     | -1.419                  | 2.118                      | 1.000                     |
| 2c x 2 CH     | 0.925                   | 0.593                      | 1.000                     | -0.065                  | 1.584                      | 0.644                     |
| 2c x 3wl      | 0.092                   | 1.594                      | 0.989                     | 0.771                   | 0.920                      | 0.734                     |
| 2c x 4wl      | 1.507                   | 0.192                      | 1.000                     | 1.507                   | 0.192                      | 1.000                     |
| 2c x Tel      | 0.834                   | 0.327                      | 0.250                     | -1.208                  | 2.412                      | 0.597                     |
| 2c x Ur       | 0.354                   | 0.760                      | 1.000                     | 0.734                   | 0.380                      | 0.250                     |
| 2CH x 3wl     | -2.393                  | 2.686                      | 0.989                     | 1.358                   | 0.207                      | 0.144                     |
| 2CH x 4wl     | 1.208                   | 0.323                      | 1.000                     | 1.578                   | 0.078                      | 0.644                     |
| 2CH x 5wl     | 2.473                   | -0.531                     | 0.113                     | 1.820                   | -0.107                     | 0.350                     |
| 2CH x Tel     | 0.323                   | 0.552                      | 0.250                     | -1.193                  | 1.581                      | 0.998                     |
| 2CH x Ur      | -0.830                  | 1.280                      | 1.000                     | 0.583                   | 0.353                      | 0.842                     |
| 3wl x 4wl     | 1.498                   | 0.119                      | 0.989                     | 1.439                   | 0.153                      | 0.734                     |
| 3wl x 5wl     | 2.093                   | -0.254                     | 0.188                     | 1.374                   | 0.174                      | 0.272                     |
| 3wl x Tel     | 0.881                   | 0.166                      | 0.165                     | -0.483                  | 0.971                      | 0.111                     |
| 3wl x Ur      | 0.319                   | 0.471                      | 0.989                     | 1.125                   | -0.013                     | 0.000                     |
| 4wl x 5 wl    | 4.458                   | -1.643                     | 0.113                     | 1.643                   | 0.012                      | 0.000                     |
| 4wl x Tel     | -1.740                  | 1.708                      | 0.250                     | -20.166                 | 12.578                     | 0.597                     |
| 4wl x Ur      | -5.617                  | 3.962                      | 1.000                     | -2.252                  | 1.981                      | 0.250                     |
| 5wl x Tel     | 0.401                   | 0.452                      | 0.420                     | 10.281                  | -5.503                     | 0.397                     |
| 5wl x Ur      | 1.556                   | -0.271                     | 0.113                     | 4.152                   | -1.834                     | 0.745                     |
| Tel x Ur      | 0.432                   | 0.580                      | 0.250                     | 0.845                   | 0.228                      | 0.876                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

**Table 2.3.8** Values of intercept (a) , regression coefficient (b), correlation coefficient(r) of different morphometric measurements of *Parapandalus spinipes*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -0.414                  | 0.887                      | 0.441                     | -1.142                  | 1.264                      | 0.755                     |
| TL x RL       | -0.695                  | 1.110                      | 0.506                     | -0.524                  | 1.008                      | 0.425                     |
| TL x 1chl     | 0.371                   | 0.592                      | 0.450                     | -2.576                  | 2.079                      | 0.846                     |
| TL x 2 i      | -0.991                  | 0.941                      | 0.387                     | 0.018                   | 0.442                      | 0.075                     |
| TL x 2 m      | 0.579                   | 0.172                      | 0.018                     | -0.943                  | 0.947                      | 0.349                     |
| TL x 2 c      | -0.312                  | 0.714                      | 0.369                     | -1.043                  | 1.108                      | 0.488                     |
| TL x 2 p      | -4.143                  | 2.214                      | 0.280                     | -1.342                  | 0.818                      | 0.106                     |
| TL x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| TL x 2 CH     | 0.171                   | 0.668                      | 0.513                     | -0.154                  | 0.848                      | 0.573                     |
| TL x 3wl      | 2.215                   | -0.154                     | 0.022                     | -0.173                  | 1.059                      | 0.360                     |
| TL x 4wl      | 1.963                   | -0.015                     | 0.000                     | 3.063                   | -0.594                     | 0.041                     |
| TL x 5wl      | 1.968                   | -0.005                     | 0.000                     | 3.577                   | -0.836                     | 0.166                     |
| CL x RL       | 1.069                   | 0.306                      | 0.069                     | 0.554                   | 0.675                      | 0.403                     |
| CL x 1chl     | 1.134                   | 0.298                      | 0.204                     | -0.114                  | 1.220                      | 0.616                     |
| CL x 2 i      | -0.173                  | 0.773                      | 0.466                     | 0.267                   | 0.460                      | 0.171                     |
| CL x 2 m      | 0.419                   | 0.377                      | 0.155                     | 0.205                   | 0.536                      | 0.236                     |
| CL x 2 c      | 0.547                   | 0.406                      | 0.213                     | 0.111                   | 0.764                      | 0.492                     |
| CL x 2 p      | -2.725                  | 2.204                      | 0.494                     | -0.188                  | 0.346                      | 0.040                     |
| CL x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| CL x 2CH      | 0.745                   | 0.555                      | 0.630                     | 0.735                   | 0.581                      | 0.570                     |
| CL x 3wl      | 2.128                   | -0.163                     | 0.043                     | 1.053                   | 0.641                      | 0.279                     |
| CL x 4wl      | 2.369                   | -0.330                     | 0.117                     | 2.799                   | -0.668                     | 0.109                     |
| CL x 5wl      | 2.173                   | -0.163                     | 0.055                     | 2.883                   | -0.705                     | 0.250                     |
| RL x 1chl     | 1.069                   | 0.306                      | 0.069                     | 0.196                   | 0.923                      | 0.399                     |
| RL x 2 i      | -0.173                  | 0.773                      | 0.466                     | 0.671                   | 0.154                      | 0.022                     |
| RL x 2 m      | 0.419                   | 0.377                      | 0.155                     | 0.257                   | 0.462                      | 0.198                     |
| RL x 2 c      | 0.547                   | 0.406                      | 0.213                     | 0.361                   | 0.540                      | 0.277                     |
| RL x 2 p      | -2.725                  | 2.204                      | 0.494                     | -0.643                  | 0.628                      | 0.149                     |
| RL x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| RL x 2CH      | 0.745                   | 0.555                      | 0.630                     | 0.925                   | 0.411                      | 0.322                     |
| RL x 3wl      | 2.128                   | -0.163                     | 0.043                     | 1.149                   | 0.530                      | 0.216                     |
| RL x 4wl      | 2.369                   | -0.330                     | 0.117                     | 2.253                   | -0.251                     | 0.017                     |
| RL x 5wl      | 2.173                   | -0.163                     | 0.055                     | 2.528                   | -0.415                     | 0.098                     |
| 1chl x 2 i    | -0.564                  | 0.923                      | 0.290                     | 0.683                   | 0.138                      | 0.037                     |
| 1chl x 2 m    | 1.112                   | -0.129                     | 0.008                     | 0.187                   | 0.482                      | 0.462                     |
| 1chl x 2 c    | 0.082                   | 0.655                      | 0.242                     | 0.377                   | 0.501                      | 0.511                     |
| 1chl x 2 p    | -4.114                  | 2.812                      | 0.352                     | -0.026                  | 0.201                      | 0.033                     |
| 1chl x 2 d    | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 1chl x 2 CH   | 0.587                   | 0.583                      | 0.303                     | 0.947                   | 0.375                      | 0.574                     |
| 1chl x 3wl    | 2.181                   | -0.175                     | 0.022                     | 1.346                   | 0.377                      | 0.233                     |
| 1chl x 4wl    | 1.083                   | 0.557                      | 0.145                     | 2.338                   | -0.293                     | 0.051                     |
| 1chl x 5wl    | 1.310                   | 0.425                      | 0.162                     | 2.492                   | -0.371                     | 0.166                     |
| 2i x 2 c      | 0.730                   | 0.417                      | 0.288                     | 0.663                   | 0.555                      | 0.321                     |
| 2i x 2CH      | 1.013                   | 0.548                      | 0.789                     | 1.111                   | 0.471                      | 0.462                     |
| 2i x 3wl      | 2.047                   | -0.157                     | 0.052                     | 1.574                   | 0.402                      | 0.136                     |
| 2i x 4wl      | 1.958                   | -0.029                     | 0.001                     | 1.755                   | 0.139                      | 0.006                     |
| 2i x 5wl      | 1.916                   | 0.051                      | 0.007                     | 2.037                   | -0.138                     | 0.012                     |
| 2m x 2 CH     | 1.169                   | 0.336                      | 0.212                     | 1.159                   | 0.398                      | 0.326                     |
| 2m x 3wl      | 1.874                   | 0.043                      | 0.003                     | 1.510                   | 0.452                      | 0.168                     |
| 2m x 5wl      | 2.293                   | -0.366                     | 0.252                     | 2.538                   | -0.664                     | 0.269                     |

Table 2.3.8 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2c x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2c x 2 CH     | 0.844                   | 0.584                      | 0.540                     | 0.775                   | 0.653                      | 0.855                     |
| 2c x 3wl      | 2.033                   | -0.110                     | 0.015                     | 1.412                   | 0.451                      | 0.164                     |
| 2c x 4wl      | 1.407                   | 0.487                      | 0.197                     | 2.285                   | -0.348                     | 0.035                     |
| 2c x 5wl      | 1.628                   | 0.306                      | 0.149                     | 2.485                   | -0.493                     | 0.145                     |
| 2p x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2p x 2 CH     | 1.454                   | 0.126                      | 0.317                     | 1.519                   | 0.055                      | 0.015                     |
| 2p x 3wl      | 1.918                   | -0.026                     | 0.011                     | 1.908                   | 0.094                      | 0.018                     |
| 2p x 4wl      | 1.934                   | 0.000                      | 0.000                     | 1.845                   | 0.122                      | 0.011                     |
| 2p x 5wl      | 1.954                   | 0.023                      | 0.011                     | 1.898                   | 0.050                      | 0.004                     |
| 2CH x 3wl     | 2.155                   | -0.184                     | 0.021                     | 0.644                   | 0.842                      | 0.285                     |
| 2CH x 4wl     | 2.013                   | -0.054                     | 0.002                     | 2.764                   | -0.576                     | 0.048                     |
| 2CH x 5wl     | 1.900                   | 0.040                      | 0.002                     | 3.176                   | -0.823                     | 0.202                     |
| 3wl x 4wl     | 2.425                   | -0.257                     | 0.043                     | 2.235                   | -0.183                     | 0.012                     |
| 3wl x 5wl     | 2.494                   | -0.280                     | 0.099                     | 2.599                   | -0.355                     | 0.093                     |
| 3wl x Tel     | 2.149                   | -0.571                     | 0.061                     | 0.609                   | 0.261                      | 0.068                     |
| 4wl x 5 wl    | 0.637                   | 0.683                      | 0.894                     | 0.727                   | 0.630                      | 0.815                     |
| 4wl x Tel     | 1.939                   | -0.456                     | 0.059                     | 0.554                   | 0.298                      | 0.246                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

**Table 2.3.9** Values of intercept (a) , regression coefficient (b), correlation coefficient(r) of different morphometric measurements of *Plesionika martia*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | 1.279                   | 0.000                      | 0.000                     | -0.500                  | 0.914                      | 0.859                     |
| TL x RL       | 1.191                   | 0.167                      | 0.057                     | -1.029                  | 1.270                      | 0.726                     |
| TL x 1chl     | -1.387                  | 1.425                      | 0.519                     | -1.275                  | 1.358                      | 0.871                     |
| TL x 2 i      | 0.778                   | 0.000                      | 1.000                     | -1.275                  | 1.029                      | 0.810                     |
| TL x 2 m      | -1.418                  | 1.139                      | 0.340                     | -0.779                  | 0.794                      | 0.667                     |
| TL x 2 c      | 1.311                   | -0.163                     | 0.022                     | -1.490                  | 1.256                      | 0.785                     |
| TL x 2 p      | 0.000                   | 0.000                      | 1.000                     | -5.583                  | 2.860                      | 0.789                     |
| TL x 2 d      | -12.148                 | 6.126                      | 0.486                     | -1.055                  | 0.511                      | 0.054                     |
| TL x 2 CH     | 0.555                   | 0.422                      | 0.233                     | -0.874                  | 1.140                      | 0.907                     |
| TL x 3wl      | 0.651                   | 0.401                      | 0.274                     | -0.001                  | 0.731                      | 0.932                     |
| TL x 4wl      | -0.487                  | 1.016                      | 0.891                     | -0.208                  | 0.867                      | 0.863                     |
| TL x 5wl      | 0.855                   | 0.303                      | 0.076                     | 0.125                   | 0.682                      | 0.643                     |
| TL x Tel      | 2.812                   | -0.942                     | 0.745                     | -1.345                  | 1.203                      | 0.674                     |
| CL x RL       | 0.783                   | 0.575                      | 0.500                     | -0.100                  | 1.212                      | 0.643                     |
| CL x 1chl     | 3.285                   | -1.466                     | 0.409                     | -0.273                  | 1.290                      | 0.764                     |
| CL x 2 i      | 0.778                   | 0.000                      | 1.000                     | -0.585                  | 1.030                      | 0.788                     |
| CL x 2 m      | 0.858                   | -0.031                     | 0.000                     | -0.064                  | 0.656                      | 0.443                     |
| CL x 2 c      | 1.004                   | -0.011                     | 0.000                     | -0.428                  | 1.090                      | 0.575                     |
| CL x 2 p      | 0.000                   | 0.000                      | 1.000                     | -3.440                  | 2.692                      | 0.679                     |
| CL x 2 d      | 8.243                   | -6.541                     | 0.412                     | -1.065                  | 0.778                      | 0.122                     |
| CL x 2CH      | 1.643                   | -0.203                     | 0.040                     | 0.028                   | 1.036                      | 0.729                     |
| CL x 3wl      | 1.452                   | -0.011                     | 0.000                     | 0.603                   | 0.646                      | 0.706                     |
| CL x 4wl      | 1.141                   | 0.287                      | 0.053                     | 0.527                   | 0.751                      | 0.630                     |
| CL x 5wl      | 2.758                   | -1.023                     | 0.646                     | 0.867                   | 0.468                      | 0.293                     |
| CL x ur       | 2.257                   | -1.005                     | 0.421                     | -0.437                  | 1.123                      | 0.486                     |
| CL x Tel      | 0.950                   | 0.011                      | 0.000                     | -0.290                  | 1.015                      | 0.467                     |
| RL x 1chl     | 3.362                   | -1.285                     | 0.208                     | 0.125                   | 0.870                      | 0.794                     |
| RL x 2 i      | 0.778                   | 0.000                      | 1.000                     | -0.102                  | 0.585                      | 0.580                     |
| RL x 2 m      | -1.094                  | 1.260                      | 0.205                     | 0.049                   | 0.502                      | 0.592                     |
| RL x 2 c      | -0.332                  | 0.872                      | 0.314                     | -0.093                  | 0.736                      | 0.599                     |
| RL x 2 p      | 0.000                   | 0.000                      | 1.000                     | -2.309                  | 1.615                      | 0.558                     |
| RL x 2 d      | 8.638                   | -5.768                     | 0.212                     | -0.142                  | 0.070                      | 0.002                     |
| RL x 2CH      | 0.598                   | 0.517                      | 0.172                     | 0.406                   | 0.660                      | 0.675                     |
| RL x 3wl      | 1.903                   | -0.306                     | 0.079                     | 0.777                   | 0.452                      | 0.790                     |
| RL x 4wl      | 0.376                   | 0.745                      | 0.236                     | 0.730                   | 0.526                      | 0.704                     |
| RL x 5wl      | 2.818                   | -0.901                     | 0.332                     | 0.953                   | 0.354                      | 0.384                     |
| RL x ur       | 0.981                   | -0.005                     | 0.000                     | -0.003                  | 0.699                      | 0.430                     |
| RL x Tel      | 0.947                   | 0.011                      | 0.000                     | -0.216                  | 0.844                      | 0.737                     |
| 1chl x 2 i    | 0.778                   | 0.000                      | 1.000                     | -0.057                  | 0.582                      | 0.548                     |
| 1chl x 2 m    | 0.345                   | 0.336                      | 0.116                     | 0.001                   | 0.560                      | 0.702                     |
| 1chl x 2 c    | 1.237                   | -0.174                     | 0.100                     | -0.213                  | 0.856                      | 0.773                     |
| 1chl x 2 p    | 0.000                   | 0.000                      | 1.000                     | -2.798                  | 2.035                      | 0.846                     |
| 1chl x 2 d    | -6.191                  | 4.304                      | 0.939                     | -0.888                  | 0.594                      | 0.155                     |
| 1chl x 2 CH   | 1.176                   | 0.147                      | 0.111                     | 0.302                   | 0.765                      | 0.865                     |
| 1chl x 3wl    | 1.122                   | 0.224                      | 0.335                     | 0.764                   | 0.483                      | 0.861                     |
| 1chl x 4wl    | 1.120                   | 0.275                      | 0.255                     | 0.680                   | 0.586                      | 0.834                     |
| 1chl x 5wl    | 0.894                   | 0.394                      | 0.504                     | 0.855                   | 0.440                      | 0.566                     |
| 2 chbx ur     | 0.296                   | 0.480                      | 0.505                     | 0.020                   | 0.717                      | 0.432                     |
| 1chl x Tel    | 1.533                   | -0.404                     | 0.537                     | -0.030                  | 0.756                      | 0.564                     |



Table 2.3.9 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2i x 3wl      | 1.404                   | 0.042                      | 0.012                     | 1.030                   | 0.549                      | 0.687                     |
| 2i x 4wl      | 1.157                   | 0.436                      | 0.627                     | 0.998                   | 0.671                      | 0.676                     |
| 2i x 5wl      | 1.674                   | -0.278                     | 0.246                     | 1.104                   | 0.491                      | 0.436                     |
| 2ix ur        | 0.881                   | 0.114                      | 0.028                     | 0.191                   | 1.102                      | 0.630                     |
| 2i x Tel      | 1.147                   | -0.228                     | 0.167                     | 0.303                   | 0.964                      | 0.567                     |
| 2m x 2 c      | 0.711                   | 0.342                      | 0.375                     | 0.110                   | 1.123                      | 0.594                     |
| 2m x 2 p      | 0.000                   | 0.000                      | 1.000                     | -1.757                  | 2.331                      | 0.495                     |
| 2m x 2 d      | -0.734                  | 0.749                      | 0.028                     | -0.412                  | 0.466                      | 0.042                     |
| 2m x 2 CH     | 0.900                   | 0.599                      | 0.911                     | 0.544                   | 1.062                      | 0.744                     |
| 2m x 3wl      | 1.305                   | 0.162                      | 0.171                     | 0.961                   | 0.617                      | 0.626                     |
| 2m x 4wl      | 1.174                   | 0.407                      | 0.546                     | 0.832                   | 0.856                      | 0.795                     |
| 2m x 5wl      | 1.550                   | -0.122                     | 0.047                     | 0.869                   | 0.767                      | 0.767                     |
| 2m x ur       | 0.600                   | 0.456                      | 0.444                     | 0.364                   | 0.850                      | 0.271                     |
| 2m x Tel      | 1.243                   | -0.342                     | 0.375                     | 0.208                   | 1.051                      | 0.487                     |
| 2c x 2 p      | 0.000                   | 0.000                      | 1.000                     | -2.097                  | 2.185                      | 0.925                     |
| 2c x 2 d      | 3.139                   | -3.289                     | 0.167                     | -0.141                  | 0.102                      | 0.004                     |
| 2c x 2 CH     | 0.613                   | 0.785                      | 0.487                     | 0.566                   | 0.821                      | 0.944                     |
| 2c x 3wl      | 1.697                   | -0.262                     | 0.140                     | 0.948                   | 0.502                      | 0.881                     |
| 2c x 4wl      | 1.444                   | 0.064                      | 0.004                     | 0.889                   | 0.622                      | 0.892                     |
| 2c x 5wl      | 1.789                   | -0.342                     | 0.116                     | 0.976                   | 0.503                      | 0.702                     |
| 2c x Ur       | 0.477                   | 0.500                      | 0.167                     | 0.135                   | 0.901                      | 0.646                     |
| 2c x Tel      | 0.716                   | 0.250                      | 0.063                     | 0.256                   | 0.786                      | 0.579                     |
| 2p x 2 CH     | 21.500                  | 2.750                      | 0.587                     | 1.356                   | 0.352                      | 0.895                     |
| 2p x 3wl      | 28.000                  | -0.500                     | 0.062                     | 1.431                   | 0.215                      | 0.834                     |
| 2p x 4wl      | 29.500                  | 2.250                      | 0.460                     | 1.488                   | 0.262                      | 0.821                     |
| 2p x 5wl      | 27.000                  | 1.000                      | 0.118                     | 1.462                   | 0.198                      | 0.561                     |
| 2p x Ur       | 8.500                   | 0.750                      | 0.375                     | 1.004                   | 0.364                      | 0.547                     |
| 2p x Tel      | 9.500                   | -0.250                     | 0.062                     | 1.015                   | 0.317                      | 0.487                     |
| 2CH x 3wl     | 1.378                   | 0.043                      | 0.007                     | 0.614                   | 0.603                      | 0.906                     |
| 2CH x 4wl     | 0.709                   | 0.573                      | 0.632                     | 0.459                   | 0.759                      | 0.947                     |
| 2CH x 5wl     | 1.566                   | -0.084                     | 0.013                     | 0.637                   | 0.607                      | 0.730                     |
| 2CH x Ur      | 0.121                   | 0.611                      | 0.465                     | -0.406                  | 1.040                      | 0.614                     |
| 2CH x Tel     | 1.424                   | -0.331                     | 0.205                     | -0.280                  | 0.954                      | 0.607                     |
| 3wl x 4wl     | 0.465                   | 0.725                      | 0.266                     | -0.190                  | 1.174                      | 0.908                     |
| 3wl x 5wl     | 1.643                   | -0.134                     | 0.009                     | 0.121                   | 0.936                      | 0.695                     |
| 3wl x Ur      | 0.702                   | 0.188                      | 0.012                     | -1.634                  | 1.841                      | 0.772                     |
| 3wl x Tel     | 2.765                   | -1.253                     | 0.773                     | -1.455                  | 1.722                      | 0.793                     |
| 4wl x 5 wl    | 1.506                   | -0.037                     | 0.001                     | 0.242                   | 0.818                      | 0.805                     |
| 4wl x ur      | 0.056                   | 0.608                      | 0.240                     | -0.946                  | 1.312                      | 0.594                     |
| 4wl x Tel     | 2.248                   | -0.852                     | 0.707                     | -1.024                  | 1.366                      | 0.758                     |
| 5wl x Ur      | -0.008                  | 0.676                      | 0.309                     | -0.963                  | 1.353                      | 0.525                     |
| 5wl x Tel     | 1.069                   | -0.073                     | 0.005                     | -0.835                  | 1.271                      | 0.545                     |
| Ur x Tel      | 1.288                   | -0.333                     | 0.167                     | 0.267                   | 0.750                      | 0.661                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

Table 2.3.10 Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Plesionika ensis*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | 1.481                   | -0.052                     | 0.001                     | -3.108                  | 2.262                      | 0.713                     |
| TL x RL       | -1.792                  | 1.627                      | 0.899                     | 1.817                   | -0.174                     | 0.025                     |
| TL x 1chl     | 1.675                   | -0.135                     | 0.004                     | 0.603                   | 0.439                      | 0.024                     |
| TL x 2 i      | 2.644                   | -0.876                     | 0.968                     | -1.517                  | 1.224                      | 0.741                     |
| TL x 2 m      | 6.242                   | -2.659                     | 0.968                     | -0.397                  | 0.651                      | 0.086                     |
| TL x 2 c      | -0.539                  | 0.786                      | 0.557                     | -0.184                  | 0.631                      | 0.140                     |
| TL x 2 p      | 0.301                   | 0.000                      | 1.000                     | -1.869                  | 1.095                      | 0.468                     |
| TL x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| TL x 2 CH     | 2.340                   | -0.496                     | 0.894                     | 0.069                   | 0.648                      | 0.184                     |
| TL x 3wl      | 0.035                   | 0.733                      | 0.673                     | 0.502                   | 0.496                      | 0.514                     |
| TL x 4wl      | 0.624                   | 0.411                      | 0.114                     | 1.895                   | -0.206                     | 0.031                     |
| TL x 5wl      | 0.789                   | 0.349                      | 0.880                     | 0.839                   | 0.332                      | 0.144                     |
| TL x Tel      | -0.093                  | 0.571                      | 0.968                     | -0.192                  | 0.623                      | 0.485                     |
| CL x RL       | 1.077                   | 0.292                      | 0.083                     | 1.817                   | -0.174                     | 0.025                     |
| CL x 1chl     | 3.078                   | -1.215                     | 0.991                     | 0.603                   | 0.439                      | 0.024                     |
| CL x 2 i      | 0.734                   | 0.109                      | 0.043                     | -1.517                  | 1.224                      | 0.741                     |
| CL x 2 m      | 0.440                   | 0.330                      | 0.043                     | -0.397                  | 0.651                      | 0.086                     |
| CL x 2 c      | 1.628                   | -0.427                     | 0.474                     | -0.184                  | 0.631                      | 0.140                     |
| CL x 2 p      | 0.301                   | 0.000                      | 1.000                     | -1.869                  | 1.095                      | 0.468                     |
| CL x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| CL x 2CH      | 1.469                   | -0.092                     | 0.088                     | 0.069                   | 0.648                      | 0.184                     |
| CL x 3wl      | 1.941                   | -0.314                     | 0.356                     | 0.502                   | 0.496                      | 0.514                     |
| CL x 4wl      | 2.388                   | -0.681                     | 0.904                     | 1.895                   | -0.206                     | 0.031                     |
| CL x 5wl      | 1.395                   | 0.070                      | 0.101                     | 0.839                   | 0.332                      | 0.144                     |
| CL x Tel      | 1.152                   | -0.071                     | 0.043                     | -0.192                  | 0.623                      | 0.485                     |
| RL x 1chl     | 2.081                   | -0.457                     | 0.144                     | 0.167                   | 0.893                      | 0.116                     |
| RL x 2 i      | 1.556                   | -0.455                     | 0.768                     | 1.107                   | -0.124                     | 0.009                     |
| RL x 2 m      | 2.937                   | -1.380                     | 0.768                     | 1.990                   | -0.740                     | 0.132                     |
| RL x 2 c      | 0.590                   | 0.304                      | 0.246                     | 0.522                   | 0.377                      | 0.059                     |
| RL x 2 p      | 0.301                   | 0.000                      | 1.000                     | 0.478                   | -0.108                     | 0.005                     |
| RL x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| RL x 2CH      | 1.795                   | -0.306                     | 1.000                     | 1.451                   | -0.060                     | 0.002                     |
| RL x 3wl      | 1.050                   | 0.310                      | 0.355                     | 1.799                   | -0.210                     | 0.109                     |
| RL x 4wl      | 1.428                   | 0.015                      | 0.000                     | 0.145                   | 0.911                      | 0.722                     |
| RL x 5wl      | 1.170                   | 0.217                      | 0.999                     | 1.919                   | -0.284                     | 0.125                     |
| RL x Tel      | 0.616                   | 0.296                      | 0.768                     | 1.672                   | -0.422                     | 0.265                     |
| 1chl x 2 i    | 0.952                   | -0.049                     | 0.013                     | 0.760                   | 0.111                      | 0.050                     |
| 1chl x 2 m    | 1.103                   | -0.148                     | 0.013                     | 0.518                   | 0.260                      | 0.111                     |
| 1chl x 2 c    | 0.601                   | 0.313                      | 0.379                     | 0.776                   | 0.203                      | 0.117                     |
| 1chl x 2 p    | 0.301                   | 0.000                      | 1.000                     | 0.323                   | -0.004                     | 0.000                     |
| 1chl x 2 d    | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 1chl x 2 CH   | 1.205                   | 0.098                      | 0.149                     | 1.075                   | 0.195                      | 0.136                     |
| 1chl x 3wl    | 1.195                   | 0.223                      | 0.267                     | 1.506                   | -0.010                     | 0.002                     |
| 1chl x 4wl    | 0.695                   | 0.538                      | 0.841                     | 1.444                   | 0.027                      | 0.004                     |
| 1chl x 5wl    | 1.594                   | -0.073                     | 0.166                     | 1.426                   | 0.051                      | 0.028                     |
| 1chl x Tel    | 1.009                   | 0.032                      | 0.013                     | 1.092                   | -0.028                     | 0.008                     |
| 2i x 2 m      | -1.788                  | 3.036                      | 1.000                     | 0.521                   | 0.413                      | 0.070                     |
| 2i x 2 c      | 1.931                   | -1.009                     | 0.727                     | 0.711                   | 0.395                      | 0.111                     |
| 2i x 2 p      | 0.301                   | 0.000                      | 1.000                     | -0.234                  | 0.596                      | 0.280                     |
| 2i x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2i x 2CH      | 0.887                   | 0.515                      | 0.761                     | 0.996                   | 0.396                      | 0.139                     |
| 2i x 3wl      | 2.315                   | -0.913                     | 0.826                     | 1.188                   | 0.327                      | 0.453                     |
| 2i x 4wl      | 2.054                   | -0.683                     | 0.250                     | 1.646                   | -0.174                     | 0.045                     |

Table 2.3.10 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2 m x 2 c     | 1.338                   | -0.332                     | 0.727                     | 0.711                   | 0.404                      | 0.283                     |
| 2m x 2 p      | 0.301                   | 0.000                      | 1.000                     | 0.032                   | 0.315                      | 0.192                     |
| 2m x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2m x 2 CH     | 1.190                   | 0.170                      | 0.761                     | 0.839                   | 0.580                      | 0.731                     |
| 2m x 3wl      | 1.778                   | -0.301                     | 0.826                     | 1.336                   | 0.172                      | 0.306                     |
| 2m x 4wl      | 1.652                   | -0.225                     | 0.250                     | 1.698                   | -0.236                     | 0.202                     |
| 2m x 5wl      | 1.598                   | -0.119                     | 0.742                     | 1.304                   | 0.219                      | 0.310                     |
| 2m x Tel      | 1.246                   | -0.215                     | 1.000                     | 0.901                   | 0.166                      | 0.170                     |
| 2c x 2 p      | 0.301                   | 0.000                      | 1.000                     | -0.107                  | 0.394                      | 0.173                     |
| 2c x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2c x 2 CH     | 1.596                   | -0.244                     | 0.239                     | 0.508                   | 0.794                      | 0.789                     |
| 2c x 3wl      | 0.632                   | 0.843                      | 0.986                     | 1.200                   | 0.271                      | 0.437                     |
| 2c x 4wl      | 0.395                   | 1.014                      | 0.772                     | 1.244                   | 0.224                      | 0.105                     |
| 2c x 5wl      | 1.319                   | 0.166                      | 0.220                     | 1.396                   | 0.098                      | 0.036                     |
| 2c x Tel      | 0.565                   | 0.470                      | 0.727                     | 0.971                   | 0.074                      | 0.020                     |
| 2p x 2 d      | 0.000                   | 0.000                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2p x 2 CH     | 0.138                   | 4.000                      | 0.000                     | 1.195                   | 0.529                      | 0.314                     |
| 2p x 3wl      | 1.509                   | 0.000                      | 0.000                     | 1.410                   | 0.254                      | 0.346                     |
| 2p x 4wl      | 2.655                   | -4.000                     | 0.000                     | 1.500                   | -0.047                     | 0.004                     |
| 2p x 5wl      | 1.491                   | 0.000                      | 0.000                     | 1.394                   | 0.341                      | 0.389                     |
| 2CH x 3wl     | 2.855                   | -1.003                     | 0.347                     | 1.044                   | 0.328                      | 0.512                     |
| 2CH x 4wl     | 1.491                   | -0.030                     | 0.000                     | 1.528                   | -0.032                     | 0.002                     |
| 2CH x 5wl     | 2.443                   | -0.709                     | 0.999                     | 1.143                   | 0.263                      | 0.207                     |
| 2CH x Tel     | 2.347                   | -0.964                     | 0.761                     | 0.762                   | 0.212                      | 0.128                     |
| 3wl x 4wl     | -0.222                  | 1.109                      | 0.665                     | 2.184                   | -0.469                     | 0.077                     |
| 3wl x 5wl     | 1.132                   | 0.238                      | 0.326                     | 0.742                   | 0.510                      | 0.163                     |
| 3wl x Tel     | 0.164                   | 0.590                      | 0.826                     | -0.068                  | 0.751                      | 0.337                     |
| 4wl x 5 wl    | 1.495                   | -0.003                     | 0.000                     | 1.954                   | -0.305                     | 0.166                     |
| 4wl x Tel     | 0.708                   | 0.239                      | 0.250                     | 1.462                   | -0.277                     | 0.131                     |
| 5wl x Tel     | -0.945                  | 1.341                      | 0.742                     | -0.052                  | 0.735                      | 0.516                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

**Table 2.3.11** Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Plesionika atcocki*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -1.332                  | 1.380                      | 0.964                     | -3.136                  | 2.407                      | 0.939                     |
| TL x RL       | -0.673                  | 1.151                      | 0.714                     | -2.517                  | 2.199                      | 0.762                     |
| TL x 1chl     | -0.383                  | 0.817                      | 0.324                     | -1.110                  | 1.250                      | 0.939                     |
| TL x 2 m      | -2.228                  | 1.729                      | 0.796                     | -0.361                  | 0.672                      | 0.073                     |
| TL x 2 c      | -2.886                  | 2.153                      | 0.711                     | -9.263                  | 5.817                      | 0.999                     |
| TL x 2 p      | -3.585                  | 2.208                      | 0.993                     | 0.301                   | 0.000                      | 1.000                     |
| TL x 2 d      | -6.642                  | 3.775                      | 0.993                     | 0.000                   | 0.000                      | 1.000                     |
| TL x 2 CH     | 1.204                   | 0.000                      | 1.000                     | 1.204                   | 0.000                      | 1.000                     |
| TL x 3wl      | -0.446                  | 0.993                      | 0.993                     | 1.869                   | -0.311                     | 0.055                     |
| TL x 4wl      | 0.538                   | 0.401                      | 0.182                     | 0.856                   | 0.236                      | 0.073                     |
| TL x 5wl      | 0.469                   | 0.425                      | 0.182                     | 0.808                   | 0.249                      | 0.073                     |
| TL x Tel      | 0.845                   | 0.000                      | 1.000                     | -0.141                  | 0.582                      | 0.073                     |
| TL x Ur       | 1.411                   | -0.275                     | 0.182                     | 1.890                   | -0.582                     | 0.073                     |
| CL x RL       | 0.584                   | 0.706                      | 0.530                     | 0.275                   | 0.980                      | 0.934                     |
| CL x 1chl     | 0.250                   | 0.729                      | 0.511                     | 0.519                   | 0.519                      | 1.000                     |
| CL x 2 i      | -0.400                  | 1.077                      | 0.927                     | 2.261                   | -1.448                     | 1.000                     |
| CL x 2 m      | -0.375                  | 1.090                      | 0.625                     | 0.272                   | 0.500                      | 0.250                     |
| CL x 2 c      | -0.535                  | 1.320                      | 0.528                     | -1.496                  | 2.248                      | 0.920                     |
| CL x 2 p      | -1.360                  | 1.518                      | 0.927                     | 0.301                   | 0.000                      | 1.000                     |
| CL x 2 d      | -2.839                  | 2.595                      | 0.927                     | 0.000                   | 0.000                      | 1.000                     |
| CL x 2CH      | 1.204                   | 0.000                      | 1.000                     | 1.204                   | 0.000                      | 1.000                     |
| CL x 3wl      | 0.554                   | 0.683                      | 0.927                     | 1.314                   | 0.007                      | 0.000                     |
| CL x 4wl      | 1.066                   | 0.166                      | 0.062                     | 1.078                   | 0.175                      | 0.250                     |
| CL x 5wl      | 1.030                   | 0.176                      | 0.062                     | 1.043                   | 0.185                      | 0.250                     |
| CL x Ur       | 1.049                   | -0.114                     | 0.062                     | 1.342                   | -0.433                     | 0.250                     |
| RL x 1chl     | 1.016                   | 0.044                      | 0.002                     | 0.421                   | 0.495                      | 0.934                     |
| RL x 2 i      | -0.594                  | 1.022                      | 0.785                     | 2.534                   | -1.379                     | 0.934                     |
| RL x 2 m      | -1.098                  | 1.415                      | 0.991                     | -0.120                  | 0.696                      | 0.499                     |
| RL x 2 c      | -1.632                  | 1.873                      | 1.000                     | -1.694                  | 1.973                      | 0.730                     |
| RL x 2 p      | -1.633                  | 1.441                      | 0.785                     | 0.301                   | 0.000                      | 1.000                     |
| RL x 2 d      | -3.306                  | 2.463                      | 0.785                     | 0.000                   | 0.000                      | 1.000                     |
| RL x 2CH      | 1.204                   | 0.000                      | 1.000                     | 1.204                   | 0.000                      | 1.000                     |
| RL x 3wl      | 0.431                   | 0.648                      | 0.785                     | 1.128                   | 0.143                      | 0.073                     |
| RL x 4wl      | 0.449                   | 0.582                      | 0.713                     | 0.940                   | 0.244                      | 0.499                     |
| RL x 5wl      | 0.375                   | 0.618                      | 0.713                     | 0.897                   | 0.258                      | 0.499                     |
| RL x Tel      | 0.845                   | 0.000                      | 1.000                     | 0.067                   | 0.603                      | 0.499                     |
| RL x Ur       | 1.472                   | -0.399                     | 0.713                     | 1.681                   | -0.603                     | 0.499                     |
| 1chl x 2 i    | 0.230                   | 0.548                      | 0.250                     | 3.708                   | -2.788                     | 1.000                     |
| 1chl x 2 m    | 0.660                   | 0.185                      | 0.019                     | -0.228                  | 0.963                      | 0.250                     |
| 1chl x 2 c    | 0.885                   | 0.069                      | 0.002                     | -3.744                  | 4.330                      | 0.920                     |
| 1chl x 2 p    | -0.472                  | 0.773                      | 0.250                     | 0.301                   | 0.000                      | 1.000                     |
| 1chl x 2 d    | -1.321                  | 1.321                      | 0.250                     | 0.000                   | 0.000                      | 1.000                     |
| 1chl x 2 CH   | 1.204                   | 0.000                      | 1.000                     | 1.204                   | 0.000                      | 1.000                     |
| 1chl x 4wl    | 1.606                   | -0.328                     | 0.250                     | 0.903                   | 0.338                      | 0.250                     |
| 1chl x 5wl    | 1.603                   | -0.347                     | 0.250                     | 0.858                   | 0.357                      | 0.250                     |
| 1chl x Tel    | 0.845                   | 0.000                      | 1.000                     | -0.026                  | 0.834                      | 0.250                     |
| 1chl x Ur     | 0.679                   | 0.224                      | 0.250                     | 1.774                   | -0.834                     | 0.250                     |
| 2i x 2 m      | -0.077                  | 1.142                      | 0.858                     | 1.053                   | -0.345                     | 0.250                     |
| 2i x 2 c      | -0.218                  | 1.437                      | 0.783                     | 0.865                   | 0.299                      | 0.250                     |
| 2i x 2 p      | -0.796                  | 1.409                      | 1.000                     | 2.014                   | -1.553                     | 0.920                     |
| 2i x 5wl      | 0.969                   | 0.317                      | 0.250                     | 1.352                   | -0.121                     | 0.250                     |
| 2i x Tel      | 0.845                   | 0.000                      | 1.000                     | 1.332                   | -0.128                     | 0.250                     |
| 2i x Ur       | 1.088                   | -0.205                     | 0.250                     | 1.083                   | -0.299                     | 0.250                     |

Table 2.3.11 Continued.....

| Relationships | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
| 2 m x 2 c     | -0.167                  | 1.311                      | 0.990                     | 0.525                   | 0.551                      | 0.055                     |
| 2m x 3wl      | 0.918                   | 0.476                      | 0.858                     | 0.937                   | 0.467                      | 0.762                     |
| 2m x 4wl      | 0.925                   | 0.383                      | 0.623                     | 0.982                   | 0.351                      | 1.000                     |
| 2m x 5wl      | 0.880                   | 0.406                      | 0.623                     | 0.942                   | 0.371                      | 1.000                     |
| 2m x Tel      | 0.845                   | 0.000                      | 1.000                     | 0.171                   | 0.866                      | 1.000                     |
| 2m x Ur       | 1.145                   | -0.262                     | 0.623                     | 1.577                   | -0.866                     | 1.000                     |
| 2c x 2 p      | -0.377                  | 0.788                      | 0.783                     | 0.301                   | 0.000                      | 1.000                     |
| 2c x 2 d      | -1.159                  | 1.313                      | 0.783                     | 0.000                   | 0.000                      | 1.000                     |
| 2c x 2 CH     | 1.204                   | 0.000                      | 1.000                     | 1.204                   | 0.000                      | 1.000                     |
| 2c x 3wl      | 0.996                   | 0.345                      | 0.783                     | 1.382                   | -0.061                     | 0.072                     |
| 2p x 2 d      | -0.515                  | 1.710                      | 1.000                     | 0.000                   | 0.000                      | 1.000                     |
| 2p x 2 CH     | 1.204                   | 0.000                      | 1.000                     | 0.000                   | 4.000                      | 1.000                     |
| 3wl x 4wl     | 0.628                   | 0.471                      | 0.250                     | 0.515                   | 0.572                      | 0.762                     |
| 3wl x 5wl     | 0.565                   | 0.500                      | 0.250                     | 0.448                   | 0.604                      | 0.762                     |
| 3wl x Tel     | 0.845                   | 0.000                      | 1.000                     | -0.983                  | 1.412                      | 0.762                     |
| 3wl x Ur      | 1.349                   | -0.323                     | 0.250                     | 2.731                   | -1.412                     | 0.762                     |
| 4wl x 5 wl    | -0.101                  | 1.061                      | 1.000                     | -0.097                  | 1.057                      | 1.000                     |
| 4wl x Tel     | 0.845                   | 0.000                      | 1.000                     | -2.255                  | 2.470                      | 1.000                     |
| 4wl x Ur      | 1.780                   | -0.685                     | 1.000                     | 4.003                   | -2.470                     | 1.000                     |
| 5wl x Tel     | 0.845                   | 0.000                      | 1.000                     | -2.029                  | 2.336                      | 1.000                     |
| 5wl x Ur      | 1.714                   | -0.646                     | 1.000                     | 3.778                   | -2.336                     | 1.000                     |
| Tel x Ur      | 1.301                   | -0.441                     | 0.250                     | 1.748                   | -1.000                     | 1.000                     |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2c - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped

**Table 2.3.12** Values of intercept (a) , regression coefficient (b), correlation coefficient(r) of different morphometric measurements of *Ophiophorus typus*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -1.962                  | 1.734                      | 0.656                     | -2.273                  | 1.911                      | 0.979                     |
| TL x RL       | -2.914                  | 2.312                      | 0.834                     | -1.136                  | 1.332                      | 0.775                     |
| TL x 1chl     | -9.385                  | 5.837                      | 0.997                     | -4.343                  | 3.014                      | 0.959                     |
| TL x 2 i      | -8.795                  | 5.142                      | 0.834                     | -16.225                 | 9.241                      | 0.980                     |
| TL x 2 m      | -0.618                  | 0.582                      | 0.011                     | -9.800                  | 5.750                      | 0.972                     |
| TL x 2 c      | -24.645                 | 13.932                     | 0.834                     | -21.431                 | 12.225                     | 0.952                     |
| TL x 2 p      | -15.549                 | 8.790                      | 0.834                     | -8.367                  | 4.730                      | 0.445                     |
| TL x 2 d      | -23.074                 | 12.937                     | 0.937                     | -17.035                 | 9.459                      | 0.445                     |
| TL x 2 CH     | -10.771                 | 6.577                      | 0.745                     | -13.707                 | 8.222                      | 0.959                     |
| TL x 3wl      | -9.286                  | 5.824                      | 0.949                     | -5.683                  | 3.773                      | 0.678                     |
| TL x 4wl      | -8.073                  | 5.174                      | 0.973                     | -5.108                  | 3.477                      | 0.619                     |
| TL x 5wl      | -5.681                  | 3.808                      | 0.979                     | -0.159                  | 0.680                      | 0.036                     |
| TL x Tel      | -5.259                  | 3.427                      | 0.979                     | -3.369                  | 2.368                      | 0.714                     |
| TL x Ur       | -8.257                  | 5.116                      | 0.468                     | -0.532                  | 0.818                      | 0.346                     |
| CL x RL       | 0.538                   | 0.591                      | 0.250                     | 0.420                   | 0.723                      | 0.851                     |
| CL x 1chl     | -1.577                  | 2.299                      | 0.709                     | -0.739                  | 1.563                      | 0.961                     |
| CL x 2 i      | -1.118                  | 1.315                      | 0.250                     | -5.208                  | 4.818                      | 0.994                     |
| CL x 2 m      | 1.896                   | -1.315                     | 0.250                     | -2.934                  | 2.989                      | 0.979                     |
| CL x 2 c      | -3.846                  | 3.563                      | 0.250                     | -6.929                  | 6.437                      | 0.984                     |
| CL x 2 p      | -2.426                  | 2.248                      | 0.250                     | -2.588                  | 2.343                      | 0.407                     |
| CL x 2 d      | -6.573                  | 5.812                      | 0.867                     | -5.478                  | 4.686                      | 0.407                     |
| CL x 2CH      | -0.672                  | 1.433                      | 0.162                     | -3.878                  | 4.263                      | 0.960                     |
| CL x 3wl      | -0.979                  | 1.834                      | 0.431                     | -1.267                  | 2.040                      | 0.738                     |
| CL x 4wl      | -1.327                  | 2.194                      | 0.802                     | -1.100                  | 1.933                      | 0.713                     |
| CL x 5wl      | -0.349                  | 1.288                      | 0.514                     | 0.444                   | 0.538                      | 0.084                     |
| CL x Tel      | -0.768                  | 1.433                      | 0.785                     | -0.649                  | 1.325                      | 0.833                     |
| CL x Ur       | -3.004                  | 3.431                      | 0.964                     | 0.369                   | 0.492                      | 0.466                     |
| RL x 1chl     | -1.461                  | 2.051                      | 0.789                     | -1.358                  | 1.929                      | 0.899                     |
| RL x 2 i      | -2.314                  | 2.224                      | 1.000                     | -6.911                  | 5.781                      | 0.879                     |
| RL x 2 m      | -0.919                  | 1.112                      | 0.250                     | -4.058                  | 3.641                      | 0.893                     |
| RL x 2 c      | -7.087                  | 6.026                      | 1.000                     | -8.728                  | 7.340                      | 0.786                     |
| RL x 2 p      | -4.471                  | 3.802                      | 1.000                     | -4.347                  | 3.560                      | 0.577                     |
| RL x 2 d      | -5.002                  | 4.125                      | 0.611                     | -3.611                  | 3.855                      | 0.896                     |
| RL x 2CH      | -2.658                  | 2.991                      | 0.988                     | -5.568                  | 5.262                      | 0.899                     |
| RL x 3wl      | -1.704                  | 2.317                      | 0.963                     | -2.650                  | 2.980                      | 0.968                     |
| RL x 4wl      | -0.936                  | 1.726                      | 0.694                     | -2.476                  | 2.877                      | 0.971                     |
| RL x 5wl      | -0.860                  | 1.463                      | 0.926                     | -0.801                  | 1.495                      | 0.400                     |
| RL x Tel      | -0.547                  | 1.155                      | 0.713                     | -1.322                  | 1.754                      | 0.898                     |
| RL x Ur       | -0.309                  | 0.966                      | 0.107                     | -0.092                  | 0.822                      | 0.799                     |
| 1chl x 2 i    | -0.501                  | 0.856                      | 0.789                     | -2.855                  | 3.011                      | 0.986                     |
| 1chl x 2 m    | 0.373                   | 0.045                      | 0.002                     | -1.499                  | 1.892                      | 0.997                     |
| 1chl x 2 c    | -2.173                  | 2.319                      | 0.789                     | -3.611                  | 3.855                      | 0.896                     |
| 1chl x 2 p    | -1.371                  | 1.463                      | 0.789                     | -1.784                  | 1.791                      | 0.605                     |
| 1chl x 2 d    | -2.296                  | 2.242                      | 0.962                     | -3.868                  | 3.583                      | 0.605                     |
| 1chl x 2 CH   | -0.153                  | 1.086                      | 0.694                     | -1.863                  | 2.728                      | 1.000                     |
| 1chl x 3wl    | 0.095                   | 0.981                      | 0.921                     | -0.368                  | 1.369                      | 0.845                     |
| 1chl x 4wl    | 0.242                   | 0.892                      | 0.988                     | -0.218                  | 1.268                      | 0.780                     |
| 1chl x 5wl    | 0.450                   | 0.645                      | 0.960                     | 0.612                   | 0.428                      | 0.135                     |
| 1chl x Tel    | 0.249                   | 0.590                      | 0.992                     | 0.029                   | 0.798                      | 0.769                     |
| 1chl x Ur     | -0.080                  | 0.927                      | 0.525                     | 0.598                   | 0.319                      | 0.498                     |

Table 2.3.12 Continued.....

| Relationships | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r |
|---------------|----------------------------|-------------------------------|------------------------------|----------------------------|-------------------------------|------------------------------|
| 2i x 2 m      | 0.239                      | 0.500                         | 0.250                        | 0.296                      | 0.624                         | 0.996                        |
| 2i x 2 c      | -0.816                     | 2.710                         | 1.000                        | 0.035                      | 1.313                         | 0.957                        |
| 2i x 2 p      | -0.515                     | 1.710                         | 1.000                        | -0.068                     | 0.530                         | 0.487                        |
| 2i x 2 d      | -0.709                     | 1.855                         | 0.611                        | -0.437                     | 1.060                         | 0.487                        |
| 2i x 2CH      | 0.455                      | 1.345                         | 0.988                        | 0.727                      | 0.893                         | 0.986                        |
| 2i x 3wl      | 0.707                      | 1.042                         | 0.963                        | 0.935                      | 0.436                         | 0.788                        |
| 2i x 4wl      | 0.860                      | 0.776                         | 0.694                        | 0.988                      | 0.409                         | 0.747                        |
| 2i x 5wl      | 0.862                      | 0.658                         | 0.926                        | 1.022                      | 0.124                         | 0.105                        |
| 2i x Tel      | 0.655                      | 0.519                         | 0.713                        | 0.784                      | 0.271                         | 0.815                        |
| 2i x Ur       | 0.696                      | 0.434                         | 0.107                        | 0.901                      | 0.104                         | 0.483                        |
| 2m x 2 c      | -0.408                     | 1.355                         | 0.250                        | -0.572                     | 2.070                         | 0.928                        |
| 2m x 2 p      | -0.257                     | 0.855                         | 0.250                        | -0.344                     | 0.902                         | 0.550                        |
| 2m x 2 d      | 0.107                      | -0.355                        | 0.022                        | -0.988                     | 1.804                         | 0.550                        |
| 2m x 2 CH     | 0.604                      | 0.800                         | 0.350                        | 0.300                      | 1.438                         | 0.997                        |
| 2m x 3wl      | 0.938                      | 0.345                         | 0.105                        | 0.722                      | 0.712                         | 0.821                        |
| 2m x 4wl      | 1.164                      | -0.058                        | 0.004                        | 0.790                      | 0.664                         | 0.768                        |
| 2m x 5wl      | 1.029                      | 0.168                         | 0.060                        | 0.957                      | 0.213                         | 0.121                        |
| 2m x Tel      | 0.853                      | -0.025                        | 0.002                        | 0.659                      | 0.428                         | 0.793                        |
| 2m x Ur       | 1.216                      | -0.870                        | 0.429                        | 0.851                      | 0.168                         | 0.493                        |
| 2c x 2 p      | -3.701                     | 0.631                         | 1.000                        | -0.042                     | 0.302                         | 0.285                        |
| 2c x 2 d      | -0.151                     | 0.685                         | 0.611                        | -0.386                     | 0.604                         | 0.285                        |
| 2c x 2 CH     | 0.860                      | 0.496                         | 0.988                        | 0.721                      | 0.634                         | 0.896                        |
| 2c x 3wl      | 1.021                      | 0.384                         | 0.963                        | 0.938                      | 0.293                         | 0.644                        |
| 2c x 4wl      | 1.094                      | 0.286                         | 0.694                        | 0.988                      | 0.283                         | 0.642                        |
| 2c x 5wl      | 1.060                      | 0.243                         | 0.926                        | 1.030                      | 0.067                         | 0.055                        |
| 2c x Tel      | 0.812                      | 0.192                         | 0.713                        | 0.778                      | 0.205                         | 0.841                        |
| 2c x Ur       | 0.827                      | 0.160                         | 0.107                        | 0.900                      | 0.073                         | 0.427                        |
| 2p x 2 d      | -0.151                     | 1.085                         | 0.611                        | -0.301                     | 2.000                         | 1.000                        |
| 2p x 2 CH     | 0.860                      | 0.787                         | 0.988                        | 0.899                      | 0.922                         | 0.606                        |
| 2p x 3wl      | 1.021                      | 0.609                         | 0.963                        | 1.011                      | 0.548                         | 0.719                        |
| 2p x 4wl      | 1.094                      | 0.454                         | 0.694                        | 1.063                      | 0.470                         | 0.570                        |
| 2p x 5wl      | 1.060                      | 0.385                         | 0.926                        | 1.037                      | 0.257                         | 0.260                        |
| 2p x Tel      | 0.812                      | 0.304                         | 0.713                        | 0.842                      | 0.203                         | 0.263                        |
| 2p x Ur       | 0.827                      | 0.254                         | 0.107                        | 0.920                      | 0.113                         | 0.333                        |
| 2CH x 3wl     | 0.379                      | 0.749                         | 0.911                        | 0.567                      | 0.502                         | 0.845                        |
| 2CH x 4wl     | 0.643                      | 0.529                         | 0.590                        | 0.648                      | 0.465                         | 0.781                        |
| 2CH x 5wl     | 0.659                      | 0.468                         | 0.859                        | 0.904                      | 0.157                         | 0.136                        |
| 2CH x Tel     | 0.509                      | 0.355                         | 0.610                        | 0.574                      | 0.292                         | 0.768                        |
| 2CH x Ur      | 0.647                      | 0.218                         | 0.049                        | 0.815                      | 0.117                         | 0.498                        |
| 3wl x 4wl     | 0.262                      | 0.811                         | 0.853                        | 0.097                      | 0.951                         | 0.973                        |
| 3wl x 5wl     | 0.405                      | 0.642                         | 0.993                        | 0.482                      | 0.545                         | 0.489                        |
| 3wl x Tel     | 0.258                      | 0.540                         | 0.868                        | 0.290                      | 0.539                         | 0.777                        |
| 3wl x Ur      | 0.172                      | 0.629                         | 0.252                        | 0.643                      | 0.271                         | 0.798                        |
| 4wl x 5wl     | 0.303                      | 0.699                         | 0.907                        | 0.385                      | 0.611                         | 0.570                        |
| 4wl x Tel     | 0.090                      | 0.660                         | 1.000                        | 0.212                      | 0.588                         | 0.860                        |
| 4wl x Ur      | -0.439                     | 1.134                         | 0.632                        | 0.600                      | 0.299                         | 0.904                        |
| 5wl x Tel     | -0.106                     | 0.862                         | 0.918                        | 0.387                      | 0.446                         | 0.324                        |
| 5wl x Ur      | -0.369                     | 1.111                         | 0.327                        | 0.566                      | 0.344                         | 0.780                        |

TL- Total length

CL- Carapace length

RL- Rostral length

TEL- Telson length

Ur- uropod length

2i - ischium of 2nd cheliped

2m - merus of 2nd cheliped

2c - carpus of 2nd cheliped

2p - propodus of 2nd cheliped

2d - dactylus of 2nd cheliped

1 CH- Length of 1st cheliped

2 CH- Length of 2nd cheliped

3CH- Length of 3rd cheliped

4CH- Length of 4th cheliped

5 CH- Length of 5th cheliped

**Table 2.3.13 Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Acanthephyra sanguinea***

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -11.276                 | 6.304                      | 0.903                     | -1.478                  | 1.383                      | 0.974                     |
| TL x RL       | -4.603                  | 3.013                      | 0.755                     | 0.028                   | 0.697                      | 0.934                     |
| TL x 1chl     | 1.430                   | -0.013                     | 0.000                     | 0.149                   | 0.644                      | 0.863                     |
| TL x 2 i      | -10.254                 | 5.485                      | 0.755                     | -6.367                  | 3.529                      | 0.996                     |
| TL x 2 m      | -15.642                 | 8.244                      | 0.998                     | -3.809                  | 2.324                      | 0.996                     |
| TL x 2 c      | -8.171                  | 4.481                      | 0.755                     | -7.717                  | 4.224                      | 0.982                     |
| TL x 2 p      | -19.425                 | 9.966                      | 0.755                     | -5.131                  | 2.801                      | 0.996                     |
| TL x 2 d      | -33.723                 | 17.037                     | 0.755                     | -9.287                  | 4.789                      | 0.996                     |
| TL x 2 CH     | -13.468                 | 7.422                      | 0.862                     | -5.239                  | 3.292                      | 1.000                     |
| TL x 3wl      | -8.202                  | 4.829                      | 0.887                     | -0.628                  | 1.035                      | 0.816                     |
| TL x 4wl      | -9.055                  | 5.276                      | 0.957                     | 0.837                   | 0.315                      | 0.200                     |
| TL x 5wl      | -3.904                  | 2.690                      | 0.539                     | 0.380                   | 0.533                      | 0.643                     |
| TL x Tel      | -4.504                  | 2.875                      | 0.745                     | -2.117                  | 1.666                      | 0.975                     |
| TL x Ur       | -5.338                  | 3.271                      | 1.000                     | -1.910                  | 1.542                      | 0.996                     |
| CL x RL       | 0.949                   | 0.351                      | 0.451                     | 0.763                   | 0.512                      | 0.990                     |
| CL x 1chl     | 1.270                   | 0.104                      | 0.094                     | 0.890                   | 0.424                      | 0.735                     |
| CL x 2 i      | -0.149                  | 0.639                      | 0.451                     | -2.480                  | 2.462                      | 0.952                     |
| CL x 2 m      | -0.712                  | 1.164                      | 0.876                     | -1.249                  | 1.622                      | 0.952                     |
| CL x 2 c      | 0.086                   | 0.522                      | 0.451                     | -3.224                  | 3.072                      | 0.999                     |
| CL x 2 p      | -1.063                  | 1.161                      | 0.451                     | -2.046                  | 1.954                      | 0.952                     |
| CL x 2 d      | -2.332                  | 1.985                      | 0.451                     | -4.013                  | 3.341                      | 0.952                     |
| CL x 2CH      | 0.133                   | 0.923                      | 0.587                     | -1.652                  | 2.327                      | 0.980                     |
| CL x 3wl      | 0.634                   | 0.811                      | 0.624                     | 0.576                   | 0.673                      | 0.677                     |
| CL x 4wl      | 0.554                   | 0.703                      | 0.747                     | 1.273                   | 0.150                      | 0.089                     |
| CL x 5wl      | 1.109                   | 0.268                      | 0.236                     | 0.905                   | 0.421                      | 0.788                     |
| CL x Tel      | 0.595                   | 0.491                      | 0.955                     | -0.335                  | 1.204                      | 1.000                     |
| CL x Ur       | 0.580                   | 0.467                      | 0.895                     | -0.213                  | 1.075                      | 0.952                     |
| RL x 1chl     | 1.859                   | -0.326                     | 0.250                     | 0.337                   | 0.772                      | 0.644                     |
| RL x 2 i      | -1.876                  | 1.820                      | 1.000                     | -5.935                  | 4.656                      | 0.902                     |
| RL x 2 m      | -2.182                  | 2.116                      | 0.791                     | -3.524                  | 3.067                      | 0.902                     |
| RL x 2 c      | -1.326                  | 1.487                      | 1.000                     | -7.749                  | 5.962                      | 0.996                     |
| RL x 2 p      | -4.202                  | 3.307                      | 1.000                     | -4.788                  | 3.696                      | 0.902                     |
| RL x 2 d      | -7.699                  | 5.654                      | 1.000                     | -8.700                  | 6.318                      | 0.902                     |
| RL x 2CH      | -1.880                  | 2.284                      | 0.981                     | -4.969                  | 4.438                      | 0.944                     |
| RL x 3wl      | -0.621                  | 1.456                      | 0.970                     | -0.284                  | 1.213                      | 0.583                     |
| RL x 4wl      | -0.621                  | 1.483                      | 0.908                     | 1.182                   | 0.198                      | 0.041                     |
| RL x 5wl      | 0.014                   | 1.029                      | 0.949                     | 0.230                   | 0.856                      | 0.862                     |
| RL x Tel      | 0.550                   | 0.480                      | 0.250                     | -2.096                  | 2.327                      | 0.990                     |
| RL x Ur       | 0.021                   | 0.826                      | 0.766                     | -1.722                  | 2.034                      | 0.902                     |
| 1chl x 2 i    | 2.623                   | -1.394                     | 0.250                     | -6.273                  | 4.839                      | 0.901                     |
| 1chl x 2 m    | 1.021                   | -0.176                     | 0.002                     | -3.747                  | 3.187                      | 0.901                     |
| 1chl x 2 c    | 2.350                   | -1.139                     | 0.250                     | -6.771                  | 5.207                      | 0.703                     |
| 1chl x 2 p    | 3.973                   | -2.533                     | 0.250                     | -5.056                  | 3.841                      | 0.901                     |
| 1chl x 2 d    | 6.277                   | -4.330                     | 0.250                     | -9.159                  | 6.566                      | 0.901                     |
| 1chl x 2 CH   | 3.182                   | -1.333                     | 0.142                     | -4.948                  | 4.371                      | 0.848                     |
| 1chl x 3wl    | 2.500                   | -0.774                     | 0.117                     | -0.925                  | 1.648                      | 0.996                     |
| 1chl x 4wl    | 2.167                   | -0.511                     | 0.046                     | 0.381                   | 0.758                      | 0.558                     |
| 1chl x 5wl    | 3.003                   | -1.106                     | 0.467                     | 0.721                   | 0.502                      | 0.274                     |
| 1chl x Tel    | 0.189                   | 0.736                      | 0.250                     | -1.795                  | 2.089                      | 0.738                     |
| 1chl x Ur     | 1.214                   | -0.028                     | 0.000                     | -1.869                  | 2.114                      | 0.901                     |



Table 2.3.13 Continued.....

| Relationships       | Regression constant (a) | Regression coefficient (b)    | correlation coefficient r | Regression constant (a)      | Regression coefficient (b) | correlation coefficient r |
|---------------------|-------------------------|-------------------------------|---------------------------|------------------------------|----------------------------|---------------------------|
| 2i x 2 c            | 0.207                   | 0.817                         | 1.000                     | -0.085                       | 1.178                      | 0.936                     |
| 2i x 2 p            | -0.793                  | 1.817                         | 1.000                     | -0.078                       | 0.794                      | 1.000                     |
| 2i x 2 d            | -1.870                  | 3.106                         | 1.000                     | -0.647                       | 1.357                      | 1.000                     |
| 2i x 2CH            | 0.475                   | 1.255                         | 0.981                     | 0.703                        | 0.928                      | 0.993                     |
| 2i x 3wl            | 0.880                   | 0.800                         | 0.970                     | 1.237                        | 0.301                      | 0.860                     |
| 2i x 4wl            | 0.908                   | 0.815                         | 0.908                     | 1.400                        | 0.100                      | 0.250                     |
| 2i x 5wl            | 1.075                   | 0.565                         | 0.949                     | 1.346                        | 0.144                      | 0.585                     |
| 2i x Tel            | 1.045                   | 0.264                         | 0.250                     | 0.892                        | 0.466                      | 0.954                     |
| 2i x Ur             | 0.873                   | 0.454                         | 0.766                     | 0.871                        | 0.437                      | 1.000                     |
| 2m x 2 c            | 0.322                   | 0.556                         | 0.791                     | -0.773                       | 1.789                      | 0.936                     |
| 2m x 2 p            | -0.538                  | 1.236                         | 0.791                     | -0.541                       | 1.205                      | 1.000                     |
| 2m x 2 d            | -1.435                  | 2.113                         | 0.791                     | -1.440                       | 2.060                      | 1.000                     |
| 2m x 2 CH           | 0.604                   | 0.914                         | 0.890                     | 0.161                        | 1.409                      | 0.993                     |
| 2m x 3wl            | 0.954                   | 0.594                         | 0.912                     | 1.061                        | 0.456                      | 0.860                     |
| 2m x 4wl            | 0.952                   | 0.645                         | 0.972                     | 1.341                        | 0.151                      | 0.250                     |
| 2m x 5wl            | 1.190                   | 0.338                         | 0.581                     | 1.262                        | 0.218                      | 0.585                     |
| 2m x Tel            | 0.958                   | 0.339                         | 0.707                     | 0.620                        | 0.707                      | 0.954                     |
| 2m x Ur             | 0.869                   | 0.396                         | 0.999                     | 0.616                        | 0.663                      | 1.000                     |
| 2c x 2 p            | -1.253                  | 2.224                         | 1.000                     | 0.008                        | 0.630                      | 0.936                     |
| 2c x 2 d            | -2.657                  | 3.802                         | 1.000                     | -0.501                       | 1.077                      | 0.936                     |
| 2c x 2 CH           | 0.157                   | 1.536                         | 0.981                     | 0.793                        | 0.753                      | 0.970                     |
| 2c x 3wl            | 0.677                   | 0.979                         | 0.970                     | 1.286                        | 0.213                      | 0.644                     |
| 2c x 4wl            | 0.701                   | 0.997                         | 0.908                     | 1.434                        | 0.043                      | 0.070                     |
| 2c x 5wl            | 0.931                   | 0.692                         | 0.949                     | 1.345                        | 0.139                      | 0.816                     |
| 2c x Tel            | 0.978                   | 0.323                         | 0.250                     | 0.928                        | 0.391                      | 0.998                     |
| 2c x Ur             | 0.758                   | 0.555                         | 0.766                     | 0.918                        | 0.347                      | 0.936                     |
| 2p x 2 d            | -0.515                  | 1.710                         | 1.000                     | -0.515                       | 1.710                      | 1.000                     |
| 2p x 2 CH           | 1.023                   | 0.691                         | 0.981                     | 0.794                        | 1.170                      | 0.993                     |
| 2p x 3wl            | 1.229                   | 0.440                         | 0.970                     | 1.266                        | 0.379                      | 0.860                     |
| 2p x 4wl            | 1.263                   | 0.448                         | 0.908                     | 1.409                        | 0.126                      | 0.250                     |
| 2p x 5wl            | 1.321                   | 0.311                         | 0.949                     | 1.360                        | 0.181                      | 0.585                     |
| 2p x Tel            | 1.160                   | 0.145                         | 0.250                     | 0.937                        | 0.587                      | 0.954                     |
| 2p x Ur             | 1.071                   | 0.250                         | 0.766                     | 0.914                        | 0.550                      | 1.000                     |
| 2CH x 3wl           | 0.573                   | 0.641                         | 0.999                     | 1.025                        | 0.311                      | 0.800                     |
| 2CH x 4wl           | 0.579                   | 0.665                         | 0.971                     | 1.344                        | 0.092                      | 0.183                     |
| 2CH x 5wl           | 0.890                   | 0.428                         | 0.872                     | 1.225                        | 0.164                      | 0.663                     |
| 2CH x Tel           | 0.886                   | 0.256                         | 0.376                     | 0.532                        | 0.507                      | 0.982                     |
| 2CH x Ur            | 0.675                   | 0.382                         | 0.871                     | 0.544                        | 0.467                      | 0.993                     |
| 3wl x 4wl           | -0.023                  | 1.043                         | 0.982                     | 0.772                        | 0.484                      | 0.620                     |
| 3wl x 5wl           | 0.523                   | 0.657                         | 0.846                     | 1.049                        | 0.272                      | 0.219                     |
| 3wl x Tel           | 0.631                   | 0.418                         | 0.413                     | -0.548                       | 1.215                      | 0.681                     |
| 3wl x Ur            | 0.322                   | 0.604                         | 0.695                     | -0.638                       | 1.250                      | 0.860                     |
| 4wl x 5wl           | 0.605                   | 0.584                         | 0.739                     | 1.678                        | -0.166                     | 0.031                     |
| 4wl x Tel           | 0.559                   | 0.456                         | 0.546                     | 0.127                        | 0.722                      | 0.091                     |
| 4wl x Ur            | 0.313                   | 0.595                         | 0.962                     | -0.459                       | 1.096                      | 0.250                     |
| 5wl x Tel           | 0.837                   | 0.264                         | 0.084                     | -2.044                       | 2.247                      | 0.784                     |
| 5wl x Ur            | 0.212                   | 0.664                         | 0.552                     | -1.408                       | 1.777                      | 0.585                     |
| Tel x Ur            | 0.149                   | 0.841                         | 0.733                     | 0.086                        | 0.894                      | 0.954                     |
| TL- Total length    |                         | 2i - ischium of 2nd cheliped  |                           | 1 CH- Length of 1st cheliped |                            |                           |
| CL- Carapace length |                         | 2m - merus of 2nd cheliped    |                           | 2 CH- Length of 2nd cheliped |                            |                           |
| RL- Rostral length  |                         | 2c - carpus of 2nd cheliped   |                           | 3CH- Length of 3rd cheliped  |                            |                           |
| TEL- Telson length  |                         | 2p - propodus of 2nd cheliped |                           | 4CH- Length of 4th cheliped  |                            |                           |
| Ur- uropod length   |                         | 2d - dactylus of 2nd cheliped |                           | 5 CH- Length of 5th cheliped |                            |                           |

**Table 2.3.14** Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Acanthephyra armata*

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -4.645                  | 2.975                      | 0.788                     | -1.730                  | 1.538                      | 0.999                     |
| TL x RL       | -9.864                  | 5.587                      | 0.769                     | 0.575                   | 0.444                      | 1.000                     |
| TL x 1chl     | -3.273                  | 2.316                      | 0.902                     | 0.812                   | 0.313                      | 0.967                     |
| TL x 2 i      | -8.345                  | 3.441                      | 0.970                     | -3.682                  | 2.094                      | 0.655                     |
| TL x 2 m      | -4.388                  | 2.519                      | 0.961                     | -3.286                  | 1.952                      | 0.831                     |
| TL x 2 c      | -3.537                  | 2.189                      | 0.848                     | -0.479                  | 0.650                      | 0.911                     |
| TL x 2 p      | -5.159                  | 2.811                      | 0.490                     | -1.551                  | 1.056                      | 0.923                     |
| TL x 2 d      | 0.000                   | 0.000                      | 1.000                     | -6.016                  | 2.954                      | 0.965                     |
| TL x 2 CH     | -3.638                  | 2.456                      | 0.854                     | -1.780                  | 1.519                      | 0.813                     |
| TL x 3wl      | -3.766                  | 2.667                      | 0.781                     | 1.251                   | 0.198                      | 0.967                     |
| TL x 4wl      | -4.944                  | 3.231                      | 0.930                     | 0.869                   | 0.359                      | 0.901                     |
| TL x 5wl      | -3.851                  | 2.691                      | 0.740                     | 1.005                   | 0.270                      | 0.898                     |
| TL x Tel      | -8.856                  | 4.952                      | 1.000                     | -0.647                  | 0.882                      | 1.000                     |
| TL x Ur       | -5.977                  | 3.565                      | 0.998                     | -0.815                  | 1.004                      | 0.921                     |
| CL x RL       | -1.167                  | 1.900                      | 1.000                     | 1.075                   | 0.288                      | 0.998                     |
| CL x 1chl     | 0.417                   | 0.718                      | 0.974                     | 1.166                   | 0.202                      | 0.953                     |
| CL x 2 i      | -0.771                  | 0.994                      | 0.910                     | -1.377                  | 1.395                      | 0.688                     |
| CL x 2 m      | -0.320                  | 0.736                      | 0.923                     | -1.118                  | 1.288                      | 0.856                     |
| CL x 2 c      | -0.082                  | 0.707                      | 0.994                     | 0.245                   | 0.427                      | 0.930                     |
| CL x 2 p      | -1.009                  | 1.138                      | 0.903                     | -0.372                  | 0.693                      | 0.941                     |
| CL x 2 d      | 0.000                   | 0.000                      | 1.000                     | -2.709                  | 1.931                      | 0.976                     |
| CL x 2CH      | 0.242                   | 0.790                      | 0.993                     | -0.094                  | 1.003                      | 0.839                     |
| CL x 3wl      | 0.394                   | 0.900                      | 1.000                     | 1.475                   | 0.128                      | 0.953                     |
| CL x 4wl      | 0.236                   | 0.977                      | 0.956                     | 1.270                   | 0.236                      | 0.921                     |
| CL x 5wl      | 0.318                   | 0.932                      | 0.997                     | 1.306                   | 0.178                      | 0.919                     |
| CL x Tel      | -0.700                  | 1.322                      | 0.801                     | 0.347                   | 0.573                      | 0.997                     |
| CL x Ur       | -0.122                  | 0.965                      | 0.822                     | 0.305                   | 0.658                      | 0.939                     |
| RL x 1chl     | 0.860                   | 0.376                      | 0.967                     | 0.405                   | 0.706                      | 0.969                     |
| RL x 2 i      | -0.156                  | 0.519                      | 0.896                     | -6.366                  | 4.700                      | 0.649                     |
| RL x 2 m      | 0.136                   | 0.385                      | 0.911                     | -5.799                  | 4.389                      | 0.826                     |
| RL x 2 c      | 0.353                   | 0.371                      | 0.990                     | -1.318                  | 1.462                      | 0.907                     |
| RL x 2 p      | -0.314                  | 0.603                      | 0.916                     | -2.914                  | 2.377                      | 0.919                     |
| RL x 2 d      | 0.000                   | 0.000                      | 1.000                     | -8.835                  | 6.652                      | 0.962                     |
| RL x 2CH      | 0.728                   | 0.415                      | 0.988                     | -3.735                  | 3.416                      | 0.808                     |
| RL x 3wl      | 0.947                   | 0.474                      | 1.000                     | 0.993                   | 0.448                      | 0.969                     |
| RL x 4wl      | 0.840                   | 0.511                      | 0.946                     | 0.406                   | 0.808                      | 0.898                     |
| RL x 5wl      | 0.890                   | 0.491                      | 0.999                     | 0.656                   | 0.608                      | 0.895                     |
| RL x Tel      | 0.121                   | 0.688                      | 0.783                     | -1.792                  | 1.989                      | 1.000                     |
| RL x Ur       | 0.477                   | 0.503                      | 0.805                     | -2.111                  | 2.259                      | 0.918                     |
| 1chl x 2 i    | -1.393                  | 1.418                      | 0.979                     | -7.498                  | 5.597                      | 0.474                     |
| 1chl x 2 m    | -0.774                  | 1.046                      | 0.986                     | -7.298                  | 5.526                      | 0.674                     |
| 1chl x 2 c    | -0.476                  | 0.972                      | 0.993                     | -1.891                  | 1.891                      | 0.781                     |
| 1chl x 2 p    | -1.510                  | 1.463                      | 0.789                     | -3.867                  | 3.088                      | 0.798                     |
| 1chl x 2 d    | 0.000                   | 0.000                      | 1.000                     | -12.738                 | 8.802                      | 0.867                     |
| 1chl x 2 CH   | -0.201                  | 1.067                      | 0.994                     | -4.865                  | 4.276                      | 0.651                     |
| 1chl x 3wl    | -0.085                  | 1.220                      | 0.972                     | 0.736                   | 0.634                      | 1.000                     |
| 1chl x 4wl    | -0.347                  | 1.372                      | 0.997                     | 0.094                   | 1.042                      | 0.767                     |
| 1chl x 5wl    | -0.165                  | 1.253                      | 0.954                     | 0.423                   | 0.783                      | 0.763                     |
| 1chl x Tel    | -1.597                  | 1.940                      | 0.912                     | -2.811                  | 2.735                      | 0.972                     |
| 1chl x Ur     | -0.768                  | 1.409                      | 0.927                     | -3.013                  | 2.933                      | 0.796                     |
| 2i x 2 m      | 0.254                   | 0.735                      | 0.999                     | 0.240                   | 0.811                      | 0.959                     |

Table 2.3.14 Continued.....

| Relationships       | Regression constant (a) | Regression coefficient (b)    | correlation coefficient r | Regression constant (a)      | Regression coefficient (b) | correlation coefficient r |
|---------------------|-------------------------|-------------------------------|---------------------------|------------------------------|----------------------------|---------------------------|
| 2i x 2 p            | -0.029                  | 0.934                         | 0.661                     | 0.386                        | 0.400                      | 0.885                     |
| 2i x 2 d            | 0.000                   | 0.000                         | 1.000                     | -0.548                       | 1.053                      | 0.820                     |
| 2i x 2CH            | 0.878                   | 0.743                         | 0.953                     | 0.956                        | 0.641                      | 0.968                     |
| 2i x 4wl            | 1.007                   | 0.955                         | 0.991                     | 1.526                        | 0.139                      | 0.908                     |
| 2i x 5wl            | 1.087                   | 0.838                         | 0.875                     | 1.499                        | 0.105                      | 0.911                     |
| 2i x Tel            | 0.293                   | 1.400                         | 0.976                     | 1.018                        | 0.273                      | 0.639                     |
| 2i x Ur             | 0.608                   | 1.013                         | 0.983                     | 1.025                        | 0.381                      | 0.887                     |
| 2m x 2 c            | 0.256                   | 0.907                         | 0.960                     | 0.629                        | 0.316                      | 0.986                     |
| 2m x 2 p            | -0.365                  | 1.293                         | 0.685                     | 0.255                        | 0.508                      | 0.980                     |
| 2m x 2 d            | 0.000                   | 0.000                         | 1.000                     | -0.918                       | 1.366                      | 0.946                     |
| 2m x 2 CH           | 0.618                   | 1.015                         | 0.963                     | 0.770                        | 0.787                      | 0.999                     |
| 2m x 4wl            | 0.675                   | 1.301                         | 0.995                     | 1.481                        | 0.176                      | 0.989                     |
| 2m x 5wl            | 0.791                   | 1.150                         | 0.891                     | 1.465                        | 0.133                      | 0.990                     |
| 2m x Tel            | -0.186                  | 1.896                         | 0.967                     | 0.906                        | 0.372                      | 0.818                     |
| 2m x Ur             | 0.260                   | 1.373                         | 0.976                     | 0.900                        | 0.483                      | 0.981                     |
| 2c x 2 p            | -0.835                  | 1.559                         | 0.852                     | -0.761                       | 1.615                      | 1.000                     |
| 2c x 2 d            | 0.000                   | 0.000                         | 1.000                     | -3.695                       | 4.390                      | 0.987                     |
| 2c x 2 CH           | 0.333                   | 1.118                         | 1.000                     | -0.759                       | 2.450                      | 0.979                     |
| 2c x 3wl            | 0.506                   | 1.265                         | 0.992                     | 1.436                        | 0.262                      | 0.781                     |
| 2c x 4wl            | 0.338                   | 1.397                         | 0.982                     | 1.132                        | 0.556                      | 1.000                     |
| 2c x 5wl            | 0.437                   | 1.304                         | 0.982                     | 1.202                        | 0.419                      | 1.000                     |
| 2c x Tel            | -0.595                  | 1.932                         | 0.860                     | 0.119                        | 1.230                      | 0.901                     |
| 2p x 2 d            | 0.000                   | 0.000                         | 1.000                     | -1.629                       | 2.724                      | 0.992                     |
| 2p x 2 CH           | 0.976                   | 0.609                         | 0.846                     | 0.400                        | 1.512                      | 0.973                     |
| 2p x 3wl            | 1.222                   | 0.716                         | 0.908                     | 1.558                        | 0.164                      | 0.798                     |
| 2p x 4wl            | 1.157                   | 0.721                         | 0.746                     | 1.394                        | 0.344                      | 0.999                     |
| 2p x 5wl            | 1.170                   | 0.753                         | 0.934                     | 1.400                        | 0.259                      | 0.998                     |
| 2p x Tel            | 0.585                   | 0.879                         | 0.507                     | 0.695                        | 0.767                      | 0.913                     |
| 2d x 2 CH           | 1.228                   | 0.008                         | 0.000                     | 1.308                        | 0.542                      | 0.935                     |
| 2d x 3wl            | 1.526                   | -0.161                        | 0.046                     | 1.656                        | 0.062                      | 0.867                     |
| 2d x 4wl            | 1.446                   | 0.004                         | 0.000                     | 1.600                        | 0.125                      | 0.983                     |
| 2d x 5wl            | 1.492                   | -0.203                        | 0.068                     | 1.555                        | 0.094                      | 0.982                     |
| 2d x Tel            | 0.906                   | 0.311                         | 0.063                     | 1.152                        | 0.287                      | 0.958                     |
| 2d x Ur             | 1.054                   | 0.200                         | 0.051                     | 1.227                        | 0.346                      | 0.991                     |
| 2CH x 3wl           | 0.140                   | 1.114                         | 0.949                     | 1.532                        | 0.097                      | 0.651                     |
| 2CH x 4wl           | -0.113                  | 1.269                         | 1.000                     | 1.310                        | 0.223                      | 0.984                     |
| 2CH x 5wl           | 0.070                   | 1.141                         | 0.926                     | 1.336                        | 0.168                      | 0.985                     |
| 2CH x Tel           | -1.301                  | 1.821                         | 0.942                     | 0.549                        | 0.468                      | 0.799                     |
| 2CH x Ur            | -0.550                  | 1.321                         | 0.954                     | 0.430                        | 0.612                      | 0.974                     |
| 3wl x 5wl           | -0.091                  | 1.035                         | 0.998                     | -0.486                       | 1.235                      | 0.763                     |
| 3wl x Tel           | -1.270                  | 1.463                         | 0.795                     | -5.984                       | 4.313                      | 0.972                     |
| 3wl x Ur            | -0.539                  | 1.068                         | 0.816                     | -6.416                       | 4.625                      | 0.796                     |
| 4wl x 5 wl          | 0.169                   | 0.901                         | 0.930                     | 0.349                        | 0.754                      | 1.000                     |
| 4wl x Tel           | -1.134                  | 1.432                         | 0.939                     | -2.366                       | 2.201                      | 0.891                     |
| 4wl x Ur            | -0.429                  | 1.039                         | 0.951                     | -3.192                       | 2.761                      | 0.999                     |
| 5wl x Tel           | -1.087                  | 1.375                         | 0.755                     | -3.376                       | 2.914                      | 0.888                     |
| 5wl x Ur            | -0.407                  | 1.006                         | 0.778                     | -4.468                       | 3.663                      | 0.998                     |
| Tel x Ur            | 0.398                   | 0.720                         | 0.999                     | -0.071                       | 1.132                      | 0.912                     |
| TL- Total length    |                         | Zi - ischium of 2nd cheliped  |                           | 1 CH- Length of 1st cheliped |                            |                           |
| CL- Carapace length |                         | 2m - merus of 2nd cheliped    |                           | 2 CH- Length of 2nd cheliped |                            |                           |
| RL- Rostral length  |                         | 2c - carpus of 2nd cheliped   |                           | 3CH- Length of 3rd cheliped  |                            |                           |
| TEL- Telson length  |                         | 2p - propodus of 2nd cheliped |                           | 4CH- Length of 4th cheliped  |                            |                           |
| Ur- uropod length   |                         | 2d - dactylus of 2nd cheliped |                           | 5 CH- Length of 5th cheliped |                            |                           |

**Table 2.3.15 Values of intercept (a) , regression coefficient (b),correlation coefficient(r) of different morphometric measurements of *Parapeneus investigatoris***

| Relationships | Males                   |                            |                           | Females                 |                            |                           |
|---------------|-------------------------|----------------------------|---------------------------|-------------------------|----------------------------|---------------------------|
|               | Regression constant (a) | Regression coefficient (b) | correlation coefficient r | Regression constant (a) | Regression coefficient (b) | correlation coefficient r |
| TL x CL       | -0.007                  | 0.701                      | 0.743                     | 1.027                   | 0.142                      | 0.465                     |
| TL x RL       | -0.448                  | 0.690                      | 0.276                     | 2.101                   | -0.713                     | 0.967                     |
| TL x 1chl     | 0.400                   | 0.420                      | 0.372                     | 0.492                   | 0.352                      | 0.203                     |
| TL x 2 i      | -0.071                  | 0.305                      | 0.250                     | 0.477                   | 0.000                      | 1.000                     |
| TL x 2 m      | -0.493                  | 0.646                      | 0.332                     | 0.699                   | 0.000                      | 1.000                     |
| TL x 2 c      | -0.493                  | 0.646                      | 0.332                     | 0.109                   | 0.337                      | 0.206                     |
| TL x 2 p      | -1.274                  | 0.904                      | 0.220                     | -1.941                  | 1.281                      | 0.206                     |
| TL x 2 d      | -2.000                  | 1.142                      | 0.283                     | -5.648                  | 3.206                      | 0.967                     |
| TL x 2 CH     | -0.049                  | 0.695                      | 0.644                     | 0.184                   | 0.581                      | 0.458                     |
| TL x 3wl      | 0.282                   | 0.585                      | 0.686                     | 0.890                   | 0.247                      | 0.206                     |
| TL x 4wl      | 0.414                   | 0.517                      | 0.297                     | 2.331                   | -0.543                     | 0.334                     |
| TL x 5wl      | 0.145                   | 0.727                      | 0.682                     | 1.022                   | 0.233                      | 0.697                     |
| TL x Tel      | -1.381                  | 1.251                      | 0.822                     | -1.610                  | 1.393                      | 0.602                     |
| TL x Ur       | -0.939                  | 1.087                      | 0.769                     | -1.881                  | 1.623                      | 0.900                     |
| CL x RL       | -1.238                  | 1.595                      | 0.760                     | 3.385                   | -2.004                     | 0.333                     |
| CL x 1chl     | 0.032                   | 0.884                      | 0.849                     | -2.504                  | 2.828                      | 0.570                     |
| CL x 2 i      | 0.093                   | 0.308                      | 0.132                     | 0.477                   | 0.000                      | 1.000                     |
| CL x 2 m      | -0.751                  | 1.122                      | 0.517                     | 0.699                   | 0.000                      | 1.000                     |
| CL x 2 c      | -0.751                  | 1.122                      | 0.517                     | 2.240                   | -1.185                     | 0.111                     |
| CL x 2 p      | -1.140                  | 1.188                      | 0.196                     | 6.161                   | -4.504                     | 0.111                     |
| CL x 2 d      | -1.863                  | 1.525                      | 0.260                     | -11.420                 | 9.009                      | 0.333                     |
| CL x 2CH      | -0.137                  | 1.059                      | 0.772                     | 1.579                   | -0.268                     | 0.004                     |
| CL x 3wl      | 0.387                   | 0.754                      | 0.589                     | 2.451                   | -0.868                     | 0.111                     |
| CL x 4wl      | 0.410                   | 0.742                      | 0.315                     | 5.113                   | -2.930                     | 0.424                     |
| CL x 5wl      | 0.196                   | 0.998                      | 0.665                     | 1.129                   | 0.245                      | 0.034                     |
| CL x Tel      | -0.498                  | 1.105                      | 0.331                     | -6.096                  | 5.454                      | 0.403                     |
| CL x Ur       | -0.575                  | 1.271                      | 0.543                     | -6.061                  | 5.539                      | 0.458                     |
| RL x 1chl     | 0.753                   | 0.512                      | 0.954                     | 1.521                   | -0.483                     | 0.201                     |
| RL x 2 i      | 0.371                   | 0.147                      | 0.100                     | 0.477                   | 0.000                      | 1.000                     |
| RL x 2 m      | 0.159                   | 0.656                      | 0.591                     | 0.699                   | 0.000                      | 1.000                     |
| RL x 2 c      | 0.159                   | 0.656                      | 0.591                     | 1.199                   | -0.591                     | 0.333                     |
| RL x 2 p      | 0.109                   | 0.350                      | 0.057                     | 2.201                   | -2.248                     | 0.333                     |
| RL x 2 d      | -0.277                  | 0.470                      | 0.083                     | 3.800                   | -4.497                     | 1.000                     |
| RL x 2CH      | 0.804                   | 0.521                      | 0.626                     | 1.982                   | -0.920                     | 0.604                     |
| RL x 3wl      | 1.101                   | 0.317                      | 0.348                     | 1.688                   | -0.433                     | 0.333                     |
| RL x 4wl      | 1.012                   | 0.433                      | 0.360                     | 0.899                   | 0.556                      | 0.184                     |
| RL x 5wl      | 1.211                   | 0.335                      | 0.251                     | 1.727                   | -0.350                     | 0.825                     |
| RL x Tel      | 0.777                   | 0.187                      | 0.032                     | 2.564                   | -2.039                     | 0.678                     |
| RL x Ur       | 0.691                   | 0.459                      | 0.237                     | 2.907                   | -2.284                     | 0.937                     |
| 1chl x 2 i    | 0.045                   | 0.381                      | 0.185                     | 0.477                   | 0.000                      | 1.000                     |
| 1chl x 2 m    | -0.721                  | 1.210                      | 0.552                     | 0.699                   | 0.000                      | 1.000                     |
| 1chl x 2 c    | -0.721                  | 1.210                      | 0.552                     | 0.974                   | -0.226                     | 0.057                     |
| 1chl x 2 p    | -1.011                  | 1.197                      | 0.183                     | 1.346                   | -0.859                     | 0.057                     |
| 1chl x 2 d    | -1.417                  | 1.300                      | 0.174                     | -1.956                  | 1.867                      | 0.201                     |
| 1chl x 2 CH   | -0.054                  | 1.095                      | 0.760                     | 1.278                   | -0.038                     | 0.001                     |
| 1chl x 3wl    | 0.628                   | 0.625                      | 0.372                     | 1.524                   | -0.165                     | 0.057                     |
| 1chl x Tel    | 0.266                   | 0.567                      | 0.080                     | -1.259                  | 1.920                      | 0.700                     |
| 1chl x Ur     | -0.049                  | 0.951                      | 0.290                     | -0.564                  | 1.433                      | 0.430                     |
| 2i x Tel      | 0.629                   | 0.617                      | 0.074                     | 0.480                   | 0.990                      | 0.829                     |
| 2i x Ur       | 0.734                   | 0.685                      | 0.113                     | 0.728                   | 0.752                      | 0.527                     |
| 2i x 2 m      | 0.364                   | 0.688                      | 0.140                     | 0.654                   | 0.150                      | 0.111                     |
| 2i x 2 c      | 0.364                   | 0.688                      | 0.140                     | 0.654                   | 0.150                      | 0.111                     |
| 2i x 2 p      | -0.520                  | 1.864                      | 0.347                     | 0.129                   | 0.570                      | 0.111                     |
| 2i x 2 d      | -0.735                  | 1.721                      | 0.238                     | -0.343                  | 1.140                      | 0.333                     |
| 2i x 2CH      | 0.755                   | 0.975                      | 0.470                     | 1.044                   | 0.439                      | 0.489                     |
| 2i x 3wl      | 1.209                   | 0.313                      | 0.073                     | 1.289                   | 0.110                      | 0.111                     |
| 2i x 4wl      | 1.171                   | 0.405                      | 0.068                     | 1.259                   | 0.210                      | 0.137                     |
| 2i x 5wl      | 1.416                   | 0.148                      | 0.011                     | 1.405                   | 0.089                      | 0.275                     |

Table 2.3.15 Continued.....

| Relationships | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r | Regression constant<br>(a) | Regression coefficient<br>(b) | correlation coefficient<br>r |
|---------------|----------------------------|-------------------------------|------------------------------|----------------------------|-------------------------------|------------------------------|
| 2m x Ur       | 0.687                      | 0.547                         | 0.245                        | -0.067                     | 1.558                         | 0.458                        |
| 2c x 2 p      | 0.342                      | 0.080                         | 0.002                        | -2.358                     | 3.802                         | 1.000                        |
| 2c x 2 d      | 0.248                      | -0.192                        | 0.010                        | -1.671                     | 2.535                         | 0.333                        |
| 2c x 2 CH     | 0.787                      | 0.638                         | 0.683                        | 0.424                      | 1.127                         | 0.649                        |
| 2c x 3wl      | 0.981                      | 0.544                         | 0.747                        | 0.810                      | 0.732                         | 1.000                        |
| 2c x 4wl      | 0.936                      | 0.619                         | 0.534                        | 1.208                      | 0.198                         | 0.024                        |
| 2c x 5wl      | 1.144                      | 0.491                         | 0.391                        | 1.209                      | 0.325                         | 0.750                        |
| 2c x Tel      | 0.674                      | 0.368                         | 0.090                        | 0.380                      | 0.764                         | 0.100                        |
| 2c x Ur       | 0.687                      | 0.547                         | 0.245                        | 0.523                      | 1.016                         | 0.195                        |
| 2p x 2 d      | -0.160                     | 0.684                         | 0.376                        | -0.100                     | 0.667                         | 0.333                        |
| 2p x 2 CH     | 1.135                      | 0.252                         | 0.315                        | 1.123                      | 0.296                         | 0.649                        |
| 2p x 3wl      | 1.340                      | 0.058                         | 0.025                        | 1.264                      | 0.193                         | 1.000                        |
| 2p x 4wl      | 1.389                      | -0.046                        | 0.009                        | 1.330                      | 0.052                         | 0.024                        |
| 2p x 5wl      | 1.435                      | 0.136                         | 0.089                        | 1.411                      | 0.086                         | 0.750                        |
| 2p x Tel      | 0.803                      | 0.325                         | 0.206                        | 0.833                      | 0.201                         | 0.100                        |
| 2p x Ur       | 1.028                      | 0.108                         | 0.028                        | 0.953                      | 0.267                         | 0.195                        |
| 2d x 2 CH     | 1.218                      | 0.159                         | 0.156                        | 1.190                      | 0.292                         | 0.843                        |
| 2d x 3wl      | 1.362                      | 0.016                         | 0.002                        | 1.322                      | 0.096                         | 0.333                        |
| 2d x 4wl      | 1.377                      | -0.057                        | 0.017                        | 1.369                      | -0.124                        | 0.184                        |
| 2d x 5wl      | 1.475                      | 0.122                         | 0.089                        | 1.431                      | 0.078                         | 0.825                        |
| 2d x Tel      | 0.901                      | 0.277                         | 0.187                        | 0.841                      | 0.453                         | 0.678                        |
| 2d x Ur       | 1.033                      | 0.341                         | 0.349                        | 0.977                      | 0.508                         | 0.937                        |
| 2CH x 3wl     | 0.584                      | 0.647                         | 0.630                        | 0.816                      | 0.422                         | 0.649                        |
| 2CH x 4wl     | 0.604                      | 0.620                         | 0.320                        | 1.429                      | -0.064                        | 0.005                        |
| 2CH x 5wl     | 0.625                      | 0.699                         | 0.474                        | 1.119                      | 0.262                         | 0.951                        |
| 2CH x Tel     | -0.128                     | 0.858                         | 0.290                        | -0.799                     | 1.384                         | 0.641                        |
| 2CH x Ur      | -0.043                     | 0.901                         | 0.397                        | -0.741                     | 1.454                         | 0.779                        |
| 3wl x 4wl     | 0.138                      | 0.904                         | 0.452                        | 0.989                      | 0.270                         | 0.024                        |
| 3wl x 5wl     | -0.018                     | 1.105                         | 0.786                        | 0.849                      | 0.444                         | 0.750                        |
| 3wl x Tel     | -0.966                     | 1.392                         | 0.508                        | -0.486                     | 1.043                         | 0.100                        |
| 3wl x Ur      | -0.661                     | 1.271                         | 0.524                        | -0.802                     | 1.388                         | 0.195                        |
| 4wl x 5 wl    | 0.966                      | 0.381                         | 0.169                        | 1.516                      | -0.054                        | 0.033                        |
| 4wl x Tel     | 0.271                      | 0.482                         | 0.110                        | 1.030                      | -0.090                        | 0.002                        |
| 4wl x Ur      | 0.413                      | 0.481                         | 0.135                        | 1.869                      | -0.604                        | 0.110                        |
| 5wl x Tel     | -0.921                     | 1.245                         | 0.630                        | -5.276                     | 4.266                         | 0.444                        |
| 5wl x Ur      | -0.555                     | 1.093                         | 0.601                        | -6.191                     | 5.020                         | 0.671                        |
| Tel x Ur      | 0.437                      | 0.681                         | 0.574                        | 0.244                      | 0.890                         | 0.873                        |

DEVIATIONS FROM REGRESSION

| species                 | df | (x2       | (xy       | (y2       | RC        | df | SS        | MS      |
|-------------------------|----|-----------|-----------|-----------|-----------|----|-----------|---------|
| <i>p.jerryi</i>         | 50 | 36.257534 | 26.451408 | 19.297423 | 0.7295424 | 49 | 0.0378052 | 0.00143 |
| <i>A.alcocki</i>        | 77 | 4136.4695 | 3081.372  | 2310.323  | 0.7473455 | 76 | 0.0003235 | 0.00000 |
| <i>S.hexti</i>          | 45 | 918.8499  | 690.54098 | 518.98054 | 0.7515275 | 44 | 0.0014481 | 0.00000 |
| <i>P.investigatoris</i> | 21 | 209.03149 | 146.40215 | 102.53762 | 0.7003633 | 20 | 0.0068305 | 0.00005 |
| <i>M.andamanensis</i>   | 88 | 248.17115 | 177.73099 | 127.28435 | 0.716163  | 87 | 0.0056265 | 0.00003 |

|            |     |           |           |
|------------|-----|-----------|-----------|
| WITH IN    | 276 | 0.0520338 | 0.00019   |
| Reg.Coeff. | 4   | 0.6408936 | 0.16017   |
| COMMON     | 281 | 5548.7785 | 4132.4975 |
| Adj.Means  | 280 | 3078.403  | 0.7447579 |
| TOTAL      | 279 | 5573.9783 | 4151.399  |
|            |     | 3092.6007 |           |

Comparison of slopes F = (4,280)  
 Comparison of elevation F = (4,284)

849.60 P<0.05  
 2.12 P>0.05

| Treatments                                      | df  | t    | Probability |
|---|-----|------|-------------|
| <i>p.jerryi</i> X <i>A.alcocki</i>              | 127 | 2.89 | P<0.01      |
| <i>p.jerryi</i> X <i>S.hexti</i>                | 95  | 3.08 | P<0.05      |
| <i>p.jerryi</i> X <i>P.investigatoris</i>       | 71  | 1.76 |             |
| <i>p.jerryi</i> X <i>M.andamanensis</i>         | 138 | 3.79 | P<0.05      |
| <i>A.alcocki</i> X <i>S.hexti</i>               | 122 | 2.80 | P<0.01      |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 78  | 4.21 | P<0.05      |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 165 | 3.9  | P<0.05      |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 109 | 2.06 |             |
| <i>P.investigatoris</i> X <i>S.hexti</i>        | 66  | 3.79 | P<0.05      |

**TABLE 1. Analysis of variance of regression coefficients of female larvae in relation to substrate utilization in species in the super family Pteromalidae (Hymenoptera).**

| Treatments                          | DEVIATIONS FROM REGRESSION |                   |          |                   |       |     |                          |       |  |  |
|-------------------------------------|----------------------------|-------------------|----------|-------------------|-------|-----|--------------------------|-------|--|--|
|                                     | df                         | {x <sup>2</sup> } | {xy}     | {y <sup>2</sup> } | RC    | df  | SS (d y.x <sup>2</sup> ) | MS    |  |  |
| <i>P.jerryi</i>                     | 50                         | 36.258            | 26.451   | 19.297            | 0.730 | 49  | 0.038                    | 0.001 |  |  |
| <i>A.alcocki</i>                    | 77                         | 4136.469          | 3091.372 | 2310.323          | 0.747 | 76  | 0.000                    | 0.000 |  |  |
| <i>S.hextili</i>                    | 45                         | 918.850           | 690.541  | 518.961           | 0.752 | 44  | 0.001                    | 0.000 |  |  |
| <i>P.investigatoris</i>             | 62                         | 209.031           | 146.402  | 102.538           | 0.700 | 61  | 0.007                    | 0.000 |  |  |
| <i>M.andamanensis</i>               | 88                         | 248.171           | 177.731  | 127.284           | 0.716 | 87  | 0.006                    | 0.000 |  |  |
| WITH IN                             |                            |                   |          |                   |       | 317 | 0.052                    | 0.000 |  |  |
| Reg.Coeff.                          |                            |                   |          |                   |       | 4   | 0.641                    | 0.160 |  |  |
| COMMON                              | 281                        | 5548.780          | 4132.497 | 3078.403          | 0.745 | 321 | 0.893                    | 0.002 |  |  |
| Adj.Means                           |                            |                   |          |                   |       | 4   | 0.021                    | 0.005 |  |  |
| TOTAL                               | 279                        | 5573.979          | 4151.399 | 3092.601          |       | 325 | 0.714                    |       |  |  |
| Comparison of slopes F = (4,321)    |                            | 975.80791         | P<0.05   |                   |       |     |                          |       |  |  |
| Comparison of elevation F = (4,325) |                            | 2.425822          | P<0.05   |                   |       |     |                          |       |  |  |

| Treatments                                      | df  | t    | Probability |
|---|-----|------|-------------|
| <i>p.jerryi</i> X <i>A.alcocki</i>              | 127 | 3.28 | P<0.05      |
| <i>p.jerryi</i> X <i>S.hextili</i>              | 95  | 2.78 | P<0.01      |
| <i>p.jerryi</i> X <i>P.investigatoris</i>       | 112 | 2.94 | P<0.01      |
| <i>p.jerryi</i> X <i>M.andamanensis</i>         | 138 | 4.02 | P<0.05      |
| <i>A.alcocki</i> X <i>S.hextili</i>             | 122 | 3.57 | P<0.01      |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 139 | 2.76 | P<0.01      |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 165 | 3.11 | P<0.01      |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 150 | 2.69 | P<0.01      |
| <i>P.investigatoris</i> X <i>S.hextili</i>      | 107 | 2.57 | P<0.01      |

Table 3.2.5. Summary of the ANOVA for the data collected in the water quality monitoring program.

| Treatments              | Deviations from Regression |                   |           |                   |           |     |                          |          |  |  |
|-------------------------|----------------------------|-------------------|-----------|-------------------|-----------|-----|--------------------------|----------|--|--|
|                         | df                         | (x <sup>2</sup> ) | (xy)      | (y <sup>2</sup> ) | RC        | df  | SS (d y.x <sup>2</sup> ) | MS       |  |  |
| <i>P.jerryi</i>         | 48                         | 11.528802         | 2.8431042 | 0.7640834         | 0.2486516 | 47  | 0.3228072                | 0.11354  |  |  |
| <i>A.alcocki</i>        | 61                         | 86.059817         | 41.669545 | 21.240775         | 0.4841939 | 60  | 0.0227955                | 0.000547 |  |  |
| <i>S.hexti</i>          | 27                         | 38.488761         | 6.7929989 | 1.4114618         | 0.176493  | 26  | 0.1250427                | 0.018408 |  |  |
| <i>P.investigatoris</i> | 60                         | 236.43612         | 3.7840522 | 0.9441884         | 0.0160045 | 59  | 0.0169506                | 0.004479 |  |  |
| <i>M.andamanensis</i>   | 62                         | 2869.5699         | 8.8908401 | 2.8621684         | 0.0030983 | 61  | 0.0010825                | 0.000122 |  |  |
| WITH IN                 |                            |                   |           |                   |           | 253 | 0.4886785                | 0.001932 |  |  |
| Reg. Coeff.             |                            |                   |           |                   |           | 4   | 25.471381                | 6.367845 |  |  |
| COMMON                  | 258                        | 3242.0812         | 63.980538 | 27.222677         | 0.0197344 | 257 | 25.960058                | 0.101012 |  |  |
| Adj. Means              |                            |                   |           |                   |           | 4   | 5.8306726                | 1.457668 |  |  |
| TOTAL                   | 279                        | 3267.2809         | 74.846327 | 33.505299         |           | 281 | 31.790732                |          |  |  |

Comparison of slopes F = (4,257) 3296.7788 P<0.05  
 Comparison of elevation F = (4,261) 14.430657 P<0.05

| Treatments                                      | df  | t    | Probability |
|---|-----|------|-------------|
| <i>P.jerryi</i> X <i>A.alcocki</i>              | 109 | 2.63 | P<0.05      |
| <i>P.jerryi</i> X <i>S.hexti</i>                | 75  | 2.71 | P<0.01      |
| <i>P.jerryi</i> X <i>P.investigatoris</i>       | 108 | 3.05 | P<0.05      |
| <i>P.jerryi</i> X <i>M.andamanensis</i>         | 110 | 2.87 | P<0.01      |
| <i>A.alcocki</i> X <i>S.hexti</i>               | 88  | 1.05 |             |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 121 | 2.81 | P<0.01      |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 123 | 3.77 | P<0.05      |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 122 | 2.18 | P<0.05      |
| <i>P.investigatoris</i> X <i>S.hexti</i>        | 87  | 0.93 |             |



Table 2.4.4

Comparison of regression coefficients of TOTAL LENGTH X PROPODUS LENGTH  
in species in the super family Penaeoidea (females)

| Treatments                                      | Deviations from Regression |                   |             |                   |           |     |                           |          |  |  |
|---|----------------------------|-------------------|-------------|-------------------|-----------|-----|---------------------------|----------|--|--|
|   | df                         | (x <sup>2</sup> ) | (xy)        | (y <sup>2</sup> ) | RC        | df  | SS (d y, x <sup>2</sup> ) | MS       |  |  |
| <i>p.jerryi</i>                                 | 27                         | 11.044974         | 7.405656    | 4.966822          | 0.6705001 | 73  | 0.1349942                 | 0.018229 |  |  |
| <i>A.alcocki</i>                                | 49                         | 55.976203         | 44.696814   | 35.924623         | 0.7984967 | 48  | 0.022227                  | 0.000497 |  |  |
| <i>S.hexti</i>                                  | 36                         | 33.522005         | 24.63569    | 18.228996         | 0.734917  | 61  | 0.0403158                 | 0.001636 |  |  |
| <i>P.investigatoris</i>                         | 36                         | 240.47148         | 14.359569   | 9.6042521         | 0.0597142 | 35  | 0.0062175                 | 0.000433 |  |  |
| <i>M.andamanensis</i>                           | 61                         | 2868.3418         | 19.619504   | 14.10776          | 0.00684   | 60  | 0.0004848                 | 2.47E-05 |  |  |
| WITH IN   |                            |                   |             |                   |           | 277 | 0.2042393                 | 0.000737 |  |  |
| Reg.Coeff.                                      |                            |                   |             |                   |           | 4   | 78.808708                 | 19.70218 |  |  |
| COMMON  | 209                        | 3209.3564         | 110.71743   | 82.832514         | 0.0344983 | 281 | 79.012947                 | 0.281185 |  |  |
| Adj.Means                                       |                            |                   |             |                   |           | 4   | 23.61917                  | 5.904793 |  |  |
| TOTAL   | 214                        | 3248.28           | 142.51558   | 108.88487         |           | 285 | 102.63212                 |          |  |  |
| Comparison of slopes F = (4,281)                |                            |                   |             |                   |           |     |                           |          |  |  |
| Comparison of elevation F = (4,285)             |                            |                   |             |                   |           |     |                           |          |  |  |
| 28721.12 P<0.05                                 |                            |                   |             |                   |           |     |                           |          |  |  |
| 20.999681 P<0.05                                |                            |                   |             |                   |           |     |                           |          |  |  |
| Treatments                                      | df                         | t                 | Probability |                   |           |     |                           |          |  |  |
| <i>p.jerryi</i> X <i>A.alcocki</i>              | 76                         | 3.09              | P<0.05      |                   |           |     |                           |          |  |  |
| <i>p.jerryi</i> X <i>S.hexti</i>                | 63                         | 0.05              |             |                   |           |     |                           |          |  |  |
| <i>p.jerryi</i> X <i>P.investigatoris</i>       | 63                         | 0.16              |             |                   |           |     |                           |          |  |  |
| <i>p.jerryi</i> X <i>M.andamanensis</i>         | 88                         | 0.27              |             |                   |           |     |                           |          |  |  |
| <i>A.alcocki</i> X <i>S.hexti</i>               | 85                         | 2.78              | P<0.01      |                   |           |     |                           |          |  |  |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 85                         | 2.69              | P<0.01      |                   |           |     |                           |          |  |  |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 110                        | 2.91              | P<0.01      |                   |           |     |                           |          |  |  |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 97                         | 0.87              |             |                   |           |     |                           |          |  |  |
| <i>P.investigatoris</i> X <i>S.hexti</i>        | 72                         | 1.00              |             |                   |           |     |                           |          |  |  |

Table 2.4.5 Comparison of regression coefficients of TOTAL LENGTH X SECOND CHLIPPED LENGTH in species in the super family Peneaeoidea (Females)

| Treatments                                      | df  | Σx <sup>2</sup> | Σxy         | Σy <sup>2</sup> | RC        | Deviations from Regression |           |          |
|---|-----|-----------------|-------------|-----------------|-----------|----------------------------|-----------|----------|
|   |     |                 |             |                 |           | df                         | SS        | MS       |
| <i>P.jerryi</i>                                 | 74  | 11.044974       | 7.405656    | 4.968822        | 0.6705001 | 73                         | 0.1349842 | 0.018229 |
| <i>A.alcocki</i>                                | 57  | 67.535347       | 53.914299   | 43.274824       | 0.7983123 | 56                         | 0.0184475 | 0.000342 |
| <i>S.hexti</i>                                  | 60  | 33.522005       | 24.63589    | 18.228986       | 0.734917  | 61                         | 0.0403158 | 0.001636 |
| <i>P.investigatoris</i>                         | 60  | 242.80008       | 15.915322   | 10.643662       | 0.0655491 | 59                         | 0.0061585 | 0.000387 |
| <i>M.andamanensis</i>                           | 61  | 2868.3418       | 19.619504   | 14.10776        | 0.00684   | 60                         | 0.0004848 | 2.47E-05 |
| WITH IN   |     |                 |             |                 |           | 309                        | 0.2004008 | 0.000649 |
| Reg.Coeff.                                      |     |                 |             |                 |           | 4                          | 86.442491 | 21.61062 |
| COMMON  | 312 | 3223.2442       | 121.49067   | 91.222124       | 0.037692  | 313                        | 86.642892 | 0.276814 |
| Adj.Means                                       |     |                 |             |                 |           | 4                          | 21.292136 | 5.323034 |
| TOTAL   | 246 | 3258.8891       | 150.4939    | 114.88476       |           | 317                        | 107.93503 |          |
| Comparison of slopes F = (4,313)                |     | 33321.6 P<0.05  |             |                 |           |                            |           |          |
| Comparison of elevation F = (4,317)             |     | 19.22 P<0.05    |             |                 |           |                            |           |          |
| Treatments                                      | df  | t               | Probability |                 |           |                            |           |          |
| <i>p.jerryi</i> X <i>A.alcocki</i>              | 131 | 3.09            | P<0.05      |                 |           |                            |           |          |
| <i>p.jerryi</i> X <i>S.hexti</i>                | 134 | 2.81            | P<0.01      |                 |           |                            |           |          |
| <i>p.jerryi</i> X <i>P.investigatoris</i>       | 134 | 4.67            | P<0.05      |                 |           |                            |           |          |
| <i>p.jerryi</i> X <i>M.andamanensis</i>         | 135 | 3.94            | P<0.05      |                 |           |                            |           |          |
| <i>A.alcocki</i> X <i>S.hexti</i>               | 117 | 2.78            | P<0.01      |                 |           |                            |           |          |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 117 | 2.69            | P<0.01      |                 |           |                            |           |          |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 118 | 2.91            | P<0.01      |                 |           |                            |           |          |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 121 | 0.87            |             |                 |           |                            |           |          |
| <i>P.investigatoris</i> X <i>S.hexti</i>        | 120 | 2.58            | P<0.01      |                 |           |                            |           |          |

Table 2.4.6 Comparison of regression coefficients of TOTAL LENGTH X MEMBUS LENGTH in species in the super family Penaeoidea (females)

| Treatments                                      | df  | {x2       | {xy         | {y2       | RC        | Deviations from Regression |           |          |           |          |
|---|-----|-----------|-------------|-----------|-----------|----------------------------|-----------|----------|-----------|----------|
|   |     |           |             |           |           | SS {d y.x2}                | MS        |          |           |          |
| <i>p.jerryi</i>                                 | 43  | 11.526802 | 4.0844239   | 1.4605472 | 0.3526064 | 42                         | 0.2414207 | 0.059399 |           |          |
| <i>A.alcocki</i>                                | 77  | 86.056617 | 37.198936   | 57.573991 | 0.4322461 | 76                         | 0.0075077 | 0.000202 |           |          |
| <i>S.hexti</i>                                  | 45  | 38.488761 | 21.561576   | 22.405875 | 0.5802045 | 44                         | 0.0250026 | 0.00116  |           |          |
| <i>P.investigatoris</i>                         | 21  | 236.43612 | 11.015713   | 8.9881842 | 0.0465907 | 20                         | 0.0051835 | 0.000471 |           |          |
| <i>M.andamanensis</i>                           | 88  | 2869.5699 | 14.638303   | 12.91185  | 0.0051012 | 87                         | 0.0003951 | 2.7E-05  |           |          |
| <b>WITH IN</b>                                  |     |           |             |           |           |                            |           | 269      | 0.2795096 | 0.001039 |
| Reg.Coeff.                                      |     |           |             |           |           | 4                          | 100.64628 | 25.16157 |           |          |
| COMMON  | 274 | 3242.0812 | 88.478952   | 103.34045 | 0.0272908 | 273                        | 100.92579 | 0.368992 |           |          |
| Adj.Means                                       |     |           |             |           |           | 4                          | 5.9924157 | 1.498104 |           |          |
| TOTAL   | 278 | 3267.2809 | 101.33178   | 110.06092 |           | 277                        | 106.9182  |          |           |          |
| Comparison of slopes $F = (4.273)$              |     |           |             |           | 24215.491 | $P < 0.05$                 |           |          |           |          |
| Comparison of elevation $F = (4.277)$           |     |           |             |           | 4.052308  | $P < 0.05$                 |           |          |           |          |
| Treatments                                      | df  | t         | Probability |           |           |                            |           |          |           |          |
| <i>p.jerryi</i> X <i>A.alcocki</i>              | 120 | 2.36      |             |           |           |                            |           |          |           |          |
| <i>p.jerryi</i> X <i>S.hexti</i>                | 88  | 2.75      | $P < 0.01$  |           |           |                            |           |          |           |          |
| <i>p.jerryi</i> X <i>P.investigatoris</i>       | 64  | 3.06      | $P < 0.05$  |           |           |                            |           |          |           |          |
| <i>p.jerryi</i> X <i>M.andamanensis</i>         | 131 | 4.13      | $P < 0.05$  |           |           |                            |           |          |           |          |
| <i>A.alcocki</i> X <i>S.hexti</i>               | 122 | 2.8       | $P < 0.01$  |           |           |                            |           |          |           |          |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 98  | 2.88      | $P < 0.01$  |           |           |                            |           |          |           |          |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 165 | 3.06      | $P < 0.05$  |           |           |                            |           |          |           |          |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 109 | 2.57      |             |           |           |                            |           |          |           |          |
| <i>P.investigatoris</i> X <i>S.hexti</i>        | 76  | 0.3       |             |           |           |                            |           |          |           |          |

Table 2.4.7 Comparison of regression coefficients of CARAPACE LENGTH X ROSTRAL LENGTH in species in the superfamily Penaeoidea (females)

| Treatments                                      | df  | {x2       | {xy         | {y2       | RC        | Deviations from Regression |             |          |
|---|-----|-----------|-------------|-----------|-----------|----------------------------|-------------|----------|
|   |     |           |             |           |           | df                         | SS (d y.x2) | MS       |
| <i>P.jerryi</i>                                 | 43  | 19.297423 | 5.7549379   | 5.4020725 | 0.2982231 | 42                         | 0.0562053   | 0.009593 |
| <i>A.alcocki</i>                                | 77  | 2310.323  | 47.242828   | 46.383338 | 0.0204486 | 76                         | 0.0004409   | 9.33E-08 |
| <i>S.hextili</i>                                | 45  | 518.96054 | 17.040178   | 13.449544 | 0.0328352 | 44                         | 0.0024414   | 0.000143 |
| <i>P.investigatoris</i>                         | 21  | 102.53762 | 5.4938217   | 3.5568824 | 0.0535766 | 20                         | 0.0150637   | 0.002742 |
| <i>M.andamanensis</i>                           | 88  | 127.28435 | 12.617714   | 9.9066287 | 0.0991301 | 87                         | 0.0100084   | 0.000793 |
| <b>WITH IN</b>                                  |     |           |             |           |           |                            |             |          |
| Reg. Coeff.                                     |     |           |             |           |           | 269                        | 0.0831578   | 0.000309 |
| COMMON  | 274 | 3078.403  | 88.149279   | 78.698265 | 0.0288347 | 4                          | 76.090978   | 19.02274 |
| Adj.Means                                       |     |           |             |           |           | 273                        | 76.174133   | 0.279028 |
| TOTAL   | 279 | 3082.6007 | 101.30712   | 91.56928  |           | 4                          | 12.076538   | 3.019134 |
| <b>Comparison of slopes F = (4.273)</b>         |     |           |             |           |           |                            |             |          |
| <b>Comparison of elevation F = (4.277)</b>      |     |           |             |           |           |                            |             |          |
|   |     |           |             | 61635.152 | P<0.06    |                            |             |          |
|   |     |           |             | 10.820257 | P<0.05    |                            |             |          |
| Treatments                                      | df  | t         | Probability |           |           |                            |             |          |
| <i>p.jerryi</i> X <i>A.alcocki</i>              | 120 | 2.13      |             |           |           |                            |             |          |
| <i>p.jerryi</i> X <i>S.hextili</i>              | 88  | 2.47      |             |           |           |                            |             |          |
| <i>p.jerryi</i> X <i>P.investigatoris</i>       | 64  | 3.2       | P<0.05      |           |           |                            |             |          |
| <i>p.jerryi</i> X <i>M.andamanensis</i>         | 131 | 0.08      |             |           |           |                            |             |          |
| <i>A.alcocki</i> X <i>S.hextili</i>             | 122 | 2.57      |             |           |           |                            |             |          |
| <i>A.alcocki</i> X <i>P.investigatoris</i>      | 98  | 4.87      | P<0.05      |           |           |                            |             |          |
| <i>A.alcocki</i> X <i>M.andamanensis</i>        | 165 | 2.95      | P<0.05      |           |           |                            |             |          |
| <i>P.investigatoris</i> X <i>M.andamanensis</i> | 109 | 2.61      | P<0.01      |           |           |                            |             |          |
| <i>P.investigatoris</i> X <i>S.hextili</i>      | 76  | 2.09      |             |           |           |                            |             |          |

Table 2 4 8 Comparison of regression coefficients of TOTAL LENGTH X CARAPACE LENGTH in species in the super family Pandaloidea(females)

| TREATMENTS                                | df  | x2        | xy          | y2        | RC        | Deviations from Regression |           |          |
|---|-----|-----------|-------------|-----------|-----------|----------------------------|-----------|----------|
|   |     |           |             |           |           | SS                         | MS        |          |
| <i>H.laevigatus</i>                       | 20  | 10.907959 | 8.5085513   | 6.6375109 | 0.7800315 | 28                         | 0.0005732 | 2.05E-05 |
| <i>H.woodmasoni</i>                       | 21  | 0.0345167 | 0.0522648   | 0.1372332 | 1.5141855 | 20                         | 0.0580947 | 0.002905 |
| <i>H.gibbosus</i>                         | 20  | 0.0463485 | 0.032872    | 0.0373468 | 0.7092343 | 19                         | 0.0140328 | 0.000739 |
| <i>P.spinipes</i>                         | 23  | 0.0136972 | 0.0173151   | 0.0289827 | 1.2841329 | 22                         | 0.0070941 | 0.000322 |
| <i>P.martia</i>                           | 36  | 24.887202 | 16.497873   | 10.939809 | 0.8629059 | 35                         | 0.0032727 | 9.36E-05 |
| <i>P.ensis</i>                            | 23  | 23.750158 | 16.765401   | 11.884103 | 0.7059069 | 22                         | 0.04929   | 0.00224  |
| <i>P.alcocki</i>                          | 27  | 8.3045874 | 5.1961141   | 3.252886  | 0.625692  | 26                         | 0.0017188 | 6.61E-05 |
| WITH IN                                   |     |           |             |           |           | 146                        | 0.1323574 | 0.000907 |
| Reg.Coeff.                                |     |           |             |           |           | 6                          | 0.1319151 | 0.021986 |
| COMMON                                    | 152 | 59.639882 | 41.874277   | 29.664986 | 0.7021187 | 152                        | 0.2642725 | 0.001739 |
| Adj.Means                                 |     |           |             |           |           | 6                          | 0.2777469 | 0.046291 |
| TOTAL                                     | 166 | 187.0157  | 132.99614   | 95.122167 |           | 158                        | 0.5420194 |          |
| Comparison of slopes F = (6, 152)         |     |           |             |           |           | 24.252019                  |           | P<0.05   |
| Comparison of elevation F = (6, 156)      |     |           |             |           |           | 26.625005                  |           | P<0.05   |
| Treatments                                | df  | t         | Probability |           |           |                            |           |          |
| <i>H.laevigatus</i> X <i>H.woodmasoni</i> | 50  | 1         |             |           |           |                            |           |          |
| <i>H.laevigatus</i> X <i>H.gibbosus</i>   | 49  | 0.08      |             |           |           |                            |           |          |
| <i>H.laevigatus</i> X <i>P.spinipes</i>   | 52  | 5.71      | P<0.05      |           |           |                            |           |          |
| <i>H.laevigatus</i> X <i>P.martia</i>     | 75  | 3.16      | P<0.05      |           |           |                            |           |          |
| <i>H.laevigatus</i> X <i>P.ensis</i>      | 52  | 2.76      | P<0.01      |           |           |                            |           |          |
| <i>H.laevigatus</i> X <i>P.alcocki</i>    | 56  | 2.04      |             |           |           |                            |           |          |
| <i>H.woodmasoni</i> X <i>H.gibbosus</i>   | 41  | 2         |             |           |           |                            |           |          |
| <i>H.woodmasoni</i> X <i>P.spinipes</i>   | 44  | 2.27      |             |           |           |                            |           |          |
| <i>H.woodmasoni</i> X <i>P.martia</i>     | 57  | 3.76      | P<0.05      |           |           |                            |           |          |
| <i>H.woodmasoni</i> X <i>P.ensis</i>      | 24  | 3.19      | P<0.05      |           |           |                            |           |          |
| <i>H.gibbosus</i> X <i>P.spinipes</i>     | 44  | 3.32      | P<0.05      |           |           |                            |           |          |
| <i>P.spinipes</i> X <i>P.martia</i>       | 59  | 5.17      | P<0.05      |           |           |                            |           |          |
| <i>P.spinipes</i> X <i>P.ensis</i>        | 64  | 3.35      | P<0.05      |           |           |                            |           |          |
| <i>P.martia</i> X <i>P.alcocki</i>        | 63  | 2.41      |             |           |           |                            |           |          |

Table 3.4.9

Comparison of regression coefficients of TOTAL LENGTH X ROSTRAL LENGTH  
in species in the superfamily Pandaloidea (females)

| TREATMENTS           | f   | [x <sup>2</sup> ] | [xy]      | [y <sup>2</sup> ] | RC        | Deviations from Regression |           |         |
|----------------------|-----|-------------------|-----------|-------------------|-----------|----------------------------|-----------|---------|
|                      |     |                   |           |                   |           | f                          | SS        | MS      |
| <i>H. laevigatus</i> | 28  | 10.907959         | 8.3335055 | 6.3668027         | 0.7639839 | 28                         | 0.0001385 | 4.9E-06 |
| <i>H. woodmasoni</i> | 41  | 42.757583         | 30.93081  | 22.398032         | 0.7228922 | 40                         | 0.0383902 | 9.6E-04 |
| <i>H. gibbosus</i>   | 39  | 41.679887         | 32.565722 | 25.458291         | 0.7813294 | 38                         | 0.0137345 | 3.6E-04 |
| <i>P. spinipes</i>   | 23  | 0.0136972         | 0.0138064 | 0.0327463         | 1.0079703 | 22                         | 0.0188299 | 8.6E-04 |
| <i>P. martia</i>     | 46  | 26.346972         | 19.849399 | 14.968547         | 0.7533845 | 45                         | 0.0143177 | 3.2E-04 |
| <i>P. enals</i>      | 23  | 23.750158         | 17.486393 | 12.898479         | 0.7362643 | 22                         | 0.0218734 | 9.9E-04 |
| <i>P. alcocki</i>    | 27  | 8.3045874         | 6.3877986 | 4.9151498         | 0.7691893 | 26                         | 0.0017229 | 6.6E-05 |
| WITH IN              |     |                   |           |                   |           | 195                        | 0.1072841 | 5.5E-04 |
| Reg. Coeff.          |     |                   |           |                   |           | 6                          | 0.0801502 | 1.3E-02 |
| COMMON               | 201 | 145.48626         | 109.17964 | 82.120899         | 0.7504464 | 201                        | 0.1874343 | 9.3E-04 |
| Adj. Means           |     |                   |           |                   |           | 6                          | 0.090707  | 1.5E-02 |
| TOTAL                | 235 | 225.11068         | 168.64944 | 126.62769         |           | 207                        | 0.2781413 |         |

Comparison of slopes  $F = (6, 201)$

24.28  $P < 0.05$

Comparison of elevation  $F = (6, 207)$

16.21  $P < 0.05$

| Treatments                                  | df | t    | Probability |
|---|----|------|-------------|
| <i>H. laevigatus</i> X <i>H. woodmasoni</i> | 70 | 2.81 | $P < 0.05$  |
| <i>H. laevigatus</i> X <i>H. gibbosus</i>   | 68 | 4.03 | $P < 0.05$  |
| <i>H. laevigatus</i> X <i>P. spinipes</i>   | 52 | 2.62 |             |
| <i>H. laevigatus</i> X <i>P. martia</i>     | 75 | 2.03 |             |
| <i>H. laevigatus</i> X <i>P. ensis</i>      | 52 | 6.41 | $P < 0.05$  |
| <i>H. laevigatus</i> X <i>P. alcocki</i>    | 56 | 0.87 |             |
| <i>H. woodmasoni</i> X <i>H. gibbosus</i>   | 80 | 3.13 | $P < 0.05$  |
| <i>H. woodmasoni</i> X <i>P. spinipes</i>   | 64 | 2.88 | $P < 0.01$  |
| <i>H. woodmasoni</i> X <i>P. martia</i>     | 87 | 2.97 | $P < 0.05$  |
| <i>H. woodmasoni</i> X <i>P. ensis</i>      | 64 | 2.75 | $P < 0.01$  |
| <i>H. gibbosus</i> X <i>P. spinipes</i>     | 62 | 3.17 | $P < 0.05$  |
| <i>P. spinipes</i> X <i>P. martia</i>       | 69 | 2.08 |             |
| <i>P. spinipes</i> X <i>P. ensis</i>        | 46 | 0.02 |             |
| <i>P. martia</i> X <i>P. alcocki</i>        | 73 | 2.7  | $P < 0.01$  |

Table 2 d is description of regression coefficients of total length in first cheliped length in species in the superfamily Pentastelinoidea

| TREATMENTS                          | df  | Σx <sup>2</sup> | Σxy       | Σy <sup>2</sup> | RC        | Deviations from Regression |           |              |
|-------------------------------------|-----|-----------------|-----------|-----------------|-----------|----------------------------|-----------|--------------|
|                                     |     |                 |           |                 |           | SS                         | df        | MS           |
| <i>H. laevigatus</i>                | 29  | 10.907959       | 8.1677379 | 6.1160055       | 0.748787  | 28                         | 0.0001097 | 3.92E-06     |
| <i>H. woodmasoni</i>                | 41  | 42.787583       | 28.772559 | 19.3605         | 0.8724511 | 40                         | 0.0123596 | 0.000309     |
| <i>H. gibbosus</i>                  | 39  | 41.679887       | 31.624823 | 24.025459       | 0.758755  | 38                         | 0.0299656 | 0.000789     |
| <i>P. spinipes</i>                  | 23  | 0.0136972       | 0.02848   | 0.0700354       | 2.0792504 | 22                         | 0.0108184 | 0.000492     |
| <i>P. martia</i>                    | 46  | 26.346972       | 18.931234 | 13.61395        | 0.7185355 | 45                         | 0.0111869 | 0.000249     |
| <i>P. ensis</i>                     | 23  | 23.750158       | 17.596002 | 13.125037       | 0.7408794 | 22                         | 0.0885233 | 0.004024     |
| <i>P. alcocki</i>                   | 27  | 8.3045874       | 5.1449566 | 3.1877061       | 0.8195319 | 26                         | 0.0002415 | 9.29E-06     |
| WITH IN                             |     |                 |           |                 |           | 221                        | 0.153205  | 0.000693     |
| Reg. Coeff.                         |     |                 |           |                 |           | 6                          | 0.2865231 | 0.047754     |
| COMMON                              | 228 | 153.79084       | 110.26579 | 79.498694       | 0.7169854 | 227                        | 0.4397281 | 0.001937     |
| Adj. Means                          |     |                 |           |                 |           | 6                          | 0.5224517 | 0.087075     |
| TOTAL                               | 235 | 225.11068       | 165.60424 | 122.79009       |           | 233                        | 0.9621798 |              |
| Comparison of slopes F = (6,227)    |     |                 |           |                 |           |                            |           | 68.89 P<0.05 |
| Comparison of elevation F = (6,233) |     |                 |           |                 |           |                            |           | 44.95 P<0.05 |

| Treatments                                  | df | t    | Probability |
|---|----|------|-------------|
| <i>H. laevigatus</i> X <i>H. woodmasoni</i> | 70 | 2.99 | P<0.05      |
| <i>H. laevigatus</i> X <i>H. gibbosus</i>   | 68 | 1.92 |             |
| <i>H. laevigatus</i> X <i>P. spinipes</i>   | 52 | 0.01 |             |
| <i>H. laevigatus</i> X <i>P. martia</i>     | 75 | 3.99 | P<0.05      |
| <i>H. laevigatus</i> X <i>P. ensis</i>      | 52 | 7.45 | P<0.05      |
| <i>H. laevigatus</i> X <i>P. alcocki</i>    | 56 | 5.59 | P<0.05      |
| <i>H. woodmasoni</i> X <i>H. gibbosus</i>   | 80 | 0.01 |             |
| <i>H. woodmasoni</i> X <i>P. spinipes</i>   | 64 | 5.51 | P<0.05      |
| <i>H. woodmasoni</i> X <i>P. martia</i>     | 87 | 3.07 | P<0.05      |
| <i>H. woodmasoni</i> X <i>P. ensis</i>      | 64 | 2.78 | P<0.01      |
| <i>H. gibbosus</i> X <i>P. spinipes</i>     | 62 | 3.11 | P<0.05      |
| <i>P. spinipes</i> X <i>P. martia</i>       | 69 | 1.4  |             |
| <i>P. spinipes</i> X <i>P. ensis</i>        | 46 | 0.2  |             |
| <i>P. martia</i> X <i>P. alcocki</i>        | 73 | 0.59 |             |

Table 2-4-11 Comparison of regression coefficients of TOTAL LENGTH X CARAPACE LENGTH in species of the super family Ophiophoroidea (females)

| TREATMENTS                             | df  | (x2       | (xy         | (y2       | RC        | Deviations from Regression |            |             |
|--|-----|-----------|-------------|-----------|-----------|----------------------------|------------|-------------|
|  |     |           |             |           |           | df                         | SS (d y.x2 | MS          |
| <i>A. armata</i>                       | 61  | 12.897987 | 4.1371726   | 6.7752186 | 0.3207611 | 60                         | 5.4481745  | 0.090803    |
| <i>A. sanguinea</i>                    | 59  | 11.190218 | 3.4090549   | 4.5391626 | 0.304646  | 58                         | 3.5006078  | 0.060355    |
| <i>O. typus</i>                        | 12  | 8.8241912 | 2.0499642   | 3.5842713 | 0.2323119 | 11                         | 3.1090403  | 0.282549    |
| WITH IN                                |     |           |             |           |           | 129                        | 12.056823  | 0.093464    |
| Reg. Coeff.                            |     |           |             |           |           | 1                          | 0.0438904  | 0.04389     |
| COMMON                                 | 132 | 32.912396 | 9.5961917   | 14.898653 | 0.2915677 | 130                        | 12.100713  | 0.093082    |
| Adj. Means                             |     |           |             |           |           | 1                          | 0.2507699  | 0.25077     |
| TOTAL                                  | 135 | 35.273377 | 11.07725    | 15.830182 |           | 131                        | 12.351483  |             |
| Comparison of slopes F = (1,130)       |     |           |             |           |           |                            |            | 0.47 P>0.05 |
| Comparison of elevation F = (1,131)    |     |           |             |           |           |                            |            | 2.69 P>0.05 |
| Treatments                             | df  | t         | Probability |           |           |                            |            |             |
| <i>A. armata</i> X <i>A. sanguinea</i> | 120 | 0.81      |             |           |           |                            |            |             |
| <i>A. sanguinea</i> X <i>O. typus</i>  | 71  | 3.54      | P<0.05      |           |           |                            |            |             |
| <i>O. typus</i> X <i>A. armata</i>     | 73  | 2.9       | P<0.05      |           |           |                            |            |             |



Table 2 4 12 Comparison of regression coefficients of TOTAL LENGTH X ROSTRAL LENGTH  
 in species of the super family Ophiophoroidea (females)

| TREATMENTS                           | f  | {x2       | {xy         | {y2       | RC        | Deviations from Regression |           |              |
|--------------------------------------|----|-----------|-------------|-----------|-----------|----------------------------|-----------|--------------|
|                                      |    |           |             |           |           | f                          | MS        |              |
| <i>A.armata</i>                      | 42 | 12.608491 | 8.9655999   | 6.4285465 | 0.7134557 | 41                         | 0.0105842 | 0.000258     |
| <i>A.sanguinea</i>                   | 39 | 10.895808 | 7.7429248   | 5.50479   | 0.7106334 | 38                         | 0.0024092 | 6.34E-05     |
| <i>O.typus</i>                       | 15 | 9.5594278 | 4.5366693   | 4.6324    | 0.4745754 | 14                         | 2.4794083 | 0.177101     |
| WITH IN                              |    |           |             |           |           | 93                         | 2.4924017 | 0.0268       |
| Reg.Coeff.                           |    |           |             |           |           | 1                          | 0.3835929 | 0.383593     |
| COMMON                               | 96 | 33.083726 | 21.275194   | 16.565737 | 0.6434603 | 94                         | 2.8759946 | 0.030596     |
| Adj.Means                            |    |           |             |           |           | 1                          | 0.0020923 | 0.002092     |
| TOTAL                                | 99 | 34.253639 | 22.09156    | 17.125829 |           | 95                         | 2.8760869 |              |
| Comparison of slopes F = (1.94)      |    |           |             |           |           |                            |           | 14.31 P<0.05 |
| Comparison of elevation F = (1.95)   |    |           |             |           |           |                            |           | 0.07 P>0.05  |
| Treatments                           | df | t         | Probability |           |           |                            |           |              |
| <i>A.armata</i> X <i>A.sanguinea</i> | 81 | 3.76      | P<0.05      |           |           |                            |           |              |
| <i>A.sanguinea</i> X <i>O.typus</i>  | 54 | 2.84      | P<0.01      |           |           |                            |           |              |
| <i>O.typus</i> X <i>A.armata</i>     | 65 | 5.18      | P<0.05      |           |           |                            |           |              |

Table 2.4.14 Comparison of regression coefficients of CARAPACE LENGTH X ROSTRAL LENGTH in species of the super family Ophiophoroidea(females)

| TREATMENTS                           | df | {x2       | {xy         | {y2       | RC        | Deviations from Regression |            |               |
|--------------------------------------|----|-----------|-------------|-----------|-----------|----------------------------|------------|---------------|
|                                      |    |           |             |           |           | df                         | SS (d y.x2 | MS            |
| <i>A.armata</i>                      | 39 | 6.5865944 | 6.4754769   | 6.3924375 | 0.9831298 | 38                         | 0.0262035  | 0.00069       |
| <i>A.sanguinea</i>                   | 19 | 4.0618984 | 4.5315963   | 5.05958   | 1.1156351 | 18                         | 0.0039722  | 0.000221      |
| <i>O.typus</i>                       | 34 | 4.5841842 | 5.0055502   | 5.4670971 | 1.0919174 | 33                         | 0.00145    | 4.39E-05      |
| WITH IN                              |    |           |             |           |           | 89                         | 0.0316257  | 0.000355      |
| Reg.Coeff.                           |    |           |             |           |           | 1                          | 0.054984   | 0.054984      |
| COMMON                               | 92 | 15.232677 | 16.012623   | 16.919115 | 1.0512022 | 90                         | 0.0866097  | 0.000962      |
| Adj.Means                            |    |           |             |           |           | 1                          | 0.0058836  | 0.005884      |
| TOTAL                                | 95 | 15.307729 | 16.10945    | 17.045654 |           | 91                         | 0.0924932  |               |
| Comparison of slopes                 |    |           |             |           |           |                            |            | 154.73 P<0.05 |
| Comparison of elevation              |    |           |             |           |           |                            |            | 6.11 P<0.05   |
| Treatments                           | df | t         | Probability |           |           |                            |            |               |
| <i>A.armata</i> X <i>A.sanguinea</i> | 58 | 0.21      |             |           |           |                            |            |               |
| <i>A.sanguinea</i> X <i>O.typus</i>  | 53 | 2.69      | P<0.01      |           |           |                            |            |               |
| <i>O.typus</i> X <i>A.armata</i>     | 73 | 2.97      | P<0.05      |           |           |                            |            |               |

Table 2.3.4. Inhibition percentages, and mean of different ratios method and using various microelements measurements in sheep and goats ( male ) under the tiger family Pharusidae

| Ratios   | <i>P. jerryi</i> |       |       | <i>M. damianensis</i> |       |       | <i>S. heardi</i> |        |        | <i>A. atcocki</i> |       |       |       |       |       |
|----------|------------------|-------|-------|-----------------------|-------|-------|------------------|--------|--------|-------------------|-------|-------|-------|-------|-------|
|          | Min              | Max   | Mean  | Min                   | Max   | Mean  | Min              | Max    | Mean   | Min               | Max   | Mean  |       |       |       |
| CL/TL    | 0.253            | 0.328 | 0.280 | 0.277                 | 0.291 | 0.282 | 0.2577           | 0.2921 | 0.2744 | 0.244             | 0.428 | 0.339 | 0.238 | 0.320 | 0.286 |
| RL/TL    | 0.074            | 0.123 | 0.097 | 0.208                 | 0.252 | 0.229 | 0.1389           | 0.2523 | 0.1753 | 0.101             | 0.195 | 0.164 | 0.229 | 0.319 | 0.274 |
| lCH/TL   | 0.191            | 0.263 | 0.214 | 0.153                 | 0.173 | 0.161 | 0.1753           | 0.3111 | 0.2276 | 0.085             | 0.244 | 0.605 | 0.193 | 0.338 | 0.280 |
| 2 i / TL | 0.034            | 0.053 | 0.044 | 0.027                 | 0.045 | 0.037 | 0.0337           | 0.0556 | 0.0431 | 0.034             | 0.101 | 0.060 | 0.017 | 0.313 | 0.057 |
| 2 m / TL | 0.056            | 0.088 | 0.072 | 0.040                 | 0.064 | 0.049 | 0.0619           | 0.0891 | 0.0739 | 0.044             | 0.119 | 0.089 | 0.057 | 0.123 | 0.090 |
| 2 c / TL | 0.056            | 0.088 | 0.072 | 0.073                 | 0.089 | 0.081 | 0.0556           | 0.1236 | 0.1010 | 0.085             | 0.178 | 0.114 | 0.078 | 0.125 | 0.094 |
| 2 p / TL | 0.023            | 0.051 | 0.037 | 0.018                 | 0.040 | 0.031 | 0.0278           | 0.0500 | 0.0435 | 0.012             | 0.045 | 0.028 | 0.034 | 0.109 | 0.083 |
| 2 d / TL | 0.011            | 0.028 | 0.019 | 0.009                 | 0.020 | 0.016 | 0.0090           | 0.0270 | 0.0154 | 0.009             | 0.034 | 0.018 | 0.028 | 0.108 | 0.053 |
| 2CH / TL | 0.208            | 0.281 | 0.244 | 0.152                 | 0.228 | 0.192 | 0.2222           | 0.3188 | 0.2769 | 0.221             | 0.398 | 0.309 | 0.252 | 0.633 | 0.373 |
| 3CH / TL | 0.287            | 0.368 | 0.328 | 0.317                 | 0.355 | 0.341 | 0.2000           | 0.4583 | 0.3551 | 0.299             | 0.521 | 0.387 | 0.281 | 0.465 | 0.369 |
| 4CH / TL | 0.289            | 0.448 | 0.335 | 0.386                 | 0.409 | 0.401 | 0.2809           | 0.4500 | 0.3381 | 0.213             | 0.428 | 0.314 | 0.249 | 0.445 | 0.340 |
| 5CH / TL | 0.368            | 0.485 | 0.437 | 0.387                 | 0.418 | 0.407 | 0.3444           | 0.4800 | 0.3769 | 0.256             | 0.258 | 0.234 | 0.258 | 0.484 | 0.392 |
| Ur/TL    | 0.138            | 0.194 | 0.167 | 0.158                 | 0.173 | 0.164 | 0.1532           | 0.1982 | 0.1786 | 0.098             | 0.204 | 0.146 | 0.075 | 0.209 | 0.144 |
| Te/TL    | 0.103            | 0.138 | 0.122 | 0.155                 | 0.171 | 0.161 | 0.1111           | 0.1649 | 0.1475 | 0.068             | 0.192 | 0.146 | 0.061 | 0.134 | 0.107 |
| RL/CL    | 0.278            | 0.391 | 0.343 | 0.750                 | 0.903 | 0.811 | 0.4762           | 0.9032 | 0.6400 | 0.346             | 0.800 | 0.493 | 0.745 | 1.250 | 0.941 |
| lCH/CL   | 0.722            | 0.833 | 0.782 | 0.548                 | 0.694 | 0.571 | 0.6800           | 1.1667 | 0.8301 | 0.286             | 1.000 | 0.543 | 0.604 | 1.190 | 0.916 |
| 2 i / CL | 0.130            | 0.182 | 0.159 | 0.158                 | 0.294 | 0.234 | 0.1154           | 0.1905 | 0.1571 | 0.095             | 0.393 | 0.189 | 0.069 | 0.979 | 0.198 |
| 2 m / CL | 0.211            | 0.304 | 0.257 | 0.143                 | 0.219 | 0.174 | 0.2333           | 0.3214 | 0.2692 | 0.103             | 0.450 | 0.275 | 0.188 | 0.484 | 0.318 |
| 2 c / CL | 0.211            | 0.304 | 0.257 | 0.250                 | 0.321 | 0.287 | 0.1905           | 0.4583 | 0.3684 | 0.207             | 0.478 | 0.340 | 0.288 | 0.500 | 0.329 |
| 2 p / CL | 0.087            | 0.182 | 0.131 | 0.065                 | 0.143 | 0.111 | 0.0952           | 0.1923 | 0.1593 | 0.050             | 0.111 | 0.081 | 0.115 | 0.457 | 0.288 |
| 2 d / CL | 0.043            | 0.105 | 0.069 | 0.031                 | 0.071 | 0.056 | 0.0333           | 0.0968 | 0.0562 | 0.029             | 0.095 | 0.053 | 0.100 | 0.358 | 0.184 |
| 2CH/CL   | 0.789            | 1.000 | 0.873 | 0.719                 | 0.821 | 0.761 | 0.7619           | 1.1667 | 1.0102 | 0.517             | 1.321 | 0.938 | 0.904 | 1.979 | 1.303 |
| 3CH/CL   | 1.043            | 1.333 | 1.173 | 1.143                 | 1.258 | 1.207 | 0.7500           | 1.5714 | 1.2888 | 0.787             | 1.400 | 1.152 | 0.925 | 1.714 | 1.286 |
| 4CH/CL   | 0.913            | 1.391 | 1.198 | 1.406                 | 1.429 | 1.418 | 0.9615           | 1.7308 | 1.2397 | 0.617             | 1.143 | 0.928 | 0.837 | 1.568 | 1.192 |
| 5CH/CL   | 1.421            | 1.833 | 1.566 | 1.387                 | 1.500 | 1.442 | 1.1923           | 1.7692 | 1.3774 | 0.681             | 1.500 | 1.128 | 0.909 | 1.743 | 1.379 |
| Te/CL    | 0.316            | 0.529 | 0.440 | 0.531                 | 0.613 | 0.572 | 0.3810           | 0.6400 | 0.5404 | 0.190             | 0.700 | 0.448 | 0.200 | 0.538 | 0.378 |
| Ur/CL    | 0.474            | 0.737 | 0.602 | 0.571                 | 0.594 | 0.582 | 0.5484           | 0.7333 | 0.6450 | 0.288             | 0.607 | 0.435 | 0.273 | 0.793 | 0.508 |
| RU/2CH   | 0.313            | 0.450 | 0.394 | 0.913                 | 1.217 | 1.072 | 0.5000           | 0.8000 | 0.6357 | 0.300             | 0.887 | 0.545 | 0.421 | 1.128 | 0.744 |
| TE/2CH   | 0.375            | 0.600 | 0.505 | 0.696                 | 0.926 | 0.754 | 0.4286           | 0.6957 | 0.5398 | 0.286             | 0.809 | 0.477 | 0.143 | 0.448 | 0.298 |
| Ur/2 CH  | 0.563            | 0.933 | 0.693 | 0.696                 | 0.926 | 0.768 | 0.4857           | 0.8125 | 0.6535 | 0.300             | 0.733 | 0.486 | 0.200 | 0.678 | 0.395 |
| RU/2 c   | 1.000            | 1.600 | 1.346 | 2.333                 | 3.125 | 2.856 | 1.2727           | 2.5000 | 1.8185 | 0.900             | 2.857 | 1.520 | 2.333 | 3.556 | 2.874 |

Table 2 2 1 Continued

| Ratio   | <i>P. investigatoris</i> |       |       |       |       | <i>M. andamanensis</i> |        |        |        |       | <i>S. hearli</i> |       |       |       |       | <i>A. alcocki</i> |     |      |  |  |
|---------|--------------------------|-------|-------|-------|-------|------------------------|--------|--------|--------|-------|------------------|-------|-------|-------|-------|-------------------|-----|------|--|--|
|         | Min                      | Max   | Mean  | Min   | Max   | Mean                   | Min    | Max    | Mean   | Min   | Max              | Mean  | Min   | Max   | Mean  | Min               | Max | Mean |  |  |
| 2l/2 cl | 0.429                    | 0.750 | 0.624 | 0.375 | 0.556 | 0.458                  | 0.2727 | 1.0000 | 0.4714 | 0.238 | 1.429            | 0.673 | 2.000 | 3.487 | 3.072 |                   |     |      |  |  |
| 2 m/2cl | 1.000                    | 1.000 | 1.000 | 0.444 | 0.875 | 0.625                  | 0.5833 | 1.2500 | 0.7717 | 0.500 | 1.286            | 0.804 | 0.222 | 3.133 | 0.605 |                   |     |      |  |  |
| 2p/2cl  | 0.288                    | 0.800 | 0.525 | 0.222 | 0.500 | 0.389                  | 0.3636 | 0.6250 | 0.4463 | 0.125 | 0.375            | 0.261 | 0.583 | 1.462 | 0.965 |                   |     |      |  |  |
| 2d/2cl  | 0.143                    | 0.500 | 0.278 | 0.125 | 0.222 | 0.190                  | 0.0833 | 0.2500 | 0.1567 | 0.091 | 0.250            | 0.155 | 0.375 | 1.231 | 0.875 |                   |     |      |  |  |
| 2CH/2cl | 2.857                    | 3.800 | 3.428 | 2.556 | 2.875 | 2.662                  | 2.3636 | 4.0000 | 2.8460 | 2.238 | 4.143            | 2.764 | 0.308 | 1.143 | 0.562 |                   |     |      |  |  |
| TEL/2cl | 1.200                    | 2.280 | 1.742 | 1.778 | 2.125 | 2.005                  | 1.0909 | 2.0000 | 1.5413 | 0.667 | 2.000            | 1.333 | 3.000 | 6.333 | 3.971 |                   |     |      |  |  |
| 2l/2 m  | 0.429                    | 0.750 | 0.624 | 0.429 | 1.000 | 0.810                  | 0.4286 | 0.8000 | 0.5940 | 0.357 | 1.111            | 0.897 | 0.643 | 1.444 | 1.146 |                   |     |      |  |  |
| 2 c/2 m | 1.000                    | 1.000 | 1.000 | 1.143 | 2.250 | 1.731                  | 0.8000 | 1.7143 | 1.3639 | 0.778 | 2.000            | 1.328 | 0.200 | 4.273 | 0.666 |                   |     |      |  |  |
| 2 p/2m  | 0.288                    | 0.800 | 0.525 | 0.400 | 1.000 | 0.657                  | 0.4000 | 0.7143 | 0.5937 | 0.111 | 0.867            | 0.344 | 0.684 | 1.778 | 1.067 |                   |     |      |  |  |
| 2d/2 m  | 0.143                    | 0.500 | 0.278 | 0.143 | 0.500 | 0.348                  | 0.1429 | 0.3333 | 0.2046 | 0.111 | 0.333            | 0.211 | 0.368 | 1.667 | 0.944 |                   |     |      |  |  |
| 2CH/2 m | 2.857                    | 3.800 | 3.428 | 3.286 | 5.750 | 4.545                  | 3.2000 | 4.2857 | 3.7562 | 2.667 | 5.000            | 3.579 | 2.737 | 8.636 | 4.244 |                   |     |      |  |  |
| TEL/2 m | 1.200                    | 2.250 | 1.742 | 2.429 | 4.000 | 3.410                  | 1.6000 | 2.6667 | 2.0274 | 1.200 | 3.000            | 1.698 | 0.818 | 2.111 | 1.214 |                   |     |      |  |  |
| CU/2m   | 3.286                    | 4.750 | 3.944 | 1.143 | 2.250 | 1.731                  | 3.1111 | 4.2857 | 3.7581 | 2.222 | 9.667            | 4.164 | 2.154 | 5.333 | 3.265 |                   |     |      |  |  |
| RL/2 m  | 1.000                    | 1.600 | 1.346 | 3.571 | 5.600 | 4.807                  | 2.0000 | 3.1111 | 2.3829 | 1.000 | 4.333            | 1.993 | 2.211 | 4.556 | 3.032 |                   |     |      |  |  |
| Ur/2m   | 1.800                    | 3.500 | 2.378 | 2.714 | 4.000 | 3.438                  | 1.7776 | 3.1429 | 2.4440 | 0.889 | 3.667            | 1.764 |       |       |       |                   |     |      |  |  |
| 3rd/4th | 0.808                    | 1.143 | 0.990 | 0.800 | 0.886 | 0.851                  | 0.6667 | 1.3750 | 1.0676 | 1.071 | 1.542            | 1.251 |       |       |       |                   |     |      |  |  |
| 3rd/5th | 0.649                    | 0.808 | 0.751 | 0.762 | 0.907 | 0.839                  | 0.5806 | 1.1282 | 0.9413 | 0.816 | 1.276            | 1.042 |       |       |       |                   |     |      |  |  |
| 4th/5th | 0.568                    | 0.963 | 0.771 | 0.952 | 1.023 | 0.985                  | 0.8000 | 1.0000 | 0.8949 | 0.667 | 0.966            | 0.836 |       |       |       |                   |     |      |  |  |

|                     |                               |                              |
|---------------------|-------------------------------|------------------------------|
| TL- Total length    | 2l - ischium of 2nd cheliped  | 1 CH- Length of 1st cheliped |
| CL- Carapace length | 2m - merus of 2nd cheliped    | 2 CH- Length of 2nd cheliped |
| RL- Rostral length  | 2c - carpus of 2nd cheliped   | 3CH- Length of 3rd cheliped  |
| TEL- Telson length  | 2p - propodus of 2nd cheliped | 4CH- Length of 4th cheliped  |
| Ur- uropod length   | 2d - dactylus of 2nd cheliped | 5 CH- Length of 5th cheliped |

Table 2.2.2 Minimum, maximum, and mean of different ratios worked out using various morphometric measurements in deep sea prawns ( female ) under the super family Penaeoidea

| Ratios  | <i>P. investigatoris</i> |       |       | <i>P. jerryi</i> |       |       | <i>M. andamanensis</i> |        |        | <i>S. hexili</i> |       |       | <i>A. alcocki</i> |       |       |
|---------|--------------------------|-------|-------|------------------|-------|-------|------------------------|--------|--------|------------------|-------|-------|-------------------|-------|-------|
|         | Min                      | Max   | Mean  | Min              | Max   | Mean  | Min                    | Max    | Mean   | Min              | Max   | Mean  | Min               | Max   | Mean  |
| CU/TL   | 0.271                    | 0.333 | 0.300 | 0.271            | 0.286 | 0.277 | 0.2432                 | 0.2933 | 0.2665 | 0.161            | 0.492 | 0.332 | 0.236             | 0.366 | 0.287 |
| RL/TL   | 0.082                    | 0.123 | 0.102 | 0.236            | 0.252 | 0.247 | 0.1310                 | 0.1750 | 0.1586 | 0.102            | 0.185 | 0.154 | 0.146             | 0.294 | 0.250 |
| 1CH/TL  | 0.186                    | 0.246 | 0.210 | 0.136            | 0.225 | 0.180 | 0.1757                 | 0.2287 | 0.1996 | 0.094            | 0.354 | 0.197 | 0.228             | 0.310 | 0.278 |
| 21/TL   | 0.034                    | 0.053 | 0.043 | 0.027            | 0.037 | 0.034 | 0.0339                 | 0.0606 | 0.0521 | 0.031            | 0.104 | 0.066 | 0.030             | 0.075 | 0.051 |
| 2 m /TL | 0.071                    | 0.086 | 0.082 | 0.064            | 0.081 | 0.073 | 0.0652                 | 0.0968 | 0.0764 | 0.063            | 0.145 | 0.090 | 0.048             | 0.098 | 0.077 |
| 2 c /TL | 0.068                    | 0.088 | 0.082 | 0.082            | 0.108 | 0.091 | 0.0806                 | 0.1190 | 0.0977 | 0.051            | 0.143 | 0.104 | 0.048             | 0.113 | 0.080 |
| 2 p /TL | 0.027                    | 0.057 | 0.038 | 0.028            | 0.045 | 0.036 | 0.0323                 | 0.0543 | 0.0428 | 0.020            | 0.063 | 0.045 | 0.071             | 0.106 | 0.090 |
| 2 d /TL | 0.017                    | 0.029 | 0.023 | 0.018            | 0.019 | 0.018 | 0.0119                 | 0.0238 | 0.0175 | 0.010            | 0.034 | 0.020 | 0.038             | 0.063 | 0.047 |
| 2CH /TL | 0.247                    | 0.286 | 0.267 | 0.227            | 0.288 | 0.253 | 0.2706                 | 0.3065 | 0.2865 | 0.219            | 0.400 | 0.324 | 0.270             | 0.450 | 0.346 |
| 3CH /TL | 0.288                    | 0.368 | 0.339 | 0.345            | 0.351 | 0.348 | 0.2736                 | 0.4400 | 0.3585 | 0.319            | 0.627 | 0.435 | 0.379             | 0.732 | 0.476 |
| 4CH /TL | 0.274                    | 0.456 | 0.354 | 0.382            | 0.405 | 0.396 | 0.3176                 | 0.4746 | 0.4024 | 0.208            | 0.455 | 0.343 | 0.242             | 0.549 | 0.351 |
| 5CH /TL | 0.384                    | 0.474 | 0.432 | 0.387            | 0.400 | 0.393 | 0.3387                 | 0.4815 | 0.4012 | 0.266            | 0.559 | 0.420 | 0.207             | 0.419 | 0.302 |
| Ur/TL   | 0.163                    | 0.192 | 0.176 | 0.168            | 0.191 | 0.183 | 0.0888                 | 0.2235 | 0.1669 | 0.071            | 0.237 | 0.144 | 0.126             | 0.220 | 0.167 |
| TeI/TL  | 0.102                    | 0.140 | 0.127 | 0.150            | 0.173 | 0.164 | 0.0870                 | 0.1683 | 0.1254 | 0.101            | 0.188 | 0.145 | 0.075             | 0.146 | 0.104 |
| RL/CL   | 0.300                    | 0.368 | 0.338 | 0.667            | 0.931 | 0.891 | 0.5000                 | 0.6667 | 0.5964 | 0.300            | 0.889 | 0.499 | 0.400             | 1.167 | 0.906 |
| 1CH/CL  | 0.632                    | 0.750 | 0.701 | 0.500            | 0.781 | 0.645 | 0.6800                 | 0.8125 | 0.7493 | 0.387            | 0.875 | 0.591 | 0.700             | 1.300 | 0.989 |
| 21/CL   | 0.105                    | 0.168 | 0.143 | 0.160            | 0.211 | 0.190 | 0.1250                 | 0.3125 | 0.1968 | 0.087            | 0.571 | 0.242 | 0.108             | 0.250 | 0.181 |
| 2 m /CL | 0.263                    | 0.300 | 0.272 | 0.233            | 0.281 | 0.263 | 0.2400                 | 0.3750 | 0.2878 | 0.167            | 0.571 | 0.303 | 0.200             | 0.324 | 0.267 |
| 2 c /CL | 0.260                    | 0.316 | 0.273 | 0.300            | 0.375 | 0.328 | 0.3125                 | 0.4348 | 0.3665 | 0.136            | 0.643 | 0.348 | 0.200             | 0.367 | 0.279 |
| 2 p /CL | 0.100                    | 0.211 | 0.130 | 0.103            | 0.166 | 0.131 | 0.1250                 | 0.2000 | 0.1608 | 0.065            | 0.190 | 0.119 | 0.267             | 0.347 | 0.314 |
| 2 d /CL | 0.053                    | 0.105 | 0.078 | 0.063            | 0.069 | 0.066 | 0.0435                 | 0.0952 | 0.0660 | 0.032            | 0.095 | 0.060 | 0.133             | 0.204 | 0.164 |
| 2CH/CL  | 0.789                    | 1.053 | 0.896 | 0.833            | 1.000 | 0.910 | 1.0000                 | 1.1905 | 1.0781 | 0.609            | 2.000 | 1.080 | 1.033             | 1.469 | 1.206 |
| 3CH/CL  | 1.050                    | 1.263 | 1.131 | 1.219            | 1.276 | 1.254 | 1.0952                 | 1.5952 | 1.3424 | 0.906            | 2.214 | 1.392 | 1.351             | 2.000 | 1.649 |
| 4CH/CL  | 1.000                    | 1.368 | 1.171 | 1.400            | 1.483 | 1.430 | 1.1739                 | 1.7619 | 1.5162 | 0.806            | 1.714 | 1.083 | 0.865             | 1.500 | 1.217 |
| 5CH/CL  | 1.400                    | 1.526 | 1.442 | 1.344            | 1.467 | 1.420 | 1.3043                 | 1.8125 | 1.5066 | 0.813            | 1.786 | 1.309 | 0.738             | 1.367 | 1.043 |
| TeI/CL  | 0.316                    | 0.500 | 0.428 | 0.552            | 0.633 | 0.593 | 0.3200                 | 0.5938 | 0.4718 | 0.233            | 1.143 | 0.514 | 0.245             | 0.433 | 0.365 |
| Ur/CL   | 0.474                    | 0.700 | 0.596 | 0.621            | 0.700 | 0.659 | 0.3750                 | 0.8261 | 0.6250 | 0.280            | 0.667 | 0.441 | 0.500             | 0.643 | 0.576 |
| RL/2CH  | 0.300                    | 0.467 | 0.384 | 0.875            | 1.040 | 0.984 | 0.4400                 | 0.6364 | 0.5555 | 0.321            | 0.786 | 0.485 | 0.387             | 1.029 | 0.751 |
| TEI/2CH | 0.400                    | 0.596 | 0.476 | 0.594            | 0.760 | 0.656 | 0.3077                 | 0.5758 | 0.4389 | 0.286            | 0.906 | 0.461 | 0.167             | 0.387 | 0.311 |
| Ur/2 CH | 0.600                    | 0.778 | 0.663 | 0.656            | 0.840 | 0.730 | 0.3158                 | 0.8281 | 0.5865 | 0.233            | 0.786 | 0.450 | 0.417             | 0.581 | 0.482 |
| RL/2 c  | 1.000                    | 1.400 | 1.250 | 2.333            | 3.000 | 2.741 | 1.3000                 | 2.0000 | 1.6451 | 1.000            | 3.000 | 1.552 | 1.714             | 5.833 | 3.461 |



Table 2.2.3 Minimum, maximum, and mean of different ratios worked out using various morphometric measurements in deep sea prawns ( male ) under the super family Penaeoidea

| ratios   | <i>H. neovigenus</i> |       |       | <i>P. maritima</i> |       |       | <i>P. ensis</i> |       |       | <i>P. setosus</i> |       |       | <i>P. aznifipes</i> |       |       |
|----------|----------------------|-------|-------|--------------------|-------|-------|-----------------|-------|-------|-------------------|-------|-------|---------------------|-------|-------|
|          | Min                  | Max   | Mean  | Min                | Max   | Mean  | Min             | Max   | Mean  | Min               | Max   | Mean  | Min                 | Max   | Mean  |
| CL/TL    | 0.343                | 0.367 | 0.357 | 0.196              | 0.221 | 0.207 | 0.204           | 0.283 | 0.235 | 0.211             | 0.232 | 0.222 | 0.207               | 0.280 | 0.233 |
| RL/TL    | 0.286                | 0.343 | 0.314 | 0.344              | 0.384 | 0.359 | 0.271           | 0.310 | 0.295 | 0.302             | 0.421 | 0.396 | 0.267               | 0.363 | 0.332 |
| 1CH/TL   | 0.296                | 0.324 | 0.308 | 0.261              | 0.304 | 0.280 | 0.212           | 0.313 | 0.252 | 0.175             | 0.224 | 0.196 | 0.344               | 0.444 | 0.376 |
| 2 I / TL | 0.061                | 0.066 | 0.075 | 0.065              | 0.076 | 0.070 | 0.062           | 0.063 | 0.075 | 0.103             | 0.116 | 0.108 | 0.065               | 0.063 | 0.079 |
| 2 m / TL | 0.051                | 0.069 | 0.059 | 0.065              | 0.076 | 0.072 | 0.053           | 0.094 | 0.079 | 0.103             | 0.130 | 0.119 | 0.072               | 0.111 | 0.092 |
| 2 c / TL | 0.088                | 0.095 | 0.092 | 0.097              | 0.116 | 0.107 | 0.101           | 0.115 | 0.107 | 0.121             | 0.174 | 0.151 | 0.116               | 0.153 | 0.135 |
| 2 p / TL | 0.039                | 0.048 | 0.043 | 0.011              | 0.021 | 0.013 | 0.018           | 0.021 | 0.020 | 0.034             | 0.043 | 0.038 | 0.011               | 0.023 | 0.018 |
| 2 d / TL | 0.020                | 0.029 | 0.023 | 0.005              | 0.011 | 0.009 | 0.009           | 0.010 | 0.010 | 0.017             | 0.029 | 0.021 | 0.010               | 0.014 | 0.011 |
| 2CH / TL | 0.265                | 0.314 | 0.291 | 0.247              | 0.278 | 0.270 | 0.186           | 0.240 | 0.216 | 0.232             | 0.281 | 0.263 | 0.305               | 0.375 | 0.335 |
| 3CH / TL | 0.422                | 0.469 | 0.453 | 0.278              | 0.304 | 0.298 | 0.303           | 0.333 | 0.315 | 0.345             | 0.351 | 0.348 | 0.625               | 1.153 | 0.920 |
| 4CH / TL | 0.476                | 0.500 | 0.486 | 0.344              | 0.359 | 0.350 | 0.253           | 0.313 | 0.277 | 0.275             | 0.333 | 0.295 | 0.737               | 1.250 | 0.965 |
| 5CH / TL | 0.438                | 0.480 | 0.453 | 0.283              | 0.328 | 0.307 | 0.283           | 0.313 | 0.303 | 0.259             | 0.316 | 0.278 | 0.832               | 1.278 | 1.019 |
| Te/TL    | 0.112                | 0.476 | 0.134 | 0.093              | 0.116 | 0.100 | 0.106           | 0.115 | 0.111 | 0.116             | 0.123 | 0.120 | 0.082               | 0.163 | 0.129 |
| RL/CL    | 0.778                | 0.947 | 0.880 | 1.684              | 1.789 | 1.738 | 1.071           | 1.522 | 1.277 | 1.615             | 2.000 | 1.788 | 1.037               | 1.800 | 1.441 |
| 1CH/CL   | 0.806                | 0.895 | 0.862 | 1.200              | 1.556 | 1.362 | 0.750           | 1.429 | 1.103 | 0.813             | 1.000 | 0.882 | 1.185               | 1.778 | 1.624 |
| 2 I / CL | 0.167                | 0.237 | 0.211 | 0.316              | 0.368 | 0.337 | 0.286           | 0.381 | 0.324 | 0.462             | 0.500 | 0.487 | 0.286               | 0.381 | 0.339 |
| 2 m / CL | 0.139                | 0.200 | 0.166 | 0.316              | 0.389 | 0.348 | 0.281           | 0.429 | 0.337 | 0.462             | 0.583 | 0.536 | 0.318               | 0.476 | 0.398 |
| 2 c / CL | 0.250                | 0.283 | 0.257 | 0.474              | 0.558 | 0.516 | 0.357           | 0.524 | 0.468 | 0.538             | 0.750 | 0.679 | 0.476               | 0.706 | 0.584 |
| 2 p / CL | 0.111                | 0.132 | 0.119 | 0.050              | 0.105 | 0.083 | 0.071           | 0.095 | 0.085 | 0.154             | 0.188 | 0.169 | 0.048               | 0.100 | 0.076 |
| 2 d / CL | 0.086                | 0.079 | 0.084 | 0.025              | 0.056 | 0.042 | 0.036           | 0.048 | 0.042 | 0.077             | 0.125 | 0.095 | 0.037               | 0.059 | 0.048 |
| 2CH/CL   | 0.722                | 0.722 | 0.818 | 1.211              | 1.421 | 1.306 | 0.786           | 1.095 | 0.931 | 1.000             | 1.333 | 1.188 | 1.222               | 1.588 | 1.444 |
| 3CH / CL | 1.229                | 1.289 | 1.265 | 1.368              | 1.556 | 1.444 | 1.071           | 1.524 | 1.372 | 1.500             | 1.867 | 1.568 | 2.609               | 4.941 | 3.978 |
| 4CH / CL | 1.316                | 1.400 | 1.359 | 1.579              | 1.789 | 1.696 | 0.893           | 1.429 | 1.209 | 1.188             | 1.583 | 1.334 | 2.593               | 5.284 | 4.183 |
| 5CH / CL | 1.211                | 1.306 | 1.267 | 1.300              | 1.611 | 1.487 | 1.107           | 1.429 | 1.309 | 1.125             | 1.500 | 1.260 | 2.926               | 5.529 | 4.412 |
| Te/CL    | 0.306                | 0.421 | 0.376 | 0.450              | 0.526 | 0.485 | 0.393           | 0.524 | 0.479 | 0.500             | 0.583 | 0.541 | 0.364               | 0.667 | 0.556 |
| RL/2CH   | 1.067                | 1.091 | 0.349 | 1.258              | 1.404 | 1.334 | 1.130           | 1.667 | 1.367 | 1.313             | 1.750 | 1.521 | 0.821               | 1.200 | 0.998 |
| TEL/2CH  | 0.423                | 0.485 | 1.078 | 0.333              | 0.426 | 0.373 | 0.478           | 0.571 | 0.517 | 0.438             | 0.500 | 0.458 | 0.267               | 0.500 | 0.386 |
| RL/2 c   | 3.111                | 3.600 | 0.458 | 3.200              | 3.556 | 3.371 | 2.364           | 3.000 | 2.760 | 2.333             | 3.000 | 2.667 | 2.000               | 2.909 | 2.473 |
| CL/2 c   | 3.800                | 4.000 | 0.430 | 1.800              | 2.111 | 1.942 | 1.909           | 2.800 | 2.209 | 1.333             | 1.857 | 1.508 | 1.417               | 2.100 | 1.733 |

Table 2.3.3 (Continued)

| ratios  | <i>P. navigatoris</i> |       |       |       |       | <i>P. ornata</i> |       |       |       |       | <i>P. atcocki</i> |       |       |       |       | <i>P. spirripes</i> |     |      |     |     |      |  |
|---------|-----------------------|-------|-------|-------|-------|------------------|-------|-------|-------|-------|-------------------|-------|-------|-------|-------|---------------------|-----|------|-----|-----|------|--|
|         | Min                   | Max   | Mean  | Min   | Max   | Min              | Max   | Mean  | Min   | Max   | Min               | Max   | Mean  | Min   | Max   | Min                 | Max | Mean | Min | Max | Mean |  |
| 2 m/2cl | 0.556                 | 0.778 | 0.644 | 0.600 | 0.700 | 0.673            | 0.500 | 0.739 | 0.750 | 0.857 | 0.795             | 0.538 | 0.899 | 0.909 | 0.689 |                     |     |      |     |     |      |  |
| 2p/2cl  | 0.444                 | 3.800 | 0.463 | 0.100 | 0.200 | 0.122            | 0.167 | 0.200 | 0.183 | 0.222 | 0.286             | 0.083 | 0.200 | 0.200 | 0.131 |                     |     |      |     |     |      |  |
| 2d/2cl  | 0.222                 | 0.300 | 0.248 | 0.050 | 0.111 | 0.082            | 0.083 | 0.100 | 0.091 | 0.111 | 0.167             | 0.140 | 0.071 | 0.100 | 0.083 |                     |     |      |     |     |      |  |
| 2CH/2cl | 2.889                 | 3.333 | 3.174 | 2.350 | 2.700 | 2.531            | 1.750 | 2.200 | 2.014 | 1.333 | 2.286             | 1.799 | 2.250 | 2.818 | 2.487 |                     |     |      |     |     |      |  |
| TEL/2cl | 1.222                 | 1.600 | 1.459 | 0.900 | 1.000 | 0.940            | 1.000 | 1.100 | 1.033 | 0.667 | 1.000             | 0.815 | 0.615 | 1.400 | 0.966 |                     |     |      |     |     |      |  |
| 2i/2 m  | 1.143                 | 1.500 | 1.281 | 0.857 | 1.000 | 0.971            | 0.889 | 1.167 | 0.981 | 0.857 | 1.000             | 0.915 | 0.667 | 1.000 | 0.860 |                     |     |      |     |     |      |  |
| 2 c/2 m | 1.286                 | 1.800 | 1.584 | 1.429 | 1.667 | 1.490            | 1.111 | 2.000 | 1.444 | 1.167 | 1.333             | 1.262 | 1.100 | 1.857 | 1.485 |                     |     |      |     |     |      |  |
| 2 p/2m  | 0.571                 | 0.833 | 0.735 | 0.143 | 0.286 | 0.181            | 0.222 | 0.333 | 0.259 | 0.286 | 0.333             | 0.317 | 0.100 | 0.286 | 0.196 |                     |     |      |     |     |      |  |
| 2d/2 m  | 0.286                 | 1.286 | 0.395 | 0.071 | 0.167 | 0.121            | 0.111 | 0.167 | 0.130 | 0.143 | 0.222             | 0.177 | 0.100 | 0.143 | 0.122 |                     |     |      |     |     |      |  |
| 2CH/2 m | 4.286                 | 5.500 | 4.995 | 3.571 | 3.917 | 3.764            | 2.444 | 3.500 | 2.833 | 1.778 | 2.667             | 2.243 | 3.100 | 4.286 | 3.663 |                     |     |      |     |     |      |  |
| TEL/2 m | 2.000                 | 2.667 | 2.289 | 1.286 | 1.667 | 1.405            | 1.222 | 2.000 | 1.481 | 0.889 | 1.167             | 1.019 | 1.000 | 1.750 | 1.404 |                     |     |      |     |     |      |  |
| CU/2m   | 5.000                 | 7.200 | 6.178 | 2.571 | 3.167 | 2.895            | 2.333 | 3.833 | 3.093 | 1.714 | 2.167             | 1.886 | 2.100 | 3.143 | 2.548 |                     |     |      |     |     |      |  |
| RL/2 m  | 4.571                 | 6.000 | 5.390 | 4.571 | 5.500 | 5.024            | 2.889 | 5.833 | 4.019 | 3.111 | 3.500             | 3.347 | 2.556 | 5.143 | 3.678 |                     |     |      |     |     |      |  |
| 3rd/4th | 0.878                 | 0.980 | 0.932 | 0.794 | 0.875 | 0.852            | 1.067 | 1.200 | 1.144 | 1.053 | 1.263             | 1.189 | 0.638 | 1.200 | 0.965 |                     |     |      |     |     |      |  |
| 3rd/5th | 0.956                 | 4.571 | 1.000 | 0.929 | 1.077 | 0.974            | 0.968 | 1.094 | 1.043 | 1.111 | 1.333             | 1.259 | 0.600 | 1.063 | 0.909 |                     |     |      |     |     |      |  |
| 4th/5th | 1.043                 | 1.089 | 1.073 | 1.071 | 1.269 | 1.144            | 0.806 | 1.000 | 0.915 | 1.056 | 1.067             | 1.059 | 0.875 | 0.989 | 0.945 |                     |     |      |     |     |      |  |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length  
 2i - ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2cl - carpus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2d - dactylus of 2nd cheliped  
 1 CH- Length of 1st cheliped  
 2 CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped



Table 2 B.4 Minimum, maximum, and mean of different ratios worked out using various morphometric measurements in deep sea prawns (male) under the super family Paridolidae

| ratios  | <i>H. leevigatus</i> |       |       | <i>P. merita</i> |       |       | <i>P. ensis</i> |       |       | <i>P. siccocki</i> |       |       | <i>P. spinipes</i> |       |       |
|---------|----------------------|-------|-------|------------------|-------|-------|-----------------|-------|-------|--------------------|-------|-------|--------------------|-------|-------|
|         | Min                  | Max   | Mean  | Min              | Max   | Mean  | Min             | Max   | Mean  | Min                | Max   | Mean  | Min                | Max   | Mean  |
| CL/TL   | 0.360                | 0.375 | 0.361 | 0.200            | 0.231 | 0.213 | 0.221           | 0.336 | 0.261 | 0.211              | 0.233 | 0.219 | 0.221              | 0.290 | 0.242 |
| RL/TL   | 0.330                | 0.340 | 0.335 | 0.291            | 0.368 | 0.323 | 0.241           | 0.344 | 0.300 | 0.368              | 0.421 | 0.393 | 0.286              | 0.372 | 0.311 |
| 1CH/TL  | 0.310                | 0.317 | 0.313 | 0.250            | 0.304 | 0.275 | 0.213           | 0.476 | 0.311 | 0.211              | 0.217 | 0.214 | 0.330              | 0.433 | 0.376 |
| 21/TL   | 0.087                | 0.090 | 0.088 | 0.056            | 0.066 | 0.061 | 0.074           | 0.092 | 0.085 | 0.067              | 0.089 | 0.081 | 0.064              | 0.097 | 0.081 |
| 2 m /TL | 0.050                | 0.058 | 0.055 | 0.058            | 0.070 | 0.065 | 0.061           | 0.098 | 0.082 | 0.105              | 0.125 | 0.116 | 0.076              | 0.100 | 0.090 |
| 2 c /TL | 0.090                | 0.097 | 0.094 | 0.091            | 0.117 | 0.105 | 0.102           | 0.152 | 0.121 | 0.143              | 0.200 | 0.167 | 0.133              | 0.173 | 0.148 |
| 2 p /TL | 0.048                | 0.050 | 0.049 | 0.010            | 0.019 | 0.014 | 0.018           | 0.026 | 0.021 | 0.033              | 0.036 | 0.035 | 0.011              | 0.022 | 0.020 |
| 2 d /TL | 0.029                | 0.030 | 0.029 | 0.005            | 0.012 | 0.010 | 0.009           | 0.011 | 0.010 | 0.017              | 0.018 | 0.017 | 0.009              | 0.011 | 0.010 |
| 2CH /TL | 0.310                | 0.320 | 0.316 | 0.232            | 0.270 | 0.254 | 0.202           | 0.283 | 0.234 | 0.267              | 0.368 | 0.278 | 0.327              | 0.385 | 0.349 |
| 3CH /TL | 0.410                | 0.471 | 0.449 | 0.278            | 0.304 | 0.291 | 0.291           | 0.344 | 0.313 | 0.350              | 0.393 | 0.365 | 0.676              | 0.676 | 0.882 |
| 4CH /TL | 0.481                | 0.481 | 0.485 | 0.313            | 0.360 | 0.336 | 0.259           | 0.370 | 0.310 | 0.318              | 0.339 | 0.324 | 0.515              | 1.032 | 0.767 |
| 5CH /TL | 0.423                | 0.480 | 0.460 | 0.281            | 0.349 | 0.312 | 0.277           | 0.368 | 0.321 | 0.298              | 0.321 | 0.307 | 0.649              | 1.032 | 0.842 |
| Te/TL   | 0.135                | 0.146 | 0.140 | 0.099            | 0.132 | 0.115 | 0.104           | 0.126 | 0.114 | 0.123              | 0.143 | 0.133 | 0.099              | 0.156 | 0.134 |
| RL/CL   | 0.897                | 0.946 | 0.929 | 1.333            | 1.684 | 1.520 | 0.744           | 1.500 | 1.186 | 1.750              | 1.833 | 1.790 | 1.107              | 1.800 | 1.264 |
| 1CH/CL  | 0.846                | 0.886 | 0.866 | 1.143            | 1.478 | 1.293 | 0.714           | 0.744 | 1.234 | 0.929              | 1.000 | 0.976 | 1.292              | 1.762 | 1.552 |
| 21/CL   | 0.231                | 0.257 | 0.244 | 0.263            | 0.316 | 0.286 | 0.256           | 0.375 | 0.331 | 0.286              | 0.417 | 0.373 | 0.286              | 0.391 | 0.336 |
| 2 m /CL | 0.143                | 0.162 | 0.153 | 0.273            | 0.348 | 0.305 | 0.222           | 0.429 | 0.320 | 0.500              | 0.583 | 0.528 | 0.292              | 0.429 | 0.370 |
| 2 c /CL | 0.256                | 0.256 | 0.261 | 0.429            | 0.565 | 0.493 | 0.357           | 0.609 | 0.474 | 0.667              | 0.857 | 0.758 | 0.536              | 0.692 | 0.613 |
| 2 p /CL | 0.128                | 0.143 | 0.135 | 0.048            | 0.091 | 0.064 | 0.056           | 0.095 | 0.082 | 0.143              | 0.167 | 0.159 | 0.045              | 0.085 | 0.083 |
| 2 d /CL | 0.077                | 0.086 | 0.081 | 0.026            | 0.056 | 0.045 | 0.026           | 0.048 | 0.040 | 0.071              | 0.083 | 0.079 | 0.036              | 0.048 | 0.042 |
| 2CH/CL  | 0.846                | 0.892 | 0.875 | 1.095            | 1.348 | 1.193 | 0.667           | 1.095 | 0.916 | 1.143              | 1.333 | 1.270 | 1.286              | 1.619 | 1.443 |
| 3CH /CL | 1.171                | 1.297 | 1.242 | 1.238            | 1.474 | 1.368 | 0.872           | 1.524 | 1.226 | 1.500              | 1.833 | 1.667 | 2.760              | 4.941 | 3.642 |
| 4CH /CL | 1.282                | 1.400 | 1.344 | 1.429            | 1.722 | 1.561 | 0.769           | 1.545 | 1.226 | 1.357              | 1.750 | 1.480 | 2.174              | 4.381 | 3.261 |
| 5CH /CL | 1.128                | 1.371 | 1.275 | 1.260            | 1.667 | 1.466 | 0.661           | 1.667 | 1.265 | 1.286              | 1.500 | 1.401 | 2.536              | 4.667 | 3.467 |
| Te/CL   | 0.359                | 0.405 | 0.388 | 0.429            | 0.632 | 0.541 | 0.333           | 0.571 | 0.446 | 0.571              | 0.667 | 0.607 | 0.365              | 0.667 | 0.553 |
| RL/2CH  | 1.061                | 1.065 | 1.062 | 1.136            | 1.429 | 1.276 | 1.036           | 1.650 | 1.296 | 1.313              | 1.563 | 1.417 | 0.788              | 1.032 | 0.891 |
| TEL/2CH | 0.424                | 0.455 | 0.443 | 0.391            | 0.517 | 0.454 | 0.400           | 0.550 | 0.491 | 0.438              | 0.500 | 0.479 | 0.278              | 0.455 | 0.363 |
| RL/2 c  | 3.500                | 3.667 | 3.566 | 2.983            | 3.556 | 3.067 | 2.071           | 3.000 | 2.502 | 2.063              | 2.750 | 2.389 | 1.824              | 2.500 | 2.102 |
| CL/2 c  | 3.700                | 3.700 | 3.630 | 1.769            | 2.333 | 2.045 | 1.643           | 2.800 | 2.186 | 1.167              | 1.500 | 1.333 | 1.444              | 1.867 | 1.639 |

**Table 2.2.5 Minimum , maximum, and mean of different ratios worked out using various morphometric measurements in deep sea prawns under the super family Pandaloidae**

| Ratios    | <i>H.gibbosus</i> |       |       |        |      |      | <i>H.woodmasoni</i> |        |       |        |        |       |
|-----------|-------------------|-------|-------|--------|------|------|---------------------|--------|-------|--------|--------|-------|
|           | Male              |       |       | Female |      |      | Male                |        |       | Female |        |       |
|           | Min               | Max   | Mean  | Min    | Max  | Mean | Min                 | Max    | Mean  | Min    | Max    | Mean  |
| CL/TL     | 0.270             | 0.322 | 0.301 | 0.05   | 0.35 | 0.27 | 0.242               | 0.386  | 0.284 | 0.161  | 0.293  | 0.272 |
| RL/TL     | 0.339             | 0.416 | 0.383 | 0.31   | 0.40 | 0.36 | 0.267               | 0.338  | 0.301 | 0.233  | 0.337  | 0.285 |
| 1CH/TL    | 0.281             | 0.415 | 0.324 | 0.28   | 0.38 | 0.32 | 0.194               | 0.248  | 0.219 | 0.196  | 0.239  | 0.217 |
| 2g i / TL | 0.088             | 0.120 | 0.102 | 0.06   | 0.11 | 0.10 | 0.034               | 0.075  | 0.056 | 0.054  | 0.075  | 0.082 |
| 2g m /TL  | 0.082             | 0.124 | 0.105 | 0.09   | 0.13 | 0.10 | 0.026               | 0.059  | 0.043 | 0.028  | 0.059  | 0.043 |
| 2g c /TL  | 0.083             | 0.113 | 0.083 | 0.05   | 0.10 | 0.08 | 0.051               | 0.157  | 0.110 | 0.095  | 0.141  | 0.119 |
| 2g p /TL  | 0.027             | 0.067 | 0.042 | 0.03   | 0.07 | 0.05 | 0.008               | 0.022  | 0.015 | 0.008  | 0.022  | 0.015 |
| 2g d /TL  | 0.005             | 0.012 | 0.009 | 0.01   | 0.01 | 0.01 | 0.004               | 0.011  | 0.007 | 0.004  | 0.011  | 0.008 |
| 2LCH /TL  | 0.349             | 0.446 | 0.418 | 0.32   | 0.48 | 0.42 | 0.034               | 0.075  | 0.056 | 0.054  | 0.075  | 0.062 |
| 2s i / TL | 0.038             | 0.103 | 0.082 | 0.05   | 0.10 | 0.08 | 0.038               | 0.065  | 0.053 | 0.029  | 0.065  | 0.051 |
| 2s m /TL  | 0.046             | 0.081 | 0.061 | 0.03   | 0.08 | 0.06 | 0.026               | 0.059  | 0.043 | 0.028  | 0.059  | 0.043 |
| 2s c /TL  | 0.083             | 0.113 | 0.083 | 0.05   | 0.10 | 0.08 | 0.051               | 0.157  | 0.057 | 0.095  | 0.141  | 0.119 |
| 2s p /TL  | 0.027             | 0.067 | 0.042 | 0.03   | 0.07 | 0.05 | 0.032               | 0.057  | 0.043 | 0.018  | 0.031  | 0.022 |
| 2s d /TL  | 0.017             | 0.034 | 0.023 | 0.02   | 0.03 | 0.02 | 0.018               | 0.031  | 0.022 | 0.015  | 0.031  | 0.020 |
| 2SCH/TL   | 0.243             | 0.349 | 0.290 | 0.18   | 0.38 | 0.30 | 0.190               | 0.254  | 0.217 | 0.142  | 0.254  | 0.211 |
| 3CH /TL   | 0.432             | 0.651 | 0.517 | 0.37   | 0.63 | 0.53 | 0.305               | 0.374  | 0.333 | 0.294  | 0.367  | 0.330 |
| 4CH /TL   | 0.459             | 0.977 | 0.560 | 0.39   | 0.65 | 0.53 | 0.297               | 0.369  | 0.332 | 0.310  | 0.367  | 0.334 |
| 5CH /TL   | 0.368             | 0.651 | 0.509 | 0.38   | 0.64 | 0.53 | 0.286               | 0.357  | 0.309 | 0.293  | 0.357  | 0.316 |
| Tel/TL    | 0.092             | 0.155 | 0.132 | 0.09   | 0.16 | 0.14 | 0.130               | 0.198  | 0.158 | 0.104  | 0.176  | 0.150 |
| RL/CL     | 1.135             | 1.542 | 1.276 | 0.97   | 1.29 | 1.16 | 0.692               | 1.667  | 1.085 | 0.824  | 1.667  | 1.082 |
| 1CH/CL    | 0.897             | 1.391 | 1.079 | 0.78   | 1.29 | 1.04 | 0.564               | 1.400  | 0.781 | 0.742  | 1.400  | 0.850 |
| 2g i / CL | 0.290             | 0.423 | 0.339 | 0.17   | 0.38 | 0.32 | 0.125               | 0.467  | 0.200 | 0.185  | 0.467  | 0.241 |
| 2g m /CL  | 0.285             | 0.394 | 0.349 | 0.22   | 0.41 | 0.34 | 0.156               | 0.400  | 0.244 | 0.226  | 0.400  | 0.276 |
| 2g c /CL  | 0.433             | 0.739 | 0.614 | 0.36   | 0.75 | 0.61 | 0.188               | 0.733  | 0.390 | 0.355  | 0.733  | 0.463 |
| 2g p /CL  | 0.033             | 0.083 | 0.061 | 0.03   | 0.09 | 0.06 | 0.031               | 0.133  | 0.052 | 0.031  | 0.133  | 0.060 |
| 2g d /CL  | 0.017             | 0.042 | 0.031 | 0.02   | 0.04 | 0.03 | 0.016               | 0.067  | 0.024 | 0.016  | 0.067  | 0.030 |
| 2LCH /L   | 1.117             | 1.583 | 1.394 | 0.83   | 1.59 | 1.36 | 0.516               | 1.800  | 0.909 | 0.911  | 1.800  | 1.069 |
| 2s i / CL | 0.121             | 0.348 | 0.272 | 0.17   | 0.35 | 0.27 | 0.128               | 0.333  | 0.188 | 0.103  | 0.333  | 0.199 |
| 2s m /CL  | 0.143             | 0.280 | 0.203 | 0.11   | 0.25 | 0.19 | 0.083               | 0.267  | 0.153 | 0.128  | 0.267  | 0.166 |
| 2s c /CL  | 0.208             | 0.375 | 0.276 | 0.17   | 0.34 | 0.27 | 0.154               | 0.333  | 0.203 | 0.069  | 0.333  | 0.217 |
| 2s p /CL  | 0.088             | 0.250 | 0.139 | 0.08   | 0.25 | 0.16 | 0.103               | 0.267  | 0.153 | 0.069  | 0.267  | 0.163 |
| 2s d /CL  | 0.054             | 0.125 | 0.078 | 0.06   | 0.11 | 0.08 | 0.051               | 0.111  | 0.077 | 0.052  | 0.111  | 0.077 |
| 2SCH/CL   | 0.788             | 1.250 | 0.968 | 0.58   | 1.28 | 0.96 | 0.538               | 1.300  | 0.776 | 0.500  | 1.300  | 0.823 |
| 3CH /CL   | 1.412             | 2.250 | 1.722 | 1.19   | 1.94 | 1.71 | 0.872               | 2.067  | 1.189 | 1.143  | 2.067  | 1.291 |
| 4CH /CL   | 1.500             | 3.360 | 1.867 | 1.25   | 2.00 | 1.71 | 0.846               | 2.133  | 1.185 | 1.074  | 2.133  | 1.308 |
| 5CH /CL   | 1.143             | 2.250 | 1.695 | 1.22   | 2.14 | 1.71 | 0.795               | 2.067  | 1.099 | 1.000  | 2.067  | 1.236 |
| PD/CL     | 0.182             | 0.375 | 0.281 | 0.14   | 0.46 | 0.29 | 0.179               | 0.533  | 0.252 | 0.133  | 0.533  | 0.282 |
| RL/2SCH   | 1.091             | 1.593 | 1.335 | 0.98   | 2.10 | 1.24 | 1.174               | 1.931  | 1.395 | 1.037  | 1.931  | 1.328 |
| TEL/ SCH  | 0.298             | 0.583 | 0.460 | 0.28   | 0.67 | 0.47 | 0.588               | 1.241  | 0.731 | 0.478  | 1.241  | 0.746 |
| RL/2 s d  | 3.273             | 6.143 | 4.743 | 3.55   | 7.33 | 4.48 | 4.500               | 14.000 | 5.340 | 4.000  | 14.000 | 5.255 |
| CL/2s d   | 2.687             | 4.857 | 3.736 | 2.91   | 6.00 | 3.87 | 4.333               | 14.500 | 5.028 | 3.000  | 14.500 | 4.987 |

Table 2.2.5 Continued.....

| Ratio     | <i>H.gibbosus</i> |       |       |        |       |      | <i>H.woodmasoni</i> |        |       |        |        |       |
|-----------|-------------------|-------|-------|--------|-------|------|---------------------|--------|-------|--------|--------|-------|
|           | Male              |       |       | Female |       |      | Male                |        |       | Female |        |       |
|           | Min               | Max   | Mean  | Min    | Max   | Mean | Min                 | Max    | Mean  | Min    | Max    | Mean  |
| 2si/2scl  | 0.444             | 1.286 | 1.003 | 0.82   | 1.29  | 1.02 | 0.667               | 1.500  | 0.933 | 0.600  | 1.500  | 0.934 |
| 2sm/2scl  | 0.444             | 1.000 | 0.751 | 0.50   | 0.89  | 0.71 | 0.500               | 3.000  | 0.760 | 0.500  | 3.000  | 0.835 |
| 2spi/2scl | 0.273             | 0.857 | 0.512 | 0.40   | 1.00  | 0.60 | 0.600               | 1.000  | 0.758 | 0.500  | 1.000  | 0.757 |
| 2sd/2scl  | 0.182             | 0.429 | 0.288 | 0.18   | 0.43  | 0.29 | 0.333               | 0.750  | 0.383 | 0.286  | 0.750  | 0.368 |
| 2sCH/2scl | 2.889             | 4.429 | 3.554 | 3.10   | 4.29  | 3.62 | 3.333               | 7.250  | 3.834 | 3.333  | 7.250  | 3.894 |
| RL/2scl   | 3.273             | 6.143 | 4.743 | 3.55   | 7.33  | 4.48 | 4.500               | 6.500  | 5.340 | 4.000  | 14.000 | 5.567 |
| TEL/2scl  | 1.143             | 2.286 | 1.630 | 1.00   | 2.67  | 1.69 | 2.500               | 3.167  | 2.784 | 1.833  | 9.000  | 3.088 |
| RL/2im    | 1.762             | 3.000 | 2.098 | 1.52   | 2.77  | 1.92 | 1.833               | 5.667  | 2.946 | 1.867  | 2.909  | 2.341 |
| CL/2im    | 1.353             | 2.308 | 1.651 | 1.33   | 2.77  | 1.67 | 2.000               | 5.333  | 2.740 | 1.364  | 2.818  | 2.204 |
| 2li/2im   | 0.471             | 0.692 | 0.555 | 0.40   | 0.67  | 0.53 | 0.389               | 0.857  | 0.527 | 0.385  | 0.636  | 0.520 |
| 2lm/2im   | 0.471             | 0.769 | 0.574 | 0.46   | 0.67  | 0.55 | 0.500               | 1.143  | 0.646 | 0.533  | 0.727  | 0.599 |
| 2ip/2im   | 0.059             | 0.125 | 0.100 | 0.06   | 0.15  | 0.10 | 0.083               | 0.286  | 0.141 | 0.087  | 0.182  | 0.128 |
| 2id/2im   | 0.029             | 0.063 | 0.050 | 0.03   | 0.08  | 0.05 | 0.036               | 0.143  | 0.065 | 0.033  | 0.091  | 0.064 |
| 2LCH/2im  | 2.088             | 2.577 | 2.279 | 2.05   | 2.50  | 2.23 | 2.056               | 3.429  | 2.379 | 2.107  | 2.636  | 2.312 |
| 2si/2sm   | 0.571             | 2.000 | 1.368 | 1.13   | 2.00  | 1.45 | 0.600               | 1.500  | 0.934 | 0.600  | 1.500  | 0.934 |
| 2si/2sm   | 1.000             | 2.250 | 1.379 | 1.13   | 2.00  | 1.44 | 0.333               | 2.000  | 1.348 | 0.333  | 2.000  | 1.348 |
| 2spi/2sm  | 0.429             | 1.200 | 0.696 | 0.50   | 1.17  | 0.85 | 0.333               | 1.667  | 1.008 | 0.333  | 1.500  | 1.005 |
| 2sd/2sm   | 0.286             | 0.600 | 0.388 | 0.25   | 0.75  | 0.42 | 0.250               | 1.000  | 0.495 | 0.250  | 0.750  | 0.478 |
| 2sCH/2sm  | 3.714             | 6.750 | 4.831 | 4.00   | 6.75  | 5.16 | 2.417               | 8.000  | 5.095 | 2.417  | 6.667  | 5.060 |
| TEL/2sm   | 1.333             | 3.250 | 2.210 | 1.33   | 3.50  | 2.41 | 2.333               | 6.000  | 3.650 | 2.333  | 5.333  | 3.564 |
| RL/2im    | 3.077             | 4.556 | 3.678 | 4.88   | 11.00 | 6.38 | 4.500               | 11.000 | 6.900 | 4.500  | 10.667 | 6.696 |
| CL/2im    | 2.538             | 3.778 | 2.889 | 2.43   | 4.50  | 3.01 | 3.750               | 12.000 | 6.487 | 3.750  | 9.333  | 6.255 |
| 2li/2im   | 0.848             | 1.222 | 0.975 | 0.71   | 1.11  | 0.96 | 0.667               | 1.167  | 0.856 | 0.714  | 1.167  | 0.873 |
| 2lm/2im   | 1.300             | 2.125 | 1.767 | 1.50   | 2.18  | 1.82 | 0.875               | 2.000  | 1.649 | 1.375  | 1.875  | 1.683 |
| 2ip/2im   | 0.100             | 0.222 | 0.177 | 0.10   | 0.27  | 0.18 | 0.111               | 0.333  | 0.214 | 0.111  | 0.333  | 0.214 |
| 2id/2im   | 0.050             | 0.111 | 0.088 | 0.05   | 0.13  | 0.08 | 0.056               | 0.167  | 0.104 | 0.056  | 0.167  | 0.107 |
| 2LCH/2im  | 3.350             | 4.556 | 4.007 | 3.67   | 4.64  | 4.04 | 3.000               | 4.500  | 3.818 | 3.357  | 4.500  | 3.877 |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 TEL- Telson length  
 Ur- uropod length

2si - ischium of 2nd cheliped  
 2sm - merus of 2nd cheliped  
 2scl - carpus of 2nd cheliped  
 2sp - propodus of 2nd cheliped  
 2sd - dactylus of 2nd cheliped  
 2li - ischium of 2nd cheliped  
 2lm - merus of 2nd cheliped  
 2icl - carpus of 2nd cheliped

2ip - propodus of 2nd cheliped  
 2id - dactylus of 2nd cheliped  
 1 CH- Length of 1st cheliped  
 2sCH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5 CH- Length of 5th cheliped  
 2LCH- Length of 2nd cheliped

| Ratios  | A. zambesiaca |       |       |       |       |       |        |       |       |       |       |       | O. nyanus |       |       |       |       |       |        |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|---------|---------------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-----------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|         | Male          |       |       |       |       |       | Female |       |       |       |       |       | Male      |       |       |       |       |       | Female |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|         | Min           | Max   | Mean  | Min   | Max   | Mean  | Min    | Max   | Mean  | Min   | Max   | Mean  | Min       | Max   | Mean  | Min   | Max   | Mean  | Min    | Max   | Mean  | Min   | Max   | Mean  |       |       |       |       |       |       |       |       |       |       |       |       |       |
| CL/TL   | 0.184         | 0.184 | 0.191 | 0.177 | 0.220 | 0.194 | 0.231  | 0.281 | 0.259 | 0.163 | 0.243 | 0.186 | 0.211     | 0.234 | 0.225 | 0.207 | 0.233 | 0.221 | 0.260  | 0.276 | 0.268 | 0.240 | 0.265 | 0.255 | 0.229 | 0.278 | 0.248 | 0.106 | 0.301 | 0.180 | 0.274 | 0.297 | 0.267 | 0.250 | 0.286 | 0.265 |       |
| RL/TL   | 0.267         | 0.267 | 0.278 | 0.245 | 0.271 | 0.259 | 0.203  | 0.231 | 0.226 | 0.186 | 0.252 | 0.215 | 0.158     | 0.203 | 0.180 | 0.138 | 0.206 | 0.170 | 0.034  | 0.050 | 0.045 | 0.042 | 0.051 | 0.048 | 0.024 | 0.039 | 0.031 | 0.018 | 0.047 | 0.032 | 0.033 | 0.048 | 0.038 | 0.048 | 0.052 | 0.044 |       |
| 2 m /TL | 0.067         | 0.070 | 0.066 | 0.062 | 0.070 | 0.061 | 0.046  | 0.072 | 0.058 | 0.035 | 0.049 | 0.042 | 0.035     | 0.063 | 0.049 | 0.033 | 0.052 | 0.044 | 0.034  | 0.059 | 0.048 | 0.062 | 0.061 | 0.058 | 0.056 | 0.078 | 0.066 | 0.018 | 0.063 | 0.044 | 0.017 | 0.048 | 0.027 | 0.048 | 0.027 | 0.022 |       |
| 2 p /TL | 0.023         | 0.023 | 0.028 | 0.021 | 0.031 | 0.027 | 0.035  | 0.039 | 0.037 | 0.020 | 0.039 | 0.028 | 0.016     | 0.031 | 0.020 | 0.017 | 0.032 | 0.022 | 0.011  | 0.020 | 0.017 | 0.010 | 0.020 | 0.017 | 0.010 | 0.020 | 0.014 | 0.010 | 0.020 | 0.014 | 0.009 | 0.024 | 0.016 | 0.016 | 0.022 | 0.016 |       |
| 2 d /TL | 0.161         | 0.228 | 0.203 | 0.177 | 0.230 | 0.211 | 0.189  | 0.255 | 0.213 | 0.153 | 0.214 | 0.180 | 0.096     | 0.234 | 0.160 | 0.117 | 0.198 | 0.148 | 0.267  | 0.290 | 0.276 | 0.240 | 0.260 | 0.265 | 0.314 | 0.437 | 0.346 | 0.156 | 0.234 | 0.188 | 0.172 | 0.254 | 0.203 | 0.231 | 0.286 | 0.231 |       |
| 3CH /TL | 0.277         | 0.322 | 0.303 | 0.260 | 0.310 | 0.289 | 0.301  | 0.370 | 0.324 | 0.235 | 0.379 | 0.300 | 0.175     | 0.250 | 0.208 | 0.190 | 0.270 | 0.231 | 0.270  | 0.299 | 0.285 | 0.271 | 0.306 | 0.289 | 0.261 | 0.406 | 0.318 | 0.145 | 0.213 | 0.169 | 0.190 | 0.238 | 0.209 | 0.209 | 0.250 | 0.209 |       |
| Ur/TL   | 0.138         | 0.138 | 0.145 | 0.146 | 0.160 | 0.153 | 0.147  | 0.163 | 0.156 | 0.094 | 0.155 | 0.127 | 0.129     | 0.148 | 0.139 | 0.086 | 0.150 | 0.121 | 0.149  | 0.168 | 0.159 | 0.163 | 0.160 | 0.170 | 0.124 | 0.130 | 0.127 | 0.059 | 0.126 | 0.096 | 0.105 | 0.131 | 0.119 | 0.103 | 0.127 | 0.116 |       |
| Te/TL   | 1.350         | 1.500 | 1.406 | 1.182 | 1.444 | 1.326 | 0.814  | 1.200 | 0.970 | 0.692 | 1.240 | 0.915 | 1.214     | 1.333 | 1.275 | 1.071 | 1.266 | 1.202 | 1.350  | 1.563 | 1.462 | 1.182 | 1.529 | 1.348 | 0.721 | 1.120 | 0.886 | 1.040 | 1.250 | 0.887 | 0.929 | 1.266 | 1.100 | 0.770 | 1.310 | 1.000 |       |
| 1CH/CL  | 0.188         | 0.263 | 0.234 | 0.227 | 0.278 | 0.247 | 0.132  | 0.233 | 0.175 | 0.154 | 0.188 | 0.167 | 0.083     | 0.200 | 0.142 | 0.143 | 0.214 | 0.175 | 0.313  | 0.313 | 0.344 | 0.294 | 0.333 | 0.315 | 0.184 | 0.256 | 0.213 | 0.200 | 0.250 | 0.227 | 0.167 | 0.267 | 0.215 | 0.143 | 0.250 | 0.202 |       |
| 2 m /CL | 0.188         | 0.300 | 0.250 | 0.273 | 0.333 | 0.300 | 0.209  | 0.280 | 0.233 | 0.320 | 0.385 | 0.360 | 0.063     | 0.267 | 0.195 | 0.071 | 0.214 | 0.123 | 0.126  | 0.158 | 0.144 | 0.118 | 0.167 | 0.140 | 0.132 | 0.160 | 0.144 | 0.125 | 0.180 | 0.146 | 0.071 | 0.143 | 0.099 | 0.143 | 0.214 | 0.123 |       |
| 2 p /CL | 0.063         | 0.105 | 0.089 | 0.069 | 0.111 | 0.087 | 0.040  | 0.209 | 0.054 | 0.040 | 0.125 | 0.081 | 0.036     | 0.133 | 0.062 | 0.042 | 0.107 | 0.073 | 0.875  | 1.158 | 1.061 | 1.000 | 1.222 | 1.069 | 0.711 | 0.907 | 0.819 | 0.860 | 1.063 | 0.961 | 0.468 | 1.000 | 0.704 | 0.500 | 0.893 | 0.673 |       |
| 2 d /CL | 1.350         | 1.526 | 1.459 | 1.273 | 1.500 | 1.375 | 0.711  | 0.907 | 0.819 | 0.860 | 1.063 | 0.961 | 0.468     | 1.000 | 0.704 | 0.500 | 0.893 | 0.673 | 1.400  | 1.750 | 1.594 | 1.409 | 1.611 | 1.497 | 1.070 | 1.600 | 1.267 | 1.538 | 1.750 | 1.516 | 0.766 | 1.067 | 0.830 | 0.768 | 1.143 | 0.921 |       |
| 2CH/CL  | 1.400         | 1.750 | 1.594 | 1.409 | 1.611 | 1.497 | 1.070  | 1.600 | 1.267 | 1.538 | 1.750 | 1.516 | 0.766     | 1.067 | 0.830 | 0.768 | 1.143 | 0.921 | 1.421  | 1.421 | 1.489 | 1.318 | 1.667 | 1.505 | 0.930 | 1.440 | 1.123 | 1.680 | 1.769 | 1.712 | 0.843 | 0.766 | 0.839 | 0.857 | 1.071 | 0.948 |       |
| 4CH/CL  | 0.813         | 0.850 | 0.835 | 0.818 | 0.941 | 0.883 | 0.442  | 0.560 | 0.492 | 0.385 | 0.625 | 0.510 | 0.500     | 0.571 | 0.526 | 0.500 | 0.571 | 0.524 | Te/CL  | 0.750 | 0.789 | 0.763 | 0.727 | 0.833 | 0.795 | 0.563 | 0.680 | 0.605 | 0.615 | 0.813 | 0.689 | 0.571 | 0.667 | 0.620 | 0.417 | 0.643 | 0.544 |
| Ur/CL   | 1.174         | 1.714 | 1.357 | 1.130 | 1.353 | 1.222 | 0.897  | 1.429 | 1.195 | 0.892 | 1.409 | 0.955 | 1.267     | 2.909 | 1.965 | 1.440 | 2.143 | 1.861 | RL/2CH | 1.174 | 1.714 | 1.357 | 1.130 | 1.353 | 1.222 | 0.897 | 1.429 | 1.195 | 0.892 | 1.409 | 0.955 | 1.267 | 2.909 | 1.965 | 1.440 | 2.143 | 1.861 |



Table 2.5.1. Comparison of various sibship-coincidence ratios in three sex groups in the subject family (Parsanian)

| Ratio   | <i>A. alcocki</i>    | <i>P. investigatoris</i> | <i>P. jerryi</i>    | <i>M. andamanensis</i> | <i>S. hexiti</i>     | ANOVA  | t-test  | t                            | df                   | Probability                          |
|---------|----------------------|--------------------------|---------------------|------------------------|----------------------|--------|---|------------------------------|----------------------|--------------------------------------|
| CL/TL   | 0.29-0.29<br>(0.29)  | 0.30-0.28<br>(0.29)      | 0.28-0.29<br>(0.28) | 0.26-0.27<br>(0.27)    | 0.33-0.34*<br>(0.34) | P<0.05 | <i>S. hexiti</i> X <i>M. andamanensis</i><br><i>S. hexiti</i> X <i>A. alcocki</i>   | 1.91<br>2.74                 | 16<br>32             | P<0.05<br>P<0.05                     |
|         | 0.27-0.25*<br>(0.26) | 0.9-0.11<br>(0.10)       | 0.21-0.20<br>(0.21) | 0.16-0.18<br>(0.17)    | 0.15-0.16<br>(0.16)  | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hexiti</i> | 20.2<br>2.12<br>4.9<br>12.9  | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |
| 2 p /TL | 0.08-0.08*<br>(0.08) | 0.04-0.04<br>(0.04)      | 0.02-0.03<br>(0.03) | 0.03-0.05<br>(0.04)    | 0.03-0.04<br>(0.03)  | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i>   | 15.6<br>15.5<br>25.1         | 24<br>12<br>16       | P<0.05<br>P<0.05<br>P<0.05           |
|         | 0.35-0.37<br>(0.36)  | 0.24-0.27<br>(0.26)      | 0.16-0.25<br>(0.19) | 0.27-0.29<br>(0.28)    | 0.31-0.33<br>(0.32)  | P<0.05 | <i>A. alcocki</i> X <i>S. hexiti</i>  | 35.1                         | 32                   | P<0.05                               |
| RL/CL   | 0.91-0.94<br>(0.92)  | 0.33-0.35<br>(0.34)      | 0.81-0.89<br>(0.85) | 0.60-0.64<br>(0.62)    | 0.49-0.50<br>(0.50)  | P<0.05 | <i>P. jerryi</i> X <i>M. andamanensis</i>   | 3.73                         | 12                   | P<0.05                               |
| l CH/CL | 0.92-0.99*<br>(0.95) | 0.70-0.76<br>(0.73)      | 0.57-0.65<br>(0.61) | 0.75-0.83<br>(0.79)    | 0.54-0.59<br>(0.57)  | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hexiti</i> | 4.79<br>5.4<br>2.89<br>12.7  | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |
|         | 0.28-0.31*<br>(0.30) | 0.11-0.14<br>(0.13)      | 0.11-0.13<br>(0.12) | 0.16-0.16<br>(0.16)    | 0.12-0.18<br>(0.10)  | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hexiti</i> | 12.1<br>16.3<br>10<br>2.71   | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |
| RL/2 c  | 2.87-3.46*<br>(3.17) | 1.25-1.35<br>(1.30)      | 2.74-2.86<br>(2.80) | 1.65-1.82<br>(1.73)    | 1.52-1.55<br>(1.54)  | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hexiti</i> | 10.1<br>22.1<br>3.28<br>34.7 | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |

\* unique character

Table 2 5. 1 continued.

| Ratio   | <i>A. alcocki</i>    | <i>P. investigatoris</i> | <i>P. jerryi</i>    | <i>M. andamanensis</i> | <i>S. hurii</i>     | ANOVA  | t-test   | F                            | df                   | Probability                          |
|---------|----------------------|--------------------------|---------------------|------------------------|---------------------|--------|--|------------------------------|----------------------|--------------------------------------|
| 2I/2 CI | 3.07-3.79*<br>(3.43) | 0.53-0.62<br>(0.57)      | 0.37-0.46<br>(0.41) | 0.47-0.55<br>(0.51)    | 0.57-0.68<br>(0.62) | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hurii</i> | 6.51<br>16.4<br>2.97<br>37.1 | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |
| 2d/2cl  | 0.87-1.18*<br>(1.03) | 0.28-0.28<br>(0.28)      | 0.19-0.20<br>(0.20) | 0.16-0.18<br>(0.17)    | 0.16-0.20<br>(0.18) | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hurii</i> | 3.84<br>7.09<br>16.2<br>12.3 | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |
| 2CH/2cl | 0.58-0.61*<br>(0.59) | 3.28-3.43<br>(3.36)      | 2.66-2.78<br>(2.72) | 2.85-2.97<br>(2.91)    | 2.78-3.21<br>(3.00) | P<0.05 | <i>A. alcocki</i> X <i>Investigatoris</i><br><i>A. alcocki</i> X <i>P. jerryi</i><br><i>A. alcocki</i> X <i>M. andamanensis</i><br><i>A. alcocki</i> X <i>S. hurii</i> | 13.3<br>4.28<br>11<br>13.2   | 24<br>12<br>16<br>32 | P<0.05<br>P<0.05<br>P<0.05<br>P<0.05 |
| CL/2m   | 3.27-3.86<br>(3.56)  | 3.68-3.94<br>(3.81)      | 1.25-1.73<br>(1.49) | 3.76-5.71<br>(4.73)    | 3.77-4.16<br>(3.97) | P<0.05 | <i>P. jerryi</i> X <i>M. andamanensis</i>  | 6.9                          | 16                   | P<0.05                               |

\* unique character

TL - Total length  
 CL - Carapace length  
 RL - Rostral length  
 1 CH - Length of 1st cheliped  
 2 CH - Length of 2nd cheliped  
 2i - Ischium of 2nd cheliped  
 2m - merus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2cl - carpus of 2nd cheliped  
 2d - dactylus of 2nd cheliped

Table 2.2.2 Comparison of various morphometric ratios of Deep sea prawns in the super family Penaeoidea

| Ratio   | <i>P. spinipes</i>   | <i>P. martii</i>    | <i>P. ensis</i>     | <i>P. atcocki</i>    | <i>H. leevigatus</i> | <i>H. gibbosus</i>  | <i>H. woodmasoni</i> | ANOVA  | t-test   |
|---------|----------------------|---------------------|---------------------|----------------------|----------------------|---------------------|----------------------|--------|--|
| CL/TL   | 0.22-0.26<br>(0.24)  | 0.21-0.21<br>(0.21) | 0.24-0.26<br>(0.25) | 0.22-0.22<br>(0.22)  | 0.36-0.37*<br>(0.36) | 0.27-0.30<br>(0.28) | 0.27-0.28<br>(0.28)  | P<0.05 | <i>H. leevigatus</i> X <i>H. woodmasoni</i><br><i>H. leevigatus</i> X <i>P. martii</i><br><i>H. leevigatus</i> X <i>P. ensis</i><br><i>H. leevigatus</i> X <i>P. atcocki</i><br><i>H. leevigatus</i> X <i>P. spinipes</i>  |
|         | 0.31-0.33<br>(0.32)  | 0.32-0.36<br>(0.34) | 0.29-0.30<br>(0.30) | 0.39-0.40*<br>(0.39) | 0.31-0.34<br>(0.32)  | 0.36-0.38<br>(0.37) | 0.28-0.30<br>(0.29)  | P<0.05 | <i>P. atcocki</i> X <i>H. woodmasoni</i><br><i>P. atcocki</i> X <i>P. martii</i><br><i>P. atcocki</i> X <i>P. ensis</i><br><i>P. atcocki</i> X <i>H. leevigatus</i><br><i>P. atcocki</i> X <i>P. spinipes</i><br><i>P. spinipes</i> X <i>P. atcocki</i><br><i>P. spinipes</i> X <i>H. gibbosus</i> |
| I CH/TL | 0.37-0.38*<br>(0.38) | 0.28-0.28<br>(0.28) | 0.25-0.31<br>(0.28) | 0.20-0.21<br>(0.20)  | 0.31-0.32<br>(0.31)  | 0.32-0.32<br>(0.32) | 0.22-0.22<br>(0.22)  | P<0.05 | <i>P. spinipes</i> X <i>H. woodmasoni</i><br><i>P. spinipes</i> X <i>P. martii</i><br><i>P. spinipes</i> X <i>P. ensis</i>   |
|         | 0.09-0.09<br>(0.09)  | 0.06-0.07<br>(0.07) | 0.08-0.08<br>(0.08) | 0.12-0.12*<br>(0.12) | 0.06-0.06<br>(0.06)  | 0.10-0.10<br>(0.10) | 0.04-0.04<br>(0.04)  | P<0.05 | <i>P. atcocki</i> X <i>H. gibbosus</i><br><i>P. atcocki</i> X <i>H. woodmasoni</i><br><i>P. atcocki</i> X <i>P. martii</i><br><i>P. atcocki</i> X <i>P. ensis</i><br><i>P. atcocki</i> X <i>H. leevigatus</i><br><i>P. atcocki</i> X <i>P. spinipes</i>  |
| 2CH/TL  | 0.33-0.35<br>(0.34)  | 0.25-0.27<br>(0.26) | 0.22-0.23<br>(0.22) | 0.26-0.28<br>(0.27)  | 0.29-0.32<br>(0.30)  | 0.42-0.42<br>(0.42) | 0.25-0.27<br>(0.26)  | P<0.05 | <i>H. gibbosus</i> X <i>P. martii</i><br><i>H. gibbosus</i> X <i>P. ensis</i><br><i>H. gibbosus</i> X <i>P. atcocki</i><br><i>H. gibbosus</i> X <i>P. spinipes</i><br><i>H. gibbosus</i> X <i>H. leevigatus</i>  |

\* unique character



Table 2. 6. 3 continued...

| Ratio   | <i>P. spinipes</i>   | <i>P. marta</i>     | <i>P. ensis</i>     | <i>P. alcocci</i>   | <i>H. leavigatus</i> | <i>H. gibbosus</i>  | <i>H. woodmasoni</i> | ANOVA  | t-test  |
|---------|----------------------|---------------------|---------------------|---------------------|----------------------|---------------------|----------------------|--------|---|
| 3CH /TL | 0.88-0.92*           | 0.28-0.30<br>(0.28) | 0.31-0.32<br>(0.31) | 0.35-0.36<br>(0.36) | 0.44-0.46<br>(0.45)  | 0.52-0.53<br>(0.52) | 0.33-0.33<br>(0.33)  | P<0.05 | <i>P. spinipes</i> X <i>P. alcocci</i><br><i>P. spinipes</i> X <i>H. gibbosus</i><br><i>P. spinipes</i> X <i>H. woodmasoni</i><br><i>P. spinipes</i> X <i>P. marta</i><br><i>P. spinipes</i> X <i>P. ensis</i><br><i>P. spinipes</i> X <i>H. leavigatus</i> |
|         | 0.78-0.96*           | 0.34-0.35<br>(0.34) | 0.28-0.31<br>(0.29) | 0.29-0.32<br>(0.31) | 0.47-0.50<br>(0.49)  | 0.53-0.56<br>(0.55) | 0.33-0.33<br>(0.33)  | P<0.05 | <i>P. spinipes</i> X <i>P. alcocci</i><br><i>P. spinipes</i> X <i>H. gibbosus</i><br><i>P. spinipes</i> X <i>H. woodmasoni</i><br><i>P. spinipes</i> X <i>P. marta</i><br><i>P. spinipes</i> X <i>P. ensis</i><br><i>P. spinipes</i> X <i>H. leavigatus</i> |
|         | 0.84-1.01*           | 0.31-0.31<br>(0.31) | 0.30-0.32<br>(0.31) | 0.28-0.31<br>(0.29) | 0.45-0.47<br>(0.46)  | 0.51-0.53<br>(0.52) | 0.31-0.31<br>(0.52)  | P<0.05 | <i>P. spinipes</i> X <i>P. alcocci</i><br><i>P. spinipes</i> X <i>H. gibbosus</i><br><i>P. spinipes</i> X <i>H. woodmasoni</i><br><i>P. spinipes</i> X <i>P. marta</i><br><i>P. spinipes</i> X <i>P. ensis</i><br><i>P. spinipes</i> X <i>H. leavigatus</i> |
| 2 m /CL | 0.37-0.40<br>(0.38)  | 0.30-0.35<br>(0.33) | 0.32-0.34<br>(0.33) | 0.53-0.54<br>(0.43) | 0.15-0.19*<br>(0.16) | 0.34-0.35<br>(0.34) | 0.24-0.28<br>(0.26)  | P<0.05 | <i>P. spinipes</i> X <i>H. leavigatus</i><br><i>P. spinipes</i> X <i>H. woodmasoni</i>  |
|         | 0.58-0.61<br>(0.60)  | 0.49-0.52<br>(0.50) | 0.47-0.47<br>(0.47) | 0.68-0.76<br>(0.72) | 0.25-0.29*<br>(0.26) | 0.61-0.61<br>(0.61) | 0.39-0.46<br>(0.43)  | P<0.05 | <i>H. leavigatus</i> X <i>H. woodmasoni</i>   |
| 3CH /CL | 3.62-3.97*<br>(3.80) | 1.37-1.44<br>(1.41) | 1.23-1.37<br>(1.30) | 1.57-1.67<br>(1.62) | 1.20-1.26<br>(1.25)  | 1.72-1.72<br>(1.72) | 1.19-1.29<br>(1.24)  | P<0.05 | <i>P. spinipes</i> X <i>P. alcocci</i><br><i>P. spinipes</i> X <i>H. gibbosus</i><br><i>P. spinipes</i> X <i>H. woodmasoni</i><br><i>P. spinipes</i> X <i>P. marta</i><br><i>P. spinipes</i> X <i>P. ensis</i><br><i>P. spinipes</i> X <i>H. leavigatus</i> |

\* unique character

Table 2.5.2 continued.

| Ratio    | <i>P. spinipes</i> | <i>P. marila</i> | <i>P. ensis</i> | <i>P. atcocki</i> | <i>H. leevigatus</i> | <i>H. gibbosus</i> | <i>H. woodmasoni</i> | ANOVA  | t-test                                      | F     | df | Probability |
|----------|--------------------|------------------|-----------------|-------------------|----------------------|--------------------|----------------------|--------|---|-------|----|-------------|
| 4CH /CL  | 3.26-4.13*         | 1.58-1.70        | 1.21-1.22       | 1.33-1.48         | 1.32-1.36            | 1.71-1.87          | 1.18-1.29            | P<0.05 | <i>P. spinipes</i> X <i>P. atcocki</i>      | 8.38  | 12 | P<0.05      |
|          | (3.70)             | (1.64)           | (1.22)          | (1.41)            | (1.35)               | (1.79)             | (1.25)               |        | <i>P. spinipes</i> X <i>H. gibbosus</i>     | 6.35  | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>H. woodmasoni</i>   | 15.13 | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>P. marila</i>       | 7.62  | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>P. ensis</i>        | 8.00  | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>H. leevigatus</i>   | 8.45  | 12 | P<0.05      |
| 5CH /CL  | 3.48-4.41*         | 1.47-1.49        | 1.26-1.31       | 1.26-1.40         | 1.25-1.45            | 1.70-1.71          | 1.10-1.24            | P<0.05 | <i>P. marila</i> X <i>P. ensis</i>          | 2.67  | 22 | P<0.05      |
|          | (3.95)             | (1.48)           | (1.29)          | (1.33)            | (1.27)               | (1.70)             | (1.17)               |        | <i>P. spinipes</i> X <i>P. atcocki</i>      | 14.11 | 22 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>H. gibbosus</i>     | 7.62  | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>H. woodmasoni</i>   | 34.5  | 28 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>P. marila</i>       | 17.01 | 22 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>P. spinipes</i> X <i>P. ensis</i>        | 14.62 | 12 | P<0.05      |
| 2 p / 2m | 0.20-0.22          | 0.18-0.21        | 0.26-0.26       | 0.30-0.32         | 0.81-0.81*           | 0.16-0.18          | 0.20-0.22            | P<0.05 | <i>P. spinipes</i> X <i>H. leevigatus</i>   | 12.63 | 12 | P<0.05      |
|          | (0.21)             | (0.20)           | (0.26)          | (0.31)            | (0.81)               | (0.18)             | (0.21)               |        | <i>H. leevigatus</i> X <i>H. woodmasoni</i> | 3.04  | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>H. leevigatus</i> X <i>P. marila</i>     | 13.76 | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>H. leevigatus</i> X <i>P. ensis</i>      | 19.65 | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>H. leevigatus</i> X <i>P. atcocki</i>    | 13.21 | 12 | P<0.05      |
|          |                    |                  |                 |                   |                      |                    |                      |        | <i>H. leevigatus</i> X <i>P. spinipes</i>   | 11.58 | 12 | P<0.05      |

\* unique character

Table 2.5.2 continued

| Ratio          | <i>P. spinipes</i>  | <i>P. marte</i>     | <i>P. ensis</i>     | <i>P. siccocki</i>  | <i>H. laevigatus</i> | <i>H. gibbosus</i>  | <i>H. woodmasoni</i> | ANOVA  | t-test                                    | t    | df | Probability |
|----------------|---------------------|---------------------|---------------------|---------------------|----------------------|---------------------|----------------------|--------|---|------|----|-------------|
| <b>2CH/2 m</b> | 3.66-3.92<br>(3.79) | 3.76-3.93<br>(3.85) | 2.83-2.90<br>(2.86) | 2.24-2.41<br>(2.33) | 5.00-5.55<br>(5.36)  | 4.01-4.04<br>(4.03) | 3.82-3.88<br>(3.85)  | P<0.05 | <i>P. marte</i> X <i>P. ensis</i>         | 7.8  | 16 | P<0.05      |
| <b>RL/2 m</b>  | 3.49-3.68<br>(3.59) | 5.01-5.02<br>(5.02) | 3.78-4.02<br>(3.90) | 3.35-3.40<br>(3.38) | 5.50-5.92*<br>(5.74) | 3.68-6.38<br>(5.03) | 3.94-4.18<br>(4.06)  | P<0.05 | <i>P. marte</i> X <i>P. ensis</i>         | 2.82 | 16 | P<0.05      |
| <b>2s1/CL</b>  | x                   | x                   | x                   | x                   | *                    | 0.25-0.29<br>(0.27) | 0.19-0.20<br>(0.19)  | P<0.05 | <i>H. gibbosus</i> X <i>H. woodmasoni</i> | 5.25 | 42 | P<0.05      |
| <b>2SCH/CL</b> | x                   | x                   | x                   | x                   | *                    | 0.96-0.98<br>(0.97) | 0.78-0.82<br>(0.80)  | P<0.05 | <i>H. gibbosus</i> X <i>H. woodmasoni</i> | 2.82 | 42 | P<0.05      |

TL- Total length  
 CL- Carapace length  
 RL- Rostral length  
 1CH- Length of 1st cheliped  
 2CH- Length of 2nd cheliped  
 3CH- Length of 3rd cheliped  
 4CH- Length of 4th cheliped  
 5CH- Length of 5th cheliped  
 2l - ischium of 2nd(s) cheliped  
 2m - merus of 2nd cheliped  
 2p - propodus of 2nd cheliped  
 2SCH-2 (s) Cheliped

\* unique character

**Table 2 & 3 Comparison of various morphometric ratios of Deep sea prawns in the super family Ophiophoridae**

| Ratio   | <i>A. sanguinea</i>  | <i>A. armata</i>     | <i>O. typus</i>      | ANOVA  | t-test                                 | t     | df | Probability |
|---------|----------------------|----------------------|----------------------|--------|--|-------|----|-------------|
| 1 CH/TL | 0.26-0.28*<br>(0.27) | 0.21-0.23<br>(0.22)  | 0.17-0.18<br>(0.18)  | P<0.05 | <i>A. sanguinea</i> X <i>A. armata</i> | 4.25  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. sanguinea</i> X <i>O. typus</i>  | 10.65 | 12 | P<0.05      |
| 3CH /TL | 0.26-0.28<br>(0.27)  | 0.35-0.36*<br>(0.35) | 0.19-0.20<br>(0.20)  | P<0.05 | <i>A. armata</i> X <i>O. typus</i>     | 4.18  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. armata</i> X <i>A. sanguinea</i> | 3.54  | 12 | P<0.05      |
| RL/CL   | 1.33-1.41*<br>(1.37) | 0.91-0.97*<br>(0.94) | 1.20-1.28<br>(1.24)  | P<0.05 | <i>A. sanguinea</i> X <i>A. armata</i> | 3.85  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. sanguinea</i> X <i>A. armata</i> | 2.99  | 12 | P<0.05      |
| 2 m /CL | 0.32-0.34*<br>(0.33) | 0.21-0.23*<br>(0.22) | 0.20-0.22<br>(0.21)  | P<0.05 | <i>A. sanguinea</i> X <i>A. armata</i> | 2.99  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. sanguinea</i> X <i>A. armata</i> | 2.99  | 12 | P<0.05      |
| Tel/TL  | 0.16-0.17*<br>(0.16) | 0.10-0.13<br>(0.11)  | 0.12-0.14<br>(0.12)  | P<0.05 | <i>A. sanguinea</i> X <i>A. armata</i> | 4.31  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. sanguinea</i> X <i>O. typus</i>  | 6.08  | 12 | P<0.05      |
| Tel/CL  | 0.83-0.88*<br>(0.86) | 0.49-0.51*<br>(0.50) | 0.52-0.53<br>(0.53)  | P<0.05 | <i>A. sanguinea</i> X <i>A. armata</i> | 7.65  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. sanguinea</i> X <i>A. armata</i> | 7.65  | 12 | P<0.05      |
| Tel/2cl | 2.96-3.46*<br>(3.21) | 1.43-2.12*<br>(1.78) | 3.25-5.22<br>(4.21)  | P<0.05 | <i>A. sanguinea</i> X <i>A. armata</i> | 5.02  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>A. sanguinea</i> X <i>A. armata</i> | 5.02  | 12 | P<0.05      |
| 2CH/2cl | 3.63-4.30<br>(3.97)  | 2.73-3.57<br>(3.15)  | 3.90-6.22*<br>(5.06) | P<0.05 | <i>O. typus</i> X <i>A. sanguinea</i>  | 5.98  | 12 | P<0.05      |
|         |                      |                      |                      |        | <i>O. typus</i> X <i>A. armata</i>     | 13.21 | 12 | P<0.05      |

TL- Total length

CL- Carapace length

RL- Rostral length

1 CH- Length of 1st cheliped

2 CH- Length of 2nd cheliped

\* unique character

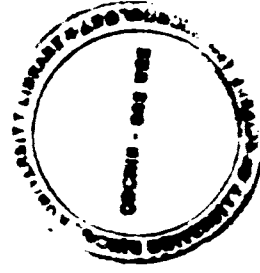
2m - merus of 2nd cheliped

2p - propodus of 2nd cheliped

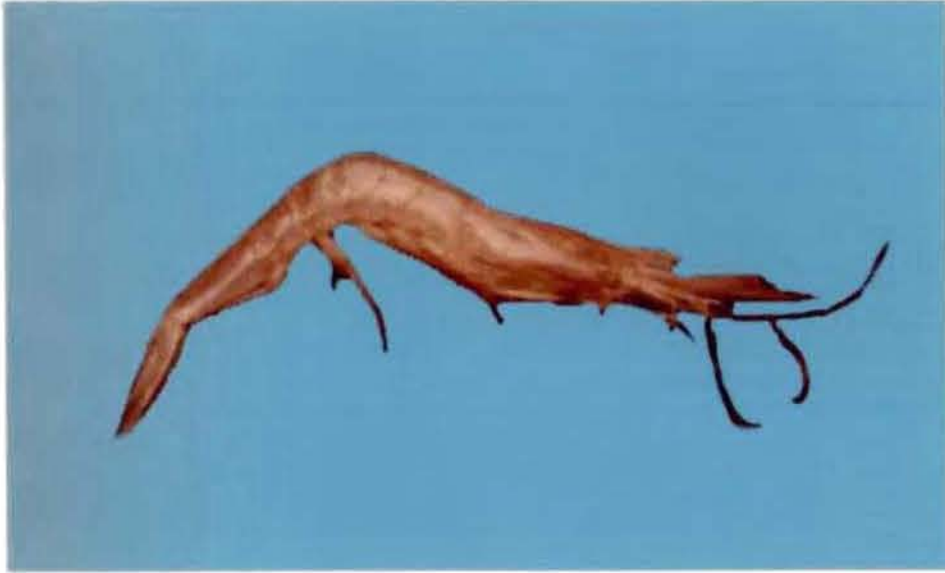
2cl - carpus of 2nd cheliped

3 CH- Length of 2nd cheliped

Tel- Telson length



**Plate 2.1**



**A. *Parapenaeus investigatoris* Alcock and Anderson, 1899**



**B. *Penaeopsis jerryi* Perez Farfante, 1979**

**Plate 2.2**



A. *Metapenaeopsis andamanensis* (Wood-Mason, 1891)



B. *Aristeus alcocki* Ramadan, 1938

**Plate 2.3**



A. *Solenocera hextil* Wood-Mason, 1891



B. *Heterocarpus gibbosus* Bate, 1888

**Plate 2.4**



**A. *Heterocarpus woodmasoni* Alcock, 1901**



**B. *Heterocarpus laevigatus* Bate, 1899**



**Plate 2.5**



**A. *Parapandalus spinipes* (Bate, 1888)**



**B. *Plesionika alcocki* (Anderson, 1898)**

**Plate 2.6**



A. *Plesionika martia* (Milne-Edwards, 1883)



B. *Plesionika ensis* (Milne-Edwards, 1881)

**Plate 2.7**



A. *Oplophorus typus* (Milne-Edwards, 1837)



B. *Acanthephyra sanguinea* (Wood-mason, 1892)

**Plate 2.8**



**A. *Acanthephyra armata* Milne-Edwards, 1881**

### 3.1. INTRODUCTION

The Arabian Sea is a contiguous basin of Indian Ocean, delimited eastwards and southwards by the Arabian and Indian coasts and it articulates Red Sea through Gulf of Aden, Persian Gulf through Gulf of Oman and Bay of Bengal through Palk Strait. Such a geographical position results in a complex hydrography owing to the presence of different water masses. The deep-water region of Arabian Sea is characterised by certain physical and hydrographic features, which are significantly different from the conventional trawling grounds of the inshore regions (Suseelan, 1985). Knowledge on the distribution and abundance of deep sea fauna in the Arabian basin comes mostly from the Indian continent where systematic surveys of the deep sea organisms have been carried out ever since 1958 (John & Kurian, 1959; Kurian, 1964,1965; George and Rao, 1966; Rao and Suseelan, 1967, Suseelan, 1985).

The rich and diversified deep sea crustacean fauna and their general distribution pattern in the Arabian Sea had been studied during the past four decades (Mohamed and Suseelan, 1973; Suseelan, 1974; Suseelan *et al.*, 1989a,b). The discovery on the availability of commercially exploitable deep sea prawns by these surveys during the recent past have offered tremendous scope for the onset of commercial

deep sea fishery to enhance production of crustaceans along Kerala coast. However, the concept of commercial deep sea prawn exploitation became a reality only quite recently and contributed immensely to the exploited fishery resource of Kerala. Analysis of exploited fishery data of deep sea prawns during 2000-02 showed wide dwindling in the catch rates and the respective contribution of various species to the fishery (for details, see Chapter 5).

Benthic communities usually have a long life cycle and stable community structure and therefore can often be used as a monitoring index for pollution (Leppakoski, 1975). In addition, deep sea community are also considered as biological indicators for assessing marine water quality because the organisms are mostly sessile and affected by factors causing environment pollution (Trong, 1996). As members of epifauna, these crustaceans have much higher mobility than do members of the infauna. Therefore, whenever there are environmental changes, these communities suddenly respond either with their disappearance, suspending recruitment at species level, or with a quicker response by the movement of individuals both in and out of an area (Chou *et al.*, 1999). Effect of fishing on ecosystem structure and processes have been studied by a number of researchers from different parts of the world, notably by Jennings and Kaiser (1988), Farina *et al.* (1997), Chou *et al.* (1999), Hall (1999), Trong *et al.* (2000) and Donghia *et al.* (2002).

In spite of the fact that the hydrographic features and the fishing intensity can affect the distribution and abundance respectively of many species and thereby influencing the diversity in marine ecosystems, such effects on the species diversity and species richness have never been the topic of research in the deeper waters off Indian coast. Therefore, in the present study, an attempt is made in this direction with reference to deep sea prawns off the coast of Kerala with the following objectives.

1. To calculate bio diversity indices of deep sea prawns off Kerala with a view to examine the change in community structure, if any, based on the taxonomic relatedness.
2. To assess the depth wise and year wise species abundance, richness and evenness.
3. To work out similarity index among the populations from month wise analysis.

### **3.2. MATERIALS AND METHODS**

The data for the study were collected from commercial deep sea trawlers operated at 150-650 m off Kerala during September 2000 to August 2002. Data on the deep sea prawn catch and effort were collected

at weekly intervals from six major harbours viz. Sakthikulangara, Neendakara, Cochin, Munambum, Beypore, and Puthiyappa and 4 minor harbours viz. Thottapally, Murikkumpadam, Ponnani and Mopla Bay spread along 6 districts of Kerala. Besides, the data on deep sea prawn resources and hydrographic parameters were also collected on board FORV Sagar Sampada during her experimental trawl fishing cruise surveys no. 174 (June – July, 1999), 183 (April, 2000), 189 (October – November, 2000), 191 (January, 2001), 196 (July, 2001) and 197 (April 2002) carried out at depths varying from 100-750m in the latitudes 7° N and 13° N and longitudes 71° E and 77° E. The hydrographical parameters were analysed using the facilities of FORV Sagar Sampada. Species level identification of the deep sea prawns were done following Alcock (1901) and Suseelan (1985). The data of individual species was expressed as numbers. Once the species was identified, their respective numbers were analysed for diversity indices at various depths using the PRIMER-5 (Plymouth Routine in Multivariate Ecological Research) tool pack. Species diversity was computed using the following Univariate ecological indices (Ludwig and Reynolds, 1988).

a) **Shannon –Wiener diversity index (H')**:

$$H' = - \sum_{i=1}^s p_i (\log_2 p_i) \text{ or } - \sum \frac{n_i}{N} (\log_2 \frac{n_i}{N})$$



where :  $p_i$  is equivalent with  $\frac{n_i}{N}$

$n_i$  : the number of individuals in  $i^{\text{th}}$  species.

$N$  : total number of individuals.

**b) Evenness Index**

$$J' = \frac{H'}{\text{Log}(S)}$$

Where :  $H'$  measured Shannon –Wiener index

$S$  : total number of species

$J'$  : evenness

**c) Margalef's species richness index**

$$d = \frac{(S - 1)}{\text{Log}_e N}$$

Where  $d$  : richness index

$S$  : total number of species

$N$  : total number of individuals.

Similarities of deep sea prawn resources at five depth zones were worked out using multivariate analysis in the PRIMER package (Carr, 1997). Before multivariate analysis, deep sea prawn numbers were fourth-root-transformed, and the Bray – Curtis similarity measure was

used to compute the similarity matrix. The abundance of each deep sea prawn species in terms of their number at 5 depths was calculated using hierarchical agglomerative clustering using the unweighted pair group mean arithmetic linking method (UPGMA). To test the significance one and two way ANOVA was employed following Snedecor and Cochran (1967).

### **3.3. RESULTS**

#### **3.3.1. Substrate characteristics**

Substrate characteristics in the survey area of FORV Sagar Sampada are described in detail (Table 3.1). It may be seen that fine sand and mud constitute the major components of bottom sediments up to 300m where good trawlable grounds exist especially beyond 125m. In the lat. 9-10<sup>0</sup>N, beyond 300 m depth, occasional rocky and muddy bottoms were encountered. Lat. 8-9<sup>0</sup>N which covers the Quilon bank is found to provide a good trawling ground at all depths with fine sandy and muddy bottom except for some rocky patches at 300-400m depths. The bottom substrata between in lat. 10<sup>0</sup> and 13<sup>0</sup>N were found to be either sandy or muddy or have a combination of both.

### 3.3.2. Hydrographic parameters

The salinity between the latitudes 7° N and 13°N showed a slight increase with an increase of depth and ranged between 34 and 36 ‰ from 200 to 500m. The temperature showed a steady decline with increase of depths which varied from 15.3°C at 150m to 9.9°C at 700m whereas the dissolved oxygen level also showed an inverse relationship with depth, which ranged from 0.13 to 0.04 ml/l between 150 m to 700m (Table 3.2) .

### 3.3.3. Species composition

Fifteen species of deep sea prawns belonging to 5 family and 10 genera were recorded in the depth zones 150-550 m off Kerala coast. The higher abundance of pandalids were observed at 250-350 m except for *Parapandalus spinipes* which showed a preponderance at 150-250 m depth along with penaeid prawns (Table 3.3). Among the deep sea prawns, *P.spinipes* appeared as the most dominant species in the total exploited stock followed by *H.gibbosus* and *H.woodmasoni* .

### 3.3.4. Year wise variation in diversity indices

Table 3.4 shows the ecological indices of Shannon diversity (H'), species richness (d) and evenness (J') of deep sea prawns off Kerala

during September 2000 to April 2001. The Shannon diversity was high in January (2.34) while it was lowest during September (1.53). On the other hand, the species richness varied from 0.818 in September to 1.422 in December while the evenness values were in the range 0.73 in September and 0.94 in January. An increasing trend in the  $H'$  values were observed from November to December (Fig. 3.1) touching as high as 2.31 in December and thereafter it gradually declined, however, no such definite trend could be discernible during 2001-02 (Fig. 3.1).

Generally, the diversity indices showed a decline during the second year, and the highest  $H'$  and  $J'$  were recorded in February with 2.03 and 0.88 respectively while high species richness value was observed during January (Table 3.4). Results of ANOVA showed that there exists significant variation ( $P < 0.001$ ) in the community structure between the first and second years (Table 3.5).

The multivariate analysis showed a clear pattern linked to seasons highlighting the similarities in the distribution and abundance of populations during 2000 to 2002 (Fig. 3.2). Maximum similarity was observed between the population of October 2001 and November 2001 followed by December 2000 and January 2001.

### **3.3.5. Depth wise variation in diversity**

Depth wise variation in diversity indices of deep sea prawns during 2000-02 is depicted in Fig. 3.3. The  $H'$  was found to be highest at 251-350m during both the years and a decline was perceptible in the contiguous higher depths. Results of ANOVA showed significant variation ( $P<0.01$ ) between  $H'$  values among various depth zones for both the years (Table 3.6).

The species richness was also found to be highest at 251-350m depth zones, however, a gradual declining trend was pronounced with an increase in depth (Fig 3.4).

### **3.3.6. Diversity indices at 151-250m**

Table 3.7 shows the diversity indices of deep sea prawns at 151-250m depths during 2000-01 & 2001-02 respectively. During 2000-01, the  $H'$  and  $d$  were highest in February with 1.96 and 0.75 respectively while  $J'$  was high in October. The Shannon diversity showed significant increase in species abundance from November to February during the first year while no such definite trend could be discernible during the second year of study (Fig. 3.5).

The  $H'$  showed a slight decrease when compared to the previous year (Fig. 3.5), showing a peak in March (1.784), on the other hand

species richness showed a sharp increase in March with 1.17. Maximum evenness was observed during October (0.932). Results of analysis of variance showed that there was significant difference ( $P < 0.001$ ) between the seasons (Table 3.8).

Results of multivariate analysis showed maximum similarity in species abundance between the population in November 2000 and April 2001 (95.33%) (Fig. 3.6). In the second year also the trend was same in November and April with 99.64% similarity between the above two months (Fig. 3.7).

### **3.3.7. Diversity indices at 251-350 m**

During 2000-01, the diversity index was high in February while the richness and evenness were maximum during October and December with 1.51 and 0.99 respectively (Fig. 3.8). Where as in the second year both the  $H'$  and  $d$  declined sharply, showing the peak value in March and December while  $J'$  remained almost constant, showing high value in March (Table 3.9). There exist significant variation between the populations during the two years ( $P < 0.001$ ) (Table 3.10).

Results of cluster analysis showed maximum similarity between the population of January 2001 and February 2001 (99.57%) in species abundance while it was between October 2002 and March 2002 during the second year (98.45%)(Fig. 3.9& 3.10).

### **3.3.8. Diversity indices at 351-450 m**

Table 3.11 shows the diversity indices at 351-450m during 2000-01. All the three indices were found highest in December registering 2.00, 0.90 and 0.90 respectively for H', d, J'. In 2001-02 H' and d were highest during October with 1.706 and 1.205 respectively while highest evenness value was observed in September (0.974).

Shannon diversity index showed an increasing trend from November to March during the first year, in contrast, a decreasing trend was discernible during the same months during the second year (Fig. 3.11). The difference was found to be statistically significant ( $P < 0.05$ ) (Table 3.12).

Results of multivariate analysis showed maximum similarity in the species abundance between the population of November 2000 and March 2001 (99.60%) during 2000-01 while the similarity was high between November 2001 and December 2001 during 2001-02 at 350-450m (97.11%) (Fig. 3.12 & 3.13).

### **3.3.9. Diversity indices at 451-550 m**

Diversity indices of deep sea prawns at 451-550m depths are given in Table 3.13. The diversity indices were maximum during December with 1.525, 0.897 and 0.737 for H', d, J' respectively. During

the second year, the diversity indices showed a declining trend and the maximum  $H'$  (1.44) and  $d$  (0.599) were attained in November while the  $J'$  was high in December (0.907).

$H'$  showed a gradual increasing trend until December and thereafter showed a decline up to February and further it increased (Fig. 3.14). During the second year, there was a steady increase until November and thereafter it declined (Fig. 3.14).

The cluster analysis showed maximum similarity between population of September 2001 and February 2001 during the preceding year while in the succeeding year the similarity was high between March 2002 and April 2002 in the populations of deep sea prawns (Fig. 3.15 & 3.16).

### **3.3.10. Diversity indices at 551-650 m**

Table 3.14 shows the diversity indices of deep sea prawns at 551-650m depths during 2000-01. Shannon diversity was observed to be high in November while the species richness and evenness were high during October and January.  $H'$  showed an increase from October to February with peak in January (Fig. 3.17). Results of multivariate analysis showed maximum similarity between the populations of November 2000 and April 2001 (97.80%) (Fig 3. 18).



### 3.4. DISCUSSION

In the present study, a pioneer attempt was made to work out the biodiversity indices of deep sea prawns off Kerala. The depth wise and month wise species diversity, species richness and evenness in the deep sea prawn population were computed using univariate analysis whereas multivariate analysis was employed in order to assess the similarities exist in the distribution and abundance of populations during different months of 2000-01 and 2001-02.

Results of the bio diversity indices of deep sea prawn species inhabiting at various depth zones off Kerala coast during 2000-01 showed that it was high at 151-250m and 251-350m whereas at higher depths of 351-450m, 451-550 and 551-650, the diversity showed a gradually declining tendency. The species richness was also found to be relatively high at lower depth zones of 251-350, against the low values registered at higher depths. During 2001-02 also, similar findings were made with high diversity as well as species richness at 251-350m while it was lowest at 451-550m thus showing that diversity as well as species richness are showing inverse relationship with depth. It appears that the depth profoundly influences the assemblage structures of deep sea prawns. Clarke *et al.* (1993) opined that community structure would change with an increase of water depth and the present finding is complementary to the above statement. The structure of decapod crustacean assemblages

on the continental regions in different geographic area are largely determined by spatial differences in environmental and oceanographic conditions, and particularly, by depth, bottom type and characteristics of the water masses (Lagard re 1973,1977; Wenner and Boesh, 1979; Gonzalez and Olaso, 1987; Abelló *et al.*, 1988; Markle *et al.*, 1988; Basford *et al.*, 1989; Olaso, 1990; Macpherson, 1991; Cartes and Sardá, 1993; Sarda *et al.*, 1994).

Off the Kerala coast, there is a marked deep sea faunal zonation along the bathymetric gradient. The distribution and abundance patterns of deep sea prawns off Kerala showed strong agreement with those reported in earlier studies (Mohamed and Suseelan, 1973; Suseelan, 1985) who had also reported that there is a reduction in species diversity as well as richness commensurate with increase of depth. Besides depth, the spatial structure of the shelf and upper slope of crustacean assemblages is well related to sediment granulometry (Bianchi, 1992; Setubal, 1992). Other habitat parameters such as character of bottom substratum, fishing disturbances, flow of various water bodies, salinity and oil spills etc. can also significantly change community structure (Wu, 1982). The variation encountered in the species diversity and species richness of deep sea prawns among various depth zones and seasons in the present study might possibly be due to the differences noticed in the bottom substratum as well as hydrographic factors at different depths. As the salinity do not shows severe change among the depth zones studied,

it can reasonably be presumed that this parameter may not have been any significant influence on the species diversity. A strong correlation, however, is exist between the richness and diversity of deep sea prawns and the existing hydrographic parameters, by and large by water temperature, which exhibits strong variation with respect to depth zones. The relatively cooler water temperature coupled with fine muddy substrate provide the most congenial habitat for the pandalid prawns between the latitudes 8 to 9<sup>o</sup>N in Quilon Bank (Suseelan,1985) ,where the species richness and diversity at 251-350 m was very high when compared to other zones. The penaeid prawns such as *Penaeopsis jerryi*, *M.andamanensis* and *Solenocera hextii* appear to be showing strong preference towards slightly higher water temperature and a substrate demarcated by mixture of sand and mud as evidenced from their distribution within 250m. John and Kurien (1959) investigated on the influence of bottom temperature and the type of substratum on the distribution of *Penaeopsis philippi* along the south west coast of India and reported that there exists a positive correlation among temperature , optimum depth and soil composition in the distribution of this species off Kerala coast.

Several workers have made effect of temperature on the distribution and abundance deep sea crustaceans. Smidt (1967) reported that *Pandalus borealis* fishery was constantly high in the warmer waters of Greenland whereas instability in temperature results in the fluctuations

of species abundance. Rasmussen (1967) and Squires (1968) observed a positive correlation between the temperature and abundance of *P borealis* from the Norwegian and Newfoundland waters. According to Dow (1967), seawater temperature, which ranged between 0°C and 16°C and soft muddy bottom had profoundly influenced the species richness of the shrimp population than any other factors. Thompson (1967) also reported similar views in the abundance of *Hymenopenaeus robustus* , which showed highest concentration in the isothermal layer between 250-450 m depths. According to Sharma and Murty (1973), the isothermal layer and gradient of temperature play a decisive role in the distribution of prawns off south west coast of India while Suseelan (1985) pointed out that the deep sea prawns dwelling in the deeper waters are more sensitive to environmental factors than the littoral species. The species richness and abundance of deep sea prawns in certain months observed in the present study might be due to the large scale periodic migration of the prawns across the various depth zones, probably influenced by the slight change in water temperatures as opined by Silas (1969) and Suseelan (1985).

Interestingly, the diversity index  $H'$  in the lower depth zones was glaringly high where intensive deep sea trawl fishing was in vogue. Though the deep sea fishing has started quite recently, there are possibilities of its impact on the deep sea prawn species diversity in Arabian Sea besides causing changes in sea bottom ecology. According

to Murawski (2000) the great  $H'$  values registered in Italian waters is caused by heavy exploitation of prawns which in turn caused an increase in evenness and interalia diversity. Present findings strongly corroborates with the above observation, wherein a glaringly high evenness values were observed during the second year irrespective of depth zones or months. The low  $H'$  reckoned invariably observed in deeper waters might be due to clear dominance of one (*A.alcocki*) or few species (*A.sanguinea*, *A.armata*) and also due to the relatively low intensity of trawl fishing. The trawl fishing impact will be more on the deep sea prawns which are less resilient than to their counter parts of coastal waters even though the commercial exploitation started only since 1999.

Though the present results are still preliminary, however, it will serve as a baseline and pioneer database relating to variations in the species diversity, abundance and evenness of deep sea prawns of various depths off Kerala. It is also indicative of showing the combined influence of soil type and water temperature as well, probably throw some light on the immediate impacts of deep sea trawling operations on biodiversity. Further data collection and analysis are required to evaluate the role of each process and to what extent these parameters interact.

**Table 3.1** Depth wise substrate characteristics in the sea bed off Kerala between latitudes 8°N -13°N

| Latitude Zones | Depth (M) |         |                  |             |             |
|----------------|-----------|---------|------------------|-------------|-------------|
|                | 100-200   | 200-300 | 300-400          | 400-500     | 500-600     |
| Latitude 8° N  | sandy     | sandy   | sandy/muddy      | sandy/muddy | muddy       |
| Latitude 9° N  | sandy     | muddy   | sandy/muddy/rock | muddy       | muddy       |
| Latitude 10° N | sandy     | muddy   | muddy/rock       | muddy/rock  | sandy/muddy |
| Latitude 11° N | sandy     | muddy   | muddy            | muddy/rock  | sandy/muddy |
| Latitude 12° N | sandy     | muddy   | muddy            | muddy       | sandy/muddy |
| Latitude 13° N | muddy     | muddy   | muddy            | muddy       | sandy/muddy |

**Table 3.2** Depth wise average hydrographic parameters of six cruises off Kerala in the latitudes 7°N- 13°N

| Depth (m) | Temperature (°C) | Salinity (‰) | Dissolved oxygen (ml/l) |
|-----------|------------------|--------------|-------------------------|
| 50        | 21               | 34.2         | 0.59                    |
| 100       | 17.43            | 34.91        | 0.54                    |
| 150       | 15.27            | 34.68        | 0.53                    |
| 200       | 13.86            | 35.1         | 0.59                    |
| 250       | 12.85            | 35.18        | 0.48                    |
| 300       | 11.81            | 35.12        | 0.28                    |
| 350       | 11.58            | 35.3         | 0.27                    |
| 400       | 11.41            | 35.74        | 0.25                    |
| 450       | 11.24            | 35.68        | 0.21                    |
| 500       | 11.11            | 36.01        | 0.21                    |
| 550       | 10.55            | 36.07        | 0.28                    |
| 600       | 10.1             | 35.98        | 0.25                    |
| 650       | 9.72             | 36.21        | 0.25                    |
| 700       | 9.19             | 36.04        | 0.21                    |
| 800       | 8.96             | 36.01        | 0.20                    |

**Table 3.3 Species composition of deep sea prawns collected from 150-550m depth zones**

| <b>Family</b> | <b>Species</b>                  | <b>Vertical<br/>Distributional<br/>range (m)</b> |
|---------------|---------------------------------|--|
| Pandalidae    | <i>Heterocarpus gibbosus</i>    | 250-350  |
|               | <i>Heterocarpus woodmasoni</i>  | 250-300  |
|               | <i>Heterocarpus laevigatus</i>  | 250-300  |
|               | <i>Parapandalus spinipes</i>    | 150-250  |
|               | <i>Plesionika ensis</i>         | 250-350  |
|               | <i>Plesionika martia</i>        | 250-350  |
|               | <i>Plesionika alcocki</i>       | 250-350  |
| Aristeidae    | <i>Aristeus alcocki</i>         | 350-550  |
| Solenoceridae | <i>Solenocera hextii</i>        | 150-250  |
| Oplophoridae  | <i>Acanthephyra sanguinea</i>   | 350-550  |
|               | <i>Acanthephyra armata</i>      | 350-550  |
|               | <i>Oplophorus typus</i>         | 250-350  |
| Penaeidae     | <i>Peneopsis jerryi</i>         | 150-250  |
|               | <i>P. investigatoris</i>        | 150-250  |
|               | <i>Metapenaeus andamanensis</i> | 150-250  |

**Table 1.4** Ecological indices of deep sea prawns off Kerala between latitudes 7°N and 13°N during 2000- 01 and 2001-02

| month     | 2000-01   |                            |                            | 2001-02   |                            |                            |
|-----------|-----------|----------------------------|----------------------------|-----------|----------------------------|----------------------------|
|           | loge (H') | species richness index (d) | pielous evenness index(J') | loge (H') | species richness index (d) | pielous evenness index(J') |
| August    | -         | -                          | -                          | 0.189     | 0.268                      | 0.272                      |
| September | 1.530     | 0.818                      | 0.736                      | 1.608     | 0.982                      | 0.732                      |
| October   | 1.703     | 0.933                      | 0.819                      | 1.921     | 1.163                      | 0.834                      |
| November  | 1.607     | 1.145                      | 0.698                      | 1.843     | 1.255                      | 0.768                      |
| December  | 2.309     | 1.422                      | 0.929                      | 1.977     | 1.332                      | 0.824                      |
| January   | 2.335     | 1.388                      | 0.940                      | 1.720     | 1.412                      | 0.692                      |
| February  | 2.136     | 1.127                      | 0.927                      | 2.035     | 1.269                      | 0.884                      |
| March     | 2.017     | 1.220                      | 0.841                      | 1.806     | 0.914                      | 0.868                      |
| April     | 1.811     | 0.864                      | 0.871                      | 1.801     | 1.207                      | 0.782                      |

**Table 1.5** Result of ANOVA of diversity indices of deep sea prawns between 2000-01 and 2001-02.

| Source        | df | SS      | MSS    | F      | Prob.                     |
|---------------|----|---------|--------|--------|---------------------------|
| bet.samples   | 3  | 1619.08 | 539.69 | 16.08* | P<0.001                   |
| within sample | 44 | 1477.04 | 33.57  |        |                           |
| Total         | 47 | 3096.12 |        |        | * significant at 1% level |

**Table 1.6** Result of ANOVA for depth wise diversity indices of deep sea prawns between 2000-01 and 2001-02.

| Source        | df | SS      | MSS    | F      | Prob.                     |
|---------------|----|---------|--------|--------|---------------------------|
| bet.samples   | 3  | 1447.87 | 482.62 | 20.29* | P<0.001                   |
| within sample | 44 | 1046.7  | 23.79  |        |                           |
| Total         | 47 | 2494.57 |        |        | * significant at 1% level |



**Table 17** Ecological indices of deep sea prawns off Kerala at 151-250m between latitudes 7°N and 13°N

| month     | 2000-01   |                            |                            | 2001-02   |                            |                            |
|-----------|-----------|----------------------------|----------------------------|-----------|----------------------------|----------------------------|
|           | loge (H') | species richness index (d) | pielous evenness index(J') | loge (H') | species richness index (d) | pielous evenness index(J') |
| August    | -         | -                          | -                          | -         | -                          | -                          |
| September | 1.227     | 0.362                      | 0.885                      | 1.358     | 0.739                      | 0.698                      |
| October   | 1.824     | 1.157                      | 0.792                      | 1.671     | 0.665                      | 0.932                      |
| November  | 1.312     | 0.571                      | 0.815                      | 1.569     | 0.791                      | 0.806                      |
| December  | 1.506     | 0.637                      | 0.936                      | 1.553     | 0.715                      | 0.867                      |
| January   | 1.887     | 0.833                      | 0.970                      | 1.575     | 0.688                      | 0.879                      |
| February  | 1.960     | 0.875                      | 0.943                      | 1.245     | 0.450                      | 0.898                      |
| March     | 1.650     | 0.855                      | 0.794                      | 1.784     | 1.177                      | 0.775                      |
| April     | 0.943     | 0.423                      | 0.680                      | 1.289     | 0.792                      | 0.662                      |

**Table 18** Result of ANOVA for depth wise diversity indices of deep sea prawns at 151-250m

| Source        | df | SS      | MSS    | F     | Prob.                     |
|---------------|----|---------|--------|-------|---------------------------|
| bet.samples   | 5  | 632.47  | 126.49 | 6.62* | P<0.001                   |
| within sample | 44 | 1313.79 | 29.86  |       |                           |
| Total         | 59 | 1946.25 |        |       | * significant at 1% level |

**Table 19** Ecological indices of deep sea prawns off Kerala at 251-350m between latitudes 7°N and 13°N

| month     | 2000-01   |                            |                            | 2001-02   |                            |                            |
|-----------|-----------|----------------------------|----------------------------|-----------|----------------------------|----------------------------|
|           | loge (H') | species richness index (d) | pielous evenness index(J') | loge (H') | species richness index (d) | pielous evenness index(J') |
| September | 0.713     | 0.259                      | 0.651                      | 1.330     | 0.612                      | 0.742                      |
| October   | 1.834     | 1.505                      | 0.746                      | 1.701     | 0.795                      | 0.874                      |
| November  | 1.164     | 0.711                      | 0.601                      | 1.688     | 0.641                      | 0.942                      |
| December  | 1.752     | 0.707                      | 0.986                      | 1.546     | 0.855                      | 0.795                      |
| January   | 1.874     | 0.893                      | 0.905                      | 1.517     | 0.581                      | 0.942                      |
| February  | 1.999     | 1.147                      | 0.872                      | 1.541     | 0.602                      | 0.957                      |
| March     | 1.780     | 0.753                      | 0.918                      | 1.767     | 0.660                      | 0.986                      |
| April     | 1.886     | 0.932                      | 0.913                      | 1.094     | 0.623                      | 0.680                      |

**Table 3.10 Result of ANOVA for depth wise diversity indices of deep sea prawns at 251-350 m**

| Source        | df | SS          | MSS       | F      | Prob.                     |
|---------------|----|-------------|-----------|--------|---------------------------|
| bet. samples  | 5  | 338332.64   | 338332.64 | 33.13* | P<0.001                   |
| within sample | 44 | 102107.89   | 10210.79  |        |                           |
| Total         | 59 | 440440.5273 |           |        | * significant at 1% level |

**Table 3.11 Ecological indices of deep sea prawns off Kerala at 351-450m between latitudes 7°N and 13°N**

| month     | 2000-01   |                            |                            | 2001-02   |                            |                            |
|-----------|-----------|----------------------------|----------------------------|-----------|----------------------------|----------------------------|
|           | loge (H') | species richness index (d) | pielous evenness index(J') | loge (H') | species richness index (d) | pielous evenness index(J') |
| September | 1.380     | 0.726                      | 0.709                      | 1.057     | 0.325                      | 0.974                      |
| October   | 1.431     | 0.816                      | 0.736                      | 1.706     | 1.205                      | 0.748                      |
| November  | 1.514     | 0.773                      | 0.778                      | 1.591     | 0.760                      | 0.822                      |
| December  | 2.003     | 0.904                      | 0.963                      | 1.532     | 0.638                      | 0.859                      |
| January   | 1.663     | 0.815                      | 0.855                      | 1.337     | 0.527                      | 0.835                      |
| February  | 1.895     | 0.780                      | 0.974                      | 0.622     | 0.169                      | 0.909                      |
| March     | 1.497     | 0.516                      | 0.930                      | 1.441     | 0.555                      | 0.901                      |
| April     | 1.129     | 0.394                      | 0.815                      | 1.574     | 0.676                      | 0.884                      |

**Table 3.12 Result of ANOVA for depth wise diversity indices of deep sea prawns at 351-450 m**

| Source        | df | SS          | MSS    | F       | Prob.                     |
|---------------|----|-------------|--------|---------|---------------------------|
| bet. samples  | 6  | 1571.440243 | 261.91 | 133.03* | P<0.001                   |
| within sample | 26 | 54.56       | 1.95   |         |                           |
| Total         | 32 | 1626.01     |        |         | * significant at 1% level |

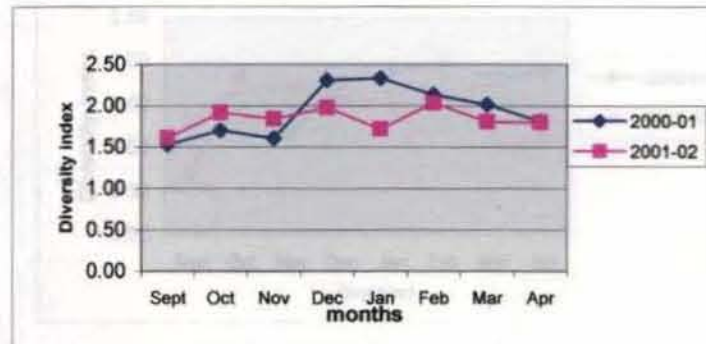
**Table 3.13 Ecological indices of deep sea prawns off Kerala at 451-550m between latitudes 7°N and 13°N**

| month     | 2000-01   |                            |                            | 2001-02   |                            |                            |
|-----------|-----------|----------------------------|----------------------------|-----------|----------------------------|----------------------------|
|           | loge (H') | species richness index (d) | pielous evenness index(J') | loge (H') | species richness index (d) | pielous evenness index(J') |
| September | 0.507     | 0.146                      | 0.736                      | 0.200     | 0.000                      | 0.000                      |
| October   | 0.870     | 0.476                      | 0.637                      | 0.700     | 0.000                      | 0.000                      |
| November  | 0.945     | 0.332                      | 0.874                      | 1.449     | 0.599                      | 0.812                      |
| December  | 1.525     | 0.897                      | 0.737                      | 0.991     | 0.277                      | 0.907                      |
| January   | 1.389     | 0.549                      | 0.866                      | 0.912     | 0.265                      | 0.834                      |
| February  | 0.740     | 0.291                      | 0.680                      | 0.320     | 0.000                      | 0.000                      |
| March     | 1.376     | 0.498                      | 0.858                      | 0.986     | 0.000                      | 0.000                      |
| April     | 0.925     | 0.379                      | 0.670                      | 0.030     | 0.000                      | 0.000                      |

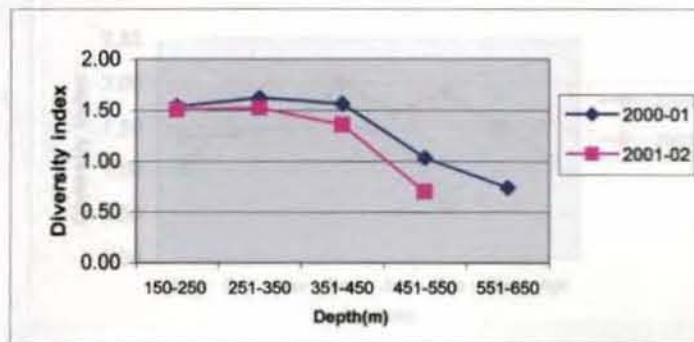
**Table 3.14 Ecological indices of deep sea prawns off Kerala at 551-650m between latitudes 7°N and 13°N during 2000-01**

| month    | 2000-01   |                            |                            |
|----------|-----------|----------------------------|----------------------------|
|          | loge (H') | species richness index (d) | pielous evenness index(J') |
| October  | 0.581     | 0.670                      | 0.419                      |
| November | 1.347     | 0.658                      | 0.837                      |
| December | 1.280     | 0.421                      | 0.923                      |
| January  | 0.691     | 0.206                      | 0.997                      |
| February | 0.520     | 0.000                      | 0.000                      |
| March    | 0.905     | 0.251                      | 0.824                      |
| April    | 0.503     | 0.331                      | 0.457                      |

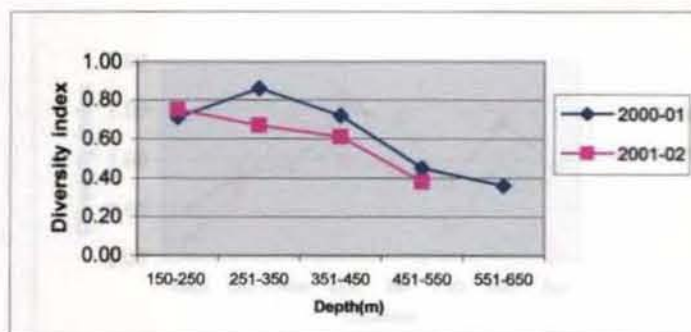
**Fig. 3.1** Shannon diversity indices of deep sea prawns off Kerala during 2000-01 and 2001-02



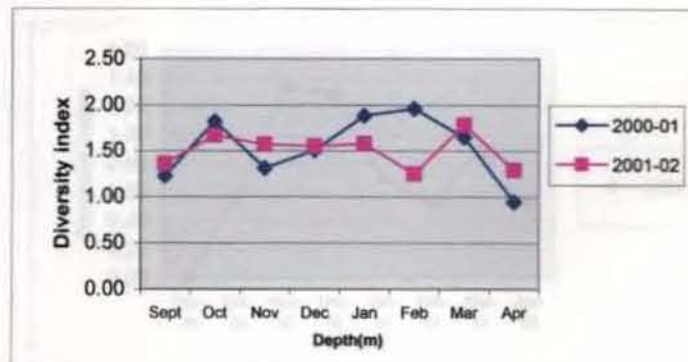
**Fig. 3.3** Depthwise indices of deep sea prawns off Kerala during 2000-02



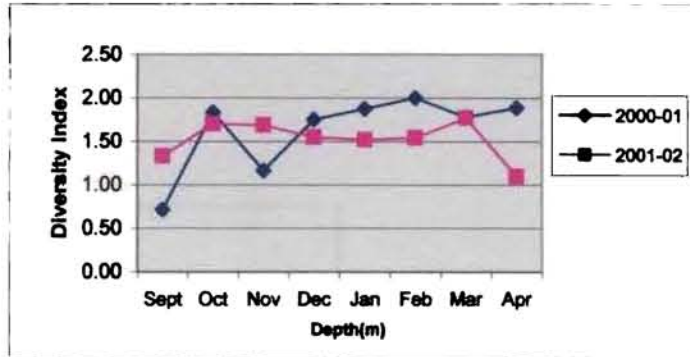
**Fig. 3.4** Depthwise species richness of deep sea prawns off Kerala



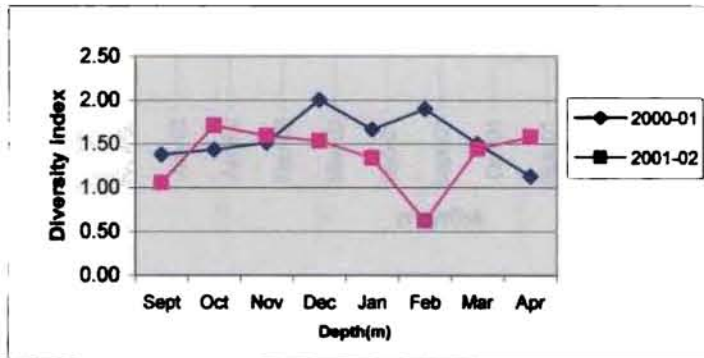
**Fig. 3.5** Depthwise diversity indices of deep sea prawns at 151-250m



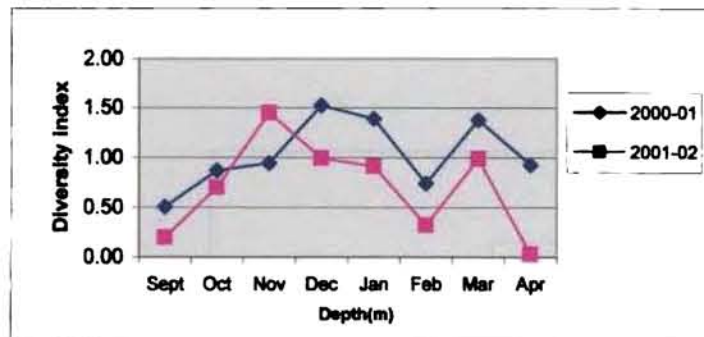
**Fig. 3.8 Depthwise diversity indices of deep sea prawns at 251-350m**



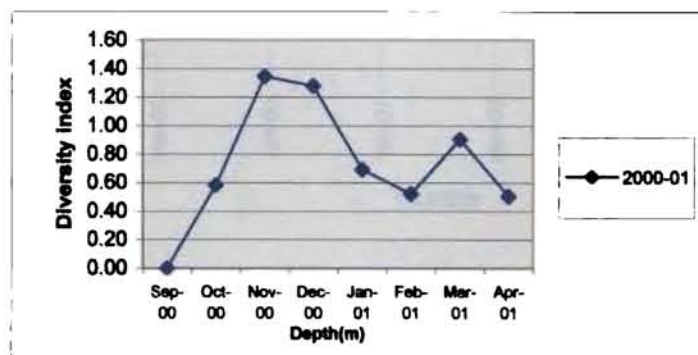
**Fig. 3.11 Depthwise diversity indices of deep sea prawns at 351-450m**



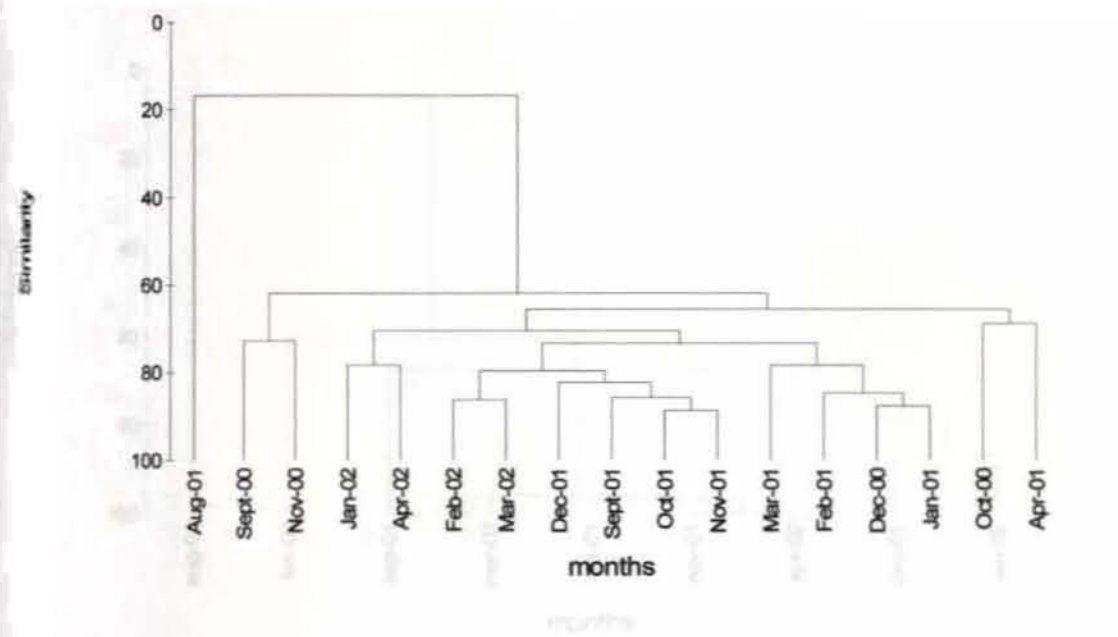
**Fig. 3.14 Depthwise diversity indices of deep sea prawns at 451-550m**



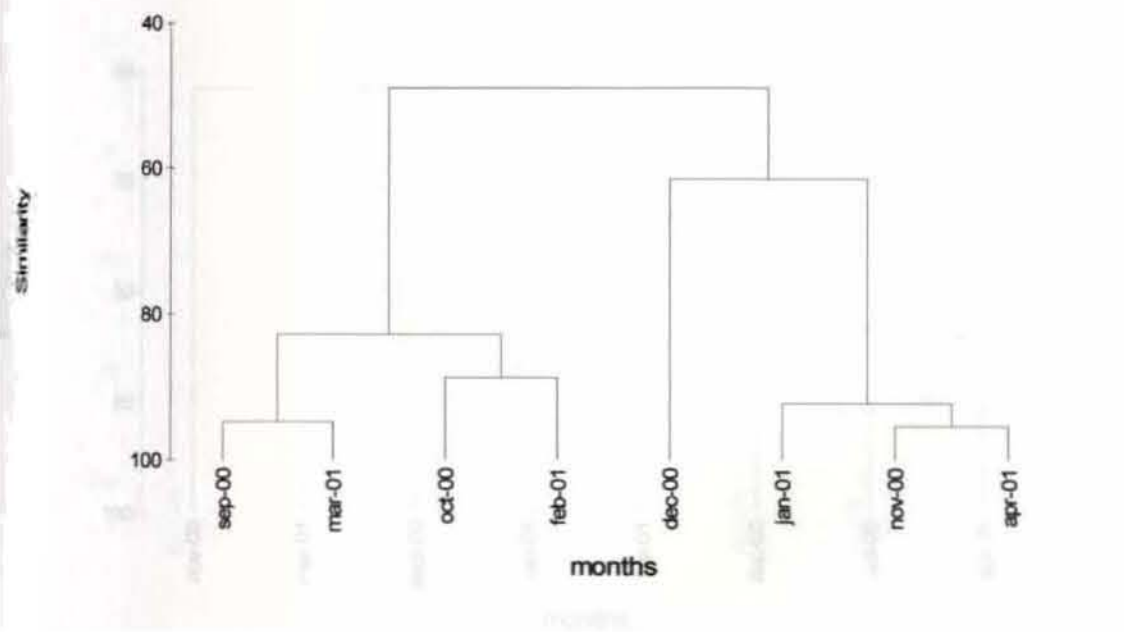
**Fig. 3.17 Depthwise diversity indices of deep sea prawns at 551-650m**



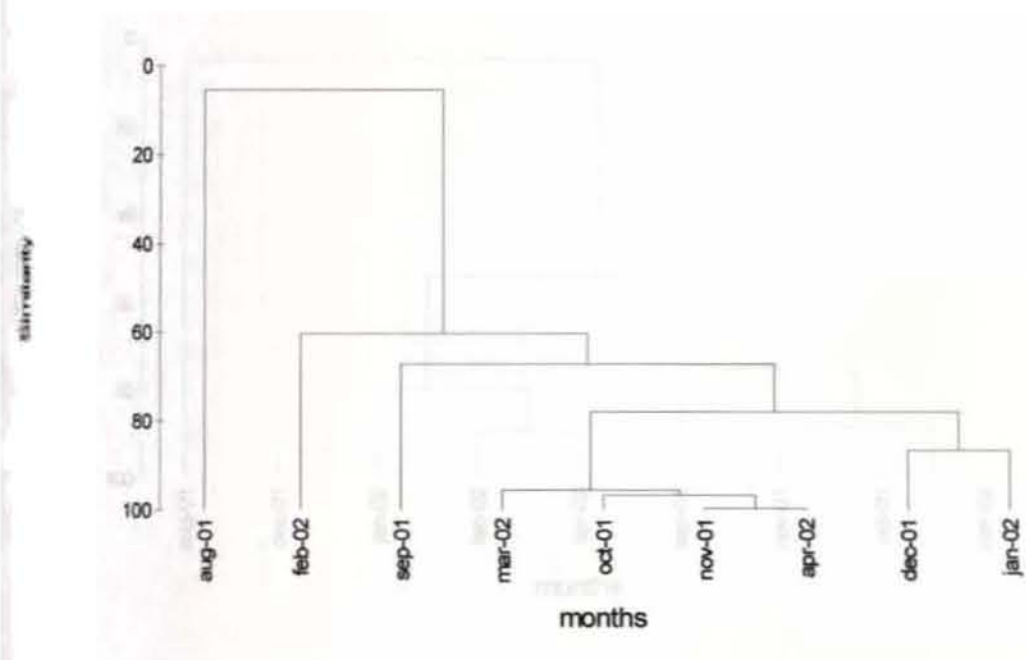
**Fig.3.2** Dendrogram of year wise similarity index(in percentage) of deep sea prawns off Kerala between latitudes 7<sup>0</sup>N and 13<sup>0</sup>N during 2000-02



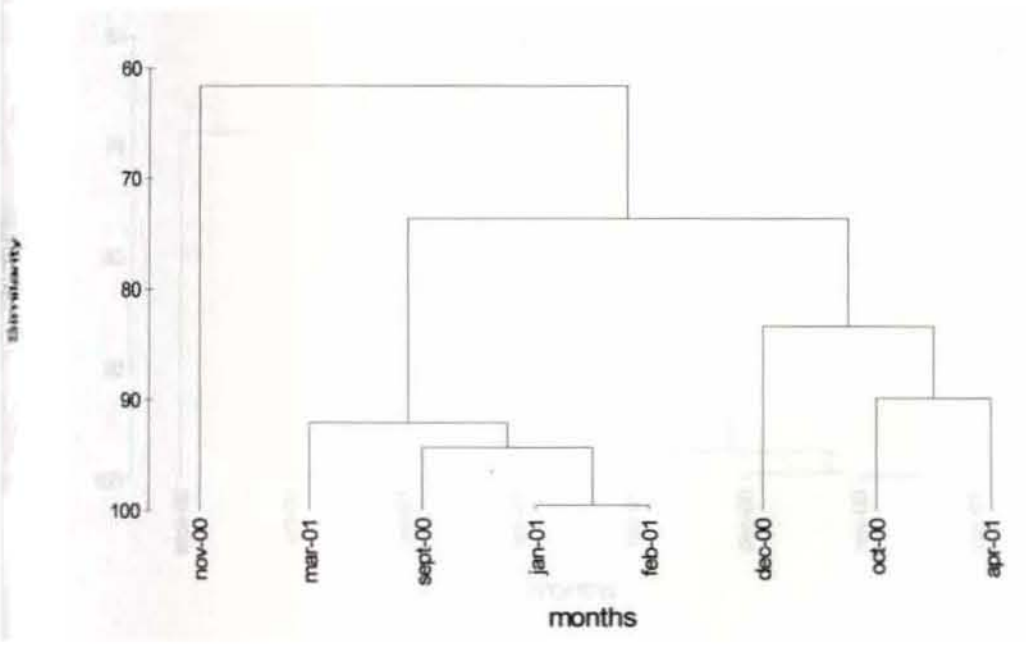
**Fig.3.6** Dendrogram of depth wise similarity index(in percentage) of deep sea prawns off Kerala at 151- 250m during 2000-01



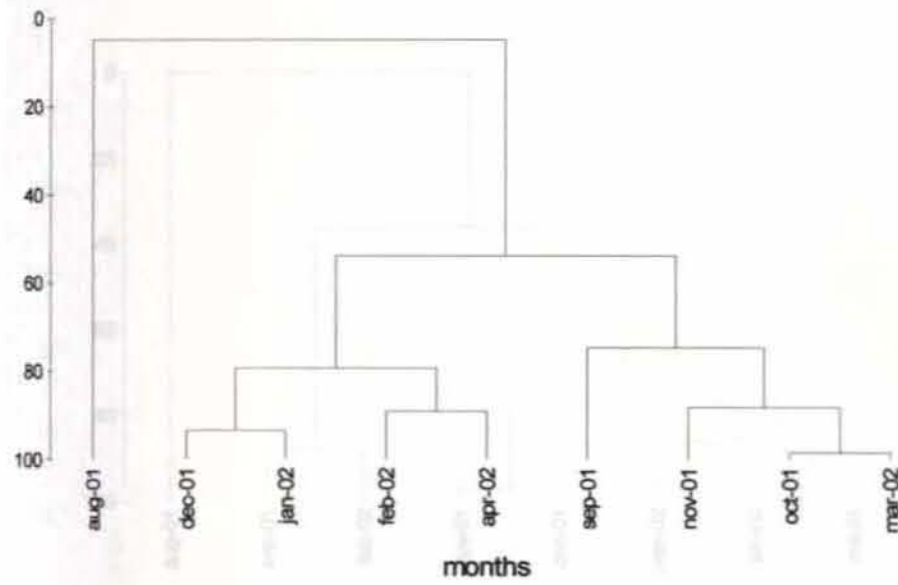
**Fig.17** Dendrogram of depth wise similarity index (in percentage) of deep sea prawns off Kerala at 151-250m depth during 2001-02



**Fig.19** Dendrogram of depth wise similarity index (in percentage) of deep sea prawns off Kerala at 251-350m depth during 2000-01



**Fig.1.10 Dendrogram of depth wise similarity index(in percentage) of deep sea prawns off Kerala at 251- 350m depth during 2001-02**



**Fig.1.12 Dendrogram of depth wise similarity index(in percentage) of deep sea prawns off Kerala at 351- 450m depth during 2000-01**

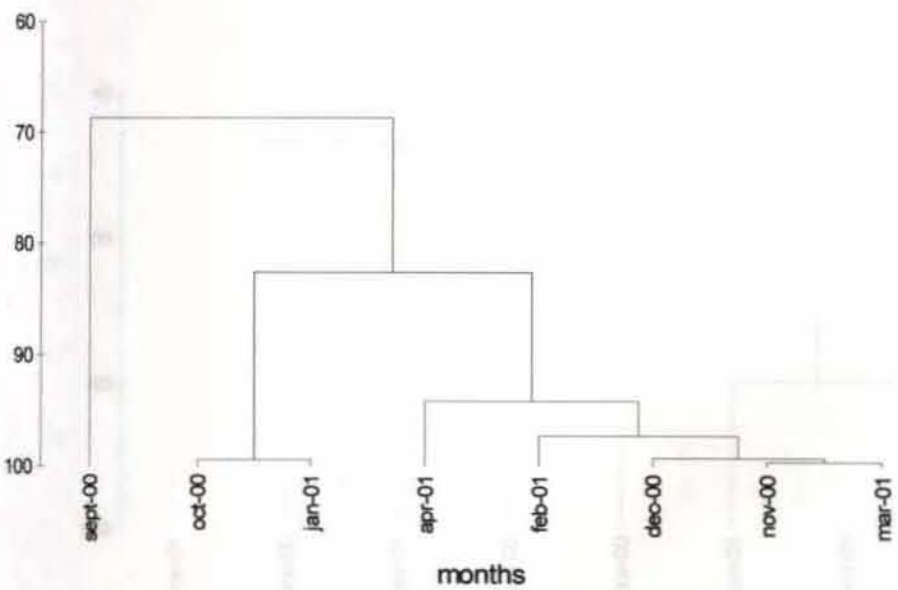




Fig. 3.13 Dendrogram of depth wise similarity Index(in percentage) of deep sea prawns off Kerala at 351-450m during 2001- 02

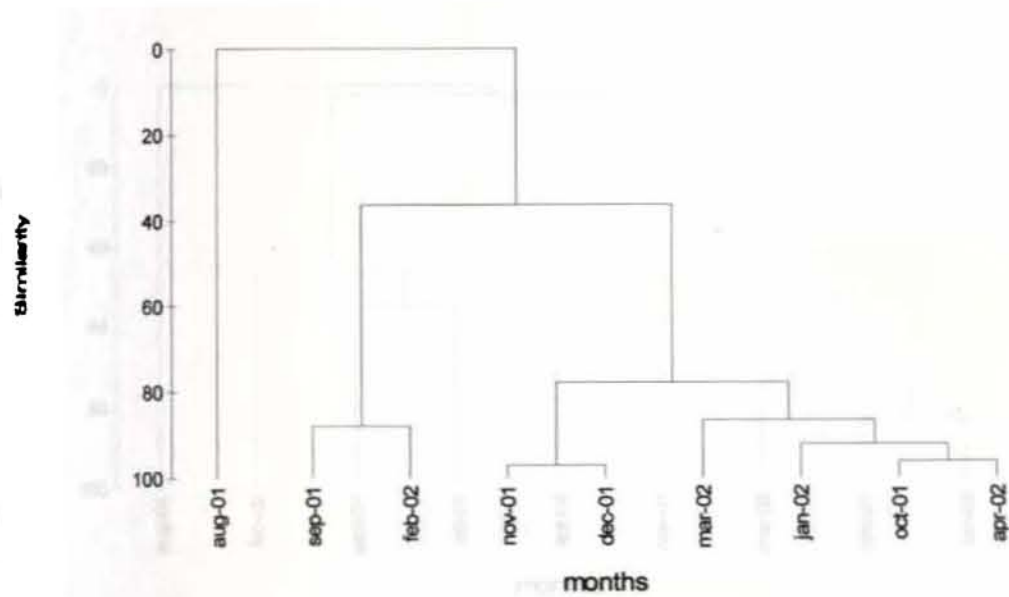
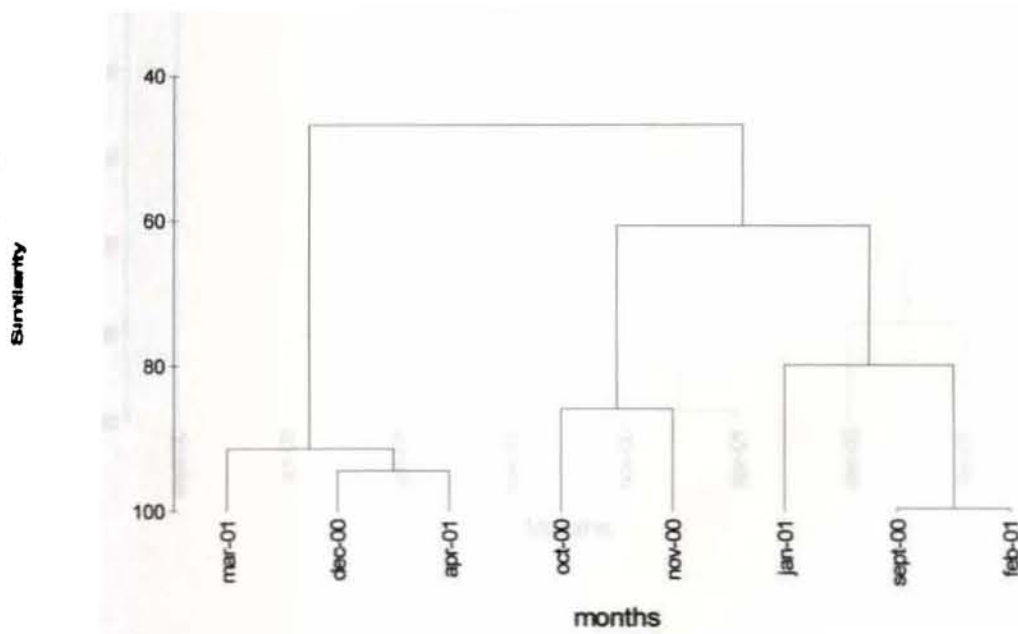
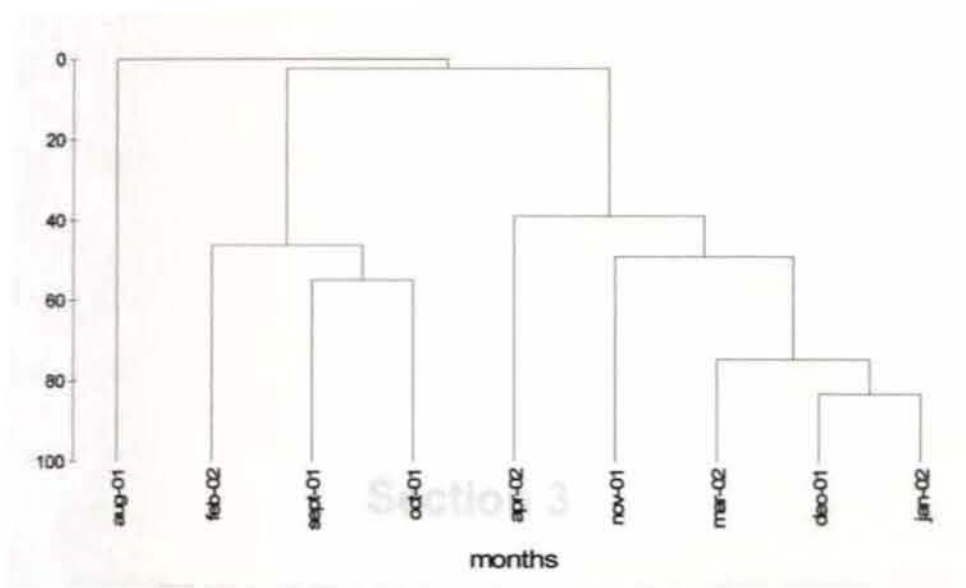


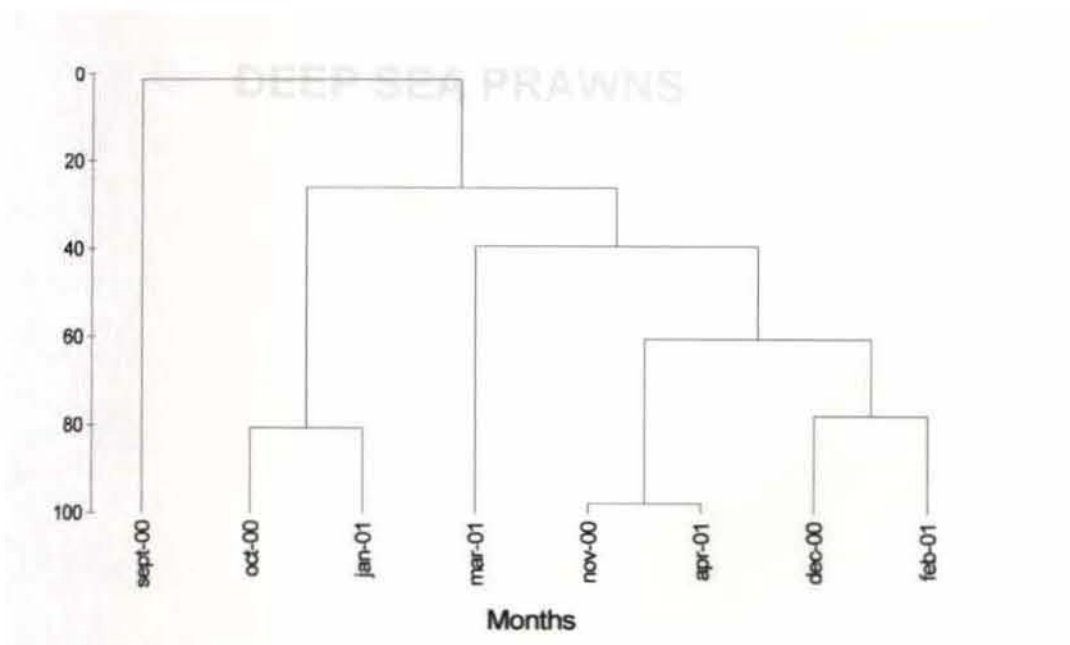
Fig. 3.15 Dendrogram of depth wise similarity index(in percentage) of deep sea prawns off Kerala at 451-550m during 2000- 01



**Fig.116 Dendrogram of depth wise similarity index(in percentage) of deep sea prawns off Kerala at 451-550m depth during 2001- 02**



**Fig.118 Dendrogram of depth wise similarity index(in percentage) of deep sea prawns off Kerala at 551-650m depth during 2000- 01**



**Section 3**

**EXPLORATORY SURVEYS**

**AND QUANTIFICATION OF EXPLOITED**

**DEEP SEA PRAWNS**

**Chapter 4**

**ASSESSMENT OF DEEP SEA PRAWN  
RESOURCES OFF KERALA ON THE BASIS  
OF EXPLORATORY SURVEYS**

#### **4.1. INTRODUCTION**

The demand for shrimps are ever increasing on a global basis, on the other hand, landings from the inshore waters is getting diminished alarmingly. This situation calls for the judicious exploitation and management of the coastal resources and exploration of new fishing grounds and resources in the offshore waters. Species contributing to capture fisheries needs to be investigated from various angles, especially their availability and abundance in those regions of inhabitation over space and time, before it is sought for the commercial exploitation (Kesteven , 1971). The exploratory surveys had been undertaken globally for the demarcation of potential fishing grounds for un exploited and under exploited deep sea crustaceans during the past many decades with the accomplishments of great oceanic expeditions viz., PORPOISE (1838-1842), CHALLENGER (1872 -1876), BLAKE (1877-1880), TRAVAILLEUR (1880 -1881), TALISMAN (1882), INVESTIGATOR (1884-1925), ALBATROSS (1891-1905), VALDIVIA (1898-1899), SIBOGA (1899-1900), KARL WOLFF (1989), ERNST HAECKEL (1982), XIANG YANGHONG (1989) and POLKA (1993). The salient features of the bathymetric and zonal distribution of the populations of pandalid

shrimps along western Mediterranean have been described by Carbonell and Abelló (1998).

Availability of a wide array of deep sea prawns and their general distribution pattern in the Indian Ocean have been studied by Alcock (1901), Wood – Mason (1891, 1892), Alcock and Anderson (1899) and Kemp and Sewell (1912) who participated in the surveys during 1884-1925 in the Royal Marine Survey Steamer ' INVESTIGATOR'. Exploratory surveys carried out by the research vessels R.V.CONCH, R.V.KALAVA and R.V.VARUNA during 1958-1968 (John & Kurian, 1959; Kurian, 1964, 1965; George and Rao, 1966; Rao and Suseelan, 1967) unravelled the exploitable deep sea prawn stock along the shelf edge and the upper continual slope off south west coast of India. Indo – Norwegian vessels M.V. KLAUS SUNNANA, M.V.TUNA and M.V. VELAMEEN (1967-1968) unfolded valuable information on the deep sea finfish and shellfish resources in the deep sea fishing grounds (Mohamed and Suseelan, 1973; Suseelan, 1974) off Kerala and Karnataka coasts and strongly suggested the possibility of their large scale exploitation. Exploratory surveys carried out by FORV Sagar Sampada since 1980's (Suseelan *et al.*, 1989 a, b) also recorded the availability, abundance and depth wise distribution of deep sea fishery resources off South West coast of India. Suseelan (1985, 1988) reported the bathymetric distribution and abundance of deep sea prawns off south west coast of India.

The revelation of commercially exploitable deep sea prawn wealth beyond the continental shelf by these surveys in the recent past has asserted immense scope for the commercial exploitation of deep sea crustaceans along Kerala coast. Following this, the commercial trawlers ventured in to the deep sea prawn fishing grounds off Kerala coast and thus the deep sea prawn fishery became a reality in Kerala since November 1999. In order to make deep sea prawn fishery more economically viable, a thorough knowledge on general distribution, area of abundance, resource characteristics etc., are essential pre requisites. Keeping this in view, the present study was undertaken to compile data relevant for their commercial exploitation such as catch and effort data, demarcation of regions of distribution and abundance of commercially important species, etc., based on the results of six exploratory survey cruises of FORV Sagar Sampada undertaken between the latitude zones  $7^{\circ}$ - $13^{\circ}$ N during 1999-2002. It is hoped that this would serve as baseline information for the judicious exploitation and management of this new high valued resource off Kerala coast.

## **4.2. MATERIALS AND METHODS**

The data for the study was collected on board research vessel FORV Sagar Sampada (Dept. of Ocean Development, Govt. of India)

during her cruise surveys no. 174 (June – July, 1999), 183 (April, 2000), 189 (October – November, 2000), 191 (January, 2001), 196 (July, 2001) and 197 (April, 2002). The experimental fishing was conducted at every  $1^{\circ} \times 1^{\circ}$  square grids at the depth ranging from 100-750m along latitude (lat.) between  $7-20^{\circ}$ N. The data collected from latitudes  $7-13^{\circ}$ N are presented. High Speed Demersal Trawl II (HSDT-II crustacean) having 30 mm square mesh and V.form otter boards were used for the trawling operation. Survey and samplings were carried out at each station and the total catch, effort and species composition were recorded. A total of 20 hauls were taken during cruise no .174, 23 hauls during cruise no. 183, 26 hauls during cruise no.189, 37 hauls and 29 hauls each during cruise no.191 and 197 respectively. The geographical position of the vessel during trawling and the depth of operation were recorded for delineating the spatial and bathymetric distribution and abundance of exploitable deep sea prawn resources. Area wise abundance of deep sea prawns were estimated by clustering the latitudes in to three regions viz. region - 1:  $7^{\circ}$ ,  $8^{\circ}$  and  $9^{\circ}$  N lat. zones, region-2:  $10^{\circ}$  and  $11^{\circ}$  N lat. zones and region -3:  $12^{\circ}$  and  $13^{\circ}$  N lat. zones. Depth wise distribution and abundance were estimated after consolidating the data collected from various stations under 9 depth zones following Suseelan (1985) viz., 151-200, 201-250, 251-300, 301-350, 351-400, 401-450, 451-500, 501-600, 601-700m.



### **4.3. RESULTS**

#### **4.3.1. Latitude wise abundance of deep sea prawns**

Table 4.1 shows the latitude wise total fishing effort expended in the area surveyed and the average catch per hr (C/hr) obtained together with minimum and maximum values recorded at various latitude zones. Of the entire Kerala coast surveyed, the effort spent in the region encompassing lat. 8 to 10<sup>0</sup> N was highest due to the intensive experimental trawling operations carried out between Quilon to Thottapally. During the period of study, a total of 2444.08 kg of deep sea prawns were harvested and the area between lat. 8<sup>0</sup> N to lat. 10<sup>0</sup> N was found to be most productive with highest average catch/hr of 66.53 kg. On the other hand, comparatively low catch rates were recorded at lat. 7<sup>0</sup> N and lat. 13<sup>0</sup> N.

#### **4.3.2. Depth wise catch per hour of deep sea prawns at different latitude zones**

In lat. 7<sup>0</sup> N, which encompasses the southern most part of the Wadge Bank, the deep sea prawns were found to be relatively less in their abundance and were encountered only in traces from 201-300 m depth (Table 4.2). The average catch rates worked out was 2.25kg/hr at 251-300 m while it was 2.97 kg /hr at 201-250m. Lat. 8–9<sup>0</sup> N was

appeared as the most productive zones of deep sea prawns. The highest average catch from lat. 8<sup>0</sup>N was recorded at 251-300 m (114.62 kg/hr) followed by the next highest catch at 301-350m (96.92kg/hr). From lat. 9<sup>0</sup>N also, the catch rates were high at 251-300m (114.83kg/hr), 301-350m (71.51kg/hr) and 401-450 m (80.07kg/hr) on Quilon Bank.

In lat. 10<sup>0</sup>N, which covers a part of Cochin to Ponnani region, the deep sea prawns were comparatively sparse and the highest catch at lat. 10<sup>0</sup>N was recorded from 301-350 m (16.62 kg/hr). Lat. 11<sup>0</sup>N, which covers the Malabar Coast from Thanur to Cannanore, the deep sea prawns were very scanty at 150 – 450m. In this zone, the highest catch rate was observed at 301-350 m (17.67kg/hr) while it was very least at 351-400m (1.33kg/hr) thus showing that their abundance was highly restricted in certain pockets.

Though the catch rates of deep sea prawns were relatively less in the lat. 12<sup>0</sup>N, however, their presence was encountered from almost all depth zones surveyed, which ranged between 201- 700m, thus unfolding their distribution to very higher depths up to 700m. In this zone, highest catch rate of 31.11kg/hr was recorded at 251-300 m, in contrast, 601-700 m showed the lowest catch rates of 0.25 kg /hr. Lat. 13<sup>0</sup> N, which encompasses the northern most part off Kerala coast, the deep sea prawns were encountered from only three depth zones, among them the

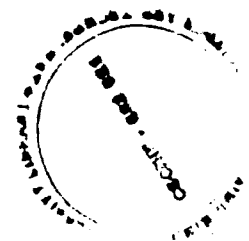
highest catch rate was recorded in 501-600 m while it was lowest in 251-300m.

### 4.3.3. Distribution of catch and effort at various depth zones

Variation in the prawn catch from different depths in relation to trawling effort is depicted in Table 4. 3. Highest concentration of deep sea prawns were found in the depth zones 251-300 and 301-350 m in all the latitude zones surveyed. Furthermore, the results indicate that the availability of prawns were moderate in depth zones 251-300 (18.09kg/hr) in lat. 7-9°N. In 351-400 and 401-450 m also, moderate catch rates of 18.94 kg/hr and 17.95 kg /hr respectively were recorded in the lat. 9° N to 13° N. Interestingly, in 601-700 m, the deep sea prawns were totally absent, however, it appeared in traces at lat. 12°N. Similarly, no deep sea prawns could also be encountered in the depth zones 151-200 m but for the negligible quantities registered in the lat. 11°N.

### 4.3.4. Region wise species composition

The deep sea prawns at the three regions evinced very distinct region specific and depth specific distribution pattern. In the region 1, which encompasses lat. 7,8 and 9°N, *H.gibbosus* emerged as the dominant species in 351-400 m (61.74%). Whereas *H.woodmasoni* was



dominant at 301-350 m (62.40%) (Table 4.4). In contrast, depth zone 201-250 m, *P.spinipes* contributed to 61.07% of the total prawn catch while *A.alcocki* appeared as the dominant species in 401-450 and 451-500m depths registering 61.68 and 51.28% of the total prawn catch respectively (Fig. 4.1).

In region 2, which encompassing lat. 10 and 11<sup>0</sup>N, *H.gibbosus* showed its dominance at 251-400 m depth while *A.alcocki* predominated at 401-500 m. On the other hand, 90.63% of the total catch at 151-200m was contributed by *M.andamanensis* while at 301-400 m *H.gibbosus* showed its dominance (Table 4.5). In 401-450m and 451-500m, *A.alcocki* dominated in the total catch with 70.7% and 95.65% respectively whereas *H.woodmasoni* formed only in traces in this region with 5.80% and 11.27% of the total catch obtained from 301-350m and 351-400m depth zones respectively (Fig. 4.1).

In region 3, coming under lat. 12 and 13<sup>0</sup>N, *P.spinipes* (60.45%) and *M.andamanensis* (38.18%) appeared as the major deep sea prawns both in 201-250 and 251-300 depth zones (Table 4.6). There was the dominance of *H.gibbosus* at 301-350 m, which accounted for 66.48% of the total catch. Its vertical distributional range was observed even up to 500m while *A.alcocki* appeared as the single most dominant species in the higher depths of 501-600 m with a contribution of 90.09% while it represents 100 % in the catches observed from 600-700 m (Fig. 4.1).

#### 4.3.5. Depth wise species composition

A comparison of deep sea prawns recorded in the landings from various depth zones of different latitudes revealed that lat. 7<sup>o</sup>, 8<sup>o</sup> and 9<sup>o</sup> N were characterised by highest numerical species strength, predominantly represented by pandalids at various depth zones. Lat. 10<sup>o</sup> and 11<sup>o</sup> appeared as the region of second highest species assemblage of deep sea prawns where both penaeids and pandalids were represented equally in the total exploited catch. On the contrary, in lat. 12<sup>o</sup> and 13<sup>o</sup>, only very few species of pandalid shrimps were found, however, the penaeid and aristeid prawns showed a modest representation in the deep sea prawn catch from these latitudes (Table 4.7) .

While assessing the species strength and the preponderance of individual species in the entire region of investigation, it can be seen that the deep sea prawns were represented by 15 species, among them *P.spinipes* appeared as the most predominant species followed by *H.woodmasoni*. In lat. 7-8<sup>o</sup>N *S.hextii* appeared as the dominant species in the depth zones 151-200 whereas the dominance of *P.jerryi* was observed at 201-250 m.

In lat. 8 -9<sup>o</sup>N, four species were found in appreciable quantities viz. *P.spinipes*, *H.woodmasoni*, *H.gibbosus* and *S.hextii*, among them *P. spinipes* showed the dominance at 251-300m while *H.woodmasoni*

was dominant at 301-350 m whereas *H.gibbosus* caught in moderate quantities at 301-350 and 351-400 m depth zone. In lat. 9 °N, which accommodate part of Quilon Bank, the depths between 201-250 and 401-450 m were delineated as the most productive region for deep sea prawns as manifested by highest species diversity and catch rates. Nine species were identified from this area, among them *H.woodmasoni*, *H.gibbosus* and *A.alcocki* showed very high concentration at 201-450 depth. Other species encountered from this area include *P.martia* (9.23kg/hr), *S.hextii* (8kg/hr) at 251-300m depth zones, *P.jerryi* (8kg/hr) at 201-250 m and *P.ensis* at 401-450m (2.79kg/hr).

Altogether 9 species of deep sea prawns were recorded from the five depth zones viz. 251-300,301-350,351-400,401-450,451-500m surveyed at lat. 10<sup>0</sup>-11<sup>0</sup>N. The catch rates recorded in almost all the species were so negligible and there is no clear-cut dominance of a single species in any of the regions surveyed except for *H.gibbosus* in 301-350m was discernible. *H.gibbosus*, *P.spinipes*, *M.andamanensis*, *S.hextii* and *A.alcocki* were found mainly concentrated in the depth range 251-400m in lat. 11<sup>0</sup>N – 12<sup>0</sup>N. *H.gibbosus* appeared as the dominant species in this region followed by *M.andamanensis* at 301-350 m whereas *P.spinipes*, *A.alcocki*, *S.hextii* and *P.martia* were found in traces at 251-300 m.

*M.andamanensis* and *P.spinipes* appeared as the dominant species in lat. 12<sup>o</sup> to 13<sup>o</sup> N at 251-300 m. *P.ensis*, *P.spinipes* and *A.alcocki* were found in all the three depth zones viz. 251-300, 451-500 and 600-700 m in the lat.13<sup>o</sup> N.

#### **4.3.6. Distribution and abundance of deep sea prawns in lat. 7<sup>o</sup> N –13<sup>o</sup>N**

The results of the present exploratory trawling surveys revealed that *H.woodmasoni* was distributed in varying quantities from off Cape Comorin to off Cochin (lat.8<sup>o</sup>N-10<sup>o</sup>N) in the depths between 201 and 600m (Fig. 4.2). Highest concentration of this species was encountered at 8<sup>o</sup> to 9<sup>o</sup>N between 251and 350 m depth zones. Average catch rate in the area of highest concentration was estimated to be 57.42kg/hr. The species was rarely encountered beyond 400m and restricted between lat.8<sup>o</sup> and 10<sup>o</sup>N.

Among the various deep sea prawns, *Heterocarpus gibbosus* showed more or less wider distribution along the Kerala coast. This species was recorded between the lat. 8<sup>o</sup>N to 12<sup>o</sup>N at 251-500m (Fig. 4.3). Comparatively higher catch rates were encountered at 301-350m in all the latitudes surveyed, except for lat. 9<sup>o</sup> N, where the highest concentration of *H.gibbosus* was recorded at 351-400m (24.31kg/hr). Beyond 400m, a gradual reduction in abundance was showed by the

species. In lat.9<sup>0</sup>N where maximum concentration was observed, the average catch rate was worked out to be 18.65 kg/hr and the same for entire distribution area of *H.gibbosus* was computed as 7.94kg/hr.

In the present exploratory surveys, *A.alcocki* was recorded in varying quantities between Lat.9<sup>0</sup> N and 13<sup>0</sup>N in the depth zones ranging from 301-700m (Fig.4.4). This species invariably showed its inhabitation in the deeper waters. Bathymetrically, the highest abundance of this species was encountered in 401-450m and 451-500m in lat. 9<sup>0</sup> N that encompasses part of Quilon Bank also, the catch rates were high in 351-500 m while in the north off Ezhimala this species showed a wider distribution in 301-600 m depth. Average catch rate of *A.alcocki* in the area of highest concentration was worked out to be 49.76kg/hr while the same for the entire region of distribution was computed as 6.01kg/hr.

Among the various species of deep sea prawns , *P.spinipes* emerged as the most predominant one of the Kerala coast . This species was recorded in varying quantities along the entire coast between 7<sup>0</sup>N to 13<sup>0</sup>N at 151-400m depths (Fig. 4.5). It preferred to inhabit in relatively shallower grounds as evidenced from the highest catch rates and density at 251-300 in both the latitude zones 8<sup>0</sup>N – 9<sup>0</sup>N of Quilon Bank. In the northern part of Kerala coast, comparatively better catch rates were registered at lat.12<sup>0</sup>N, off Ezhimala between 150-250m depth ranges. In the area of highest concentration, the average catch rate of *P.spinipes*



was computed was 42.46kg/hr while the average catch rates for the entire distributed area was estimated to be 12.52kg/hr.

*M.andamanensis* showed a highly restricted distribution in the lat. 10°N to 12°N, off Alleppey to off Cannanore (Fig. 4.6). This species was mostly found inhabiting in the shallow waters in the depth 150-250m. However, the catch rate was highest at 251-300m showing very high concentration at lat.11°N to 12° N. The catch rate of this species in the area of highest concentration was computed as 8.12kg/hr while the same for the entire area of distribution was worked out to be 4.23kg/hr. Bathymetrically the species was found distributed up to 350 m between 10°N to 11°N while in 12°N the distribution was found very much confined to 300m.

#### 4.4. DISCUSSION

Results of the catch composition of deep sea prawns in different latitudinal and bathymetric zones revealed that the deep sea prawn resources of Lat.9 °N and Lat.10° N (Off Quilon to Off Cochin) are comprised of multi species and have a numerical strength of 15 species viz., *P.spinipes*, *H.woodmasoni*, *H.gibbosus*, *H.laevigatus*, *M.andamanensis*, *A.alcocki*, *P.martia*, *P.ensis*, *P.alcocki*, *H.alfonsi*, *O.typus*, *A.sanguinea*, *P.investigatoris*, *P.jerryi* and *S.hextii*. The patterns

of catch trends recorded from different latitude zones showed that there exist distinct variation in the availability and abundance in these species in various depth zones. The highest C/hr was observed at Lat.8<sup>0</sup>N (58.91kg/hr) followed by Lat.9<sup>0</sup>N (55.92kg/hr) at 251-300m depth Zones. The results of the exploratory surveys of INP vessels M.V.Velameen, M.V.Tuna and M.V. Klaus Sunnana (Oommen , 1980) also almost corroborated with the present findings . Among them, the catch rates of Tuna and Velameen show very strong agreement with the present results. The catch rates of deep sea prawns by M.V. Tuna was reported to be 48.65kg/hr at lat. 8<sup>0</sup>N while M.V.Velameen registered 34.73kg/hr. At lat.9<sup>0</sup>N Velameen registered a catch rate of 37.06 kg/hr (Suseelan, 1985).

In the latitudes 8-13<sup>0</sup>N, it is observed that the depth zones 201-500m were rich in deep sea prawn resources, which can very well sustain and support a commercial fishery. The existence of a very well established deep – sea prawn fisheries in the temperate and arctic oceans (Gulland, 1971; Holthuis, 1980) are primarily based on the shrimp stock located on the upper continental slope and are comparable with the depth zones demarcated in the present study.

Based on the results emerged from the present synoptic surveys, it can reasonably be concluded that there exists strong spatial and bathymetric variation in the species composition as well as stock availability of deep sea prawn resources off Kerala coast. Depth varying

from 151-200m in the latitudes 7- 13<sup>0</sup>N is found to be significantly unproductive for deep sea prawn resources and were sparsely represented only by penaeids such as *P. jerryi* and *M. andamanensis* and solenocerid shrimps in traces, however, with an increase of depth (201-250m) smaller pandalids like *P. spinipes* also appeared along with the penaeid prawns. With a further increase in depth, species like *H. woodmasoni* showed its emergence especially at 251 to 350m. Depth zones beyond 300m are characterised exclusively by the presence of pandalid shrimps such as *H. woodmasoni*, *P. martia* and *H. gibbosus* and reciprocally there is a decline of penaeid prawns to insignificant quantities. From 350 m onwards, the availability of *H. woodmasoni* became so scarce, on the contrary, the deep sea dwelling species like *A. alcocki* showed its emergence and abundance. Interestingly, beyond 400m. there was the preponderance of aristeid prawns, while the availability of *H. gibbosus*, *A. armata* and *A. sanguinea* became stray.

A scrutiny of literature on the inhabitation of deep sea crustaceans indicated that invariably at lower depths, penaeid prawns showed its abundance in tropical and sub tropical seas as reported by Gulland (1971) and Holthuis (1980), followed by solenocerid shrimps (Anderson and Lindner, 1971). Whereas in western Africa, the penaeid prawn *Parapaneaus longirostris* showed its abundance at 150-350 m followed by *Plesionika martia* between 250-400 m, *Plesiopenaeus edwardsianus*, *Aristeus antennatus* and *Aristeus varidens* up to 700 m

depth ranges (Crosnier and Forest , 1973 ; Holthuis ,1980). Exploratory fishing conducted off Madagascar and Africa revealed that the solenocerid shrimp *Haliporoides triarthrus* inhabited at 360 – 550m depth while *H.woodmasoni* at 300–400m depth (Crosnier and Jouannic, 1973; Holthuis,1980; Miquel,1984). The depth and latitude wise variation in the distribution and abundance of species might be due to the difference in the nature of substratum, bottom contour, water temperature or owing to some other hydrographic or environmental factors that influence the habitat of the species (Cartes and Sardá , 1993; Chou *et al.*, 1999; Dow, 1967; Farina *et al.*, 1997). Mary and Ioannis (1999) also reported similar observation on 5 deep water decapods from the experimental trawl surveys along the continental slope of Eastern Mediterranean. According to them, the differences in the distribution patterns of *Plesionika ensis*, *Polycheles typhlops*, *Parapenaeus longirsotris* and *Plesionika heterocarpus* between the depth gradient 100-1000 m were due to highly diverse diet habitats among the species. The species occurring shallower depths become active predators with higher dietary diversity than those living above 500 m. Since the dietary overlap when they co exist was high, it is possible that competitive trophic interactions accounted for the low overlap in the bathymetrical distribution of the species. Food and feeding analysis of *H.gibbosus* and *H.woodmasoni* also support this view where the deep water dwelling *H.gibbosus* showed less dietary diversity

when compared to the lesser deeper dwelling *H.woodmasoni* (Refer Chapter 7 for details ) .

Results of depth wise prawn catch in relation to trawling effort in different latitude zones revealed that region one encompassing lat 8<sup>0</sup>N-9<sup>4</sup>N which covers Quilon bank appeared as the most productive ground for deep sea prawns ,especially at 251-350 m . This region was also demarcated as the most important ground for pandalid shrimps where the dominance of *H.woodmasoni*, *H.gibbosus*, *P.spinipes*, *P. ensis* were discernible. Suseelan (1985) reported similar findings based on results compiled from the exploratory surveys of R.V. Varuna along south west coast of India.

Region two encompassing off Ponnani and off Aleppey was delineated as the next important deep sea prawn ground from the commercial point of view due to the abundance of both penaeid prawns as well as pandalid shrimps in deeper waters of 251-500m depth. The next important deep sea prawn ground delineated in the present study was north off Ezhimala between 300-600 m depth where aristeid and pandalid shrimps emerged as the most predominant species. Deep sea trawlers operated from various harbours recorded very good catches of *A.alcocki* from these ground during February to April.

Catch and effort data from various depth zones showed that the depth zones between 151-200m and 600-700 m were not good grounds

for the commercial exploitation of deep sea prawns between 7<sup>o</sup>N and 13<sup>o</sup>N. On the other hand, comparatively shallower depth zones of 251-300 and 301-350m were found to be ideal for commercial fishery as evidenced from higher catch rates. Variations in the abundance of deep sea prawns at different depths in deeper waters have been reported by Lagardère (1972) and Maria Figueiredo *et al.* (2001) from Portugal waters, Demestre (1994) from north western Mediterranean Ocean and Ragonese *et al.* (1994) from the western Mediterranean and Oommen (1980) and Suseelan (1985) from south west coast of India.

It appears that the population of *H.woodmasoni* is found well restricted with in lat. 8<sup>o</sup> N and lat.10<sup>o</sup>N in the Quilon Bank and the presence of this species was not observed beyond this zone whereas *Heterocarpus gibbous* was found distributed between 8-12<sup>o</sup>N (off Quilon – off Ezhimala). The occurrence of *Aristeus alcocki*, the principal species constituting the deep sea prawn fishery in Kerala, is distributed in the southern latitude zones 9-10<sup>o</sup>N (off Alleppey and Cochin) at 401-500m depth zones. In the northern zones, off Ezhimala (lat.12<sup>o</sup>-13<sup>o</sup>N), where this species was observed in high concentration at 401-600m, appeared to be a potential ground for commercial exploitation of *Aristeus alcocki*.

*P.spinipes* was distributed in the latitude zones 8-12<sup>o</sup>N at 201-350 m. The distribution of *Metapenaeopsis andamanensis* was restricted to only Lat 10-12<sup>o</sup>N in the depth zones 200 to 350 m (4.45kg). In contrast to

the observations made in the exploratory surveys by Suseelan (1985), in the present study, *P.spinipes* emerged as the principal species in the trawl catches leaving other species far behind in percentage composition. In the commercial deep sea prawn landings also *P.spinipes* appeared as the dominant species contributing 19% and 40% during 2000-01 and 2001-02 respectively to the total deep sea prawn landings of Kerala (Refer Chapter 5 for details).

The present results will be utmost useful in predicting the size and number of vessels needed for the deep sea prawn exploitation off Kerala coast. Besides, the data on the standing stock gives an idea of resource position and depth of occurrence of various species in different regions, which in turn, would be helpful for the policy makers in taking decisions for the rational exploitation of deep sea prawns for catering to the ever-increasing demand of prawns on a global basis.

**Table 4.1 Latitude-wise catch and effort of deep sea prawns off Kerala**

| Latitudes      | Fishing effort |  | Minimum C/hr (kg) | Maximum C/hr (kg) | Average C/hr (kg) |
|----------------|----------------|--|-------------------|-------------------|-------------------|
|                | (hrs)          |  |                   |                   |                   |
| Latitude 7° N  | 0.92           |  | 0.36              | 11.11             | 5.73              |
| Latitude 8° N  | 1.55           |  | 0.80              | 51.67             | 16.43             |
| Latitude 9° N  | 1.49           |  | 0.24              | 524.00            | 58.19             |
| Latitude 10° N | 1.40           |  | 0.40              | 154.00            | 22.24             |
| Latitude 11° N | 0.47           |  | 0.80              | 136.00            | 26.78             |
| Latitude 12° N | 0.77           |  | 10.00             | 71.21             | 16.60             |
| Latitude 13° N | 0.96           |  | 4.00              | 10.00             | 6.55              |

**Table 4.3 Details of catch obtained , effort extended and C/hr of deep sea prawns at 150-700m off Kerala (Lat.7°N-13°N)**

| Catch Effort Catch/hr (kg) | Depth (m) |         |         |         |         |         |         |         |         |  |
|----------------------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|--|
|                            | 150-200   | 201-250 | 251-300 | 301-350 | 351-400 | 401-450 | 451-500 | 501-600 | 600-700 |  |
| 8.00                       | 114.85    | 433.90  | 1218.75 | 478.30  | 149.00  | 14.00   | 27.00   | 0.25    |         |  |
| 2.5                        | 6.35      | 11.2    | 36.2    | 25.25   | 8.3     | 3.6     | 5.6     | 1       |         |  |
| 3.2                        | 18.1      | 38.7    | 33.7    | 18.9    | 18.0    | 3.9     | 4.8     | 0.25    |         |  |



TABLE 2

Depth (m) in 50 m intervals for the following months  
(in parentheses) in 10 m intervals (in parentheses)

| Latitude | Depth Zones (m) |         |         |         |         |         |         |         |         |
|----------|-----------------|---------|---------|---------|---------|---------|---------|---------|---------|
|          | 150-200         | 201-250 | 251-300 | 301-350 | 351-400 | 401-450 | 451-500 | 501-600 | 601-700 |
| 7° N     | C*              | ...     | 5.5     |         |         |         |         |         |         |
|          | E**             |         | 1.85    |         |         |         |         |         |         |
|          | C/hr            |         | 2.97    |         |         |         |         |         |         |
| 8° N     | C               |         | 0.25    | 149     | 126     | 89      |         |         |         |
|          | E               |         | 0.45    | 1.3     | 4.25    |         |         |         |         |
|          | C/hr            |         | 0.56    | 114.62  | 96.92   | 20.94   |         |         |         |
| 9° N     | C               |         | 83      | 210     | 659.65  | 379     | 121     | 9       | 13      |
|          | E               |         | 2.15    | 1.45    | 9.25    | 12.5    | 1.5     | 3       | 3       |
|          | C/hr            |         | 38.60   | 144.83  | 71.31   | 30.32   | 80.67   | 3.00    | 4.33    |
| 10° N    | C               |         |         | 3       | 319.1   | 0.8     | 10      | 2       |         |
|          | E               |         |         | 1       | 19.2    | 1       | 3.9     | 0.3     |         |
|          | C/hr            |         |         | 3.00    | 16.62   | 0.80    | 2.56    | 6.67    |         |
| 11° N    | C               |         |         | 16.4    | 106     | 2       |         |         |         |
|          | E               |         |         | 2.8     | 6       | 1.5     |         |         |         |
|          | C/hr            |         |         | 5.86    | 17.67   | 1.33    |         |         |         |
| 12° N    | C               |         | 28      | 42      | 8       | 7.5     | 10      | 3       | 2       |
|          | E               |         | 2.15    | 1.35    | 0.45    | 6       | 1.5     | 0.3     | 0.6     |
|          | C/hr            |         | 13.02   | 31.11   | 17.78   | 1.25    | 6.67    | 10.00   | 3.33    |
| 13° N    | C               |         |         | 8       |         |         | 8.00    | ...     | 12.00   |
|          | E               |         |         | 1.45    |         |         | 1.4     |         | 2       |
|          | C/hr            |         |         | 5.52    |         |         | 5.71    |         | 6.00    |

C\* - in Kg E\*\* - Hr

Table 4.4

Percentage wise species composition of deep sea prawns in region - 1  
(Lat.7,8&9°N) at 150-500 m depth off Kerala coast

| Species                           | Depth (m) |         |         |         |         |         |         |
|-----------------------------------|-----------|---------|---------|---------|---------|---------|---------|
|                                   | 150-200   | 201-250 | 251-300 | 301-350 | 351-400 | 401-450 | 451-500 |
| <i>Stomatopoda hextii</i>         | 100       | 15.19   | 4.14    | 1.21    | 1.29    |         |         |
| <i>Parapandalus spinipes</i>      |           | 61.07   | 56.21   | 14.27   | 1.56    |         |         |
| <i>Parapandalus jerryi</i>        |           | 23.74   | 1.74    |         |         |         |         |
| <i>Metastomatopoda woodmesoni</i> |           |         | 31.77   | 62.40   | 33.03   | 4.57    | 10.26   |
| <i>Metastomatopoda gibbosus</i>   |           |         | 2.57    | 21.46   | 61.74   | 30.14   | 31.46   |
| <i>Metastomatopoda atcocki</i>    |           |         |         | 0.30    |         | 61.68   | 58.28   |
| <i>Parastomatopoda martha</i>     |           |         | 3.56    | 0.36    | 2.38    | 0.15    |         |
| <i>Parastomatopoda ensis</i>      |           |         | 0.01    |         |         | 3.46    |         |
| <i>Parastomatopoda sanguinea</i>  |           |         | 0.001   |         |         |         |         |
| <i>Metastomatopoda laevigatus</i> |           |         | 0.001   |         |         |         |         |
| <i>Parastomatopoda atcocki</i>    |           |         | 0.001   |         |         |         |         |
| <i>Stomatopoda typus</i>          |           |         | 0.001   |         |         |         |         |

Table 4.5

Percentage wise species composition of deep sea prawns in region - 2  
(Lat.10&11 °N) at 150-500 m depth off Kerala coast

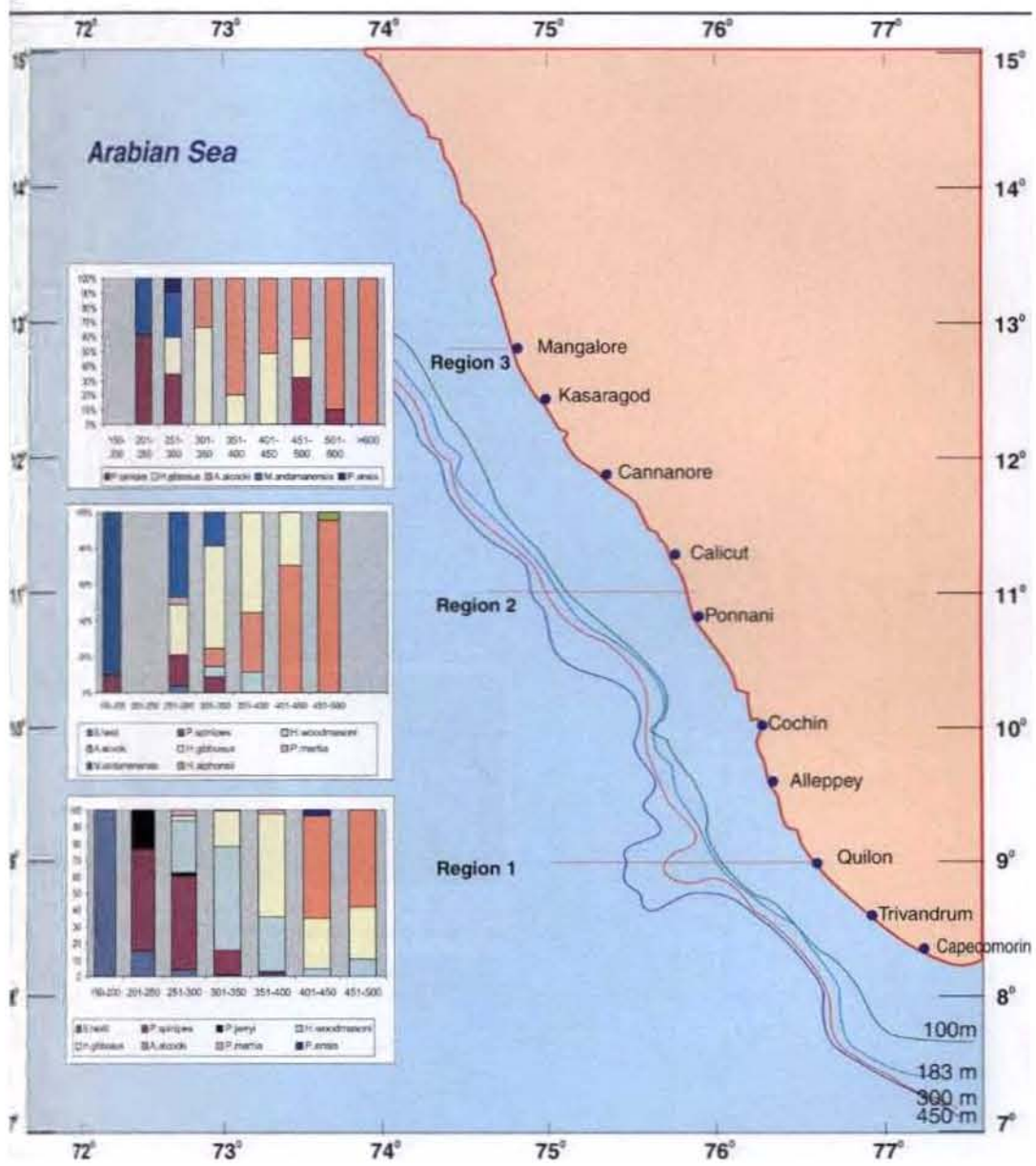
| Species                           | Depth (m) |         |         |         |         |         |         |
|-----------------------------------|-----------|---------|---------|---------|---------|---------|---------|
|                                   | 150-200   | 201-250 | 251-300 | 301-350 | 351-400 | 401-450 | 451-500 |
| <i>Stomatopoda hextii</i>         |           |         | 3.84    |         |         |         |         |
| <i>Parapandalus spinipes</i>      | 9.38      |         | 17.16   | 8.72    |         |         |         |
| <i>Parapandalus jerryi</i>        |           |         |         | 5.80    | 11.27   |         |         |
| <i>Metastomatopoda woodmesoni</i> |           |         |         | 9.97    | 32.86   | 70.70   | 95.65   |
| <i>Metastomatopoda gibbosus</i>   |           |         | 27.77   | 57.13   | 55.87   | 29.30   |         |
| <i>Metastomatopoda atcocki</i>    |           | No data | 4.06    |         |         |         |         |
| <i>Parastomatopoda martha</i>     | 90.63     |         | 47.18   | 18.37   |         |         |         |
| <i>Parastomatopoda ensis</i>      |           |         |         |         |         |         | 4.35    |

Table 4.6

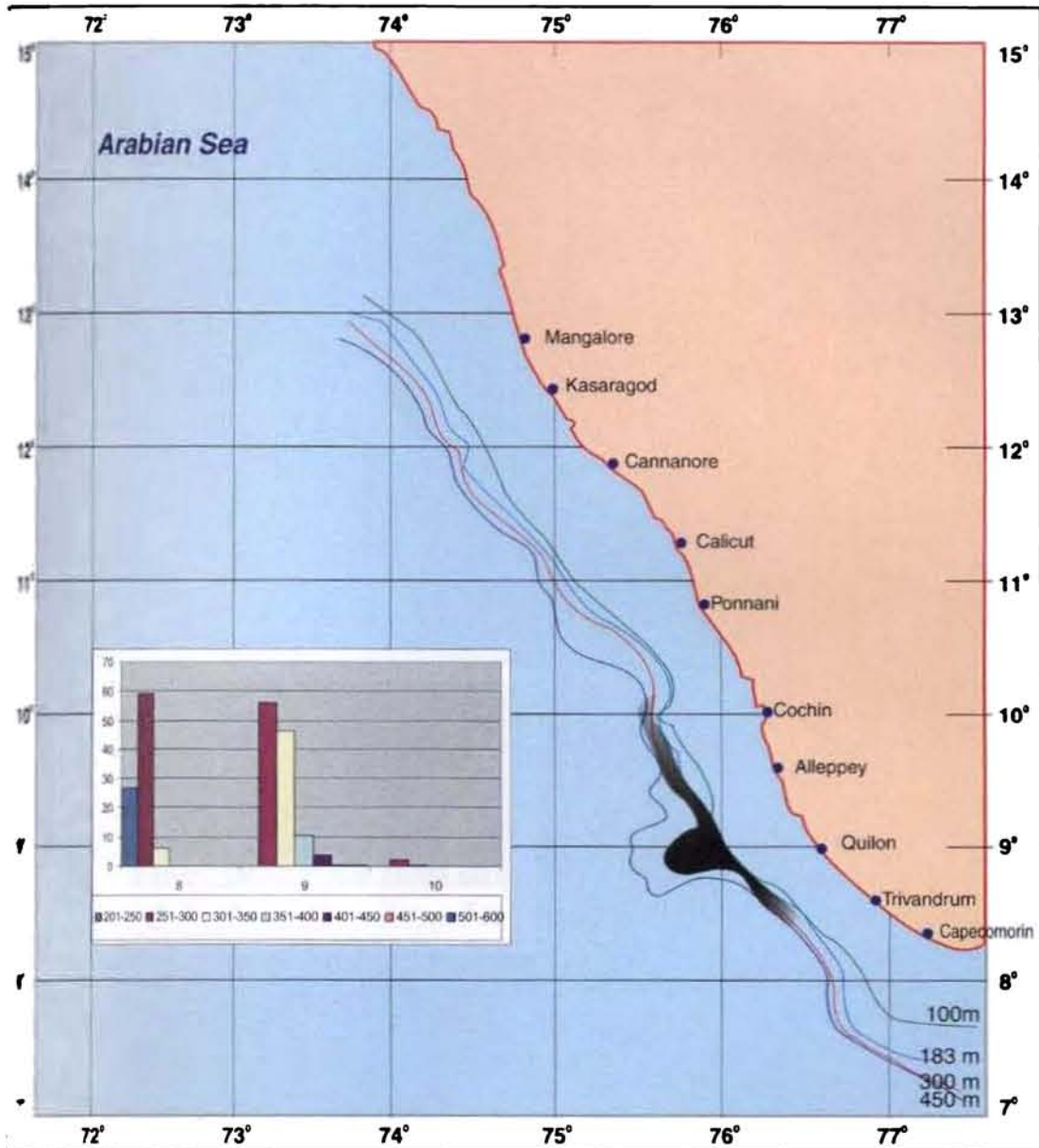
Percentage wise species composition of deep sea prawns in region - 3  
( Lat.12&13 °N) at 150-700 m depth off Kerala coast

| Species                             | Depth (m) |         |         |         |         |         |         |         |         |
|-------------------------------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|
|                                     | 150-200   | 201-250 | 251-300 | 301-350 | 351-400 | 401-450 | 451-500 | 501-600 | 601-700 |
| <i>Parapandalus spinipes</i>        |           | 60.45   | 34.53   |         |         |         | 32.1    | 9.91    |         |
| <i>Metastomatopoda gibbosus</i>     |           |         | 25.25   | 66.48   | 20.00   | 48.13   | 26.1    |         |         |
| <i>Metastomatopoda atcocki</i>      |           |         |         | 33.52   | 80.00   | 51.87   | 41.80   | 90.09   | 100     |
| <i>Metastomatopoda andamanensis</i> |           | 38.18   | 30.60   |         |         |         |         |         |         |
| <i>Parastomatopoda ensis</i>        |           |         | 9.61    |         |         |         |         |         |         |

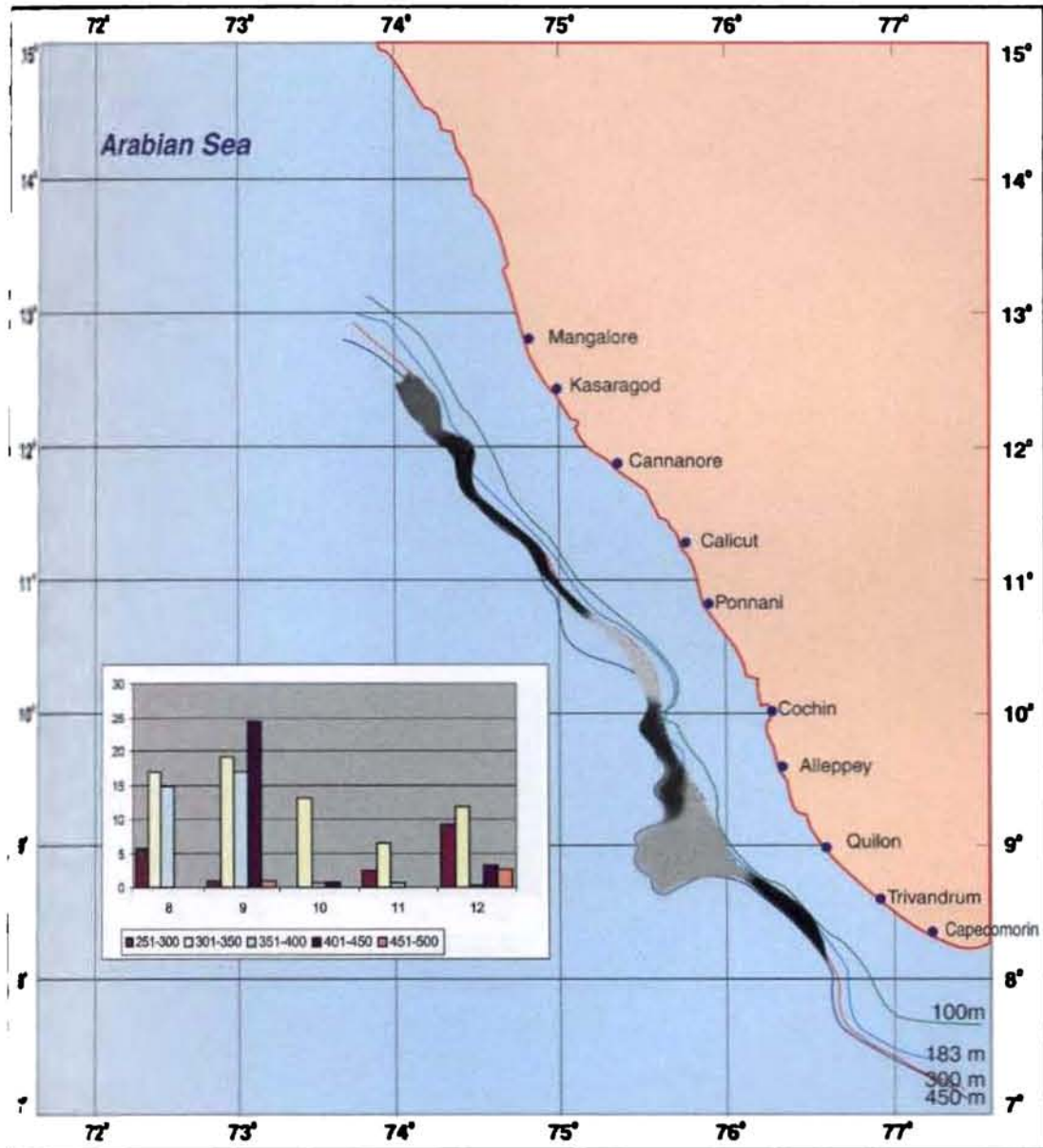
**Fig. 4.1.**  
**Region wise species composition of Deep Sea Prawns off Kerala**



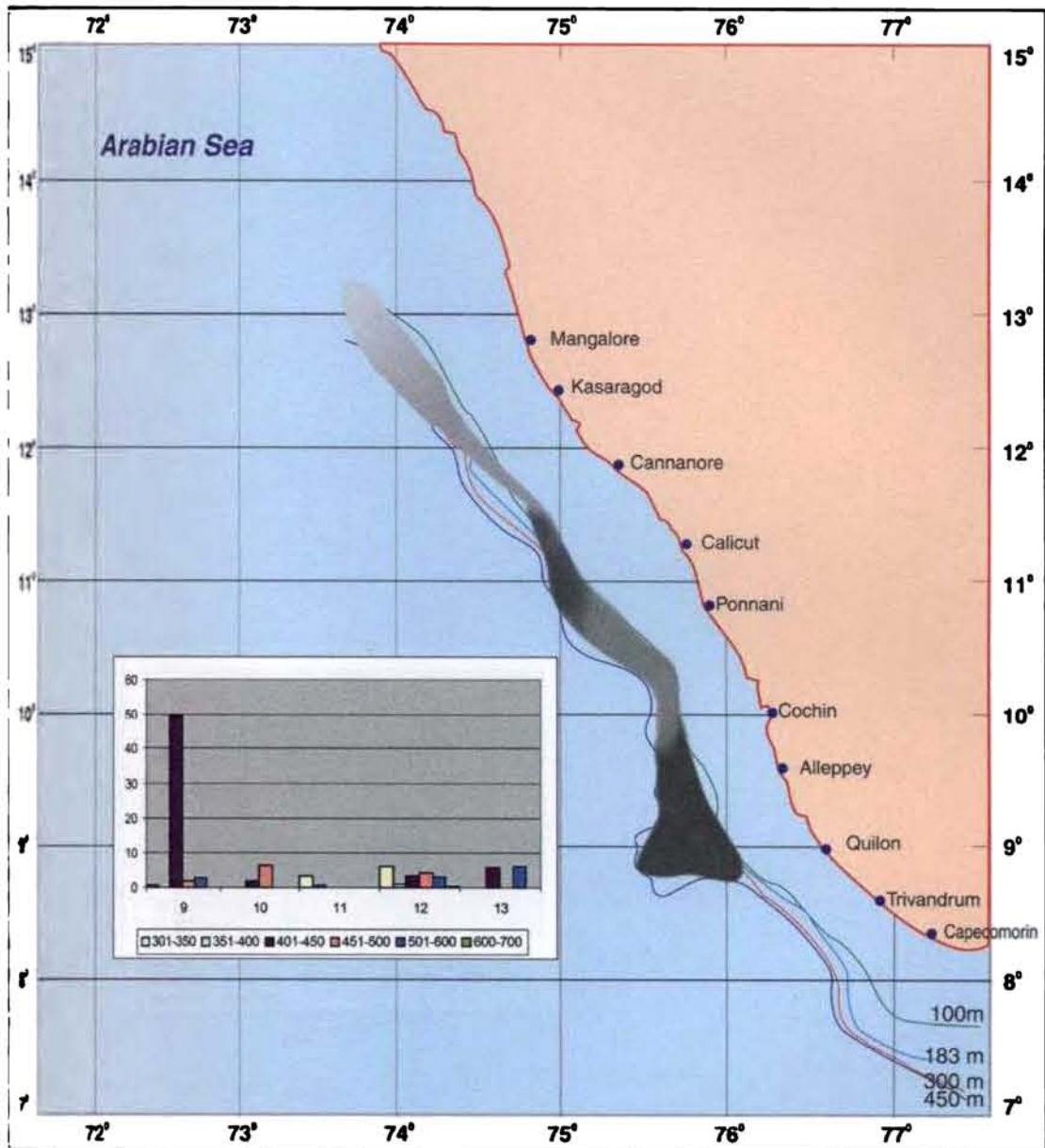
**Fig. 4.2.**  
 Distribution and abundance of  
*Heterocarpus woodmasoni* between 7° and 13°



**Fig. 4.3.**  
 Distribution and abundance of  
*Heterocarpus gibbosus* between 7° and 13°

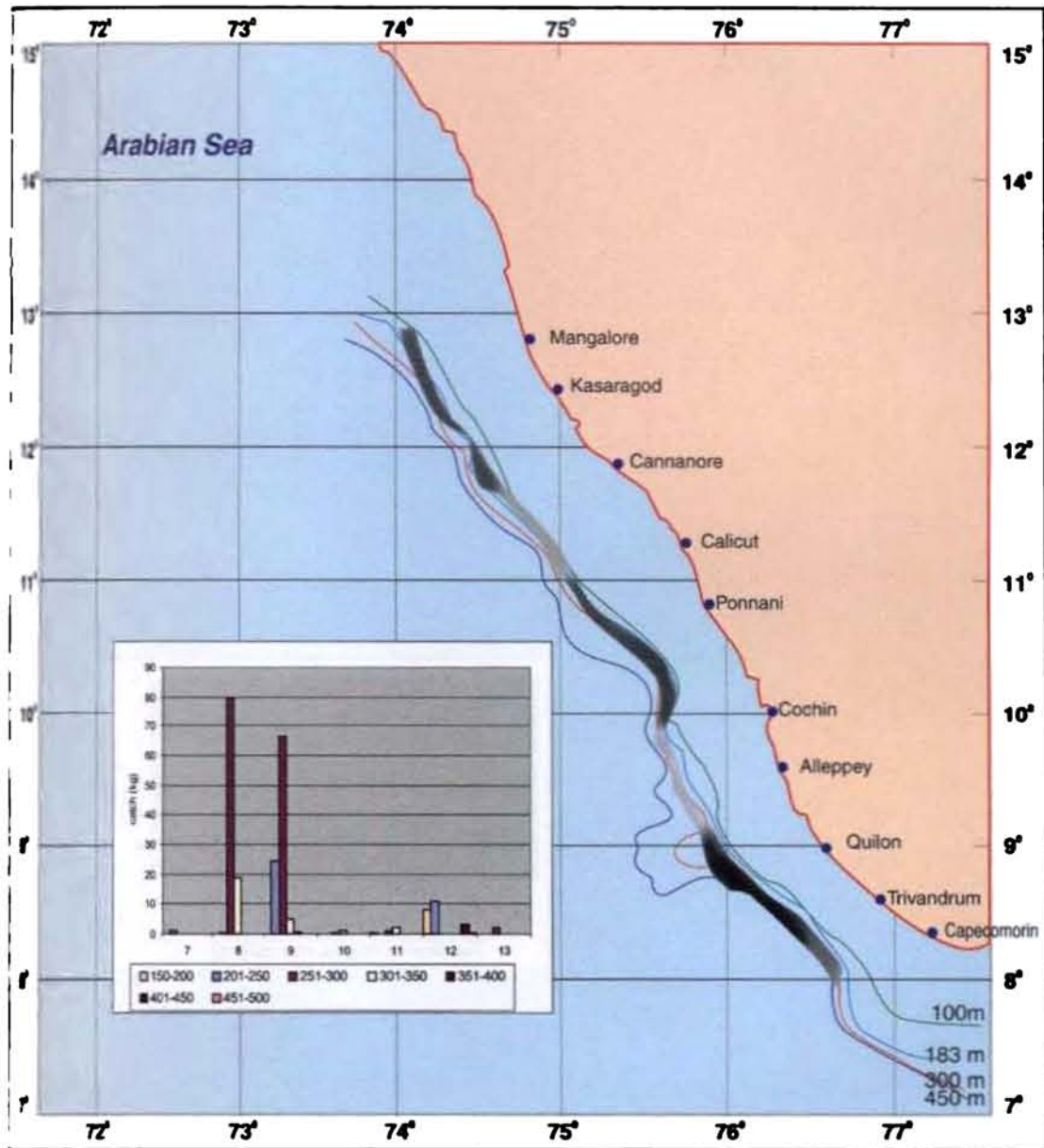


**Fig. 4.4.**  
 Distribution and abundance of  
*Aristeus alcocki* between 7° and 13°

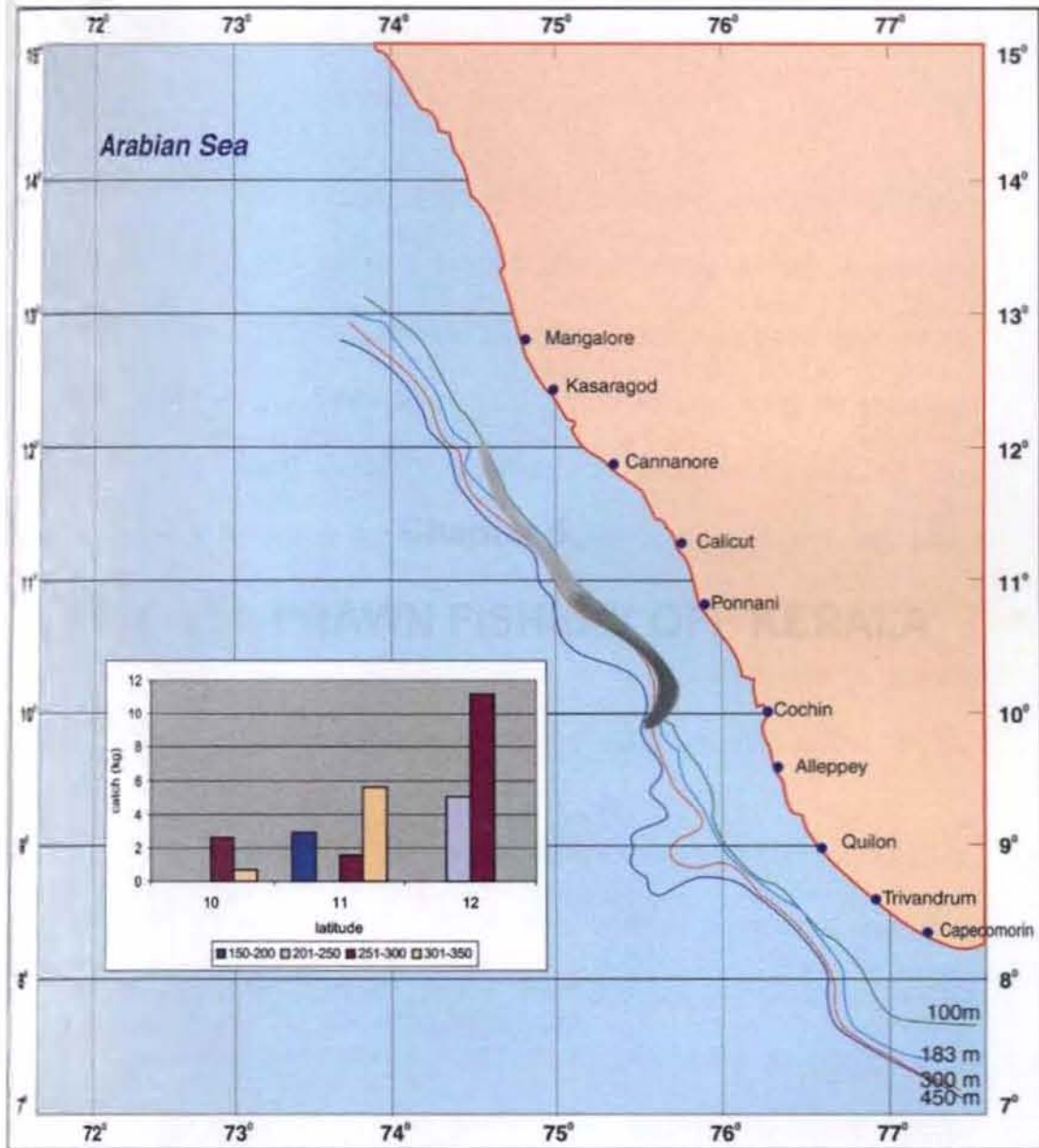




**Fig. 4.5**  
 Distribution and abundance of  
*Parapandalus spinipes* between 7° and 13°



**Fig. 4.6**  
 Distribution and abundance of  
*Metapenaeopsis andamanensis* between 7° and 13°





**Chapter 5**

**DEEP SEA PRAWN FISHERY OFF KERALA**

## 5.1. INTRODUCTION

The deep sea environment is both dark and cold and therefore, generally been regarded as a system characterised by low energy and low productivity. Until the past few decades, there had been little activity or interest in the deep sea apart from an occasional foray by scientists (Merrett and Haedrich, 1997). However, deep water fisheries on the upper continental slope beyond 600m, have developed and are today become an important component of commercial fisheries in a number of countries and continued to be an area of potential interest to nations whose coastal and shelf fisheries are fully or over exploited (Clark, 2001).

Deep sea fisheries include groups like deep sea prawns, lobsters, red shrimps, orange roughies, oreos, red fishes, a number of dogfishes and other fin fishes (Hopper, 1995). Among them, the deep sea prawn fishery is an important commercial activity performed by bottom trawl fleets all over the globe (Paulo Sartor *et al.*, 2001). The lucrative price offered for the penaeid prawns has eventually led to over exploitation of them in most of the tropical maritime states in the territorial waters and further prompted many countries for deep sea fishing. Information on their

commercial exploitation and potential fishing grounds of deep sea prawns such as *Solenocera membranacea* (Risso), *Aristeus antennatus* (Risso), *Aristaeomprpha foliacea* (Risso), *Plesiopeaneus edwardsianus* (Johnson) and *Parapenaeus longirsotris* (Lucan) from Mediterranean sea had been reported by a series of workers, South Portuguese and Barents Sea in Russia (Massuti, 1959; Maurin ,1965 ; Monod ,1966 ; Williams ,1968; Alvarez , 1968; Longhurst ,1970; Crosnier and Forest ,1973; Holthuis , 1980 ; Arrobas and Cascalho, 1987; Berenboim ,1989, Ivanov ,2000 ; Martineze Bano *et al.* , 1991). The multi faceted decline of shrimp fisheries in the Greater Gulf of Alaska has been reported by Oren Sanz *et al.* (1998). Analysis of harvest strategies for pandalid shrimp populations has been reported by Caihong *et al.* (2000) where as Aquilla (1991) reported the existence of commercially feasible quantities of deep sea prawns in the Var Maritime Fishery Area.

Availability of a number of deep sea crustaceans in the Indian Ocean region was reported by a few workers notably by Hida and Pereyra (1966), Gulland (1971) and Holthuis (1980) from the upper continental slope of Mozambique, Pakistan, Sumatra, North Western Malaysia and Burma. Studies on the deep sea crustacean resources of the south west coast of India were comparatively little, however, the work of John and Kurien (1959) and Kurien (1964,1965) based on exploratory catches of R. V. Conch and George (1966), George and Rao (1966) , Rao and Suseelan (1967) and Mohamed and Sueelan (1968) on the

basis of materials collected from R.V. Varuna are worth mentioning. Silas (1969), Mohamed and Suseelan (1973), Kathiravel *et al.* (1989) Suseelan (1974), Oommen (1980) and Suseelan (1985) investigated the deep sea resources of Indian Sea by giving emphasis to area wise and depth wise distribution and abundance on the basis on exploratory fishery survey cruises conducted in the EEZ of India.

The prawns occupy a prominent position because of their high export value in marine fishery resources of Kerala. The tremendous developments taken place in the fisheries sector of the state during the past four decades can be attributed to the growing demand for shrimps in the overseas markets. Increasing fishing effort exerted indiscriminately targeting the crustacean resources along the coast has resulted in the drastic decline of catch rates and this coupled with rapid blooming of the prawn processing industry followed by the great hike in the operational cost necessitated for a vigorous search for new fishing ground and new resources. As a result, the deep sea prawn fishery became a reality in Kerala since November 1999. Rajan and Nandakumar (2001) quantified the deep sea prawn landings from three major harbours of Kerala for a period of five months during 1999 while Nandakumar *et al.* (2001) quantified the deep sea prawn landings during September 2000 to March 2001 based on landings from the same harbours.

In the present study, an attempt is made to quantify the exploited deep sea prawn fishery resources by the deep sea prawn fishing trawlers based on observation from ten fishing harbours of Kerala during September 2000 to August 2002. Information on craft and gears employed, fishing area, season, depth of operation, month wise, depth wise, species wise and harbour wise landing trends were also compiled. Comparison on the magnitude of fishery between the two years was based on the data on catch per unit (CPU) and catch per hour (C/hr). A close monitoring of the landings of deep sea prawns is found very essential in view of its unique life history traits such as recruitment, growth, fecundity and regeneration. As there is no comprehensive information is available on the deep sea prawn fishery, the information generated in this study would be invaluable for a judicious exploitation and management required for the sustainability of these resources.

## **5.2. MATERIALS AND METHODS**

Data on the deep sea prawn catch and effort were collected at weekly intervals from 6 major harbours viz. Sakthikulangara, Neendakara, Cochin, Munambum, Beypore, and Puthiyappa and 4 minor harbours viz. Thottapally, Murikkumpadam, Ponnani and Mopla Bay spread over 6 districts on Kerala during September 2000 to August 2002. The

observations on deep sea trawl landings were carried out for a period of 12 hrs during daytime while details of night landing, if any, were compiled on the basis of enquiries to boat crew, fish vendors, auctioneers, etc. Selections of trawl units for detailed observation were done following Alagaraja (1984). Deep sea fishing boats deployed from each harbour were enumerated on the day of observation and all the trawlers landed were observed from each harbour since their number is very few. Details on OAL (LOA), gear specifications, make and size of the craft, engine with model size, catch and species composition, etc., were recorded from the selected units while data on cruise time, facilities on board, fishing endurance and actual fishing hours exerted along with the number of hauls, crew strength, duration and number of hauls performed, depth of fishing, fishing ground details, etc. were collected from the fishing crews on the basis of personal interviews.

The daily catch was computed by multiplying the average catch arrived at from the observed units multiplied by total units operated from the harbour on a daily basis. The monthly catch was estimated by multiplying the daily landings with actual number of fishing days recorded in every month. Details of number of deep sea trawlers operated from different fisheries harbours of Kerala were collected from the harbour offices and the data so obtained were cross verified with the help of auctioneers, Government officials, boat owners association, boat crews, etc. On the other hand, the average number of deep sea trawlers operated

on a daily basis from each harbour was enumerated based on visual counts done during the four visits made in a month at each harbour. The catch per unit of individual trawl net and species were computed following Scariah *et al.* (1999). The effort in terms of fishing hours was worked out on the basis on actual time spent for fishing (Anon, 1984).

### **5.3. RESULTS**

#### **5.3.1 Craft and gear**

Deep sea prawns were exploited exclusively by trawl nets operated from bottom trawlers constructed of either steel or wood coated with fiberglass, measuring an Over All Length ( $L_{OA}$ ) ranged between 48 to 72ft  $L_{OA}$  powered by 106-140Hp diesel engines. From Sakthikulangara harbour, smaller crafts of 40-45ft  $L_{OA}$  were also used for deep sea prawn fishery, having an endurance of three days. The fleet strength of deep sea prawn fishing is around 325 numbers at present, majority of them (>50 ft  $L_{OA}$ ) operating with their base at Munambum harbour (Table 5.1).

#### **5.3.2 Facilities onboard**

Almost all the boats at Munambum and around 80% of the boats from Sakthikulangara and Cochin were equipped with hi tech devices such as Global Positioning System (GPS) enabling to locate the vessel position in the sea and to reach the identified fishing grounds during the

subsequent trips (Table 5.2). Echo sounders were also employed to determine the depth of operation and to identify the resources. Recently some of the vessels have started using wireless sets also. Most of the larger trawlers were provided with television and radio sets for entertainment.

### **5.3.3 Fishing area and season**

Deep sea trawl fishing season commences during the post monsoon period in September and continues up to April while the same remain suspended during the south west monsoon period (June to August) due to the imposition of ban for 45 days both in the territorial and the entire EEZ of Kerala and also due to inclement weather conditions. At the onset, very few vessels ventured for deep sea fishing from Sakthikulangara and Munambum harbours. With the high returns registered, vessels belonging to the large size classes shifted their area of operation towards deep sea, targeting deep sea prawns. In the beginning, the duration of fishing lasted three to four days with 4 hauls each of 2-2½ hour duration every day and as the season advances the duration of fishing trip extended even for five to six days. The cruising time itself varied between 24 to 38 hrs depending on the depth and area of operation. Trawling operations were generally being carried out off Quilon to Alleppey in the south at 200-400m depth ranges, off Ponnani (250-350m) and off Ezhimala (300-600m). In the lean season, the area of



operation shifted to off Kanyakumari to Tuticorin at 250-380m, mainly targeting for *H.woodmasoni*, *H.gibbosus* and *S.hextii*.

Details of deep sea prawn fishing showing LOA of trawlers, endurance, fishing area and depth of operation of boats operated from three major harbours of Kerala are summarized in Table 5.3 a-c. In Cochin fisheries harbour, the size of boats was in the range of 40-60' LOA. At the beginning of fishery, fishing endurance was limited for 4-6 days, and the fishing was conducted at 250-350m along Quilon to Aleppey belt targeting *P. spinipes*, *H. woodmasoni* and *H.gibbosus*. The depth of operation was further extended to 430m in the Quilon bank where *Aristeus alcocki* was found abundant. A glut in the catch was observed during January to March in most of the boats and thereafter, most of them shifted their area of operation to Tuticorin and Kanyakumari targeting highly priced species like *H. gibbosus*, *H.woodmasoni* and *A.alcocki*. Ezhimala, off Kannur also appeared as the most productive fishing ground for *A.alcocki* and therefore many units shifted their operations to this region mostly during February – April.

In Sakthikulangara harbour, the size of the trawler deployed for deep sea prawn fishing was in the range of 40-50' LOA. Trawl units operated along Quilon Bank were mostly targeted for *H.woodmasoni*, *H.gibbosus*, *P.spinipes* and *A.alcocki*. During January and February in both the years, the main area of operation of these boats was shifted to

Kanyakumari to Tuticorin coast at 300-450m mainly targeting *A.alcocki*, *H.gibbosus* and *H.woodmasoni* as the principal species.

At Munambum fishing harbour, during both the years, only larger trawlers above 50' LOA were engaged in deep sea prawn fishing which are characterized by a prolonged fishing endurance (Plate 5.4). During September to October, area of fishery was mostly confined between Alleppey and Quilon encompassing the Quilon Bank at 280-400m. On the other hand, from November onwards, there was a total shift in the fishing area towards Ponnani while some units shifted their operation to Ezhimala targeting *A.alcocki*. During April, the fishing was mostly carried out aiming at *A.alcocki*.

#### **5.3.4 Quantification of deep sea prawn landings**

The fishing season of deep sea prawns in Kerala during 2000-01 was reckoned as September to April. The landings of deep sea prawns in Kerala during September 2000 to April 2001 was quantified as 48675t. During the second year (September – May), the same was computed at 19285t, thus registering a reduction to the tune of 60.35% in the deep sea prawn landings when compared to the preceding year.

### **5.3.5 Month wise landings**

Monthly trends in production of deep sea prawns during 2000-02 are depicted in Fig. 5.1 and 5.2. Though the fishing season commenced from September, bulk of the landings was observed during December to March. The peak fishery was observed during December followed by January and February. On the contrary, during 2001-02, the commencement of fishery was observed slightly earlier from August onwards and continued up to April with peak landings in October followed by September. The landing pattern of deep sea prawns showed wide variation between the former and latter years. In both the years, the peak fishery was observed during December to April while the fishery was appeared to be very bleak in the months of August and October.

### **5.3.6 Species composition**

The deep sea prawn fishery of Kerala was constituted by the following 15 species. However, the first ten species listed below were represented in the exploited stock in substantial quantities on a regular basis and their percentage composition during 2000-01 and 2001-02 are shown in Fig.5.3 & 5.4.

The deep sea prawn fishery of Kerala is constituted by the following species:

1. *Parapandalus spinipes* (Bate)
2. *Heterocarpus woodmasoni* Alcock
3. *Heterocarpus gibbosus* Bate
4. *Aristeus alcocki* Ramadan
5. *Penaeopsis jerryi* Perez Farfante
6. *Plesionika martia* Milne –Edwards
7. *Metapenaeopsis andamanensis* Wood-mason
8. *Solenocera hextii* Wood-mason
9. *Acanthephyra sanguinea* Wood-mason
10. *Acanthephyra armata* Milne –Edwards
11. *Heterocarpus laevigatus* Bate
12. *Plesionika alcocki* Anderson
13. *Oplophorus typus* Milne-Edwards
14. *Parapenaeus investigatoris* Alcock and Anderson
15. *Plesionika ensis* de Man

*P.spinipes* appeared as the most dominant species contributing to 9% and 40% of the total exploited stock during first and second year

respectively. *H.gibbosus* and *H.woodmasoni* accounted for 7980t (16%) and 7786t (16%) respectively to the preceding year, however, their contribution declined to 10% and 13% respectively in the succeeding year where as *M.andamanensis* accounted for 14% and 21% respectively of the total catch during 2000-01 and 2001-02. *A.alcocki* formed 12% and 10% of the total deep sea prawn landings in these years. *S.hextii* contributed to 14%, with an annual average catch of 6640t. The catch of this species was very insignificant during the second year with mere 341t forming 2% of the total landings. Similarly, the percentage of *P.jerryi* also declined drastically from 8 to 0.5% from the preceding to succeeding years. The share of *P.martia* was 600t (1%) during 2000-01, which was so insignificant in the exploited stock; however, it showed a marginal increase in the succeeding year while the stock position of *A.sanguinea* remained almost static (0.2%).

### 5.3.7 Month wise catch composition

Monthly catch composition of various species in the exploited stock of deep sea prawns from September 2000 to August 2002 are depicted in Fig. 5.5 & 5.6. Among the various species of deep sea prawns landed, *P.spinipes* formed the mainstay of the landings in almost all the months except September while both *H.woodmasoni* and *H.gibbosus* were the second most important groups of deep sea prawns in the landings in almost all the months. Both *M.andamanensis* and *A.alcocki* contributed to

a substantial portion of the exploited stock during pre-monsoon months during January to April while the contribution by *P.martia*, *P.jerryi*, *A.sanguinea* and *A.armata* were insignificant and represented in meager quantities in almost all the months.

### 5.3.8 Harbour wise landings

The harbour wise landings of deep sea prawns in the ten harbours of Kerala during 2000-01 and 2001-02 are depicted in Fig.5.7. Sakthikulangara ranked first in deep sea prawn landings during 2000-01, accounting for 61% of the total landings followed by Munambum and Cochin with the share of 21 and 10% respectively. Whereas, the contributions of Murikkumpadam (0.15%), Puthiyappa (0.62%), Ponnani (0.29%), Mopla Bay (0.04) and Thottapally harbours (1.06%) were very insignificant.

The deep sea prawn landings showed a sharp decline during 2001-02 and were found restricted to just five harbours of Kerala viz. Sakthikulangara, Cochin, Munambum, Neendakara and Thottapally. The landings from Sakthikulangara showed a drastic decline from 29863t to 12076t while in Munambum it declined from 10102t to 5105t during the second year, thus showing a decline of 40% and 47% of the total deep sea prawn landings from these harbours respectively. Whereas in Cochin harbour, the landings decreased significantly from 5105t in the former to

1580t in the latter year. The contribution of Neendakara (3.70%) and Thottapally harbours (0.69%) were almost insignificant during the second year.

### **5.3.9 Species wise landings at major harbours**

Species wise deep sea prawn landings at various harbours of Kerala from September 2000 to April 2002 are depicted in Fig.5.8 & 5.9. During the first year, highest landings of *P.spinipes* were registered at Munambum with 4939t followed by Sakthikulangara and Cochin harbours with 2867 and 716.8t respectively, occupying the second and third positions. Highest landings of deep sea prawns such as *S.hextii*, *H.woodmasoni*, *M.andamanensis* and *H.gibbosus* were also reported at Sakthikulangara. On the contrary, during the second year, *P.spinipes* showed an increase in all the harbours with respective landings of 4865t, 2260t and 339t at Sakthikulangara, Munambum and Cochin.

### **5.3.10.Catch per hour and catch per unit**

Monthly C/hr and CPU of deep sea prawns at various harbours are depicted in Fig. 5.10 & 5.11. The average C/hr was computed at 12.14kg during 2000-01, which declined to 7.13 kg during 2001-02. Highest C/hr was observed in September in both the years while the lowest was in

October and February in 2000-01 and 2001-02 respectively. In contrast, the average CPU showed an increase from 24.8 kg in the preceding year to 31.28kg in the succeeding year. The CPU varied from 12.96 kg in August to 42 kg in December in the former while during the latter year the lowest and highest values were in August and January with 5.38kg and 55.07 kg respectively.

### **5.3.11. Month wise C/hr at major harbours**

At Munambum fisheries Harbour, the highest C/hr of deep sea prawns was registered in November during 2000-01 while the same was high in December during 2001-02. The C/hr of *H.gibbosus* and *H.woodmasoni* were high in November during both the years. Highest C/hr of *M.andamanensis* and *A.alcocki* was registered in January and March during first year while similar values were found in December and April during the second year (Fig. 5.12 & 5.13) .

At Cochin fisheries harbour, C/hr of both *H.woodmasoni* and *P.spinipes* were high in November for both the years while that of *H.gibbosus* and *S.hextii*, the same was observed in January (25.53kg) and November (57kg) respectively in 2000-01. The C/hr was at its peak in December and January for *H.gibbosus* (12.5kg) and *S.hextii* (2.08kg) respectively during the succeeding year (Fig. 5.14 & 5.15).



At Sakthikulangara harbour, the highest C/hr of three species viz. *P.spinipes*, *S.hextii* and *H.woodmasoni* was observed in September during 2000-01 while the peak C/hr of *M.andamanensis*, *A.alcocki* and *H.gibbosus* was noticed in April. During 2001-02, high C/hr of *P.spinipes* was registered in December while that of *H.woodmasoni*, *H.gibbosus* and *M. andamanensis* it was in September (Fig.5.16 & 5.17).

### **5.3.12.Depth wise variation of C/hr and CPU**

C/hr of deep sea prawns at various depths during 2000-01 and 2001-02 is given in Fig.5.18. The C/hr was comparatively high in all the depths studied during 2000-01, however it sharply declined during 2001-02. The highest C/hr was at 450-550m followed by 250-350 m during both the years. On the contrary, the CPU of deep sea prawns were comparatively high during the second year in almost all the depths when compared to the first year (Fig. 5.19 ). The CPU was at its peak at 350-450m and 450-550m during the first and second years with 31.05kg and 47.16kg respectively.

### **5.3.13.Month wise variation in C/hr and CPU of major species of deep sea prawns**

The annual average C/hr and CPU of *H.gibbosus* were estimated at 8.00 kg and 20.64 kg respectively. Lowest C/hr and CPU were

registered in October while the same was highest in March with 19.81 kg and 36.05 kg respectively. The average C/hr and CPU showed a decline during the succeeding year, with 5.67kg and 26.47kg respectively. The values were high in September while the lowest value was registered in January during 2001-02 (Fig.5. 20 & 5.21). In *H.woodmasoni*, during 2000-01, high C/hr of 21.91 kg was observed in November while the CPU was high in October with 28kg. During 2001-02, high C/hr and CPU of 17.15 and 48.74 kg respectively were observed in September (Fig.5. 22 & 5.23).

The annual average C/hr of *A.alcocki* was computed at 8.64 kg during the preceding year, which declined to 3.22kg in the succeeding year whereas the CPU showed an increase from 27.96kg in the first year to 37.77kg in the second year. The highest C/hr of *A.alcocki* during 2000-01 and 2001-02 was recorded in February and January respectively while the lowest value was in September for both the years whereas the CPU of *A.alcocki* was high in October and January during the first and second year respectively. (Fig.5. 24 & 5.25).

The C/hr and CPU of *P.spinipes* showed wide fluctuations and the annual average C/hr showed a drastic decline from 21.74 kg during first year to 9.18kg during the second year. In the preceding year, the C/hr varied between 84 kg in September to 0.08kg in October while the highest and lowest CPU value could be discernible in November

(87.14kg) and October (0.15kg) respectively. In the succeeding year, the C/hr as well as CPU of *P.spinipes* showed a reduction after September and touched the lowest value in February (Fig.5. 26 & 5.27).

The annual average C/hr and CPU of *M.andamanensis* were estimated to be 11.25 kg and 22.10 kg respectively during 2000-01. The C/hr was high in November and September during both the years, with 21.9 kg and 31.7 kg respectively while CPU was at its peak in April and September with 78 kg and 32 kg respectively during the preceding and succeeding years (Fig.5. 28 & 5.29).

The annual average C/hr of *S.hextii* was worked out to be 7.09 in 2000-01, which declined to 5.58 kg during 2001-02 while the CPU showed a marginal increase from 22.30 kg from the first year to 23.01 kg in the next year. During former year, the C/hr and CPU were very low in September while very high values were registered in November. During the second year, both the C/hr and CPU of *S.hextii* were high in January (Fig. 5.30 & 5.31).

In both *P. martia* and *P.ensis*, the C/hr and CPU were estimated to be high during pre monsoon months. In *P.martia* the C/hr and CPU were high in November and January respectively during the first year, while both the values were high in March during the second year (Fig. 5.32 & 5.33). The presence of *P.ensis* in the deep sea prawn landings was observed only for six months during 2000-01 with an average C/hr and

CPU of 6.89 kg and 31.24 kg respectively. The lowest C/hr and CPU values were observed in September with 0.12 kg and 0.69 kg respectively while the highest respective values registered in January were 84.37 kg and 64.65kg. The peak C/hr and CPU of *P.ensis* during the succeeding year was observed in January where as the values were found to be very low in April. (Fig. 5.34 & 5.35).

The annual average C/hr and CPU of *P.jerryi* were estimated to be 0.74 kg and 0.92 kg respectively. During 2001-02, the average C/hr and CPU showed an improvement showing 2.76 kg and 28.26 kg respectively (Fig. 5.36 & 5.37) (Fig. 5.36 & 5.37). *A.sanguinea* registered an average C/hr and CPU of 0.78 kg and 4.78 kg respectively during 2000-01. The C/hr ranged between 2.96 kg in November to 0.01 kg in March whereas the CPU in general was moderate with peak in September (9.62kg) (Fig.5.38) .

The average C/hr and CPU of *A.aramata* during 2001-02 were computed at 0.60 kg and 5.32 kg respectively (Fig. 5.39). The C/hr varied from 0.121 kg in February to 2.46 kg in January. The CPU of the species varied from 1.20 kg in April to 19.75 kg in January. In *P.investigatoris*, both the C/hr and CPU were high during the months of winter, with peak C/hr (6.35kg) and CPU (23.14kg) in December (Fig. 5.40).

### **5.3.14. Depth-wise and Species-wise variation in C/hr and CPU**

Depth wise C/hr and CPU of deep sea prawns landed at various harbours of Kerala are depicted in Fig.5.41 to 5.64. During the present study, both the C/hr and CPU of *H.gibbosus* were high at 451-550m followed by 251-350 m. The depth zones 151-250 m are comparatively less productive as manifested by the very low CPU and C/hr values (Fig.5.41& 5.42).

The highest C/hr of *H.woodmasoni* was registered at 151-250m during both the years, showing 22.19 kg /hr and 8.85kg/hr in 2000-01 and 2001-02 respectively while peak CPU was recorded at 351-450m (42kg) during the preceding year and at 451-550m (45.57kg) during the succeeding year (Fig.5.43& 5.44). Both C/hr and CPU of *A.alcocki* was high at 451-550, the CPU showed a sharp increase from 34 kg in the first year to 99 kg during the second year (Fig. 5.45 & 5.46).

The highest C/hr of *P.spinipes* was estimated at 251-350 m depth while it was high at 351-450m during the second year. The CPU showed a sharp increase during 2001-02 when compared to the preceding year with peak at 451-550 m (Fig. 5.47 & 5.48).

The C/hr of *M.andamanensis* was high at 151-250m and 251-350 m during 2000-01 and 2001-02 while the CPU also showed peak at

these depths (Fig. 5.49 & 5.50). The c/hr of *P.martia* was found high at 251-350m during the first and second years while the CPU were high at 351-450m and 451-550m during the above periods (Fig. 5.51 & 5.52). *P.ensis* though observed in all the depth zones in negligible quantities, it showed high C/hr and CPU at 251-350 m during both the years (Fig. 5.53 & 5.54)

The high C/hr of *S.hextii* was observed at 251-350 m during 2000-01 while the same in respect of CPU was at 351-450 m (29.52kg). The C/hr showed a reduction during the second year with 12.18 kg at 251-350m(Fig. 5.55 & 5.56). The C/hr of *P.jerryi* increased from 7.65 kg in first year to 12.33 kg in second year while the CPU also showed a substantial improvement at 251-350m from 11.82 kg in the former to 36.51kg in the latter year (Fig. 5.57 & 5.58).

The presence of *A.sanguinea* was observed only in minor quantities from 251-350m depths onwards with high C/hr and CPU at 451-550m (Fig. 5.59 & 5.60). *A.armata* also caught in stray quantities from 251 to 450m depths (Fig. 5.61 & 5.62) with high C/hr and CPU at 351-450 m. The C/hr of *P.investigatoris* was high at 251-350m (1.10kg/hr) while the peak CPU was observed at 150-250m (Fig. 5.63 & 5.64).

### 5.3.15. Marketing and disposal

Though deep sea prawns gained significant attention within a very short duration, the entire landings were processed for export owing to their high demand in the overseas markets. From the harbours, after auction, prawns are directly transported to pre-processing centers and processing plants in refrigerated container vehicles (5.1B). At Cochin, Sakthikulangara, Munambum and Murikkumpadam harbours, almost the entire catch of deep sea prawns were packed in ice and transported to peeling sheds, which are located around the Cochin and Quilon belts (Plate 5.1A, 5.3 B). *A.alcocki*, *H.gibbosus* and *S.hextii* were exported as PD and PUD shrimp products because of their smaller size while the larger species such as *H.gibbosus*, *H.woodmasoni* and *A.alcocki* were either exported as whole or head less IQF or block frozen products. A very poor demand in the domestic market notwithstanding, many foreign countries prefer the cooked deep sea prawn products due to their attractive coloration and bright appearance; however, very high leaching loss and black spot formation are regularly reported. The price details of deep sea prawns prevailed in the three major harbours of Kerala are given in Table 5.4. Among the deep sea prawns, *A.alcocki*, locally known as 'red ring' is the most sought after species by virtue of its bigger size and dazzling red coloration and its price varied between Rs. 150-200/kg (according to the size) while the assorted catch of smaller varieties fetched Rs.25-30/kg (Plate 5.2).

#### 5.4. DISCUSSION

The innovative small and medium shrimp trawlers ventured in to the deep sea prawn fishing for the first time in the history of Kerala in November 1999 defying the long held concept that deep sea prawn resources could be harvested only with the help of large trawlers. This endeavor proved successful with the realization of 23426t during November 1999 and March 2000 from 3 harbours (Rajan *et al.*, 2001) and 48675t from 10 harbours of Kerala lasting between September 2000 and April 2001 (Rajasree and Kurup, 2004). Due to the encouraging results realized from the deep sea trawling operations during the first two years, more and more boat owners modified their trawlers and equipped them for deep sea trawling and started venturing to greater depth zones. Yet, during the succeeding year the fishery dwindled drastically compared to the previous years in total landings, species composition as well as catch per hour of the constituent species.

The deep sea prawn landings in Kerala showed a drastic decline from 48675t in 2000-01 to 19285t in 2001-02, thus registered a sharp decline to the tune of 60.35% in the landings during the second year. Rajan and Nandakumar (2001) also made similar observation on the decline of deep sea prawns landed at Sakthikulangara, Cochin and Munambum harbours from 23426t during 1999-2000 to 10042t during 2000-01, thus showing a plummeting of catches by 60% in the deep sea



prawn landings. The total catch reported in 2001-02 was 17888t (CMFRI, 2003) .

The harbour wise deep sea prawn landings also showed similar plummeting during 2001-02 and the landings were found confined to five harbours against the ten harbours from where landing was reported during the first year. There was a decline in the landing to the tune of 40% at Sakthikulangara, 47% at Munambum and 31% at Cochin. The overall C/hr in deep sea trawls also showed a glaring reduction to 7.13kg in 2001-02 against 12.14kg recorded in the previous year.

Among the 15 species of deep sea prawns landed at various harbours of Kerala, the commercial fishery was mostly focused on 5 species viz. *A.alcocki*, *H. woodmasoni*, *H. gibbosus*, *P.spinipes* and *M.andamanensis* in their order of preference. By virtue of the excellent demand for export, *A.alcocki* was exclusively procured by the seafood processing plants. As a result, with the onset of fishery, majority of the fishermen started selective harvesting of this species of high value by embarking in the grounds known for their predominance.

In contrast to the observation of Rajan and Nandakumar (2001) on the dominance of *H.woodmasoni* in the exploited stock, *P. spinipes* appeared as the most dominant species in the total deep sea prawn landings, contributing 19% and 40% respectively during 2000-01 and 2001-02. *H.gibbosus* and *H.woodmasoni* contributed to 16% each during

the first year and occupied second position in the landings, however, their contribution declined to 10% and 13% respectively thereby shifting to third position during the second year. These species were replaced by *M.andamanensis*, which emerged as the second dominant species during 2001-02, showed a steep increase from 14% during the former year to 21% during the latter year. The exploratory survey results on deep sea prawn fishing along Kerala coast by FORV Sagar Sampada also showed similar trends (Refer chapter 4).

A comparison of catch per hour of deep sea prawns registered for various depths during 2000-02 also showed a steady decline in all the depths during 2001-02 when compared to 2000-01. Depth wise analysis of catch in relation to effort of deep sea prawns computed based on harbours data also strongly corroborates with the results of exploratory surveys conducted during 1999-2002. For *H.gibbosus*, the depths from 151-250 m were comparatively less productive while the higher depth from 351 and 450 was endowed with rich abundance of *H.gibbosus*. Availability of *A.alcocki* at lower depth zones was only in insignificant quantities while the catch rates showed an increase commensurate with an increase in depth. *P.spinipes* was recorded from all the depth zones; however, its high catch rates recorded from 351-450 m is worth reporting.

Though the presence of *M.andamanensis* was also observed from all the depth zones studied, however, it preferred relatively shallower

grounds .The nature of species composition of deep sea prawns delineated from different depth zones on the basis of commercial data showed very strong agreement with that of exploratory survey results. The results revealed that the occurrence and abundance of deep sea prawns are both depth specific and latitude specific along Kerala coast and these findings corroborate well with that of Mohamed and Suseelan (1973) and Suseelan *et al.*(1989a, 1989b).

Due to the ever increasing demand for prawns from the processing industry, deep sea trawl units engaged in trawl fishery showed almost a double fold increase during 2001-02 when compared to 1999-2000 and consequently there was an exponential increase in the fishing effort with in a short period of two years. At present, nearly 300 shrimp trawlers have been converted for deep sea operations and also by fitting GPS and Echo sounders, besides more than a dozen of new crafts were recently commissioned in and around Munambum harbour exclusively targeting for deep sea prawn fishery. Results of spawning biology of deep sea prawns showed that the peak spawning was more or less synchronizing with peak fishing season. In addition, the results of month wise and lengthwise sex ratio analysis brought out the preponderance of females over males in a number of commercially important species such as *P.spinipes*, *H.woodmasoni*, *M. andamanensis* and *A. alcocki*. This skewness in the sex ratio by females would suggest the possibility of differential migration of male population from the fishing ground and this

can be postulated as one of the reasons for the stock depletion of deep sea prawns. Percentage of berried pandalid shrimps were found very high during December to March, in the range 71.33 to 91.25% and a decline of the fishery registered during the second year can well be attributed to the indiscriminate exploitation of berried females by the commercial fishing units.

From the results arrived at on the growth rates of deep sea prawns based on monthly distribution of length frequency collected from commercial landings, it appeared that the growth rate of deep sea prawns are very slow when compared to their counterparts inhabiting in the coastal waters. The length at maximum of *H.woodmasoni* was observed as 157.99mm in males and 178.95 mm in females during when they attain an age of around 5 yrs. The  $L_{max}$  of *H.gibbosus* was estimated at 195.44 mm at the age of 6 yrs for males and 198.60 mm at 7 yrs for females (For details refer Chapter 10). Based on the above data, the longevity of the deep sea prawns was found to be three times more than to coastal shrimps. In view of their slow growth rate, it can reasonably be inferred that the time required for their recruitment to the usable stock will be at least two times higher when compared to their counterparts in the coastal waters. The relative yield per recruit analysis of *H.woodmasoni* also showed that the present level of exploitation has exceeded the optimum exploitation rate in males while the females were subjected to the over exploitation when compared to males. In *H.gibbosus* also, the

males were over exploited than females beyond the sustainable level. The deep sea prawn stock therefore may not be in a position to withstand the rapidly increasing fishing pressures exerted in the deeper waters off Kerala and this situation calls for fishing effort management for the sustenance of stock.

The pandalid shrimps have already been proved as a very susceptible group due to their distinctive biological characters, patchy distribution and sexual segregation, makes them vulnerable to high and uncontrollable levels of fishing pressures (Maria Figueiredo *et al.*, 2001; Caihong *et al.*, 2000; Anderson, 2000). These groups are also highly variable in their annual recruitment pattern, seasonal growth and natural mortality, which have profound influence on their population dynamics. So a number of harvesting strategies have been adopted for the sustainable fishing like fishing right after hatching, fishing after spawning, implementation of minimum mesh sizes of 35mm to reduce the catch of young shrimp, imposing marine protected areas to safeguard the ovigerous females and prohibition of fishery of shrimps with carapace less than 15mm (Caihong *et al.*, 2000; Berenboim, 1989).

The annual closure of the fishery during south west monsoon and the limited period of fishing season (September to April) together with the restricted operation of trawlers in more deeper waters for minimizing the fishing pressure etc. would be some of the conservation efforts useful in

ameliorating the resource crunch of deep sea prawns off Kerala. However, the ever-increasing demand of deep sea prawns for export purpose may further aggravate the fishing pressure even at higher depths and hence there is every possibility of stock depletion in near future. The indiscriminate exploitation of berried population of deep sea prawns may lead to recruitment over fishing as defined by Pauly (1982). It would thus appear that the stock of deep sea prawns would be in a dangerous situation in near future unless otherwise the fishery is strongly regulated at optimal levels by framing strong legislations giving due weightage to maximum sustainable yield, stock-recruitment relationship and growth rate of individual species.

**Table 5.1** Number of deep sea trawlers at three major harbours of Kerala and their OAL

| Harbour         | Trawler size (L <sub>OAL</sub> ) |        |        |        | total units |
|-----------------|----------------------------------|--------|--------|--------|-------------|
|                 | 40-50'                           | 50-60' | 60-70' | 70-80' |             |
| Sakthikulangara | 200                              |        |        |        | 200         |
| Cochin          | 9                                | 16     | 1      |        | 25          |
| Munambam        |                                  | 82     | 16     | 2      | 100         |

**Table 5.2** Details of deep-sea trawfishing off Kerala showing facilities on board and gear specifications

|                     |   |
|---------------------|---|
| Commercial Fishing  | 1999  |
| Open season         | Sept- April                                   |
| Close season        | December -April                               |
| Duration of Fishing | 3-6 days                                      |
| Area of operation   | Quilon bank-Thottapally,<br>Ponnani, Ezhimala |
| Depth of operation  | 200-600                                       |
| Facilities onboard  | GPS , Echo sounder                            |
| Vessel size         | 45-80'  |
| Engine              | 100-140Hp Leyland , Turbo                     |
| Stowage capacity    | 12-20tonnes                                   |
| Ice Storage         | 5000-7000litres                               |
| Ice storage         | 150 blocks                                    |
| Total persons       | 8-10  |
| Gear                | four seam trawl net                           |
| Deck board          | V - form                                      |
| Mesh                | 10-22mm                                       |
| Head rope length    | 1800-2500m                                    |
| Foot rope length    | 100-150ft                                     |
| Total length of net | 130-150ft                                     |

**Table 5.3** Price details of deep sea prawns landed at the harbours of Kerala

| Species                | Local name      | Harbour         |         |          |
|------------------------|-----------------|-----------------|---------|----------|
|                        |                 | Sakthikulangara | Cochin  | Munambam |
| <i>A. laticockii</i>   | Red ring        | 90-160          | 120-200 | 100-175  |
| <i>A. gibbosus</i>     | Thakkali        | 60-90           | 60-120  | 60-80    |
| <i>A. woodmasoni</i>   | "               | 35-45           | 40-60   | 35-50    |
| <i>P. spinipes</i>     | Chuappu pullan  | 25-30           | 25-40   | 30-60    |
| <i>M. andamanensis</i> | Vella pullan    | 30-60           | 30-50   | 20-60    |
| <i>P. jerryi</i>       | Vella pullan    | 20-40           | 20-40   | 25-40    |
| <i>S. hearti</i>       | Mulaku chemmeen | 25-30           | 30-60   | 35-50    |

TABLE 2. a  
 Details of coastal area trawls reported during COA of Kerala - 1980-81. month-wise, number of days and depth of operation during September to April 2000-02

a  
 Cochin Fisheries Harbour

| Month     | Trawler size (L-aa in feet) | Endurance (days) | Fishing Area    | Depth of operation(m) | Target  |
|-----------|-----------------------------|------------------|-----------------|-----------------------|---|
| September | --                          |                  |                 |                       |   |
| October   | 40-50                       | 4-5              | off Thottapally | 240m                  | <i>P. spinipes</i>  |
| November  | 50-60                       | 4-6              | Aleppey-Cochin  | 280-420               | <i>H. gibbosus, H. woodmasoni, A. alcocki</i>                   |
| December  | 50-60                       | 6-7              | Aleppey-Cochin  | 430                   | <i>A. alcocki, H. gibbosus, H. woodmasoni</i>                   |
| January   | 50-60                       | 4-8              | off Kollam      | 320-420               | <i>A. alcocki, H. woodmasoni, H. gibbosus</i>                   |
| February  | 60-70                       | 6-7<br>6-8       | off Kanyakumari | 280                   | <i>H. gibbosus, H. woodmasoni</i>                               |
| March     | 40-50                       | 5                | off Thottapally | 240                   | <i>P. spinipes, M. andamanensis</i>                             |
|           | 50-60                       | 8-11             | off Ezhimala    | 450                   | <i>A. alcocki</i>   |
|           | 50-60                       | 5-7              | off Anchuthengu | 280-300               | <i>H. gibbosus, H. woodmasoni</i>                               |
| April     | 50-60                       | 5                | off Thottapally | 240m                  | <i>P. spinipes, M. andamanensis</i>                             |
|           |                             | 5-7              | off Anchuthengu | 280-400m              | <i>H. gibbosus, H. woodmasoni, P. spinipes, M. andamanensis</i> |



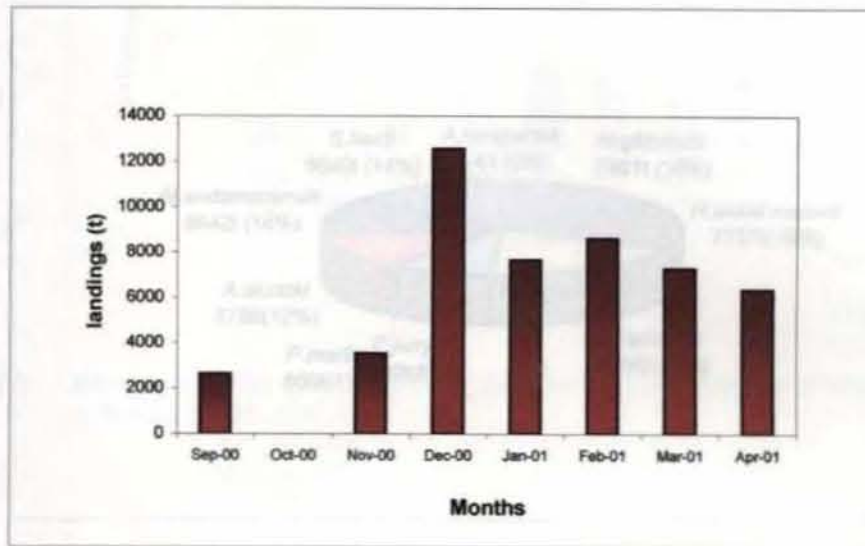
b

## Bekthikulangara fisheries harbour

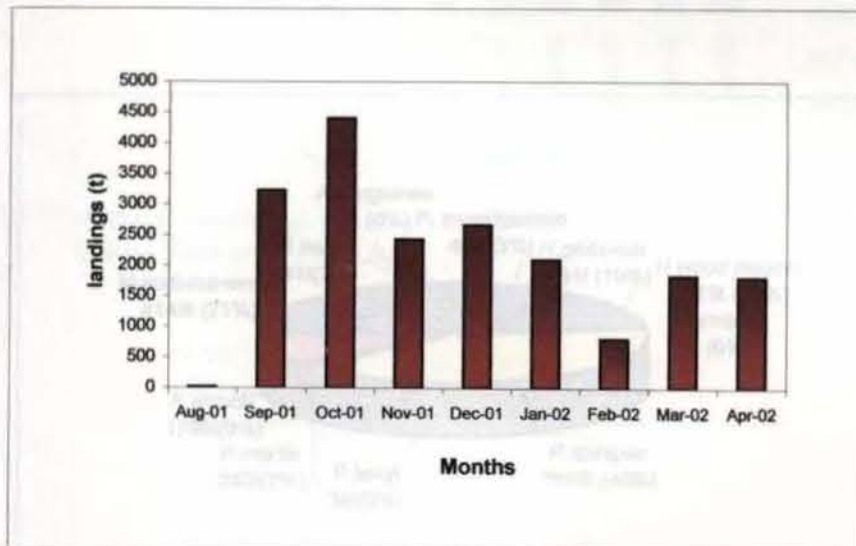
| Month     | Trawler size<br>(Loa in feet) | Endurance<br>(days) | Fishing<br>Area                             | Depth of<br>operation(m) | Target   |
|-----------|-------------------------------|---------------------|---|--------------------------|--|
| September | 40-50                         | 4-5                 | off Kayamkulam                              | 200-300                  | <i>P. spinipes</i> , <i>H. woodmasoni</i>  |
| October   | --                            |                     |   |                          |  |
| November  | 40-50<br>40-50<br>50-80       | 3-4<br>5-7<br>4-5   | off Quilon<br>off Kanyakumari<br>off Quilon | 320<br>450<br>320        | <i>P. spinipes</i> , <i>H. woodmasoni</i><br><i>A. alcocki</i> , <i>H. gibbosus</i><br><i>P. spinipes</i> , <i>H. woodmasoni</i> |
| December  | 40-50                         | 3-4                 | off Aleppey                                 | 280-320                  | <i>P. spinipes</i> , <i>M. andamanensis</i>  |
| January   | 40-50<br>40-50                | 4-5<br>5-7          | off Quilon<br>off Tuticorin                 | 320<br>380               | <i>P. spinipes</i> , <i>H. woodmasoni</i><br><i>A. alcocki</i> , <i>H. gibbosus</i> ,<br><i>H. woodmasoni</i>                    |
| February  | 40-50                         | 5-7<br>5-10         | off Tuticorin<br>off Kanyakumari            | 300-400<br>450           | <i>H. gibbosus</i> , <i>A. alcocki</i><br><i>A. alcocki</i> , <i>H. gibbosus</i> ,<br><i>H. woodmasoni</i>                       |
| March     | 40-50                         | 5                   | off Ezhimala                                | 450-550                  | <i>A. alcocki</i>  |
| April     | 40-50                         | 3-4                 | off Quilon                                  | 240-360                  | <i>P. spinipes</i>   |

| Month     | Trawler size<br>(Loo in feet) | Endurance<br>(days) | Fishing<br>Area                  | Depth of<br>operation(m) | Target  |
|-----------|-------------------------------|---------------------|----------------------------------|--------------------------|---|
| September | 50-60                         | 10-12               | off Alappuzha                    | 360-400m                 | <i>H. woodmasoni</i>  |
| October   | 50-60                         | 5-7                 | off Quilon                       | 280-440                  | <i>P. spinipes</i> , <i>H. woodmasoni</i> ,<br><i>H. gibbosus</i>   |
| November  | 50-60                         | 5-6                 | off ponnani                      | 320-420                  | <i>H. gibbosus</i> , <i>H. gibbosus</i><br><i>A. alcocki</i>  |
|           | 60-70                         | 5-6                 | off ponnani                      | 360-430                  | <i>A. alcocki</i>   |
| Decemeber | 50-60                         | 8-10                | off ponnani                      | 430-450m                 | <i>H. gibbosus</i><br><i>H. woodmasoni</i>  |
|           | "                             | 5-7                 | Off Quilon                       | 250-340                  | <i>A. alcocki</i><br><i>p. spinipes</i>   |
|           | 60-70                         | 8-9                 | off Ezhimala                     | 320-430                  | <i>H. woodmasoni</i><br><i>A. alcocki</i>   |
| January   | 50-60                         | 8-10                | off Tuticorin<br>off kanyakumari | 280-310<br>280-380       | <i>p. spinipes</i><br><i>H. woodmasoni</i><br><i>H. gibbosus</i><br><i>A. alcocki</i>                           |
|           | 60-70                         | 5                   | off Munambum                     | 290-310                  | <i>H. woodmasoni</i>  |
| February  | 50-60                         | 5                   | off Ponnani                      | 280-350                  | <i>p. spinipes</i><br><i>H. woodmasoni</i>  |
|           | 60-70                         | 7-8                 | off Kanyakumari                  | 290-310                  | <i>H. woodmasoni</i>  |
| March     | 50-60                         | 6-8                 | off Anchuthengu                  | 430                      | <i>A. alcocki</i><br><i>H. woodmasoni</i><br><i>H. gibbosus</i><br><i>M. andamanensis</i><br><i>p. spinipes</i> |
|           | 60-70                         | 5                   | off Thalassery                   | 250                      |   |
| April     | 60-70                         | 8-12                | off Ezhimala                     | 450-560m                 | <i>A. alcocki</i>   |

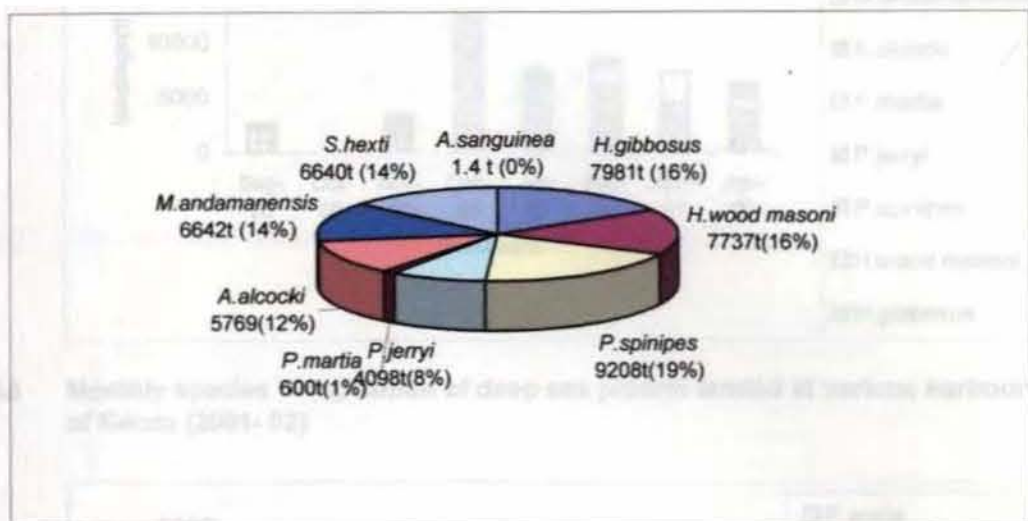
**Fig. 5.1 Monthly variation in the deep sea prawn landings in Kerala (2000-01)**



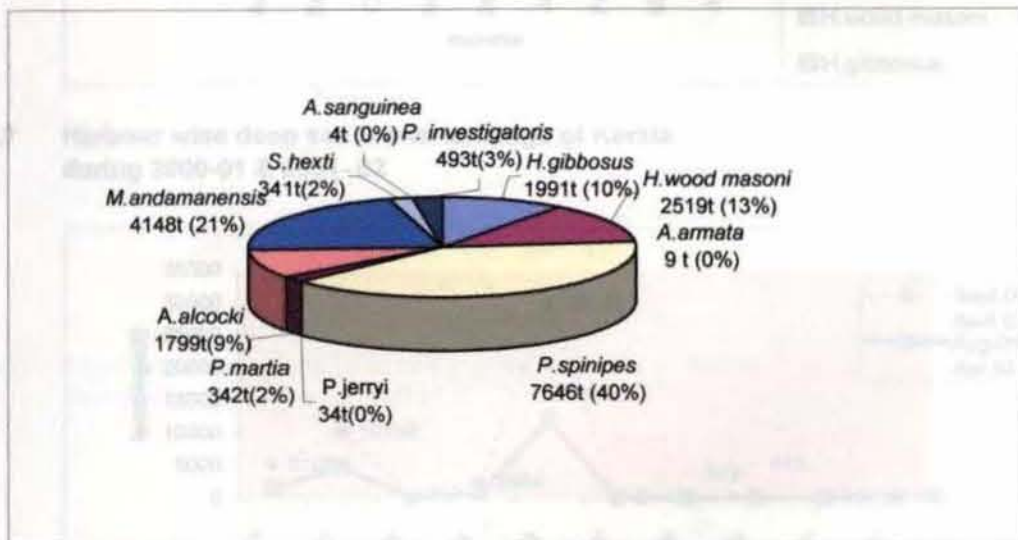
**Fig. 5.2 Monthly variation in the deep sea prawn landings in Kerala (2001-02)**



**Fig. 5.3 Percentage contribution of various species to the total deep sea landings during 2000-01**



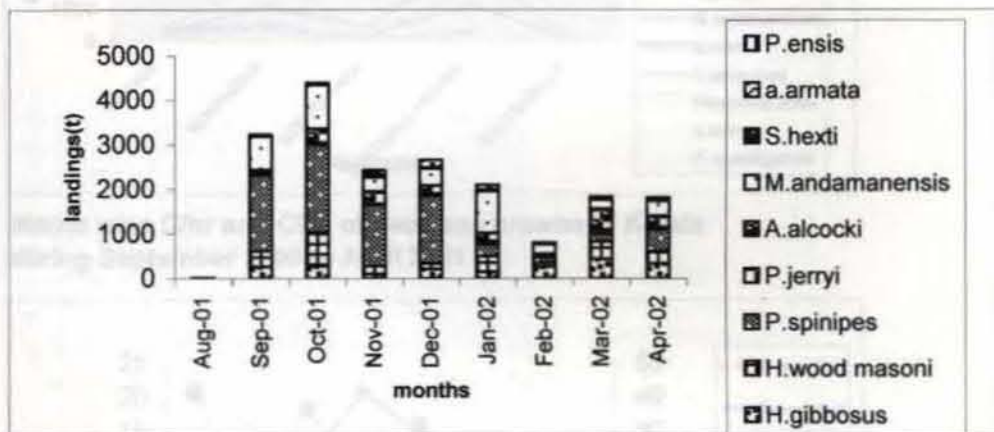
**Fig. 5.4 Percentage contribution of various species to the total deep sea landings during 2000-01**



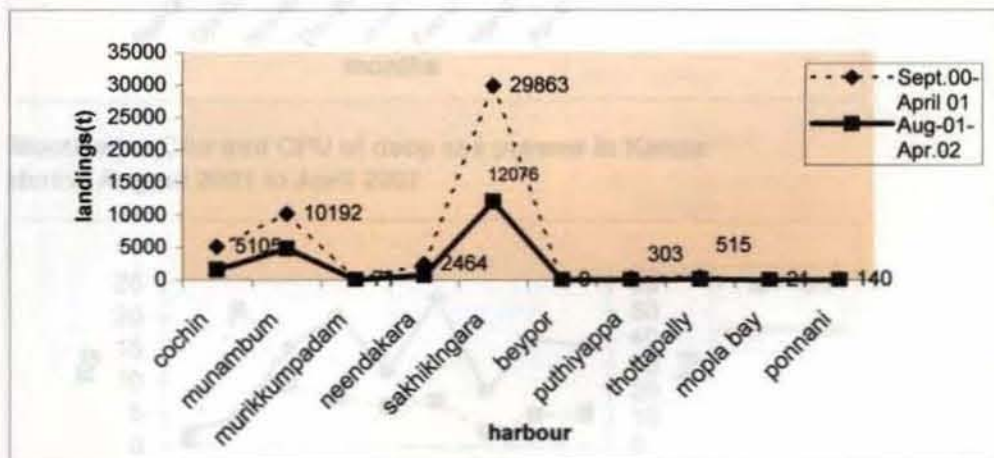
**Fig. 5.5 Monthly species composition of deep sea prawns landed at various harbours of Kerala (2000- 01)**



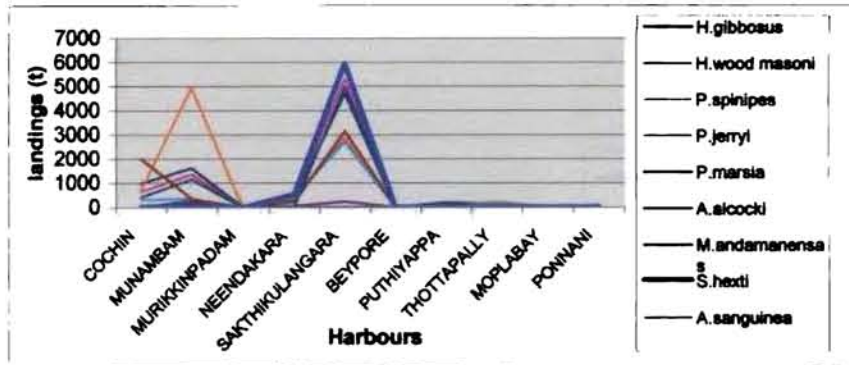
**Fig. 5.6 Monthly species composition of deep sea prawns landed at various harbours of Kerala (2001- 02)**



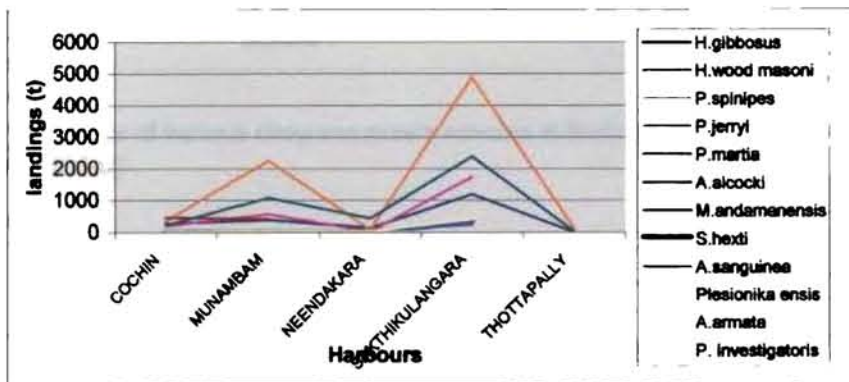
**Fig. 5.7 Harbour wise deep sea prawn landings of Kerala during 2000-01 & 2001- 02**



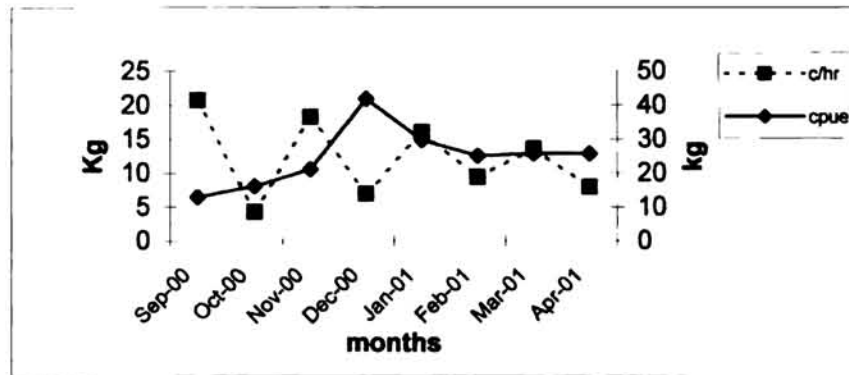
**Fig. 5.8 Harbour wise landings of deep sea prawns during 2000-01**



**Fig. 5.9 Harbour wise landings of deep sea prawns during 2001 -02**



**Fig. 5.10 Month wise C/hr and CPU of deep sea prawns in Kerala during September 2000 to April 2001**



**Fig. 5.11 Month wise C/hr and CPU of deep sea prawns in Kerala during August 2001 to April 2002**

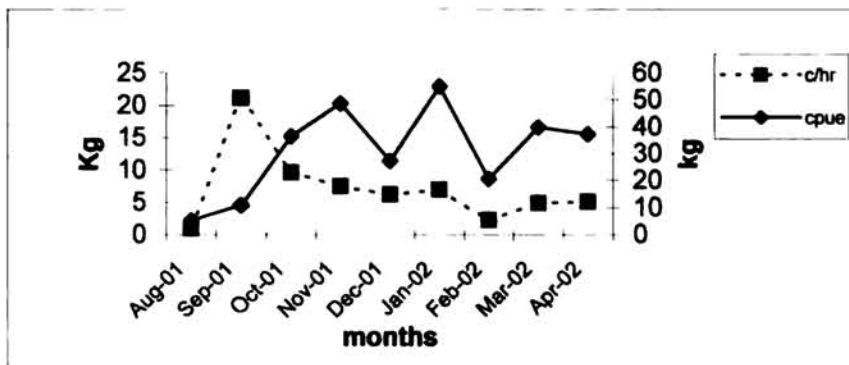




Fig. 5.12 Monthwise C/hr of various deep sea prawn species at Munambum Fisheries Harbour during 2000-01

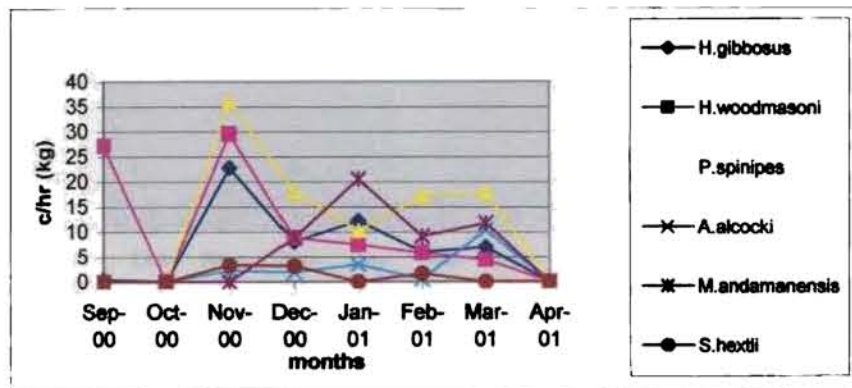


Fig. 5.13 Monthwise C/hr of various deep sea prawn species at Munambum Fisheries Harbour during 2001-02

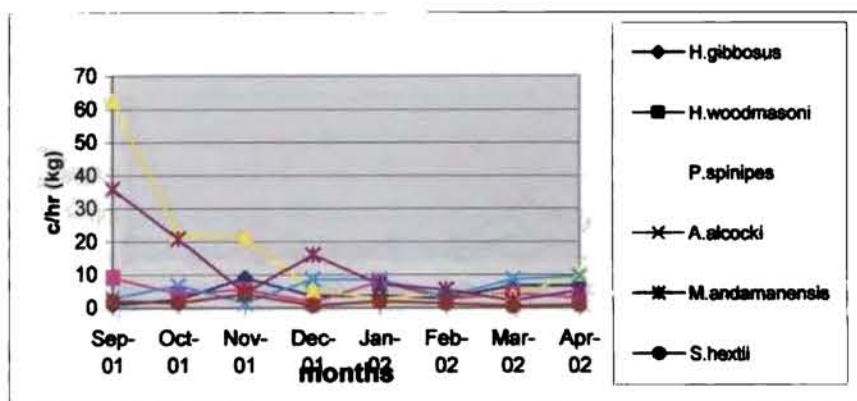
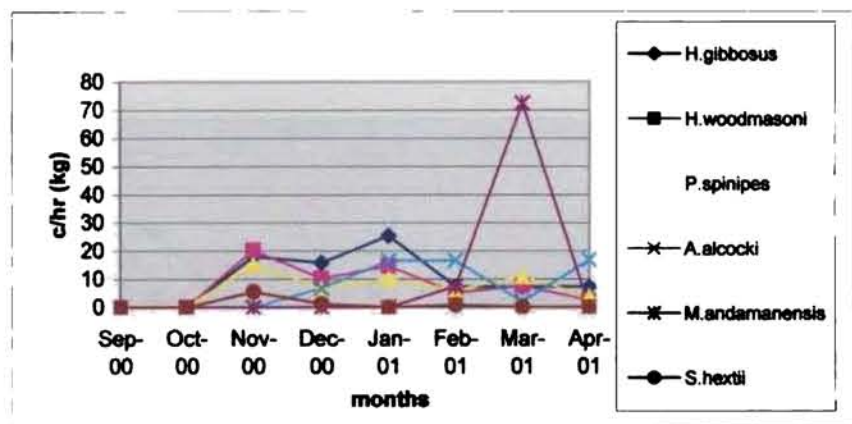
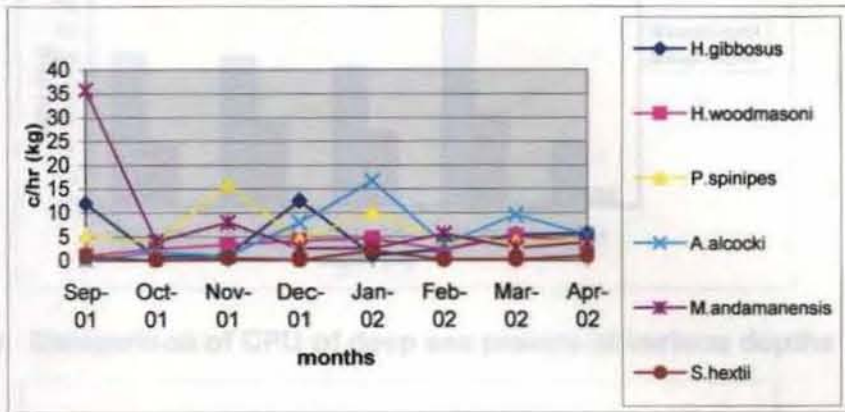


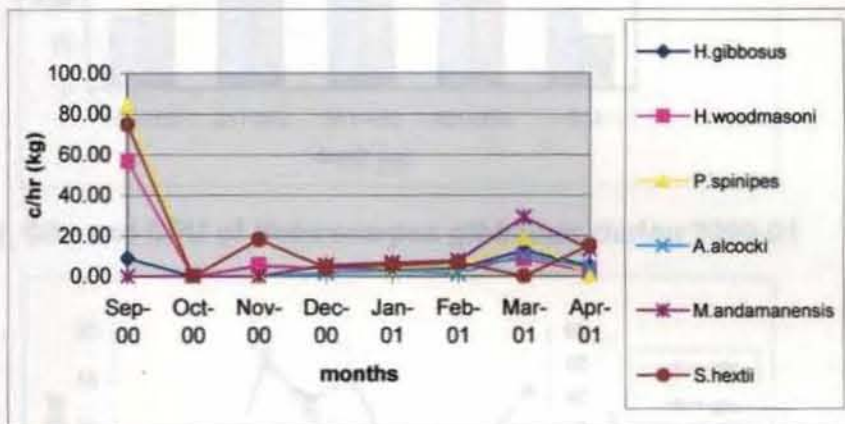
Fig. 5.14 Monthwise C/hr of various deep sea prawn species at Cochin Fisheries Harbour during 2000-01



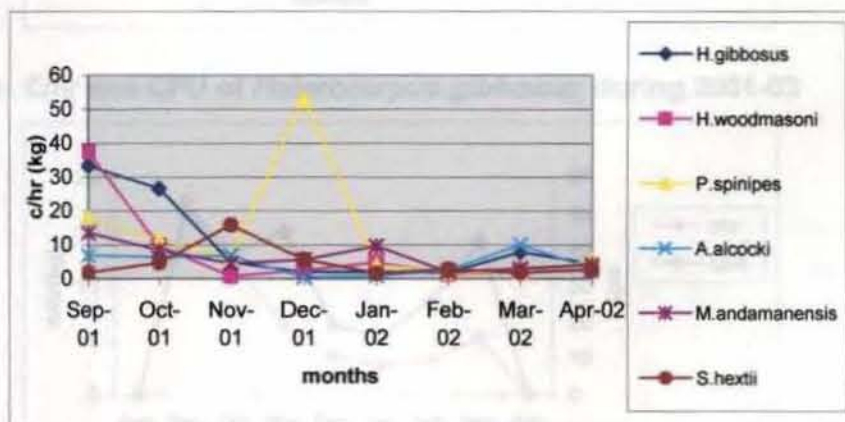
**Fig. 5.15** Monthwise C/hr of various deep sea prawn species at Cochin Fisheries Harbour during 2000-01



**Fig. 5.16** Monthwise C/hr of various deep sea prawn species at Sakthikulagara Fisheries Harbour during 2000-01

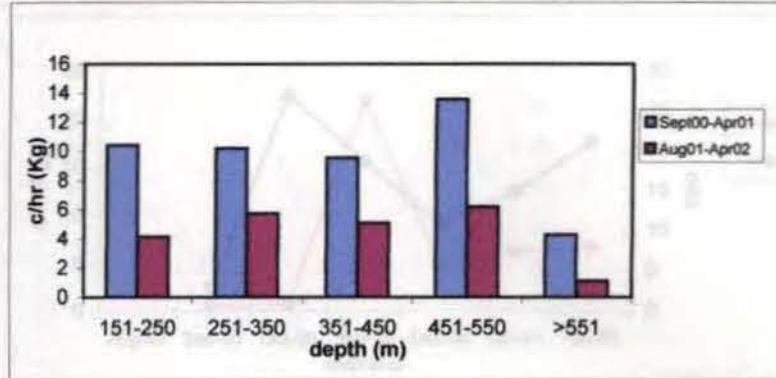


**Fig. 5.17** Monthwise C/hr of various deep sea prawn species at Sakthikulagara Fisheries Harbour during 2001-02

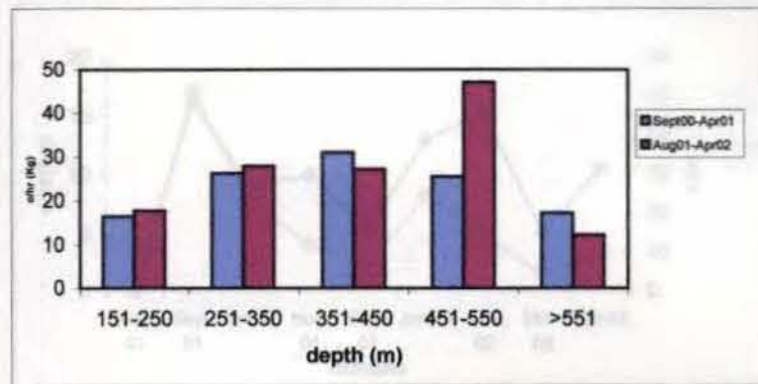




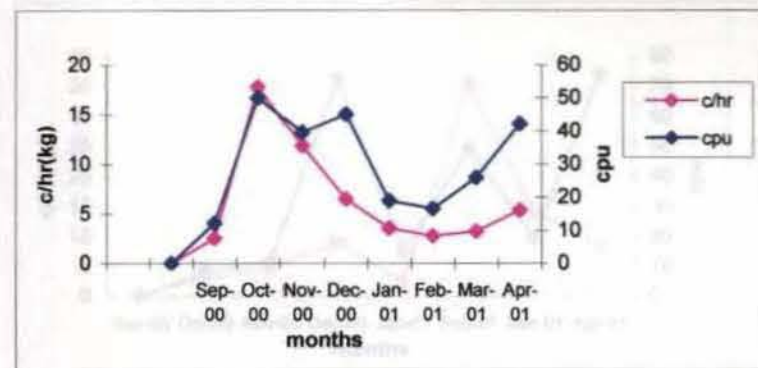
**Fig. 5.18 Comparison of c/hr of deep sea prawns at various depths**



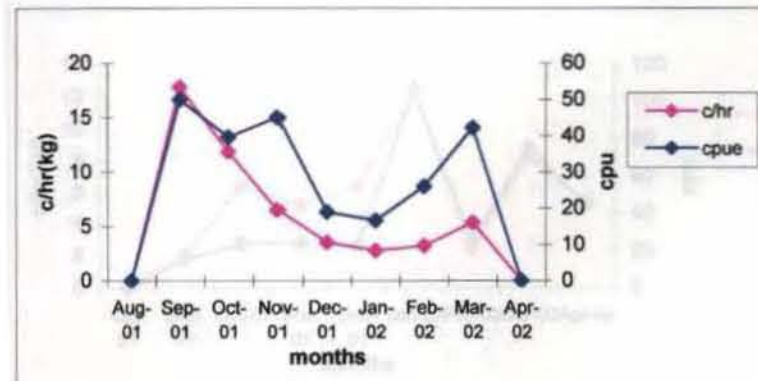
**Fig. 5.19 Comparison of CPU of deep sea prawns at various depths**



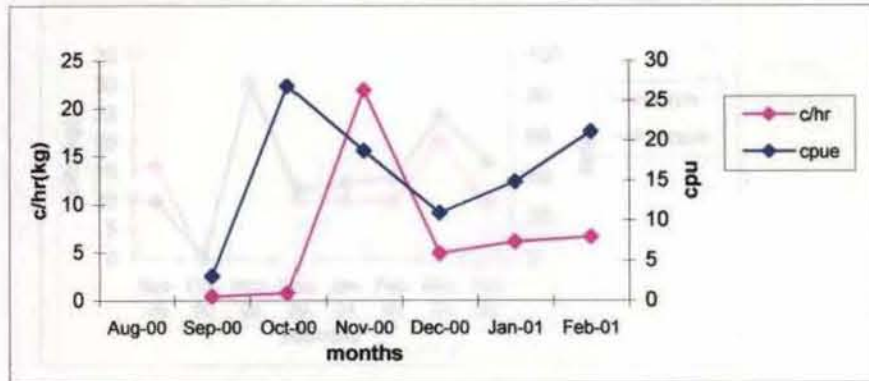
**Fig. 5.20 C/hr and CPU of *Heterocarpus gibbosus* during 2000-01**



**Fig. 5.21 C/hr and CPU of *Heterocarpus gibbosus* during 2001-02**



**Fig. 5.22 C/hr and CPU of *Heterocarpus woodmasoni* during 2000-01**



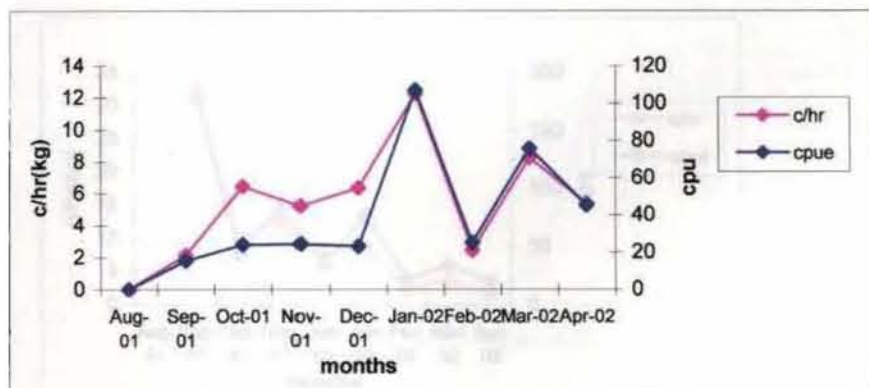
**Fig. 5.23 C/hr and CPU of *Heterocarpus woodmasoni* during 2001-02**



**Fig. 5.24 C/hr and CPU of *Aristeus alcocki* during 2000-01**



**Fig. 5.25 C/hr and CPU of *Aristeus alcocki* during 2001-02**



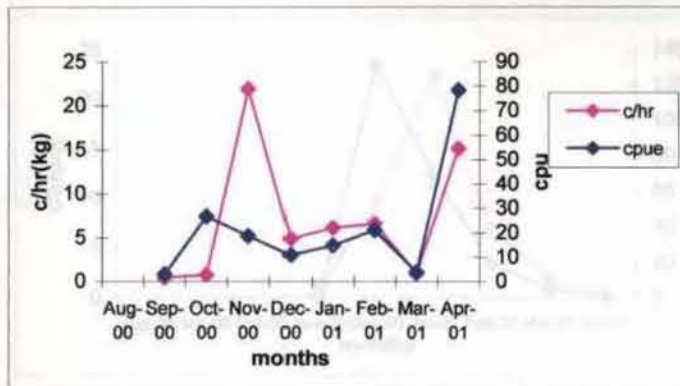
**Fig. 5.26 C/hr and cpu of *Parapandalus spinipes* during 2000- 01**



**Fig. 5.27 C/hr and cpu of *Parapandalus spinipes* during 2001-02**



**Fig. 5.28 C/hr and cpu of *Metapenaeopsis andamanensis* during 2000-01**



**Fig. 5.29 C/hr and cpu of *Metapenaeopsis andamanensis* during 2000-02**



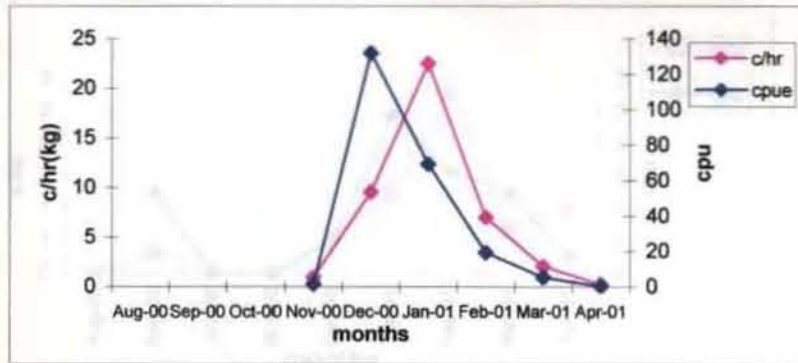
**Fig. 5.30** C/hr and cpu of *Solenocera hextii* during 2000-01



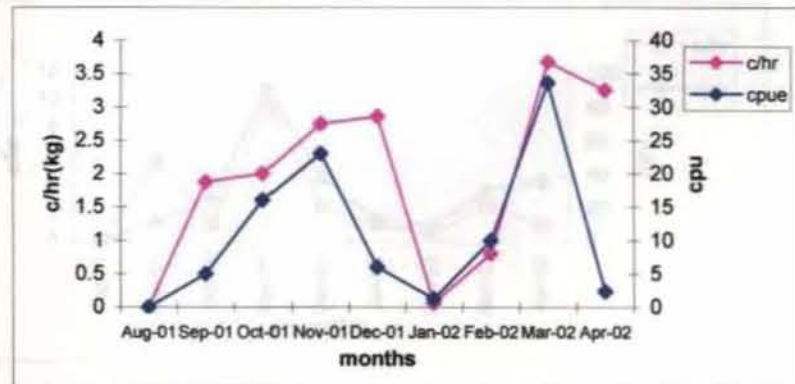
**Fig. 5.31** C/hr and cpu of *Solenocera hextii* during 2001-02



**Fig. 5.32** C/hr and cpu of *Plesionika martia* during 2000-01



**Fig. 5.33** C/hr and cpu of *Plesionika martia* during 2001-02

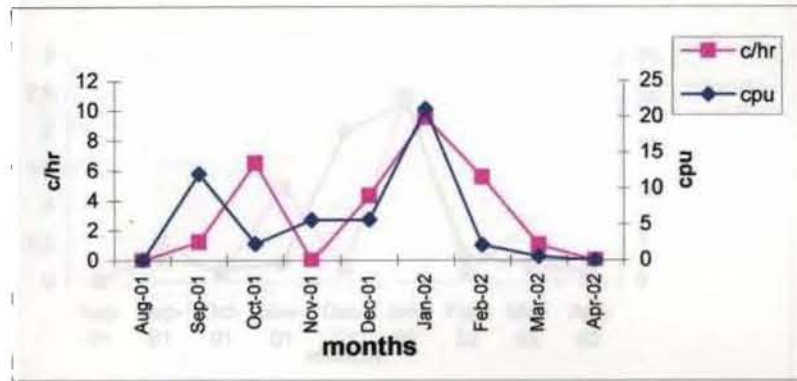




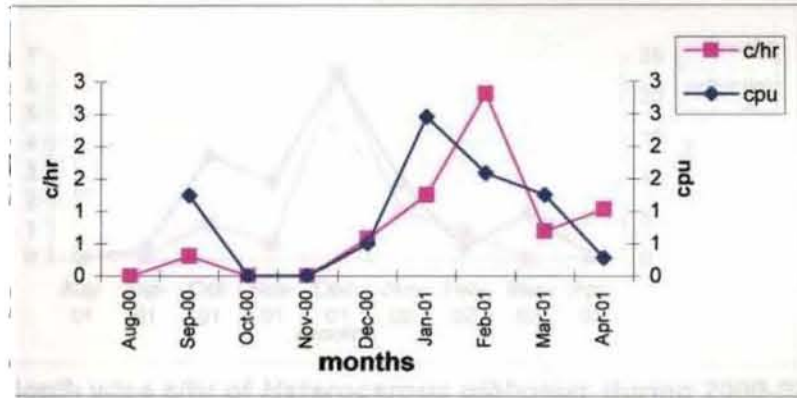
**Fig. 5.34 C/hr and cpu of *Plesionika ensis* during 2000-01**



**Fig. 5.35 C/hr and cpu of *Plesionika ensis* during 2001-02**



**Fig. 5.36 C/hr and cpu of *Penaeopsis jerryi* during 2000-01**



**Fig. 5.37 C/hr and cpu of *Penaeopsis jerryi* during 2001-02**

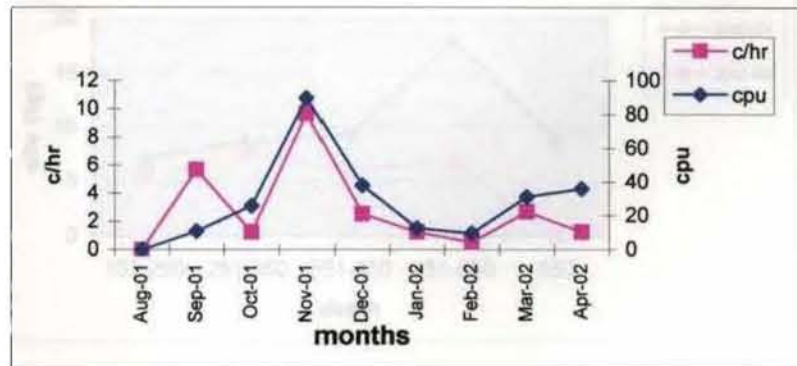


Fig. 5.38 C/hr and cpu of *Acanthephyra sanguinea* during 2001-02



Fig. 5.39 C/hr and cpu of *Acanthephyra armata* during 2001-02



Fig. 5.40 C/hr and cpu of *Parapenaeus investigatoris* during 2001-02

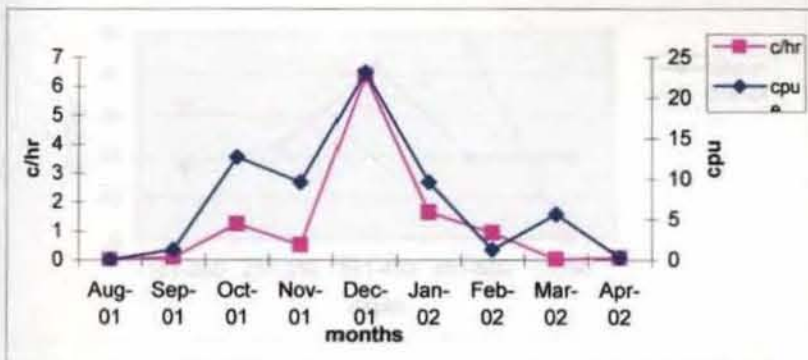


Fig. 5.41 Depth wise c/hr of *Heterocarpus gibbosus* during 2000-02

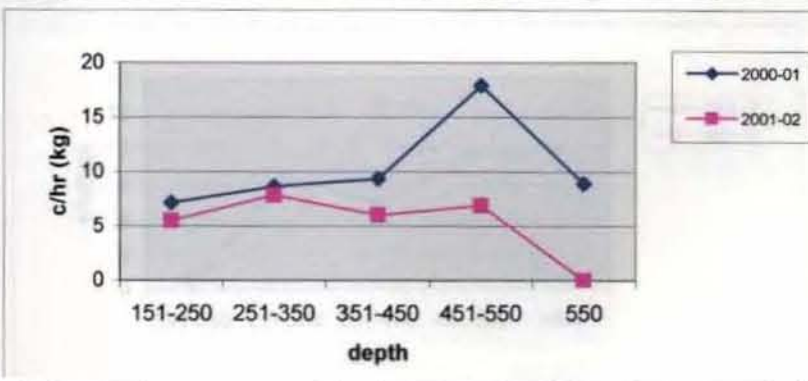


Fig. 5.42 Depth wise CPU of *Heterocarpus gibbosus* during 2000-02

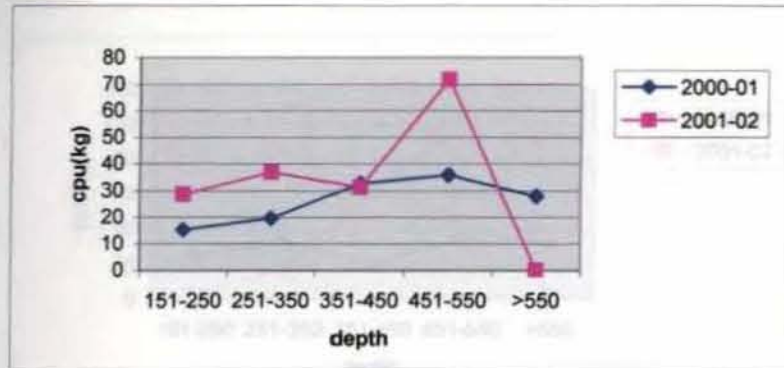


Fig. 5.43 Depth wise c/hr of *Heterocarpus woodmasoni* during 2000-02

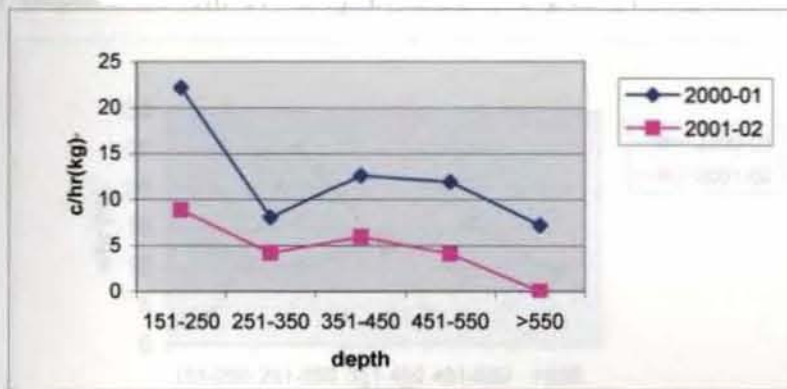


Fig. 5.44 Depth wise CPU of *Heterocarpus woodmasoni* during 2000-02

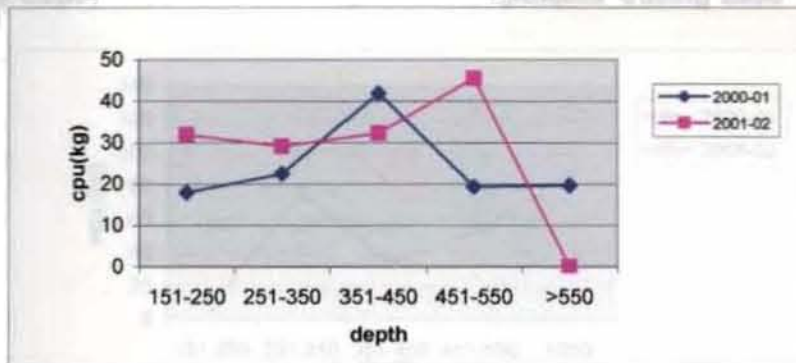
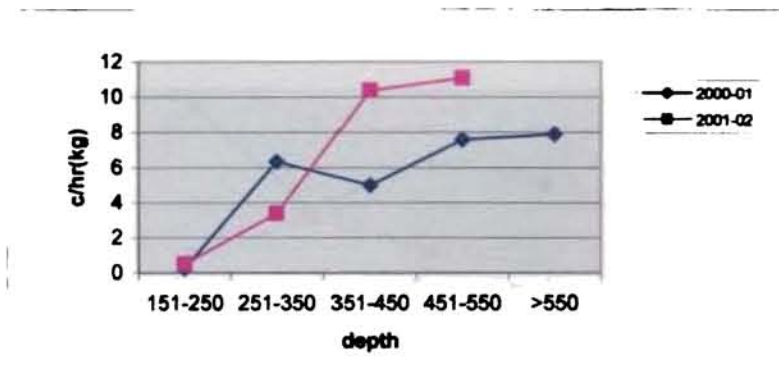
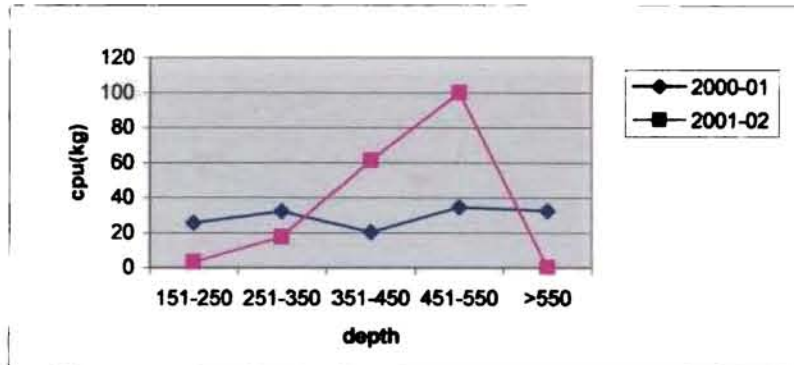


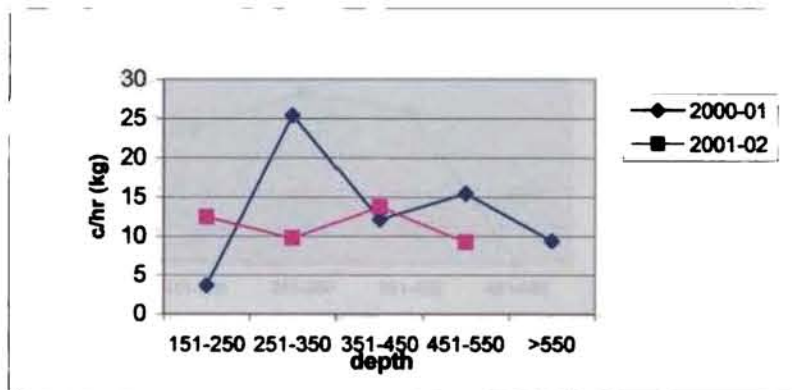
Fig. 5.45 Depth wise c/hr of *Aristeus alcocki* during 2000-02



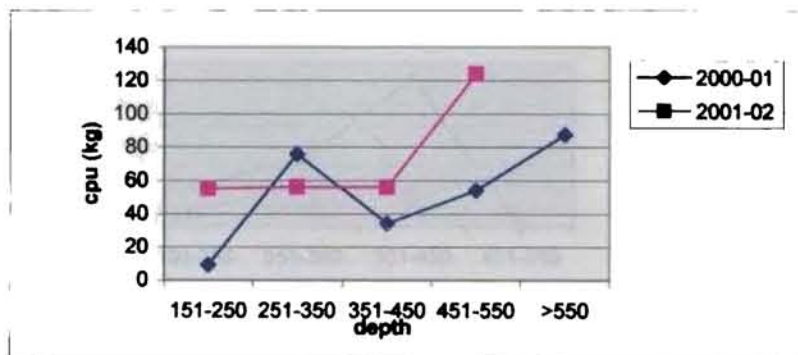
**Fig. 5.46 Depth wise CPU of *Aristeus alcocki* during 2000-02**



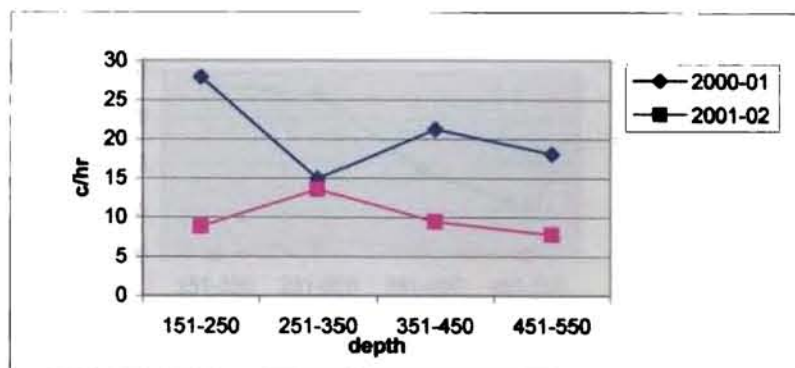
**Fig. 5.47 Depth wise c/hr of *Parapandalus spinipes* during 2000-02**



**Fig. 5.48 Depth wise CPU of *Parapandalus spinipes* during 2000-02**

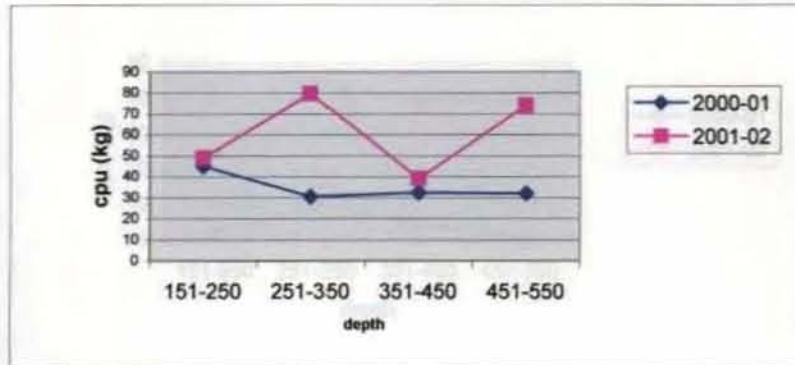


**Fig. 5.49 Depth wise c/hr of *Metapeaneopsis andamanensis* during 2000-02**





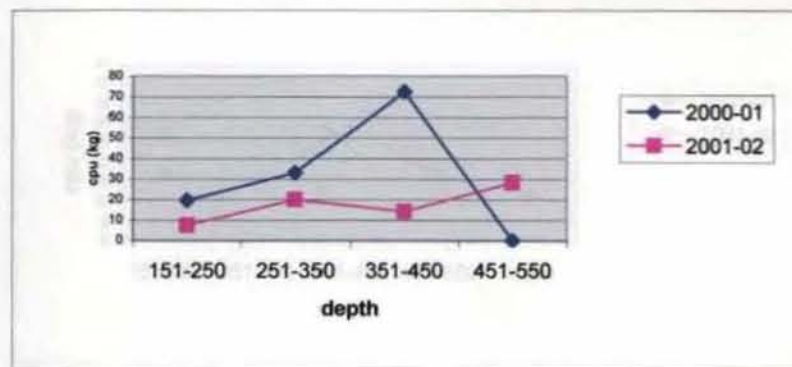
**Fig. 5.50 Depth wise CPU of *Metapenaeopsis andamanensis* during 2000-02**



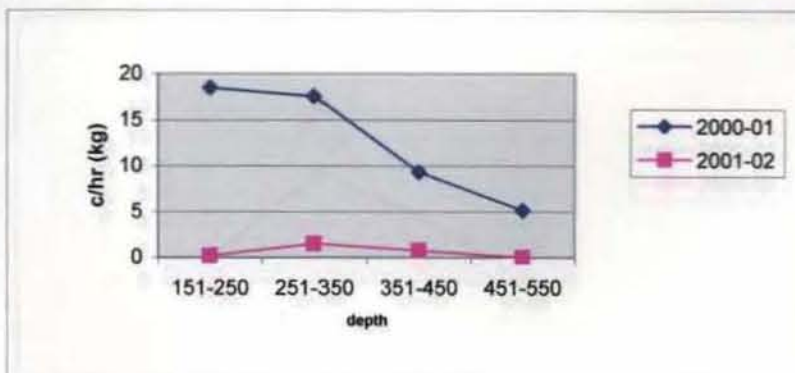
**Fig. 5.51 Depth wise c/hr of *Plesionika martia* during 2000-02**



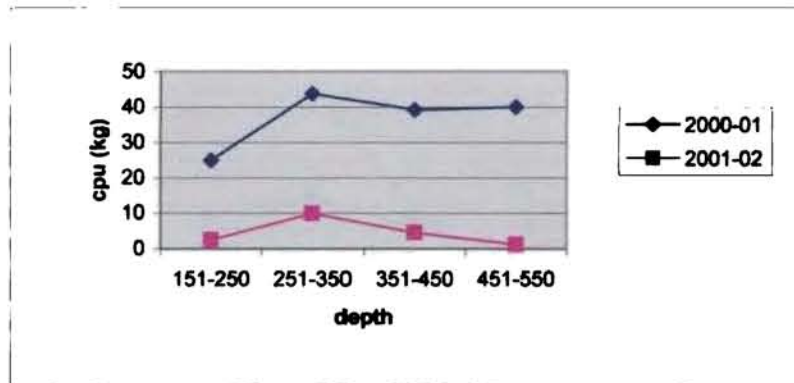
**Fig. 5.52 Depth wise CPU of *Plesionika martia* during 2000-02**



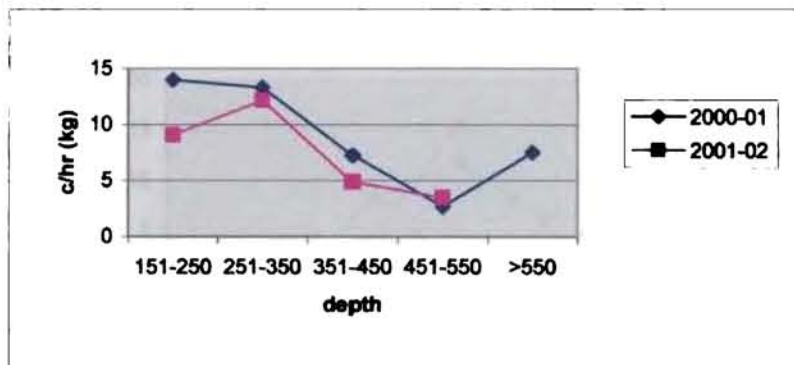
**Fig. 5.53 Depth wise c/hr of *Plesionika ensis* during 2000-02**



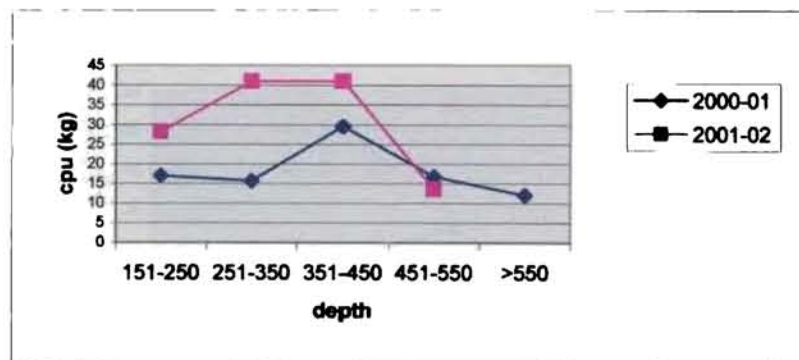
**Fig. 5.54 Depth wise CPU of *Plesionika ensis* during 2000-02**



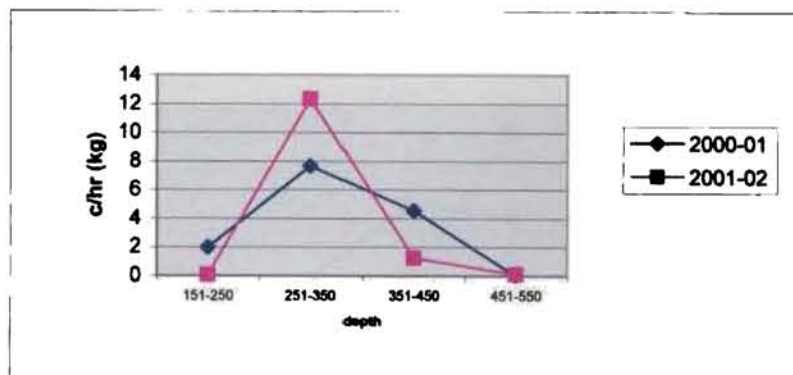
**Fig. 5.55 Depth wise c/hr of *Solenocera hextii* during 2000-02**



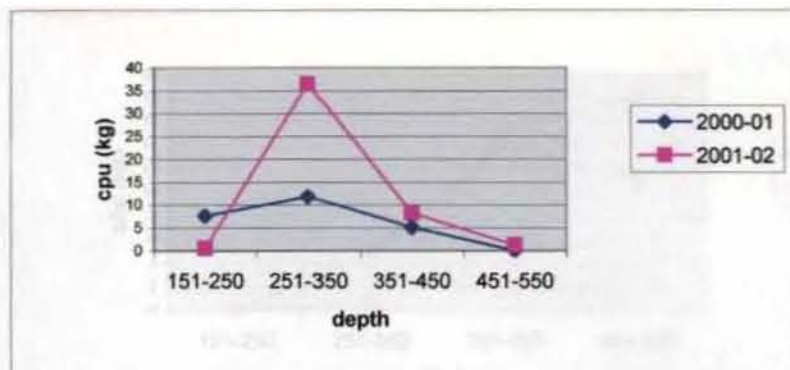
**Fig. 5.56 Depth wise CPU of *Solenocera hextii* during 2000-02**



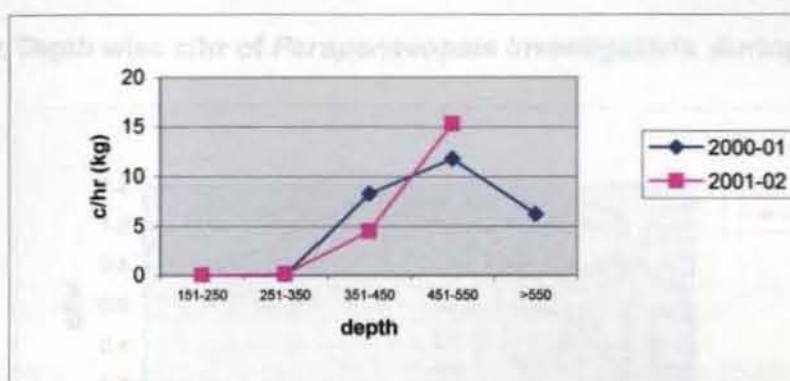
**Fig. 5.57 Depth wise c/hr of *Penaeopsis jerryi* during 2000-02**



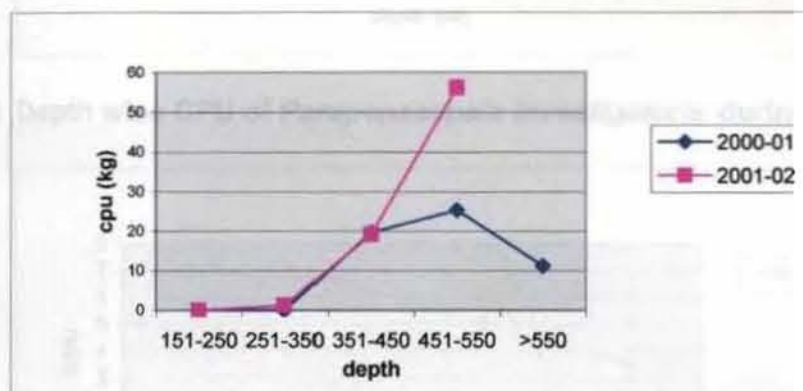
**Fig. 5.58** Depth wise CPU of *Penaeopsis jerryi* during 2000-02



**Fig. 5.59** Depth wise c/hr of *Acanthephyra sanguinea* during 2000-02



**Fig. 5.60** Depth wise CPU of *Acanthephyra sanguinea* during 2000-02



**Fig. 5.61** Depth wise c/hr of *Acanthephyra armata* during 2000-02

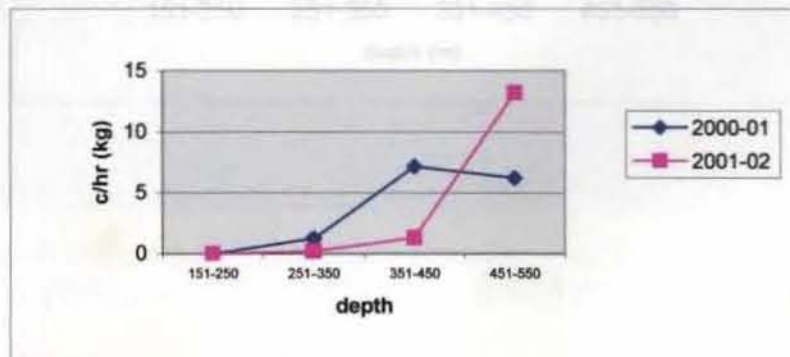


Fig. 5.62 Depth wise c/hr of *Acanthephyra armata* during 2000-02

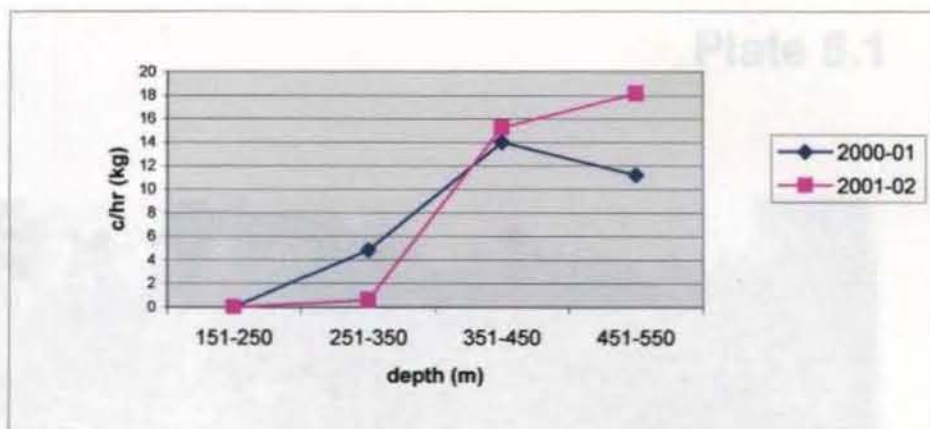


Fig. 5.63 Depth wise c/hr of *Parapenaeopsis investigatoris* during 2001-02

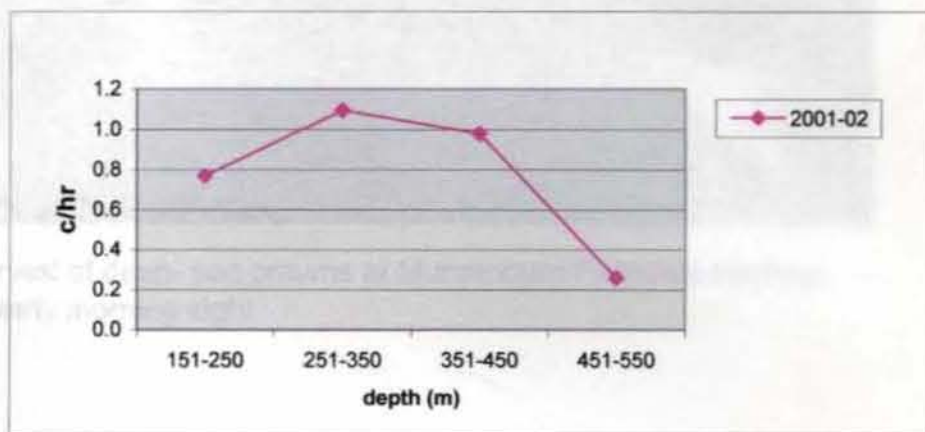
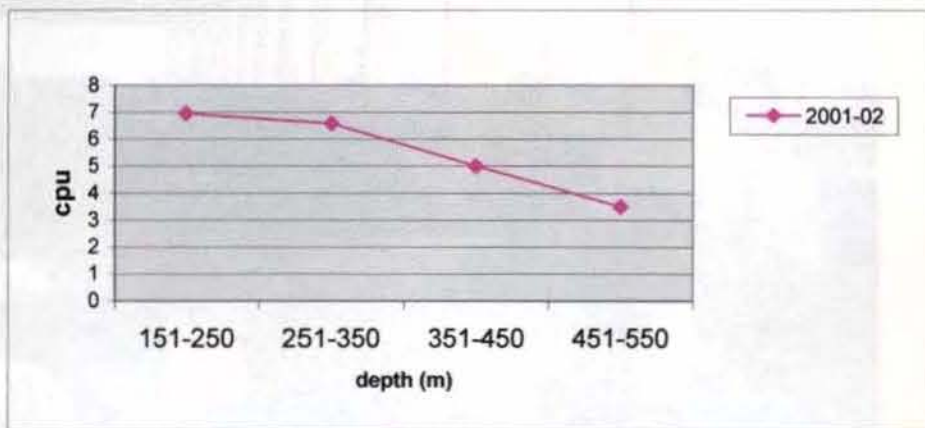


Fig. 5.64 Depth wise CPU of *Parapenaeopsis investigatoris* during 2001-02





## Plate 5.1



A Harvest of deep- sea prawns at Munambum Fisheries Harbour  
– An early morning sight



B. A busy morning at Munambum Fisheries Harbour – Deep sea prawns getting iced for dispatch to processing sheds.

## Plate 5.2



Heaps of *Aristeus alcocki* - the most prized of deep-sea prawn species -  
awaiting auction at Shakthikulangara Fisheries Harbour.



**Plate 5.3**



**A. A crate full of deep-sea prawns after auction.**



**B. Deep-sea prawn landings – A sight at the Cochin Fisheries Harbour**

**Plate 5.4**



**A fully equipped deep-sea trawler preparing for next cruise –**



**Chapter 6**

**RESOURCE CHARACTERISTICS**

## 6.1. INTRODUCTION

Life history traits of deep-water pandalid shrimps are practically unknown. This data gap is a very serious laxity since the deep sea prawns are rich and diversified for their species composition and abundance, besides offering immense potential for commercial fishery in the tropical and subtropical bathyal environment (Alvarez, 1968; Crosnier and Forest 1973, Cartes *et al.*, 1994; Sardá *et al.*, 1994). In recent years, deep sea prawns are emerging as an important resource of economical significance in the commercial deep sea fishery of Kerala. In order to make a proper evaluation on the magnitude of this newly exploited resource and assessing its sustainability for the commercial fishing off Kerala in the long run, reliable data base on the life history traits such as length-weight relationships, relative condition factor, sex ratio, size groups constituting the fishery and percentage of berried females in the exploited stock, etc. of the various species contributing to the fishery are essential prerequisites. Estimation of population size of a fish stock for the rational exploitation often calls for knowledge of individual body length-weight relationships in the population. Besides high biomass and abundance levels of the deep sea prawns, some of the pandalids show extensive diel vertical migration (Company and Sardá, 2000). Pandalids also occupy important ecological role in the marine ecosystem and forms key component in the marine food web responsible for the transfer of energy

from pelagic to the benthic habits (Relini Orsi and Relini 1990; Golani and Galil 1991; Cartes 1993; Pipitone *et al.*, 1994; Bozzano *et al.*, 1997).

A scrutiny of the relative condition factor at different size groups can give valuable information regarding the general well being, maturation and spawning or the state of development of gonad in the life span of animals whereas a close look at the conditions at different months may give definite clues regarding the breeding season (Le Cren, 1951). Determination of sex ratio will help to assess sex specific differential migration and rate of growth of deep sea prawns in the exploited stock whereas percentage of berried females to the total female population of the pandalid prawns will give an indication of annual regeneration capacity in the deep sea dwelling species when compared to their shallow water counterparts.

Studies on the resource characteristics of deep sea prawns of south west coast of India is practically nil, but for the work of Kurien (1965), Mohammed and Suseelan (1973), Suseelan (1985) and Suseelan *et al.* (1988, 1989). The above investigations were mostly in the form of exploratory surveys, nevertheless, detailed life history studies pertain to the commercially important deep sea prawn species and their intraspecific comparisons had never been hitherto attempted to. Therefore, in the present study a sincere effort is made to investigate the

resource characteristics of deep sea prawns contributing to the commercial deep sea prawn fishery of Kerala with the following objectives

1. To establish length-weight relationships of deep sea prawns and make correlations with their life habits.
2. To determine the relative condition factor both month wise and length wise
3. To reveal sex specific skewness in the ratio of commercially important species.
4. To delineate the modal class of deep sea prawns representing fishery.
5. To determine the percentage of berried population in the total female pandalids exploited.

## **6.2. MATERIALS AND METHODS**

Samples of eight deep sea prawns were collected during September 2000 to August 2002, from the commercial deep sea trawl landings at three major harbours of Kerala viz. Sakthikulangara, Cochin and Munambum at weekly intervals. Besides, the samples were also

collected during the exploratory fishery survey cruises of the research vessel FORV Sagar Sampada carried out between the latitude zones 8°-13°N. 765 specimens of *M.andamanensis*, 301 of *S.hextii*, 437 of *H.gibbosus*, 538 of *H.woodmasoni*, 891 of *P.spinipes*, 46 of *P.ensis*, 37 of *P.martia* and 345 of *A.alcocki* were examined for their length weight relationship. Sex wise sorting of the pandalid shrimps was done with the help of a binocular microscope based on the presence or absence of the appendix musculina on the second pair of pleopods. In penaeid, aristeid and solenocerid shrimps, petasma and thelycum were used for sex determination. The specimens were measured and weighed in fresh condition, total length was measured from tip of the rostrum to the extremity of the telson up to nearest millimeter with the abdomen keeping fully stretched (Nandakumar, 1997). The individual prawn was weighed to the nearest 0.1 gm using a top loader electronic balance. The sample number of both the sexes could not be maintained uniform due to the differential availability in their landings. Deep sea prawns were categorized in to 'meso pelagic' (species showing active diel migration), 'nektobenthic' (benthic species of moderate locomotary ability and no diel migrational behaviour) and 'benthic' based on the life habits of various species such as swimming behaviour, trophic aspects and peculiar harvesting methods following Heegaard (1967), Burukovsky (1992), Lagardere (1977) Omori and Ohta (1981), Cartes (1991,1993,1995), Cartes *et al.* (1993, 1994) and Company and Sardá (2000) .

Data on length and weight were analysed separately for males and females following Le Cren (1951) in order to unravel the difference, if any, in dimensional equality between the two variables for a better understanding on the growth pattern. The length – weight relation is expressed as

$$w = a l^b$$

where,  $w$  = weight (g)

$l$  = total length (mm)

$a$  &  $b$  = constants

Logarithmic transformation of the above formula gives a linear equation

$$\log w = \log a + b \log l$$

Regression analysis, ANACOVA on the regression equation, comparison of slopes and calculation of correlation coefficient values were done following standard statistical procedures (Snedecor and Cochran, 1967).

Relative condition factor of 'Kn' (Le Cren , 1951) was estimated for males and females using the formula

$$Kn = \frac{w}{\bar{W}}$$

Where 'w' is the observed weight and 'W' is the expected weight derived from the length weight relationship (Le Cren, 1951). Length weight relationship and condition factor were established for both the sexes of *H.gibbosus*, *H.woodmasoni*, *A.alcocki*, *P.spinipes* and *M.andamanensis*. Kn values for the various length groups and for different months were also calculated after obtaining the mean length and mean weight for the corresponding length groups and months (Nandakumar , 1997) .

Chi square analysis was carried out in five commercially important species of deep sea prawns viz. *H.gibbosus*, *H.woodmasoni*, *A.alcocki*, *P.spinipes* and *M.andamanensis* in order to assess the variation if any, in sex ratio from that of hypothetical value 1:1 (Snedecor and Cochran, 1967) .

In order to determine the modal size class representing the fishery and to assess the modal progressions in the length frequency distribution, the length data were collected during the same period, grouped them in to 10mm class intervals and pooled them against different months. A total of 2781 males and 1248 females of *H.gibbosus* , 1122 and 1640 males and females of *H.woodmasoni* , 728 males and 1226 females of *M.andamanensis* ,1229 and 988 males and females of *P.spinipes* , 662 males and 1037 females of *A.alcocki* were analysed. Exploitation level of ovigerous females of the most commercially important pandalid shrimps

viz. *H.woodmasoni* , *H.gibbosus* and *P.spinipes* were computed on the basis of their occurrence in the exploited stock and was expressed as percentage of berried prawns to the total female population present in numbers in the landings.

### 6.3. RESULTS

#### 6.3.1.Length weight relationships

Minimum and maximum values of total length and total weight in both the sexes of various species of deep sea prawns are given in Table 6.1. Linear relationship established between length and weight of males and females of eight species of deep sea prawns are depicted in Fig. 6.1 - 6.15. The respective logarithmic regression equations so obtained are as follows:

##### ***M.andamanensis***

$$\text{Male } \log w = -4.0899 + 2.3616 \log l \quad (r = 0.7849)$$

$$\text{Female } \log w = -4.8991 + 2.7839 \log l \quad (r = 0.8306)$$

##### ***S.hextii***



$$\text{Male } \log w = -3.9348 + 2.3259 \log l \quad (r = 0.8435)$$

$$\text{Female } \log w = -3.1280 + 1.9638 \log l \quad (r = 0.9217)$$

***H.gibbosus***

$$\text{Male } \log w = -5.8188 + 3.3392 \log l \quad (r = 0.9233)$$

$$\text{Female } \log w = -5.7165 + 3.2945 \log l \quad (r = 0.7401)$$

***H.woodmasoni***

$$\text{Male } \log w = -6.0063 + 3.3652 \log l \quad (r = 0.7362)$$

$$\text{Female } \log w = -6.2331 + 3.4953 \log l \quad (r = 0.7240)$$

***P.spinipes***

$$\text{Male } \log w = -4.8392 + 2.7308 \log l \quad (r = 0.6857)$$

$$\text{Female } \log w = -5.2426 + 2.9439 \log l \quad (r = 0.6441)$$

***P.ensis***

$$\text{Male } \log w = -3.5890 + 2.1400 \log l \quad (r = 0.3452)$$

$$\text{Female } \log w = -4.5910 + 2.6000 \log l \quad (r = 0.5203)$$

***P.martia***

$$\text{Female log } w = -5.3837 + 2.9001 \log l \quad (r = 0.7126)$$

***A.alcocki***

$$\text{Male log } w = -3.4992 + 2.1245 \log l \quad (r = 0.4676)$$

$$\text{Female log } w = -5.0550 + 3.0711 \log l \quad (r = 0.8956)$$

Scrutiny of 'r' values showed significance at 1% level in the correlation of length and weight in all the species except for *P.ensis* (Table 6.1). In *M.andamanensis*, comparison of the regression coefficients using F-test (Table 6.2) revealed that both the slope as well as elevation of both males and females is significantly different at 5% level ( $P < 0.05$ ). In *S.hextii*, the results of F-test for b values showed significance at 1% level ( $P < 0.01$ ) for both slope and elevation (Table 6.3). Results of F-test showed that *H.gibbosus* ( $P < 0.05$ ), *P.spinipes* ( $P < 0.01$ ), *S.hextii* ( $P < 0.01$ ) and *A.alcocki* ( $P < 0.05$ ) are significantly different in their b values of males and females whereas in *H.woodmasoni* and *P.ensis* the slope values were not significant but elevation showed significant difference at 5% level ( $P < 0.05$ ) (Table 6.4-6.8).

In the deep sea prawns studied, there exist three well-defined trends in regression coefficients (b) commensurate with the life habits seen in the various species. In the length-weight relationships of

mesopelagic species such as *M.andamanensis* and *S.hextii* which are exhibiting active diel vertical migration, the b value showed a strong negative allometry ( $b < 3$ ) between length and weight. Species belonging to *Plesionika*, *Parapandalus* and *Heterocarpus* which are nektobenthic, the b values were approximately equal to '3' and did not differ significantly, thus exhibiting an isometric growth pattern through out the life stages. On the other hand, *P.ensis* showed an exception to this situation; nevertheless, it was represented by a very few number of specimens. In the strictly benthic species *A.alcocki*, 'b' value of around 3 was observed in females, in contrast, a very low b value of 2.13 was observed in males, thus manifesting that the males maintain a poor body dimensional equality during their growth when compared to females.

The b values derived from the length weight relationships of deep sea prawns showed a strong correlation with their individual life habits (Fig. 6.16). The slope values showed a significant increase from the mesopelagic to nektobenthic while in the benthic habit a decrease was observed, with a mean 'b' of 2.36 for mesopelagic species, 3.09 for nektobenthic and 2.59 for the benthic habit (Table 6.9). Results of ANOVA showed that there exists significant difference in the regression coefficient values of deep sea prawns in relation to their life habits at 5 % level ( $P < 0.05$ ) (Table 6.10).

### 6.3.2. Relative condition factor

The monthly index of relative condition in respect of males and females of various species studied are depicted in Fig.6.17 – 6.21. In females of *H.gibbosus*, Kn values increased during January to March attaining its peak in February while in males a similar peak was not discernible due to insignificant representation of matured males in the commercial landings. However, a slight improvement in the Kn curve was seen during January and February, on the other hand, a distinct trough was observed during May (Fig. 6.20).

The Kn values in females of *H.woodmasoni* showed two peaks, a minor one in November (1.120) and a major one in February (1.28) (Fig. 6.19). In males also, a minor peak was noticed in November followed by a gradual increase in condition in January which attained peak in April whereas *M.andamanensis* showed an increase in Kn values during November to February in both males and females. In males, highest Kn values were observed in December and it was lowest in October while in females Kn values were invariably high in January (Fig. 6.17).

The Kn values in females of *A.alcocki* showed two peaks, a minor one in October and a major one in January while in males the Kn values were high during March and April (Fig. 6.18). In *P.spinipes* also two peaks

were observed in January and March in males, while in females only one peak was observed in November (Fig. 6.21).

Kn values at 10mm class intervals in respect of males and females of *H. gibbosus* are depicted in Fig. 6.23. It appeared that the fluctuation with reference to length seems to be more or less similar in both the sexes. The highest value was noticed at 60-65mm in both the sexes followed by a trough at 75mm in females was quite discernible. The subsequent peaks represent the cyclical gonadal development and spawning. The peak at 25 mm is not well differentiated in males.

In females of *H. woodmasoni*, the Kn showed a steady increase from 85mm onwards and registered a highest value at 135 mm. In males, higher Kn values were observed at 75mm, which showed a plummeting up to 95mm and thereafter a slow increase was recorded with peak at 135mm (Fig. 6.22).

In *M. andamanensis*, the fluctuation in the relative condition with reference to length seems to be more or less similar in both the sexes (Fig. 6.25). In females, the highest peak was observed at 105-115 mm, followed by a trough at 125-135mm whereas in males the peak was observed at 125mm.

Variation in Kn values at 10 mm length groups of males and females of *P. spinipes* showed that the relative condition was high in

younger size groups (Fig. 6.24). In males, highest Kn value was observed at 75 mm where as the lowest was at 125 mm. In females also, the peak Kn values were noticed at 75 mm while the second peak was registered at 115 mm length.

Kn values for different length groups in respect of males and females *A.alcocki* are depicted in Fig. 6.26 . The Kn values in both the sexes showed strong oscillation and in females the highest Kn values were observed at 45 mm length, thenceforth it declined gradually up to 65mm, thereafter it increased , attaining the next highest value at 145 mm. The Kn values in males oscillated strongly between 75 and 145 mm length, registering highest value at 135 mm , thus manifesting the factors other than maturation and spawning behind its oscillation tendency .

### **6.3.3. Sex ratio**

Monthly sex ratio of deep sea prawns collected from the exploited stock landed at various harbours of Kerala during 2000-01 and 2001-02 are depicted in Tables 6.11, 6.13, 6.15, 6.17 & 6.19. In the deep sea prawns, the sexes are separate through out the life history stages and no sex reversal was observed. The monthly sex ratio of *H.gibbosus* during the two years is separately shown in Table 6.11. The results indicated that there exists a significant departure from 1:1 ratio during almost all the

months due to the dominance of males in the exploited stock. Chi-square analysis of sex ratio showed significant deviation from 1:1 ratio at 5% level while there was no skewness in the sex ratio ( $P>0.05$ ) during October 2000, March 2001 and December 2002.

The sex ratio in different length groups for the two seasons showed that there exist significant deviation in *H.gibbosus* from 1:1 ratio at 5% level up to 151-160mm length group due to the out numbering of males (Table 6.12).

The monthly sex ratio of *H.woodmasoni* for the two years is shown in Table 6. 13. The chi-square value showed a significant deviation from 1:1 ratio during September to December in both the years due to the predominance of females in the catch. A further spurt in the values was observed during May to August due to the abundance of females . Sex ratio analysis in different length groups showed that males predominates the population in the lower groups (41-70mm) whereas in the higher length groups females outnumbered males ( Table 6.14) .

The month-wise sex ratio in *P.spinipes* indicated that there was significant deviation from 1:1 ratio at 5% level during all the months owing to the dominance of females except during October, March and September in 2000-01 and January and May in 2001-02. Females dominated in the population during November to February in both the years whereas predominance of males was discernible from April to

September (Table 6.17). Sex ratio in different length groups (Table 6.18) showed that females were dominant up to 70-80 mm length groups. However, in the higher length groups, from 80-90 mm onwards, only males were encountered.

In *A. alcocki*, the monthly sex ratio showed a significant departure from the hypothetical ratio 1:1 in all the months except in July in 2000-01. The skewness was due to the predominance of females in September and December while males predominated in the rest of the months. In the second year, the ratio skewed in almost all the months. The departure from the hypothetical value in September, November, December and February was due to the dominance of females while males dominated during the other months (Table 6.19).

In the lengthwise distribution of sex, the females of *A. alcocki* showed glaring predominance from 70-80mm to 190-200 mm, the overall sex ratio being 1:21.01 (Table 6.20). The chi-square values were significant in most of the length groups at 5% level ( $P < 0.05$ ).

The male to female ratio of *M. andamanensis* in the exploited stock was 1:2.44 during 2000-01 and 1:1.87 in 2001-02 thus showing the preponderance of females in the population (Table 6.15). The month wise analysis indicated a significant deviation from 1:1 ratio in September to April in both the years owing to the predominance of females ( $P < 0.05$ ). While examining the lengthwise sex ratios, males showed dominance up



to 61-70 mm where as in the higher length groups only females were exclusively represented (Table 6.16).

#### **6.3.4.Length frequency distribution**

Monthly distribution of length of males and females of *H.woodmasoni* during 2000-01 and 2001-02 are shown in Fig. 6.27 and 6.28 respectively. In 2000-01, the modal classes of male and female were 91-100 and 81-90mm respectively followed by 81-90mm and 91-100 mm respectively. In contrast, during 2001-02 the modal values were represented by two length groups of 91-100 and 101-110 mm, both in male and female population followed by 81-90 mm in both the sexes.

In males and females of *H.gibbosus*, the length frequency distribution showed a uni modal character with the modes frequently observed at 91-100mm and 111-120mm length range. The modal length for females was at 121-130mm during September to November. Smaller individuals appeared in the fishery during December. Similar observations were made in males too (Fig. 6.35) .

During 2001-02, the modal length class of males and female *H.gibbosus* was found at 91-100mm followed by 111-120mm. From December onwards, juveniles started appearing in the fishery with 51-60mm in males and 91-100 mm in females (Fig. 6.36).

In females of *A.alcocki* 131-140 mm, 141-150mm and 151-160 mm were the length classes dominated during September to November. In females, 121-130mm appeared as the modal size class followed by 101-110mm and 131-140mm (Fig.6. 33). Males found to be very smaller than females in the exploited stock. In males of *A.alcocki*, 81-90 mm formed as the modal class during July, August while 101-110mm length groups frequently represented in the catches during rest of the months (Fig. 6.34).

The fishery of *P.spinipes* was constituted by specimens ranging in length from 51-150 mm in females and 51-160 mm in males, however, specimens below 71 mm and above 121 mm were barely represented in the commercial landings. Length frequency distribution of *P.spinipes* during 2000-01 and 2001-02 are shown in Fig.6.31 & 6.32. In general, the monthly size frequency distribution during 2000-01 was appeared to be uni modal in character with the modes ranging between 81-90 mm and 111-120mm. However, the principal mode was found at 90-100 mm in females and 101-110mm in males. From May onwards, a shift in the modal class was discernible in females from 81-90 mm to 91-100mm. During 2001-02, the modal class of both male and female remained more or less the same.

The fishery of *M.andamanensis* was constituted by individuals in the range 32 to 148 mm in females and 39 to 141 mm in males in the

commercial landings (Fig. 6.29 & 6.30). The modal class of females in the fishery during 2000-01 was 91-100 mm whereas in males it was 81-90mm. Juveniles of 51-60mm were appeared from January onwards and the peak was observed during March and April indicating the spawning and entry of new recruits to the fishery. From May onwards, a predominance of 61-70mm size groups was registered in the fishery thus showing a slow shift in the monthly modal progression. During 2001-02 the modal class was found at 90-100 followed by 70-80 in both the sexes.

#### **6.3.5. Percentage of berried prawns to the female population**

The monthly percentage of berried females in the total female population exploited is given in Table 6. 21. In *H.woodmasoni*, the peak occurrence of berried females was observed during December to February during when on an average 88.7% of females were found to carry eggs attached on the pleopodal setae. The second major peak was observed in October during when 81.4% of the total female population were found ovigerous. From March onwards, there was a steady decline of egg carry females to half and the lowest value was realized during July with only 22.75% berries in the total female population.

In *H.gibbosus*, very high breeding activity was observed from December to March on the basis of occurrence of berried females, registering its peak in January (83.7%) followed by February (80%). On the other hand, lowest number of berries appeared during May (52.06%), which is indicative of its low breeding activity.

In *P.spinipes*, the percentage of berried prawns in the landings were very high through out the year except in July (48.28%). The peak breeding was observed during October to January with highest numbers registered during November (92.15%) followed by December (91.03%).

#### 6.4. DISCUSSION

In the present study three separate, well-defined trends in regression coefficients were observed corresponding to the diversified life habits of the various species of deep sea prawns. *M.andamanensis*, being a mesopelagic species, exhibited a strong negative allometric growth and maintained its dimensional equality less than 3 when length and weight were correlated which indicates that the prawns become more slender as they increase in length (Grover and Juliano, 1976). In male prawns ( $b = 2.36$ ), the departure from 3 was found more pronounced than that of females ( $b = 2.78$ ). This is in contrast with the observation made by Suseelan (1985), who reported allometric coefficients  $>3$  in males and females of *M.andamanensis* collected during exploratory

surveys off south west coast of India. In *S.hextii*, another important fast swimming mesopelagic species also, the b values were found to be less than 3, thus manifesting a greater increase in length rather than in weight by exhibiting a very strong negative allometry. A strong negative allometric value of <3 were also reported by Company and Sardá (2000) in the three mesopelagic prawns *Sergestus arcticus* , *Passiphaea sivado* and *P.multidentata* from the northwestern Mediterranean Sea and opined that the negative skewness less than 3 were due to the diel vertical migration and active swimming habits of these groups. Similar observations of negative allometry have been observed in *Metanephrops andamanicus* by Ivanov and Krylov (1980) from the western Indian Ocean.

On the contrary, a diametrically different relationship was observed in the nektobenthic species, which showed a regression coefficient value around 3 which means the body of prawns remain constant at different lengths which is indicative of the maintenance of its body dimensions during growth. In the present study the regression coefficients of *H.gibbosus* , *H.woodmasoni*, *P.spinipes*, *P.ensis* and *P.martia* showed b values around 3 and generally did not differ significantly from the isometric values and this may be attributed to their nektobenthic nature of moderate locomotary ability and no diel migratory behaviour. This finding show strong agreement with Company and Sardá (2000) who observed an isometric 'b' value of '3' in all the species of the genus *Plesionika*

except for *P.gigliolii* and *P.acanthonotus* and Ivanov and Krylov (1980) who also observed 'b' values around '3' in the deep water penaeid prawns *Penaeus marginatus*, *Penaeopsis balssi* and in *Parapenaeus sextuberculatus* from western Indian Ocean.

In the benthic species, *A.alcocki* the 'b' values were found to be lower than 3 as this species showed a strong decrease in weight and become slender with relative increase in length. Suseelan (1985) reported similar results in *A.alcocki* during the exploratory cruise surveys off west coast of India. In contrast to the present results, Company and Sardá (2000) reported an increase in weight of *Aristeus antennatus* with the increase in length from the Mediterranean Sea. However, the results of the present study agree with those of Cartes *et al.* (1993), who linked a decreased carapace length : wet weight ratio to increased adaptation to the benthic habit. Therefore, amongst other factors, the length weight relationship can be used in prescribing the life habits of deep sea decapod crustaceans as opined by Company and Sardá. (2000). According to Cartes *et al.* (1993), weight is a limiting morphological factor for deep sea crustaceans with marked migratory behaviour, but not for nekto-benthic species and a certain extent to some benthic species, in which weight does not appear to be a limiting morphological factor. A laterally compressed body with a rudimentary rostrum are two further evolutionary morphological adaptations in mesopelagic crustaceans viz. *M.andamanensis* and *S.hextii* (Cartes *et al.*, 1993), while a laterally

uncompressed carapace and a long rostrum are common features in nekto-benthic species such as *H.gibbosus* , *H.woodmasoni* , *P.spinipes* , *P.martia* and *P.ensis* (Burukovsky ,1972; Sardá and Demestre ,1989 ; Company and Sardá,2000), where as males of *A.alcocki* possess a very compressed and short body (Cartes *et al.*,1993). This may be the reason for the negative allometry shown by the males in the present study.

In the present study, higher Kn values observed during November to March invariably in all the species may be indicative of their peak spawning period. Results on the food and feeding habits of *H.gibbosus* and *H.woodmasoni* have revealed that the weight of the food ingested by them is very negligible in comparison with the body weight ( Refer Chapter 7 for details) . Therefore, it is quite evident that the food cannot affect the Kn values in pandalid shrimps. The rise in Kn values at the time of spawning was reported in the littoral penaeid *P.semisulcatus* (Thomas, 1975) and in deep sea fishes by Philip and Mathew (1996), Anibeze (2000) , Shanmugham *et al.* (2000) and Joung and Chen (1992). In both *H.woodmasoni* and *H.gibbosus*, spawning was found to be a continuous process commencing from October to April with a peak in January in the former species and December to April in the latter. Whereas in *P.spinipes* and *A.alcocki* , peak spawning season was observed during December to May while in the deep sea penaeid prawn *M.andamanensis* , the same was observed in December.

The point of inflection in the curve of Kn values at a specific length group is indicative of the length at which sexual maturity starts (Hart , 1946 ; Pillay ,1952). The present results support this observation as the point of inflection was seen in the size group 90-100mm for both the sexes of *H.woodmasoni* and the size at first maturity of male and female were estimated at 96.75mm and 100mm respectively. In *H.gibbosus* , the point of inflection was seen in the size groups 80-90mm for males and females of *H.gibbosus* while the size at first maturity arrived at for males and females were 97mm and 98.5mm( Refer Chapter 8 for details).

Results of the histological analysis of *H.gibbosus* and *H.woodmasoni* revealed that there is no incidence of sex reversal in these prawns however, the same is reported as a regular phenomenon in their counterparts inhabiting temperate waters (Rasmussen, 1953; Horsted and Smidt, 1956; Burukovsky, 1972; Hancock and Henriques , 1968; Anderson and Lindner ,1971 ; Omori ,1971). Sex ratio analysis of the exploited stock of five important deep sea prawn species indicated that, the females outnumbered males heavily in all the species except *H.gibbosus*, wherein the dominance of males in the exploited stock was quite discernible.

A comparison of the overall sex ratio of the commercial important deep sea prawns revealed that in *H.woodmasoni* , *P.spinipes* , *M.andamanensis* and *A.alcocki* , the females outnumbered the males,



with the highest preponderance in *A.alcocki* ( male : female 1:17.78) . Suseelan (1985) reported the predominance of males of *H.woodmasoni* over their counter part which is disagreement with the present study , however, similar observations were made in males of *H.gibbosus* (male : female 1:0.60 ) .Result of Chi-square analysis in *H.gibbosus* also showed that the variation is significant (  $\chi^2 = 710.71$   $P < 0.05$ ) .A season wise analysis of sex ratio showed that females of *H.woodmasoni* , *M.andamanensis* , *P.spinipes* and *A.alcocki* showed a clear preponderance over their counterparts during November to February in both the years whereas in *H.gibbosus* ,predominance of females over males during September was quite discernible.

The simultaneous occurrence of the two opposite conditions of sex disparity in the exploited stock may be due to the sex-segregated migration of animals associated with breeding (Suseelan, 1985). Females of deep sea prawns such as *Pasiphea sivado* and *P.multidentata* undertake differential migration for breeding from lower to higher depths during mid-winter months (Company *et al.*, 2001). According to George and Rao (1967), inshore prawn fishery prevailing in the coastal areas of south west coast of India might be due to the result of breeding migration of females outside the fishing areas. In contrast, Suseelan (1985) opined that the disparity of sexes among deep sea population might be due to greater natural mortality sustained by one of the sexes, however, no such finding was observed during the present study.

While examining the length wise sex ratio of the commercially important deep sea prawns during two years, while the females distinctly dominated in the higher size classes of *M.andamanensis* , *H.woodmasoni* and *A.alcocki*, a clear preponderance of males over females was observed in the higher size classes of *P.spinipes*. Interestingly, in *H.gibbosus*, males dominated in all size groups, from 41-50mm to 181-190 mm size groups. In *M.andamanensis*, dominance of females was observed from 101-110mm to 151-160mm. In *H.woodmasoni*, females were absent up to 41-50mm, hence showed a gradual increase up to 141-150mm. The occurrence of large sized females in the fishery might be due to the combined effect of differential migration and fishing intensity imposed on the fishing stock. In contrast, in the exploited stock of *P.spinipes*, females dominated in the lower size class , but showed a steady reduction with increase in size and above 121-130 mm , they were completely absent. An inverse phenomena was observed in *A.alcocki* , in which , females completely dominated the higher size groups from 111-120 mm to 171-180 mm . Donghia *et al.* (1998) also reported the dominance of large size females in the fishery of *Aristeomorpha foliacea* from Mediterranean Sea and in *Aristues antennatus* by Relini and Orsi (1987) and Sardá and Demestre (1987).

Results of the size group counts for the fishery of 5 species of deep sea prawns showed that there exists an intra specific size segregation by season and inter specific size segregation among species.

The exploited stock of deep sea prawns is an assemblage of species having wide variation in size groups, which varied from 34mm in *P.spinipes* to 268mm in *A.alcocki*. However, it appeared that a major portion of the exploited stock collected by deep sea trawlers were comprised of adults and sub adults. Female pandalid shrimps always appeared as either being in the berried stage or as head roe condition but their exact area of recruitment was not known so far.

Results of length frequency analyses showed that new individuals were continuously being recruited into fishing area and there is a very slow progression in the mean sizes observed in different months. In addition, the juveniles appeared in the fishery by the end of February and it is further inferred that the spawning might have occurred during the early winter. Like the littoral penaeid prawns, no juvenile assemblage of deep sea prawns was fished from shallow waters which would suggest that the recruitment was not taking place in shallow waters. Ohtomi (1997) noticed the larger concentration of eggs of *Pandalopsis dispar* among plankton in Pacific waters while Paulinos and George (1976) reported the occurrence of larger concentration of pandalid shrimp larvae in the offshore west coast of India. From the above observations, it may be inferred that larval recruitment, growth and maturity of deep sea prawns were taking place in the offshore waters.

Based on the intensity of occurrence of berried females in the total female population, it can reasonably be asserted that their breeding takes place continuously or almost year round in the Arabian Sea, contrary to the pandalids of temperate waters characterized by a seasonal breeding (Horsted and Smidt ,1956; Butler ,1964; Dahlstrom ,1970;Company and Sardá ,1997). However, year round breeding has been reported in deep sea prawns of tropical and sub tropical waters (Hancock and Henriques , 1968; Anderson and Lindner ,1971 ; Omori , 1971,1974; Ohtomi , 1997) and the present finding is corroboratory to these.

A perusal on the pattern of distribution of berried females in the population of *H.woodmasoni* , *H.gibbosus* and *P.spinipes* would indicate that they are continuous spawners with intensive spawning activity during October to March . Suseelan (1985) reported similar observation with two peaks of breeding in deep sea prawns, the major one during October to April and a minor one in July .Thus, present finding is corroborating with that of Suseelan(1985) . This finding was further strengthened by Hancock and Henriques (1968) on the basis of their observations on Chilean shrimp *H.reedi* , which breeds extensively during December to January while very low reproductive activity was observed during summer. Further, Anderson and Lindner (1971) reported the peak spawning season of *H.robustus* during January to May along US coasts and Company and Sardá (1997) noted the reproductive cycle of *Plesionika heterocarpus* during winter in the Mediterranean Sea.

| species                            | sex | Minimum length(mm) | Maximum length(mm) | Numbers examined | b    | log a | r      | Probability |
|------------------------------------|-----|--------------------|--------------------|------------------|------|-------|--------|-------------|
| <i>Metapenaeopsis andamanensis</i> | M*  | 43                 | 122                | 333              | 2.36 | -4.09 | 0.785* | P<0.01      |
|                                    | F** | 37                 | 140                | 432              | 2.78 | -4.90 | 0.744* | P<0.01      |
| <i>Solenocera hexfil</i>           | M   | 46                 | 199                | 139              | 2.33 | -3.13 | 0.757* | P<0.01      |
|                                    | F   | 10                 | 188                | 172              | 1.96 | -3.93 | 0.844* | P<0.01      |
| <i>Heterocarpus woodmasoni</i>     | M   | 62                 | 137                | 259              | 3.37 | -6.01 | 0.736* | P<0.01      |
|                                    | F   | 63                 | 149                | 279              | 3.50 | -6.23 | 0.717* | P<0.01      |
| <i>Heterocarpus gibbosus</i>       | M   | 47                 | 152                | 282              | 3.34 | -5.82 | 0.923* | P<0.01      |
|                                    | F   | 48                 | 135                | 155              | 3.30 | -5.72 | 0.742* | P<0.01      |
| <i>Parapandalus spinipes</i>       | M   | 63                 | 142                | 339              | 2.73 | -4.84 | 0.686* | P<0.01      |
|                                    | F   | 55                 | 122                | 552              | 2.94 | -5.24 | 0.644* | P<0.01      |
| <i>Plesionika ensis</i>            | M   | 90                 | 114                | 23               | 2.14 | -4.60 | 0.345  |             |
|                                    | F   | 86                 | 116                | 24               | 2.60 | -3.59 | 0.520  |             |
| <i>Plesionika martia</i>           | F   | 86                 | 115                | 37               | 2.90 | -5.38 | 0.713* | P<0.01      |
| <i>Aristeus alcocki</i>            | M   | 65                 | 150                | 189              | 2.13 | -3.50 | 0.466  |             |
|                                    | F   | 48                 | 179                | 155              | 3.07 | -5.51 | 0.698* | P<0.01      |

\*Male, \*\* Female

| DEVIATIONS FROM REGRESSION |    |     |             |           |          |           |         |          |          |
|----------------------------|----|-----|-------------|-----------|----------|-----------|---------|----------|----------|
| Sources                    | df | {x2 | {xy         | {y2       | RC       | f         | {d y.x2 | SS       | MS       |
| male                       |    | 330 | 1.767773989 | 4.1747667 | 12.56112 | 2.3615953 | 329     | 2.702015 | 0.008213 |
| female                     |    | 429 | 3.363158206 | 9.5446372 | 31.63816 | 2.8379983 | 428     | 4.550491 | 0.010632 |
| WITH IN                    |    |     |             |           |          |           | 757     | 7.252506 | 0.009581 |
| Reg.Coeff.                 |    |     |             |           |          |           | 1       | 0.262982 | 0.262982 |
| COMMON                     |    | 759 | 5.130932175 | 13.719404 | 44.19928 | 2.6738619 | 758     | 7.515488 | 0.009915 |
| Adj.Means                  |    |     |             |           |          |           | 1       | 0.013347 | 0.013347 |
| TOTAL                      |    | 761 | 5.166832704 | 13.837363 | 44.58686 |           | 759     | 7.528835 | 1.34616  |

\*\* Significant at 5% level

Table 6.3 Analysis of covariance for comparison of slopes in *Solenocera hexdii*

| DEVIATIONS FROM REGRESSION |    |     |             |           |          |           |         |          |          |
|----------------------------|----|-----|-------------|-----------|----------|-----------|---------|----------|----------|
| Sources                    | df | {x2 | {xy         | {y2       | RC       | f         | {d y.x2 | SS       | MS       |
| male                       |    | 137 | 3.127476862 | 7.2741163 | 20.05392 | 2.3258737 | 136     | 3.13524  | 0.023053 |
| female                     |    | 170 | 5.675088893 | 11.144861 | 28.88106 | 1.9638213 | 169     | 6.994544 | 0.041388 |
| WITH IN                    |    |     |             |           |          |           | 305     | 10.12978 | 0.033212 |
| Reg.Coeff.                 |    |     |             |           |          |           | 1       | 0.264302 | 0.264302 |
| COMMON                     |    | 307 | 8.802565755 | 18.418977 | 48.93498 | 2.0924555 | 306     | 10.39409 | 0.033968 |
| Adj.Means                  |    |     |             |           |          |           | 1       | 0.383495 | 0.383495 |
| TOTAL                      |    | 309 | 9.164399227 | 19.558183 | 52.5091  |           | 307     | 10.77758 | 11.2900  |

\*\* Significant at 1% level

| DEVIATIONS FROM REGRESSION |     |             |           |          |           |     |            |          |          |
|----------------------------|-----|-------------|-----------|----------|-----------|-----|------------|----------|----------|
| Sources                    | df  | {x2         | {xy       | {y2      | RC        | f   | SS {d y.x2 | MS       |          |
| male                       | 281 | 6.759986313 | 11.079468 | 34.99339 | 1.6369779 | 280 | 16.83436   | 0.060123 |          |
| female                     | 154 | 5.049132845 | 5.1692092 | 15.5388  | 1.0237816 | 153 | 10.24666   | 0.066972 |          |
| WITH IN                    | 433 |             |           |          |           | 433 | 27.08104   | 0.062543 |          |
| Reg.Coeff.                 | 1   |             |           |          |           | 1   | 1.093887   | 1.093887 |          |
| COMMON                     | 435 | 11.80911916 | 16.248678 | 50.53219 | 1.3759432 | 434 | 28.17493   | 0.064919 | 17.49*   |
| Adj.Means                  | 1   |             |           |          |           | 1   | 0.723402   | 0.723402 | 11.14311 |
| TOTAL                      | 437 | 11.89034631 | 16.603678 | 52.08371 |           | 435 | 28.89833   |          |          |

\*\* Significant at 5% level(P<0.05)

Table 6.5 Analysis of covariance for comparison of slopes in *Parapandalus spinipes*

| DEVIATIONS FROM REGRESSION |     |             |           |          |           |     |            |          |          |
|----------------------------|-----|-------------|-----------|----------|-----------|-----|------------|----------|----------|
| Sources                    | df  | {x2         | {xy       | {y2      | RC        | f   | SS {d y.x2 | MS       |          |
| male                       | 339 | 8.540918186 | 4.3343753 | 9.264907 | 0.5074835 | 338 | 7.065283   | 0.020903 |          |
| female                     | 552 | 8.928642157 | 5.6397686 | 16.08658 | 0.6316491 | 551 | 12.52422   | 0.02273  |          |
| WITH IN                    | 889 |             |           |          |           | 889 | 19.58951   | 0.022035 |          |
| Reg.Coeff.                 | 1   |             |           |          |           | 1   | 0.067299   | 0.067299 |          |
| COMMON                     | 891 | 17.46956034 | 9.974144  | 25.35149 | 0.5709442 | 890 | 19.65681   | 0.022086 | 3.0541** |
| Adj.Means                  | 1   |             |           |          |           | 1   | 0.100762   | 0.100762 | 4.562    |
| TOTAL                      | 893 | 17.47988909 | 10.012311 | 25.49252 |           | 891 | 19.75757   |          |          |

\*\* Significant at 1% level(P<0.01)

| DEVIATIONS FROM REGRESSION |    |     |             |           |          |           |         |          |          |
|----------------------------|----|-----|-------------|-----------|----------|-----------|---------|----------|----------|
| Sources                    | df | {x2 | {xy         | {y2       | RC       | f         | {d y x2 | SS       | MS       |
| male                       |    | 21  | 0.022028971 | 0.0471154 | 0.193673 | 2.1387919 | 20      | 0.092903 | 0.004645 |
| female                     |    | 23  | 0.021292203 | 0.0553631 | 0.419965 | 2.6001592 | 22      | 0.273012 | 0.01241  |
| WITH IN                    |    |     |             |           |          |           | 42      | 0.365915 | 0.008712 |
| Reg. Coeff.                |    |     |             |           |          |           | 1       | 0.002305 | 0.002305 |
| COMMON                     |    | 44  | 0.043321174 | 0.1024785 | 0.610638 | 2.3655523 | 43      | 0.368219 | 0.008563 |
| Adj. Means                 |    |     |             |           |          |           | 1       | 0.076684 | 0.076684 |
| TOTAL                      |    | 46  | 0.043386    | 0.1048631 | 0.698355 |           | 44      | 0.444903 |          |

\* Not significant (P>0.01)  
 \*\* Significant at 1% level (P<0.01)

Table 6.7 Analysis of covariance for comparison of slopes in *Heterocarpus woodmasoni*

| DEVIATIONS FROM REGRESSION |    |     |             |           |          |           |         |          |          |
|----------------------------|----|-----|-------------|-----------|----------|-----------|---------|----------|----------|
| Sources                    | df | {x2 | {xy         | {y2       | RC       | f         | {d y x2 | SS       | MS       |
| male                       |    | 260 | 12.52507341 | 6.801914  | 14.36033 | 0.5430838 | 259     | 10.66646 | 0.041183 |
| female                     |    | 278 | 13.15273402 | 8.9146717 | 22.93049 | 0.6777809 | 277     | 16.88829 | 0.060969 |
| WITH IN                    |    |     |             |           |          |           | 536     | 27.55475 | 0.051408 |
| Reg. Coeff.                |    |     |             |           |          |           | 1       | 0.116435 | 0.116435 |
| COMMON                     |    | 538 | 25.67780743 | 15.716586 | 37.29082 | 0.6120688 | 537     | 27.67119 | 0.051529 |
| Adj. Means                 |    |     |             |           |          |           | 1       | 0.960125 | 0.960125 |
| TOTAL                      |    | 540 | 25.73240602 | 15.979204 | 38.55401 |           | 538     | 28.63131 |          |

\* Not significant (P>0.01)  
 \*\* Significant at 1% level (P<0.01)



**Table 18 Analysis of covariance for comparison of slopes in *Aristeus alcocki***

| Source | df  | Σx <sup>2</sup> | Σxy    | Σy <sup>2</sup> | RC    | f   | DEVIATIONS FROM REGRESSION |       | F      |
|--------|-----|-----------------|--------|-----------------|-------|-----|----------------------------|-------|--------|
|        |     |                 |        |                 |       |     | SS                         | MS    |        |
|        |     |                 |        |                 |       |     | Σd y.x <sup>2</sup>        |       |        |
|        | 189 | 7.912           | 3.254  | 4.039           | 0.411 | 188 | 2.700                      | 0.014 |        |
|        | 153 | 10.017          | 8.042  | 16.293          | 0.803 | 152 | 9.836                      | 0.065 |        |
|        |     |                 |        |                 |       | 340 | 12.536                     | 0.037 |        |
|        |     |                 |        |                 |       | 1   | 0.678                      | 0.678 |        |
|        | 342 | 17.929          | 11.297 | 20.332          | 0.630 | 341 | 13.214                     | 0.039 | 18.38* |
|        |     |                 |        |                 |       | 1   | 2.255                      | 2.255 | 58.19  |
|        | 344 | 19.276          | 13.954 | 25.570          |       | 342 | 15.469                     |       |        |

\* Significant at 5% level (P<0.05)

**Table 19 Variation in slope values of deep sea prawns as a function of life habit**

| species                | life habit   | Slope value(b) |        | Mean b values |
|------------------------|--------------|----------------|--------|---------------|
|                        |              | male           | female |               |
| <i>M. andamanensis</i> | meso pelagic | 2.78           | 2.36   | 2.36          |
| <i>S. hexii</i>        | "            | 2.32           | 1.96   |               |
| <i>H. gibbosus</i>     | nektobenthic | 3.34           | 3.29   | 3.09          |
| <i>H. woodmasoni</i>   | "            | 3.37           | 3.5    |               |
| <i>P. ensis</i>        | "            | 2.14           | 2.6    |               |
| <i>P. spinipes</i>     | "            | 2.74           | 2.95   |               |
| <i>P. martia</i>       | "            | -              | 2.9    |               |
| <i>A. alcocki</i>      | benthic      | 2.12           | 3.07   |               |

**Table 110 Result of one way ANOVA showing slope coefficients against species habit in deepsea prawns**

| Source of Variation | SS    | df | MS    | F        | P-value | F crit |
|---------------------|-------|----|-------|----------|---------|--------|
| Between Groups      | 0.323 | 2  | 0.161 | 569.824* | 0.00013 | 9.552  |
| Within Groups       | 0.001 | 3  | 0.000 |          |         |        |
| Total               | 0.324 | 5  |       |          |         |        |

\* Significant at 5% level (P<0.05)

**Table 6.11 Sex ratio of *Heterocarpus gibbosus* in the exploited stock of deep sea prawns**

| <b>2000-01</b> | <b>Male</b> | <b>Female</b> | <b>M:</b> | <b>F</b>    | <b>Chi-square</b> | <b>Probability</b> |
|----------------|-------------|---------------|-----------|-------------|-------------------|--------------------|
| September 2000 | 135         | 63            | 1:        | 0.47        | 26.18             | P<0.05             |
| October        | 9           | 8             | 1:        | 0.89        | 0.06              |                    |
| November       | 311         | 26            | 1:        | 0.08        | 241.02            | P<0.05             |
| December       | 58          | 15            | 1:        | 0.26        | 25.33             | P<0.05             |
| January 2001   | 76          | 34            | 1:        | 0.45        | 16.04             | P<0.05             |
| February       | 263         | 53            | 1:        | 0.20        | 139.56            | P<0.05             |
| March          | 45          | 46            | 1:        | 1.02        | 0.01              |                    |
| April          | 380         | 73            | 1:        | 0.19        | 208.06            | P<0.05             |
| May            | 98          | 44            | 1:        | 0.45        | 20.54             | P<0.05             |
| June           | 6           | 2             | 1:        | 0.33        | 32.00             | P<0.05             |
| July           | 327         | 146           | 1:        | 0.45        | 69.26             | P<0.05             |
| <b>Total</b>   | <b>1708</b> | <b>510</b>    | <b>1:</b> | <b>0.44</b> | <b>880.54</b>     | <b>P&lt;0.05</b>   |
| <b>2001-02</b> |             |               |           |             |                   |                    |
| August 2001    | 199         | 78            | 1:        | 0.39        | 52.86             | P<0.05             |
| September      | 15          | 97            | 1:        | 6.47        | 60.04             | P<0.05             |
| October        | 39          | 21            | 1:        | 0.54        | 5.40              | P<0.05             |
| November       | 92          | 43            | 1:        | 0.47        | 17.79             | P<0.05             |
| December       | 30          | 24            | 1:        | 0.80        | 0.67              |                    |
| January 2002   | 95          | 57            | 1:        | 0.60        | 9.50              | P<0.05             |
| February       | 309         | 258           | 1:        | 0.83        | 4.59              | P<0.05             |
| March          | 261         | 147           | 1:        | 0.56        | 194.61            | P<0.05             |
| April          | 33          | 10            | 1:        | 0.30        | 19.13             | P<0.05             |
| <b>Total</b>   | <b>1073</b> | <b>735</b>    | <b>1:</b> | <b>1.22</b> | <b>194.99</b>     | <b>P&lt;0.05</b>   |

**Table 6.13 Sex ratio of *Heterocarpus woodmasoni* in the exploited stock of deep sea prawns**

| <b>2000-01</b> | <b>Male</b> | <b>Female</b> | <b>M: F</b>    | <b>Chi-square</b> | <b>Probability</b> |
|----------------|-------------|---------------|----------------|-------------------|--------------------|
| September 2000 | 127         | 267           | 1: 2.10        | 269.10            | P<0.05             |
| October        | 48          | 132           | 1: 2.75        | 134.75            | P<0.05             |
| November       | 174         | 227           | 1: 1.30        | 228.30            | P<0.05             |
| December       | 28          | 36            | 1: 1.29        | 37.29             | P<0.05             |
| January 2001   | 104         | 155           | 1: 1.49        | 156.49            | P<0.05             |
| February       | 59          | 57            | 1: 0.97        | 57.97             | P<0.05             |
| March          | 25          | 24            | 1: 0.96        | 24.96             | P<0.05             |
| April          | 51          | 47            | 1: 0.92        | 47.92             | P<0.05             |
| May            | 8           | 34            | 1: 4.25        | 38.25             | P<0.05             |
| June           | 7           | 11            | 1: 1.57        | 12.57             | P<0.05             |
| July           | 0           | 3             | 1: 0.00        | 3.00              |                    |
| August         | 14          | 25            | 1: 1.79        | 26.79             | P<0.05             |
| <b>Total</b>   | <b>645</b>  | <b>1018</b>   | <b>1: 1.62</b> | <b>588.80</b>     | <b>P&lt;0.05</b>   |
| <hr/>          |             |               |                |                   |                    |
| <b>2001-02</b> |             |               |                |                   |                    |
| August 2001    | 199         | 78            | 1: 1.16        | 95.16             | P<0.05             |
| September      | 81          | 94            | 1: 0.77        | 10.77             | P<0.05             |
| October        | 13          | 10            | 1: 0.67        | 14.67             | P<0.05             |
| November       | 21          | 14            | 1: 1.15        | 114.15            | P<0.05             |
| December       | 98          | 113           | 1: 0.43        | 77.43             | P<0.05             |
| January 2002   | 181         | 77            | 1: 6.33        | 253.33            | P<0.05             |
| February       | 39          | 247           | 1: 1.35        | 38.35             | P<0.05             |
| March          | 28          | 35            | 1: 1.10        | 12.10             | P<0.05             |
| April          | 10          | 11            | 1: 2.00        | 8.00              | P<0.05             |
| May            | 3           | 6             | 1: 2.00        | 6.00              | P<0.05             |
| June           | 2           | 4             | 1: 3.50        | 10.50             | P<0.05             |
| July           | 2           | 7             | 1: 4.00        | 8.00              | P<0.05             |
| August         | 1           | 4             | 1: 4.00        | 8.00              | P<0.05             |
| <b>Total</b>   | <b>477</b>  | <b>622</b>    | <b>1: 2.27</b> | <b>609.14</b>     | <b>P&lt;0.05</b>   |

**Table 6.15 Sex ratio of *Metapenaeopsis andamanensis* in the exploited stock of deep sea prawns**

| <b>2000-01</b> | <b>Male</b> | <b>Female</b> | <b>M: F</b>    | <b>Chi-square</b> | <b>Probability</b> |
|----------------|-------------|---------------|----------------|-------------------|--------------------|
| September 2000 | 9           | 20            | 1: 2.22        | 4.17              | P<0.05             |
| October        | 16          | 26            | 1: 1.63        | 2.38              |                    |
| November       | 18          | 42            | 1: 2.33        | 9.60              | P<0.05             |
| December       | 31          | 84            | 1: 2.71        | 24.43             | P<0.05             |
| January 2001   | 12          | 81            | 1: 6.75        | 51.19             | P<0.05             |
| February       | 36          | 124           | 1: 3.44        | 48.40             | P<0.05             |
| March          | 9           | 29            | 1: 3.22        | 10.53             | P<0.05             |
| April          | 14          | 58            | 1: 4.14        | 26.89             | P<0.05             |
| May            | 51          | 17            | 1: 0.33        | 17.00             | P<0.05             |
| June           | 14          | 4             | 1: 0.29        | 5.56              | P<0.05             |
| July           | 20          | 28            | 1: 1.40        | 1.33              |                    |
| August         | 101         | 87            | 1: 0.86        | 1.04              |                    |
| <b>Total</b>   | <b>331</b>  | <b>600</b>    | <b>1: 2.44</b> | <b>202.52</b>     | <b>P&lt;0.05</b>   |
| <b>2001-02</b> |             |               |                |                   |                    |
| September 2001 | 26          | 67            | 1: 2.58        | 18.08             | P<0.05             |
| October        | 51          | 58            | 1: 1.14        | 0.45              |                    |
| November       | 86          | 69            | 1: 0.80        | 1.86              |                    |
| December       | 19          | 83            | 1: 4.37        | 40.16             | P<0.05             |
| January 2002   | 75          | 81            | 1: 1.08        | 0.23              | P>0.05             |
| February       | 46          | 126           | 1: 2.74        | 37.21             | P<0.05             |
| March          | 9           | 25            | 1: 2.78        | 7.53              | P<0.05             |
| April          | 35          | 51            | 1: 1.46        | 2.98              | P>0.05             |
| May            | 9           | 28            | 1: 3.11        | 9.76              | P<0.05             |
| June           | 11          | 7             | 1: 0.64        | 0.89              |                    |
| July           | 8           | 4             | 1: 0.50        | 1.33              |                    |
| August         | 22          | 27            | 1: 1.23        | 0.51              |                    |
| <b>Total</b>   | <b>397</b>  | <b>626</b>    | <b>1: 1.87</b> | <b>120.98</b>     | <b>P&lt;0.05</b>   |

**Table 6.17 Sex ratio of *Parapandalus spinipes* in the exploited stock of deep sea prawns**

| <b>2000-01</b> | <b>Male</b> | <b>Female</b> | <b>M: F</b>    | <b>Chi-square</b> | <b>Probability</b> |
|----------------|-------------|---------------|----------------|-------------------|--------------------|
| September 2000 | 38          | 176           | 1: 0.22        | 1979.83           | P<0.05             |
| October        | 8           | 5             | 1: 1.60        | 0.12              |                    |
| November       | 34          | 14            | 1: 2.43        | 17.36             | P<0.05             |
| December       | 181         | 34            | 1: 5.32        | 2525.41           | P<0.05             |
| January 2001   | 212         | 11            | 1: 19.27       | 8205.68           | P<0.05             |
| February       | 27          | 14            | 1: 1.93        | 4.25              | P<0.05             |
| March          | 32          | 27            | 1: 1.19        | 0.04              |                    |
| April          | 7           | 27            | 1: 0.26        | 34.60             | P<0.05             |
| May            | 1           | 16            | 1: 0.06        | 43.79             | P<0.05             |
| June           | 10          | 39            | 1: 0.26        | 73.64             | P<0.05             |
| July           | 85          | 55            | 1: 1.55        | 10.33             | P<0.05             |
| <b>Total</b>   | <b>635</b>  | <b>418</b>    | <b>1: 3.10</b> | <b>12895.07</b>   | <b>P&lt;0.05</b>   |
| <b>2001-02</b> |             |               |                |                   |                    |
| August 2001    | 81          | 50            | 1: 1.62        | 13.45             | P<0.05             |
| September      | 46          | 35            | 1: 1.31        | 0.56              |                    |
| October        | 45          | 18            | 1: 2.50        | 33.47             | P<0.05             |
| November       | 72          | 49            | 1: 1.47        | 4.78              | P<0.05             |
| December       | 17          | 47            | 1: 0.36        | 49.44             | P<0.05             |
| January 2002   | 123         | 121           | 1: 1.02        | 0.00              |                    |
| February       | 53          | 114           | 1: 0.46        | 124.12            | P<0.05             |
| March          | 9           | 6             | 1: 1.50        | 0.09              | P>0.05             |
| April          | 2           | 20            | 1: 0.10        | 54.22             | P<0.05             |
| May            | 8           | 7             | 1: 1.14        | 0.00              |                    |
| June           | 9           | 28            | 1: 0.32        | 23.80             | P<0.05             |
| July           | 29          | 74            | 1: 0.39        | 96.63             | P<0.05             |
| <b>Total</b>   | <b>494</b>  | <b>569</b>    | <b>1: 1.02</b> | <b>400.56</b>     | <b>P&lt;0.05</b>   |

**Table 6.19 Sex ratio of *Aristeus alcocki* in the exploited stock of deep sea prawns**

| <b>2000-01</b> | <b>Male</b> | <b>Female</b> | <b>M: F</b>    | <b>Chi-square</b> | <b>Probability</b> |
|----------------|-------------|---------------|----------------|-------------------|--------------------|
| September 2000 | 19          | 14            | 1: 1.36        | 22.26             | P<0.05             |
| October        | 6           | 45            | 1: 0.13        | 16.32             | P<0.05             |
| November       | 28          | 63            | 1: 0.44        | 23.96             | P<0.05             |
| December       | 67          | 47            | 1: 1.43        | 80.51             | P<0.05             |
| January 2001   | 17          | 65            | 1: 0.26        | 21.10             | P<0.05             |
| February       | 32          | 78            | 1: 0.41        | 28.24             | P<0.05             |
| March          | 15          | 15            | 1: 1.00        | 15.00             | P<0.05             |
| April          | 27          | 43            | 1: 0.63        | 22.66             | P<0.05             |
| May            | 20          | 27            | 1: 0.74        | 17.54             | P<0.05             |
| June           | 30          | 89            | 1: 0.34        | 29.75             | P<0.05             |
| July           | 22          | 25            | 1: 0.88        | 20.69             |                    |
| <b>Total</b>   | <b>283</b>  | <b>511</b>    | <b>1: 1.22</b> | <b>298.03</b>     | <b>P&lt;0.05</b>   |
| <hr/>          |             |               |                |                   |                    |
| <b>2001-02</b> |             |               |                |                   |                    |
| August 2001    | 19          | 203           | 1: 0.09        | 79.50             | P<0.05             |
| September      | 33          | 20            | 1: 1.65        | 42.69             | P<0.05             |
| October        | 8           | 31            | 1: 0.26        | 10.06             | P<0.05             |
| November       | 73          | 43            | 1: 1.70        | 95.76             | P<0.05             |
| December       | 66          | 47            | 1: 1.40        | 78.69             | P<0.05             |
| January 2002   | 36          | 80            | 1: 0.45        | 30.69             | P<0.05             |
| February       | 125         | 61            | 1: 2.05        | 179.02            | P<0.05             |
| March          | 16          | 24            | 1: 0.67        | 13.60             | P<0.05             |
| April          | 3           | 17            | 1: 0.18        | 5.80              | P<0.05             |
| <b>Total</b>   | <b>379</b>  | <b>526</b>    | <b>1: 0.94</b> | <b>535.82</b>     | <b>P&lt;0.05</b>   |

=====

**Fig. 6.12 Length wise sex- ratio of *Heterocarpus gibbosus***

| length group (mm) | Male        | Female      | M: F           | Chi square    | Probability      |
|-------------------|-------------|-------------|----------------|---------------|------------------|
| 31-40             | 0           | 3           | 1: 0.00        | 3.00          |                  |
| 41-50             | 1           | 3           | 1: 0.33        | 0.33          |                  |
| 51-60             | 12          | 35          | 1: 0.34        | 3.46          |                  |
| 61-70             | 20          | 81          | 1: 0.25        | 20.75         | P<0.05           |
| 71-80             | 48          | 201         | 1: 0.24        | 54.85         | P<0.05           |
| 81-90             | 67          | 287         | 1: 0.23        | 81.56         | P<0.05           |
| 91-100            | 251         | 715         | 1: 0.35        | 63.45         | P<0.05           |
| 101-110           | 240         | 877         | 1: 0.27        | 179.71        | P<0.05           |
| 111-120           | 282         | 990         | 1: 0.28        | 183.31        | P<0.05           |
| 121-130           | 183         | 600         | 1: 0.31        | 91.26         | P<0.05           |
| 131-140           | 90          | 221         | 1: 0.41        | 7.61          | P<0.05           |
| 141-150           | 30          | 81          | 1: 0.37        | 5.44          | P<0.05           |
| 151-160           | 6           | 28          | 1: 0.21        | 9.14          | P<0.05           |
| 161-170           | 1           | 4           | 1: 0.25        | 1.00          |                  |
| 171-180           | 10          | 31          | 1: 3.90        | 3.90          |                  |
| 181-190           | 4           | 13          | 1: 1.92        | 1.92          |                  |
| <b>Total</b>      | <b>1245</b> | <b>4170</b> | <b>1: 0.60</b> | <b>710.71</b> | <b>P&lt;0.05</b> |

**Length wise sex- ratio of *Heterocarpus woodmasoni***

**Fig. 6.14**

| length group | Male        | Female      | M: F           | Chi square    | Probability      |
|--------------|-------------|-------------|----------------|---------------|------------------|
| 41-50        | 0           | 1           | 1: 0.00        | 0.50          |                  |
| 51-60        | 5           | 6           | 1: 0.83        | 0.05          | P<0.05           |
| 61-70        | 23          | 42          | 1: 0.55        | 5.27          | P<0.05           |
| 71-80        | 172         | 164         | 1: 1.05        | 0.19          |                  |
| 81-90        | 211         | 350         | 1: 0.60        | 34.19         | P<0.05           |
| 91-100       | 228         | 284         | 1: 0.80        | 6.13          | P<0.05           |
| 101-110      | 167         | 275         | 1: 0.61        | 26.39         | P<0.05           |
| 111-120      | 180         | 314         | 1: 0.57        | 36.35         | P<0.05           |
| 121-130      | 103         | 180         | 1: 0.57        | 20.68         | P<0.05           |
| 131-140      | 23          | 22          | 1: 1.05        | 0.06          |                  |
| 141-150      | 2           | 2           | 1: 1.00        | 0.00          |                  |
| <b>Total</b> | <b>1114</b> | <b>1640</b> | <b>1: 7.63</b> | <b>129.80</b> | <b>P&lt;0.05</b> |

**Fig. 6.16 Length wise sex- ratio of *Metapenaeopsis andamanensis***

| length group (mm) | Male       | Female      | M: F          | Chi square    | Probability      |
|-------------------|------------|-------------|---------------|---------------|------------------|
| 41-50             | 2          | 1           | 1: 2.00       | 0.33          | P>0.05           |
| 51-60             | 12         | 7           | 1: 1.71       | 1.32          | P>0.05           |
| 61-70             | 67         | 54          | 1: 1.24       | 1.40          | P>0.05           |
| 71-80             | 160        | 142         | 1: 1.13       | 1.07          | P>0.05           |
| 81-90             | 150        | 117         | 1: 1.28       | 4.08          | P<0.05           |
| 91-100            | 148        | 275         | 1: 0.54       | 38.13         | P<0.05           |
| 101-110           | 108        | 359         | 1: 0.30       | 134.91        | P<0.05           |
| 111-120           | 55         | 133         | 1: 0.41       | 32.36         | P<0.05           |
| 121-130           | 21         | 79          | 1: 0.27       | 33.64         | P<0.05           |
| 131-140           | 5          | 47          | 1: 0.11       | 33.92         | P<0.05           |
| 141-150           | 0          | 9           | 1: 0.00       | 9.00          | P<0.05           |
| 151-160           | 0          | 2           | 1: 0.00       | 2.00          | P>0.05           |
| <b>Total</b>      | <b>728</b> | <b>1225</b> | <b>0 8.99</b> | <b>292.16</b> | <b>P&lt;0.05</b> |

**Fig. 6.18 Length wise sex- ratio of *Parapandalus spinipes***

| length group (mm) | Male       | Female      | M: F           | Chi square    | Probability      |
|-------------------|------------|-------------|----------------|---------------|------------------|
| 31-40             | 2          | 1           | 1: 2.00        | 0.33          |                  |
| 41-50             | 12         | 7           | 1: 1.71        | 1.32          |                  |
| 51-60             | 67         | 54          | 1: 1.24        | 1.40          |                  |
| 61-70             | 160        | 142         | 1: 1.13        | 1.07          |                  |
| 71-80             | 150        | 117         | 1: 1.28        | 4.08          | P<0.05           |
| 81-90             | 148        | 275         | 1: 0.54        | 38.13         | P<0.05           |
| 91-100            | 108        | 359         | 1: 0.30        | 134.91        | P<0.05           |
| 101-110           | 55         | 133         | 1: 0.41        | 32.36         | P<0.05           |
| 111-120           | 21         | 79          | 1: 0.27        | 33.64         | P<0.05           |
| 121-130           | 5          | 47          | 1: 0.11        | 33.92         | P<0.05           |
| 131-140           | 0          | 9           | 1: 0.00        | 9.00          | P<0.05           |
| 141-150           | 0          | 2           | 1: 0.00        | 2.00          |                  |
| <b>Total</b>      | <b>728</b> | <b>1225</b> | <b>1: 0.75</b> | <b>292.16</b> | <b>P&lt;0.05</b> |



**Table 6.20 Length wise sex- ratio of *Aristeus alcocki***

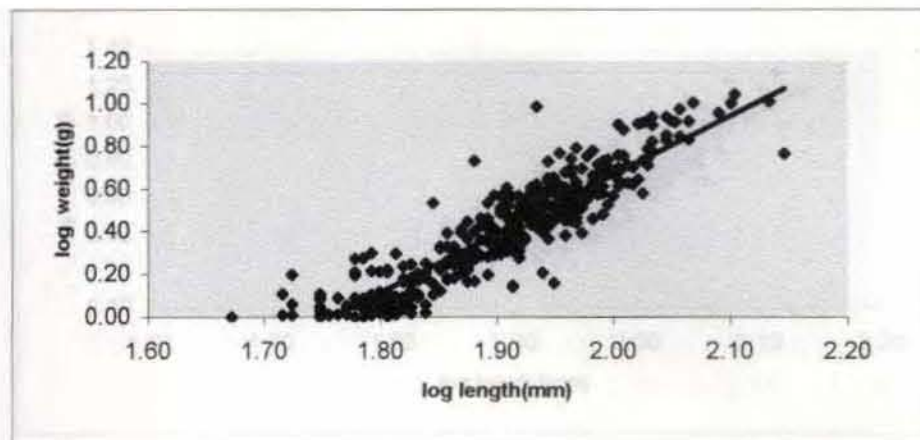
| length group(mm) | Male        | Female     | M: F            | Chi square    | Probabilit       |
|------------------|-------------|------------|-----------------|---------------|------------------|
| 71-80            | 6           | 25         | 1: 0.24         | 11.65         | P<0.05           |
| 81-90            | 35          | 145        | 1: 0.24         | 67.22         | P<0.05           |
| 91-100           | 71          | 179        | 1: 0.40         | 46.66         | P<0.05           |
| 101-110          | 115         | 127        | 1: 0.91         | 0.60          |                  |
| 111-120          | 125         | 65         | 1: 1.92         | 18.95         | P<0.05           |
| 121-130          | 134         | 41         | 1: 3.27         | 49.42         | P<0.05           |
| 131-140          | 182         | 41         | 1: 4.44         | 89.15         | P<0.05           |
| 141-150          | 158         | 24         | 1: 6.58         | 98.66         | P<0.05           |
| 151-160          | 216         | 11         | 1: 19.64        | 185.13        | P<0.05           |
| 161-170          | 176         | 1          | 1: 176.00       | 173.02        | P<0.05           |
| 171-180          | 35          | 2          | 1: 17.50        | 29.43         | P<0.05           |
| 181-190          | 7           | 0          | 1: 0.00         | 7.00          | P<0.05           |
| 191-200          | 5           | 0          | 1: 0.00         | 5.00          | P<0.05           |
| <b>Total</b>     | <b>1265</b> | <b>661</b> | <b>1: 17.78</b> | <b>781.89</b> | <b>P&lt;0.05</b> |

**Table 6.21 Monthly distribution of ovigerous females to the total female population of deep sea prawns**

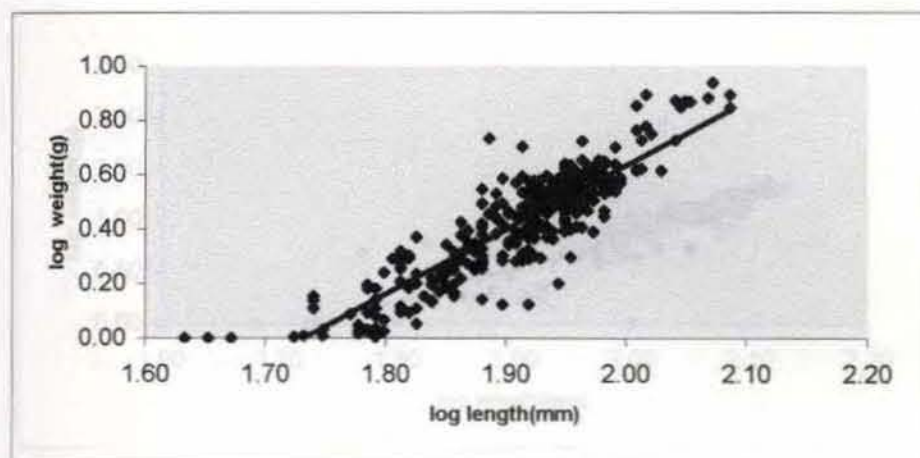
| Months    | <i>Parapandalus-spinipes</i> |                      | <i>Heterocarpus gibbosus</i> |                      | <i>Heterocarpus woodmasoni</i> |                      |
|-----------|------------------------------|----------------------|------------------------------|----------------------|--------------------------------|----------------------|
|           | females examined(nos.)       | ovigerous females(%) | females examined(nos.)       | ovigerous females(%) | females examined(nos.)         | ovigerous females(%) |
| September | 211                          | 87.5                 | 141                          | 59.7                 | 361                            | 63.4                 |
| October   | 23                           | 89.51                | 105                          | 68.3                 | 142                            | 81.4                 |
| November  | 60                           | 92.15                | 47                           | 59.78                | 241                            | 76.21                |
| December  | 81                           | 91.03                | 58                           | 71.3                 | 149                            | 82.51                |
| January   | 132                          | 89.8                 | 58                           | 83.7                 | 232                            | 88.7                 |
| February  | 128                          | 79.05                | 110                          | 80.1                 | 304                            | 84.32                |
| March     | 20                           | 87.58                | 304                          | 76.5                 | 59                             | 74.11                |
| April     | 47                           | 82.41                | 220                          | 67                   | 58                             | 63.25                |
| May       | 36                           | 75.48                | 54                           | 52.06                | *                              | *                    |
| June      | *                            | *                    | *                            | *                    | *                              | *                    |
| July      | 58                           | 48.28                | *                            | *                    | 10                             | 22.75                |
| August    | 63                           | 60.32                | *                            | *                    | 29                             | 44.81                |

\*No samples

**Fig.6.1** Length weight relationship of *Metapenaeopsis andamanensis* (Female)



**Fig.6.2** Length weight relationship of *Metapenaeopsis andamanensis* (Male)



**Fig.6.3** Length weight relationship of *Heterocarpus woodmasoni* (Female)

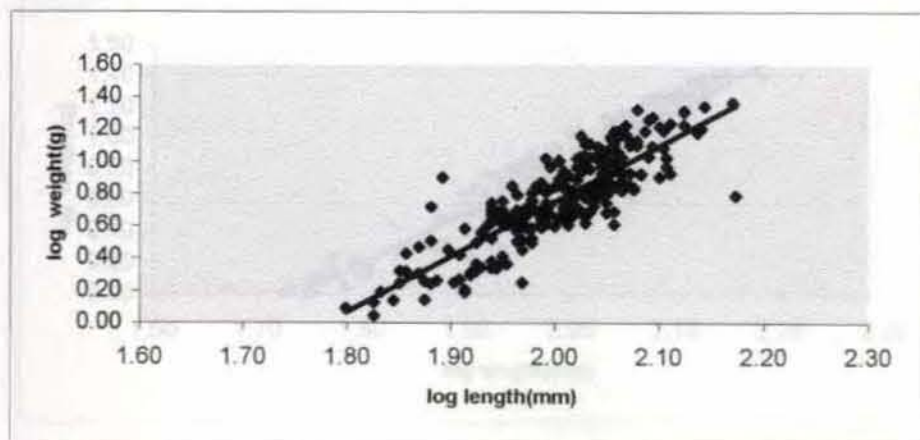


Fig.6.4 Length weight relationship of *Heterocarpus woodmasoni* (Male)

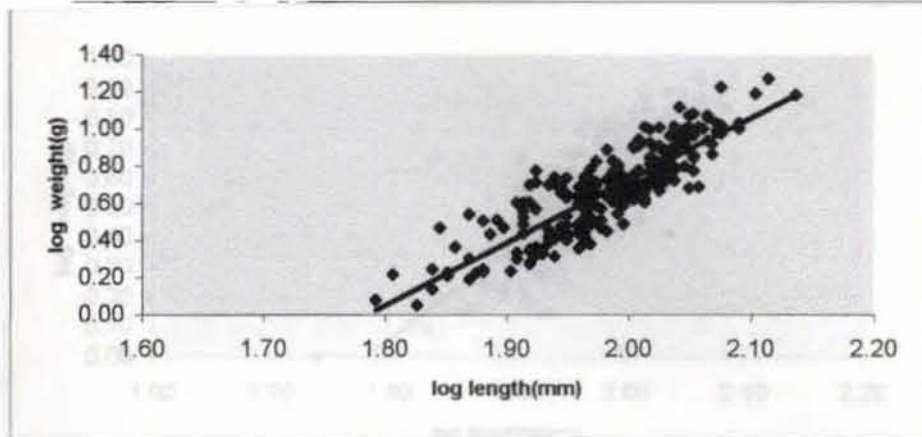


Fig.6.5 Length weight relationship of *Heterocarpus gibbosus* (Female)

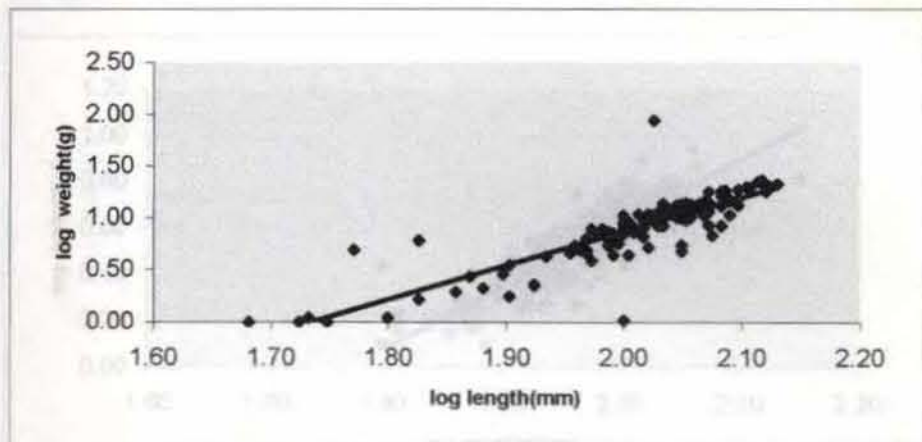


Fig.6.6 Length weight relationship of *Heterocarpus gibbosus* (Male)

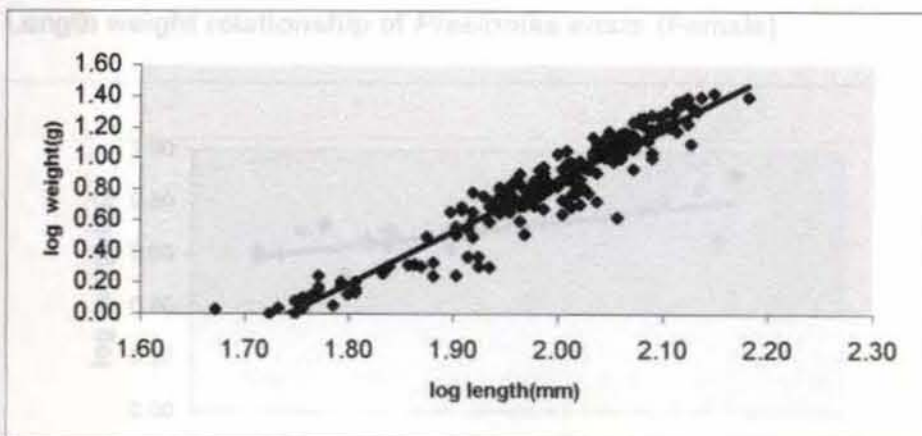


Fig.6.7 Length weight relationship of *Parapandalus spinipes* (Female)

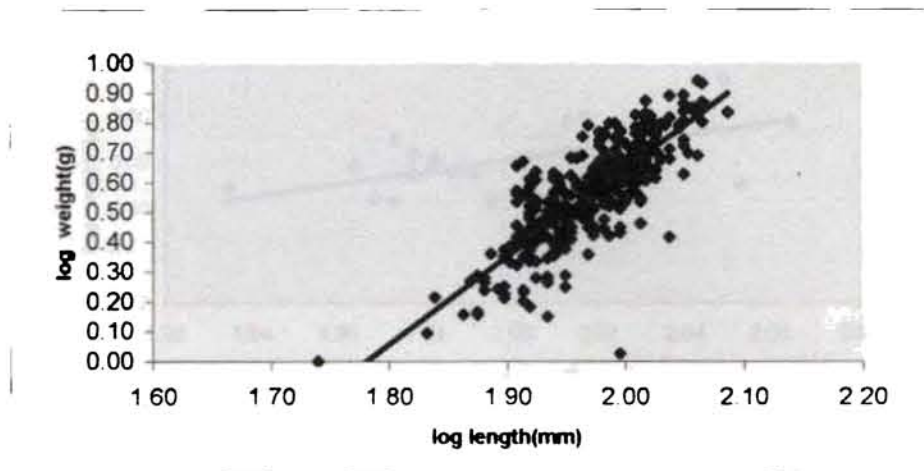


Fig.6.8 Length weight relationship of *Parapandalus spinipes* (Male)

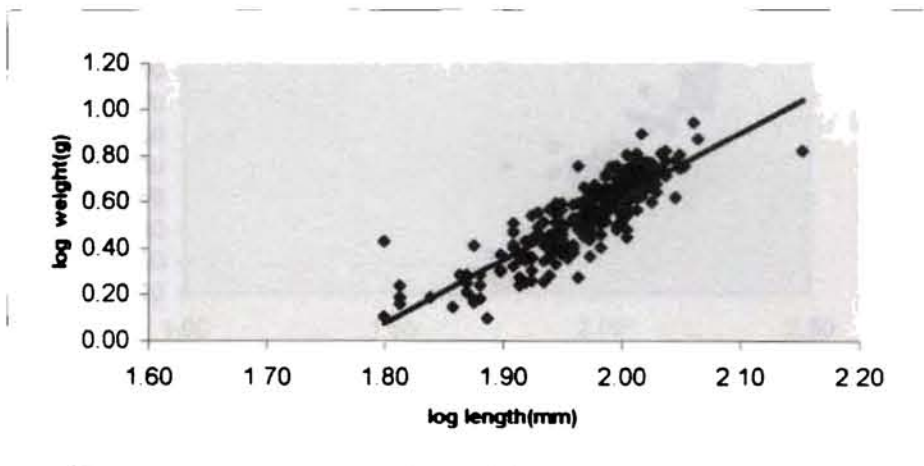
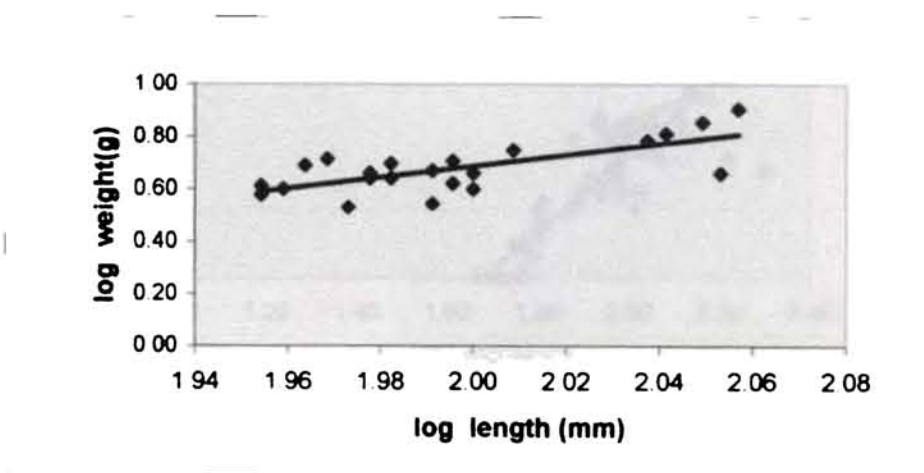
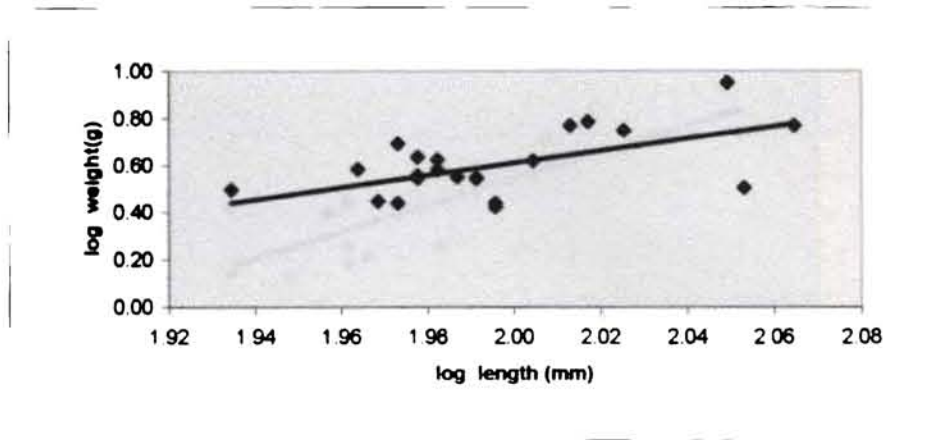


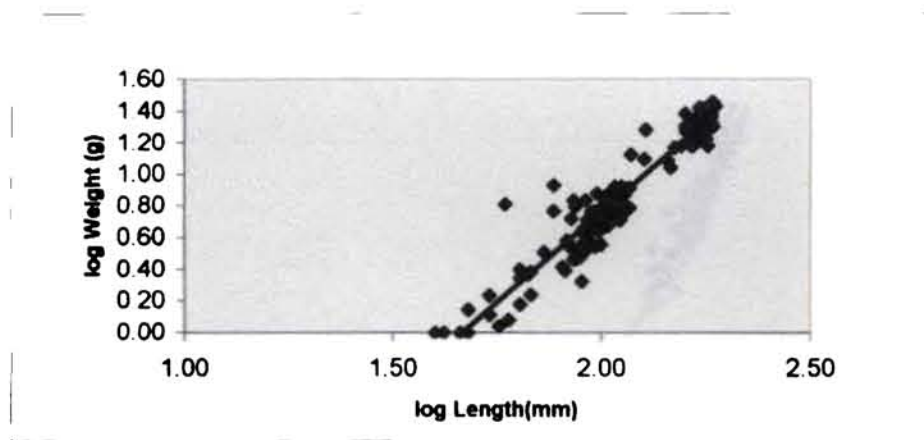
Fig.6.9 Length weight relationship of *Plesionika ensis* (Female)



**Fig.6.10** Length weight relationship of *Plesionika ensis* (Male)



**Fig.6.11** Length weight relationship of *Solenocera hextii* (Female)



**Fig.6.12** Length weight relationship of *Solenocera hextii* (Male)

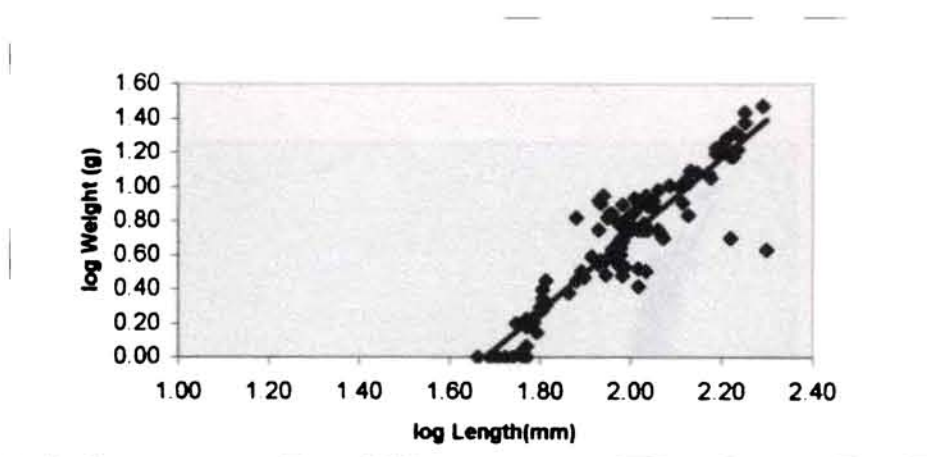


Fig.6.13 Length weight relationship of *Plesionika martia* (Female)

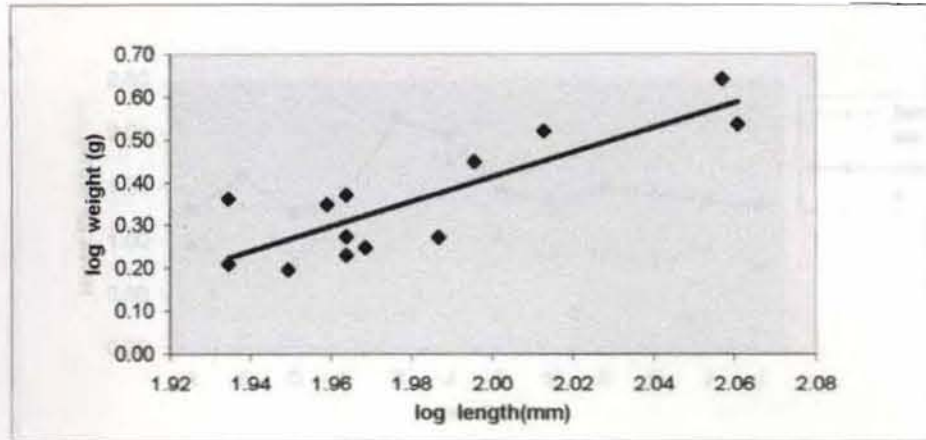


Fig.6.14 Length weight relationship of *Aristeus alcocki* (Female)

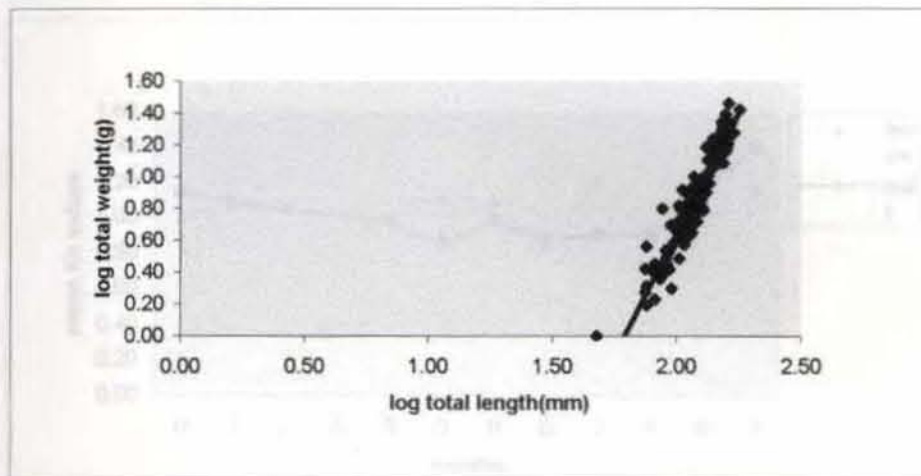


Fig. 6. 15 Length weight relationship of *Aristeus alcocki* (Male)

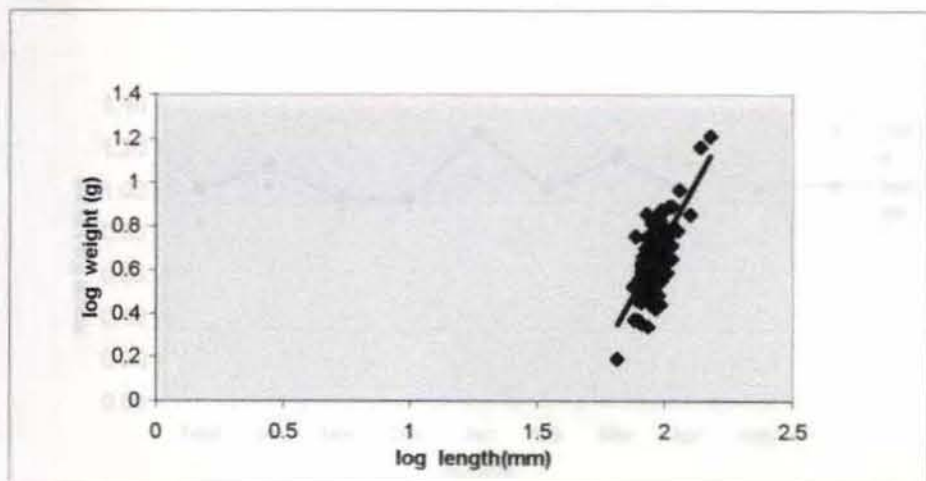




Fig. 6. 17 Monthly variations in the mean Kn values of *Metapenaeopsis andamanensis*

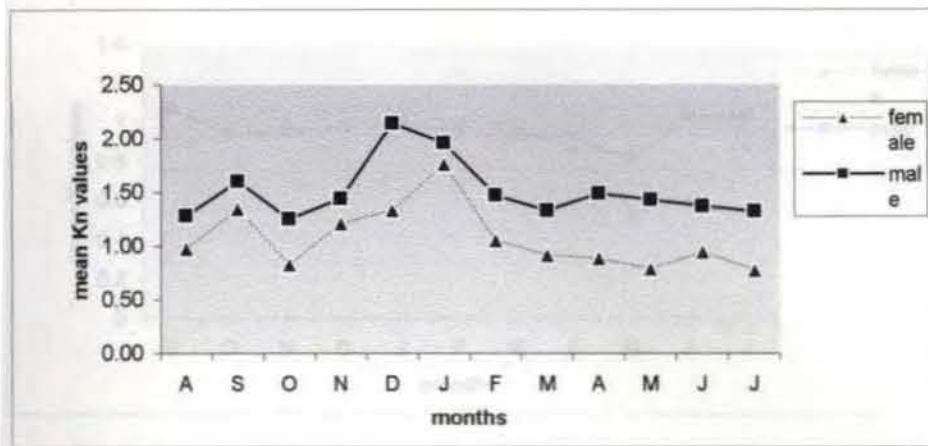


Fig. 6. 18 Monthly variations in the mean Kn values of *Aristeus alcocki*

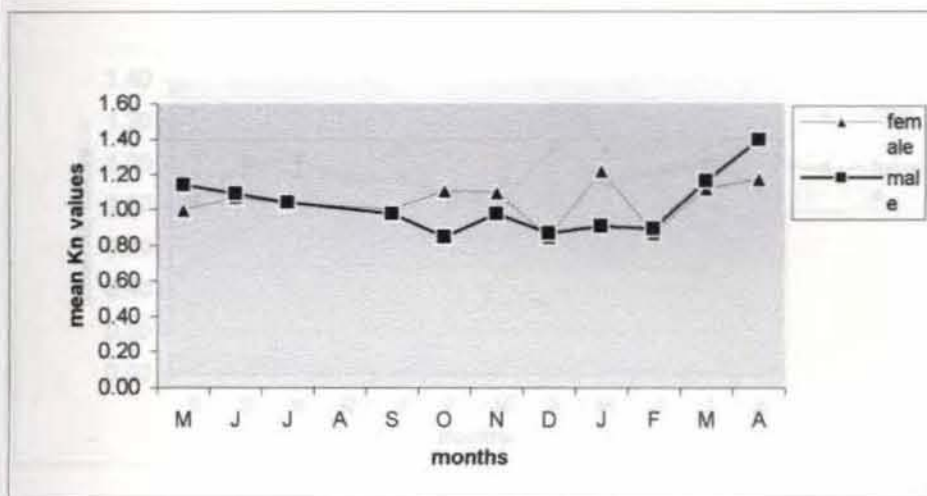


Fig. 6. 19 Monthly variations in the mean Kn values of *Heterocarpus woodmasoni*

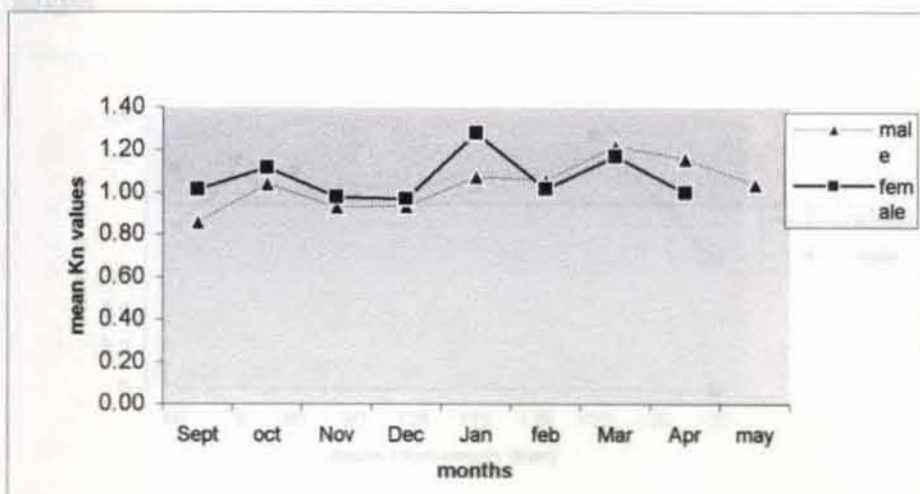


Fig. 6. 20 Monthly variations in the mean Kn values of *Heterocarpus gibbosus*

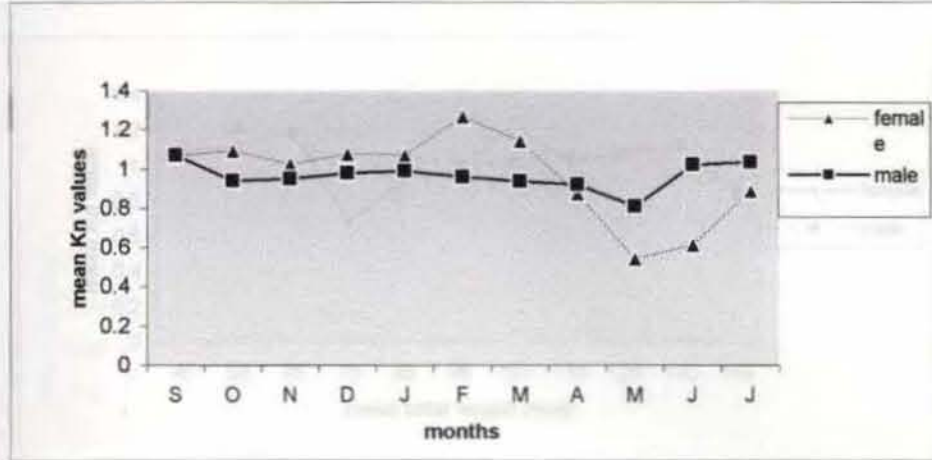


Fig. 6. 21 Monthly variations in the mean Kn values of *Parapandalus spinipes*

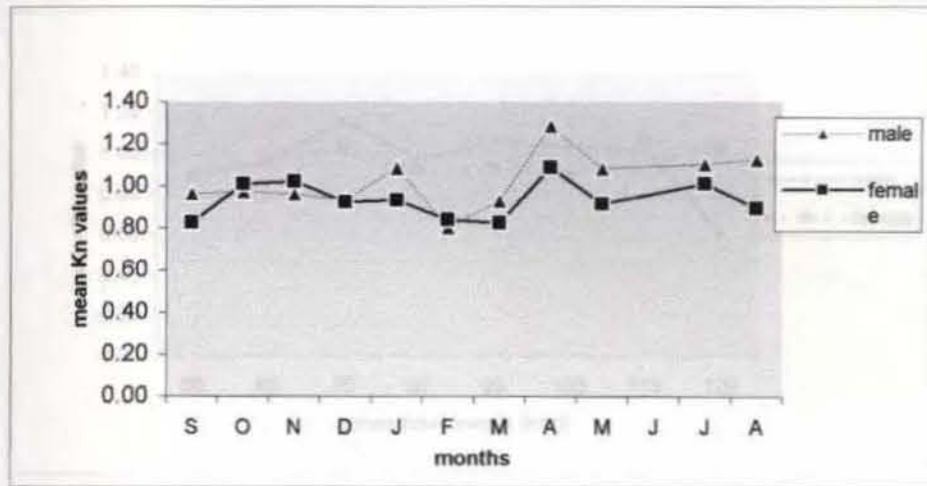


Fig. 6. 22 Relative condition factor of *Heterocarpus woodmasoni* in relation to length

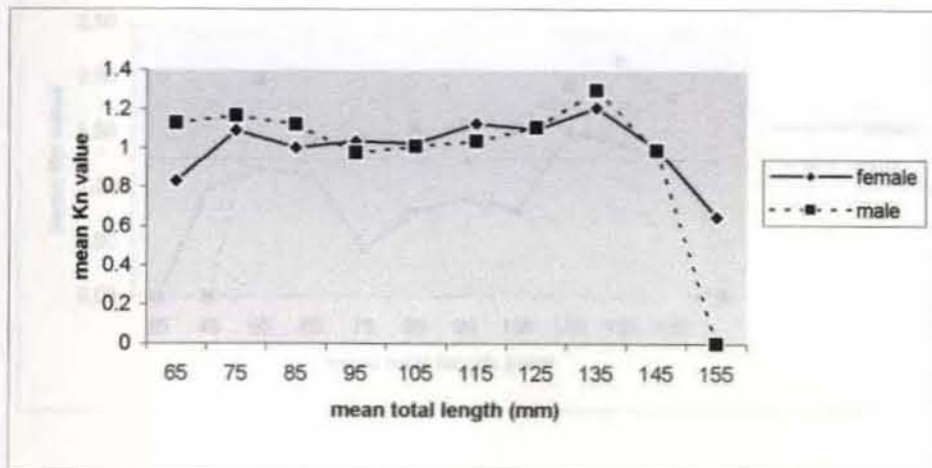




Fig. 6. 23 Relative condition factor of *Heterocarpus gibbosus* in relation to length

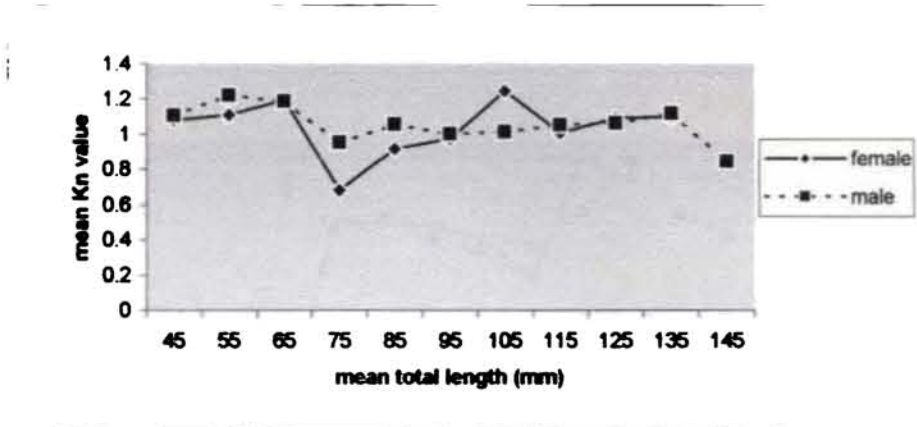


Fig. 6. 24 Relative condition factor of *Parapandalus spinipes* in relation to length

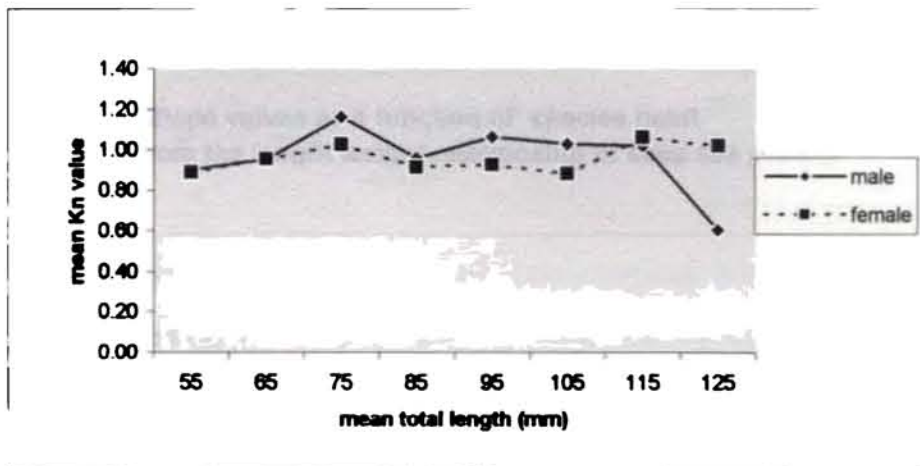


Fig. 6. 25 Relative condition factor of *Metapenaeopsis andamanensis* in relation to length

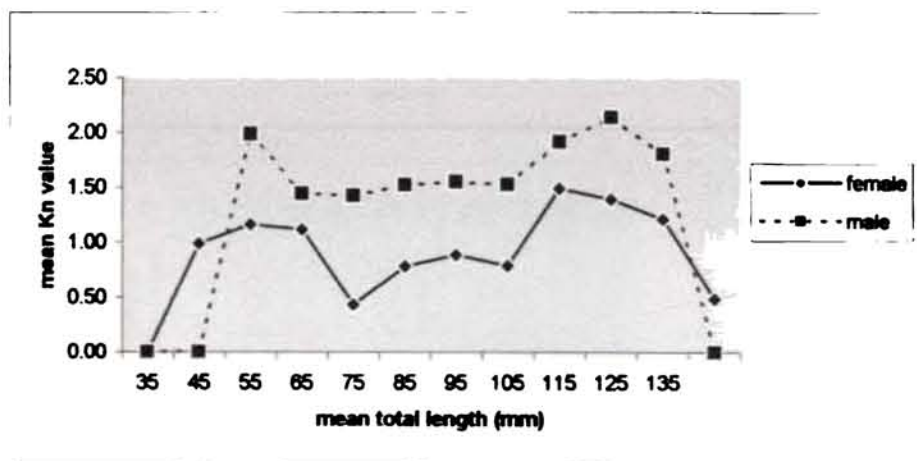


Fig. 6. 26 Relative condition factor of *Aristeus alcocki* in relation to length

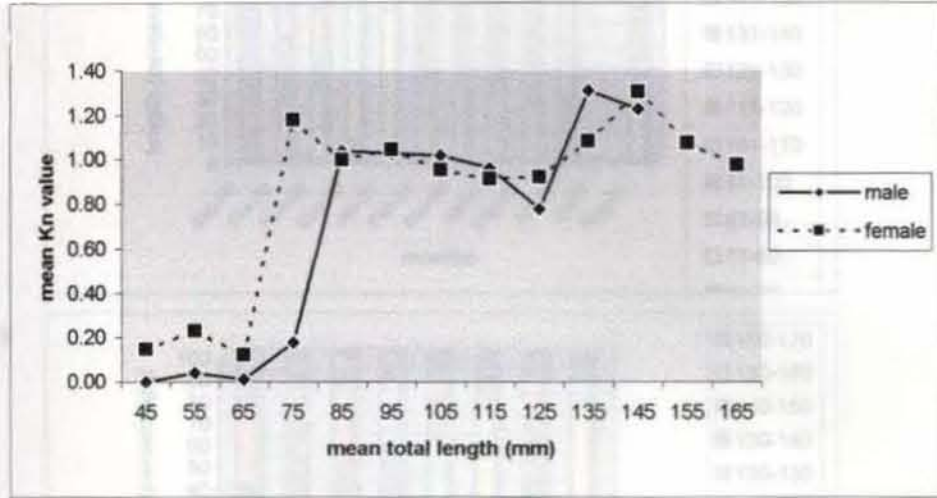
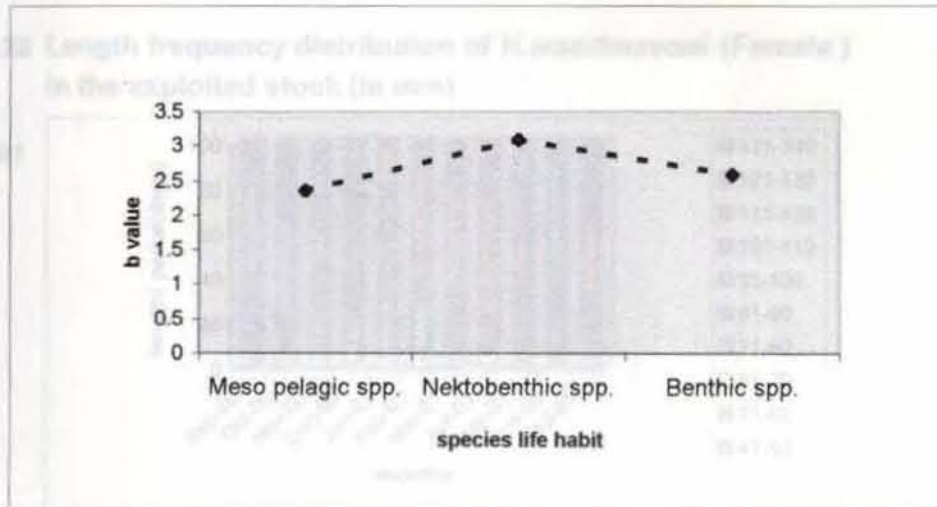


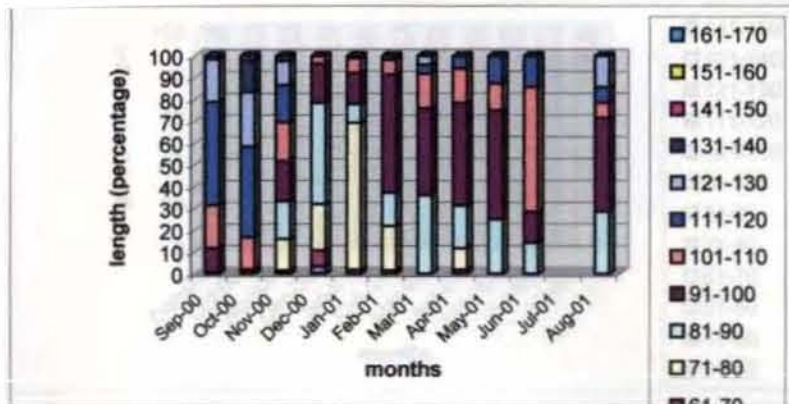
Fig. 6. 16

Slope values as a function of species habit from the length weight relationship of deep sea prawns

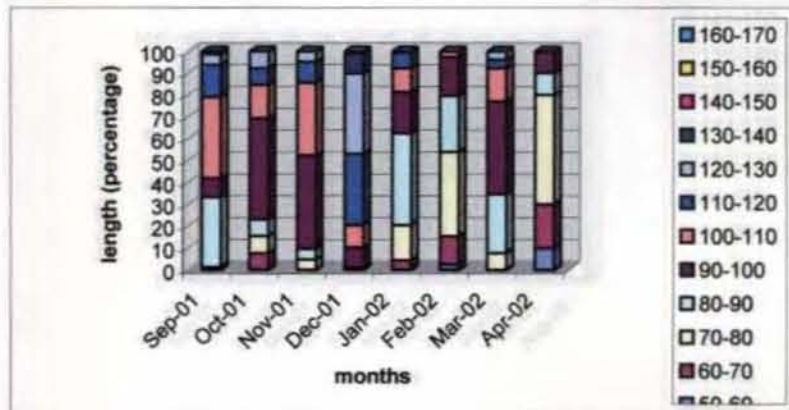


**Fig. 6.27 Length frequency distribution of *H.woodmasoni* (Male ) in the exploited stock**

2000-01

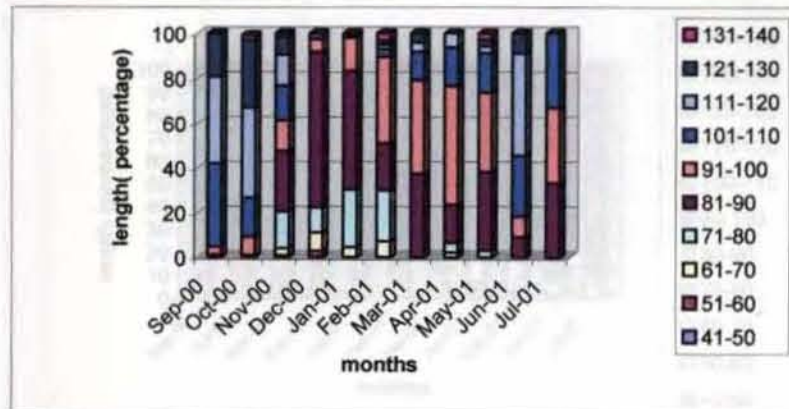


2001-02

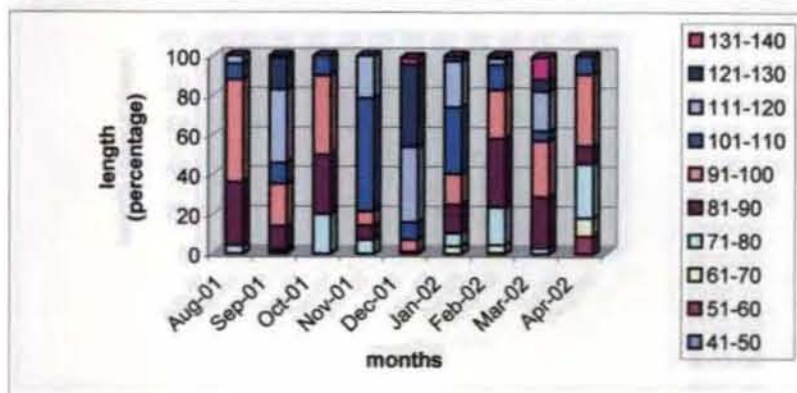


**Fig. 6.28 Length frequency distribution of *H.woodmasoni* (Female ) in the exploited stock (in mm)**

2000-01

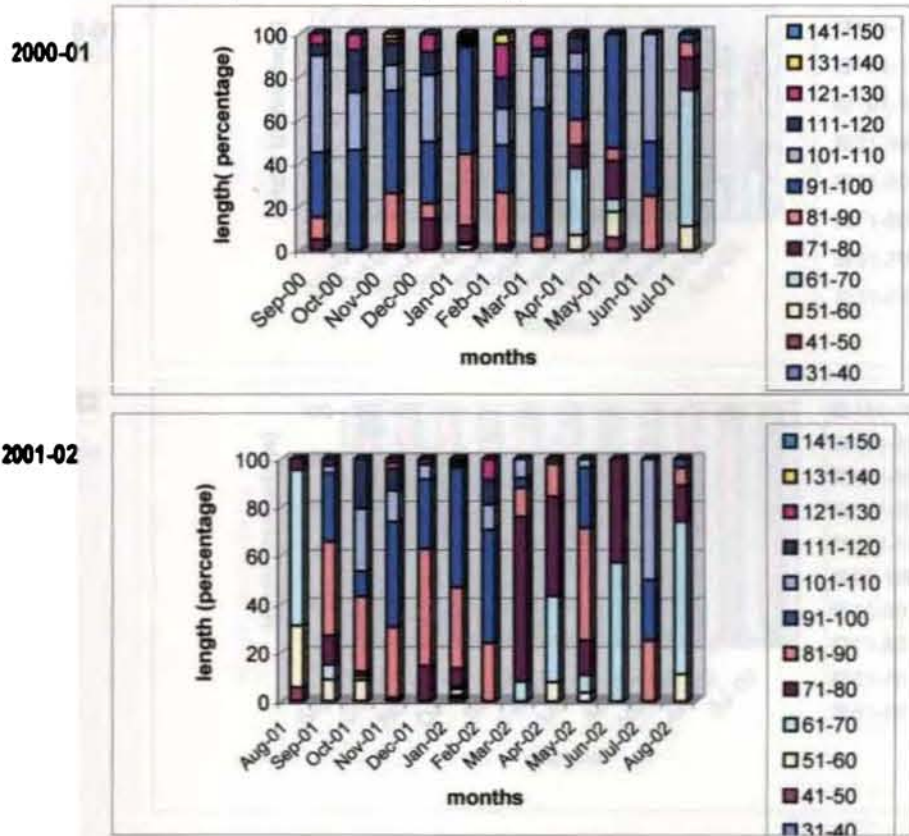


2001-02

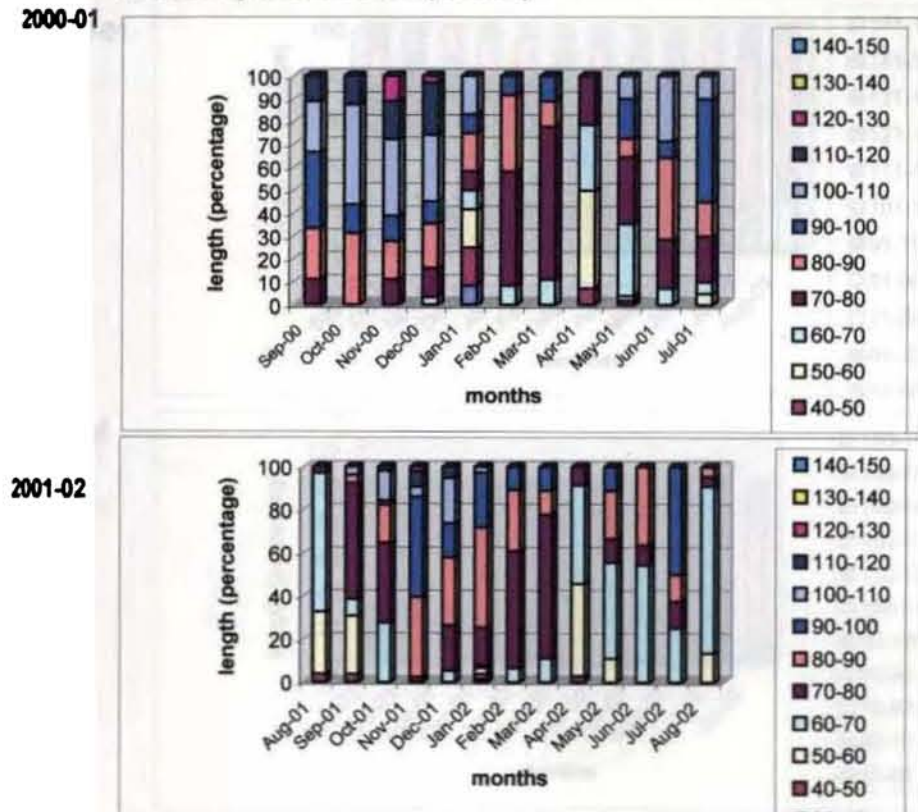




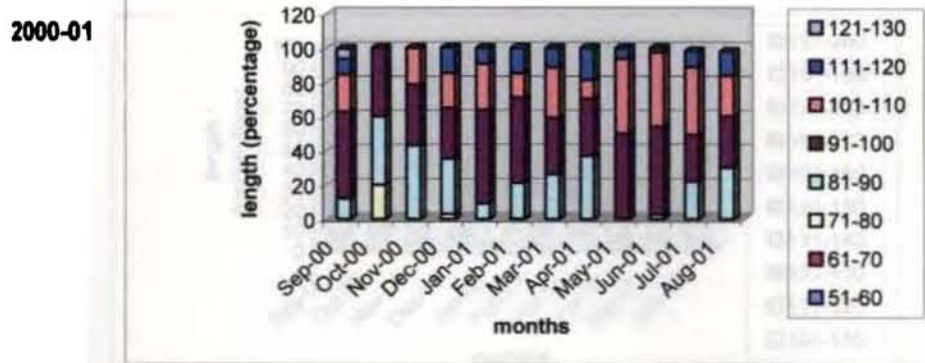
**Fig. 6.29 Length frequency distribution of *M.andamanensis* (Female ) in the exploited stock (in mm)**



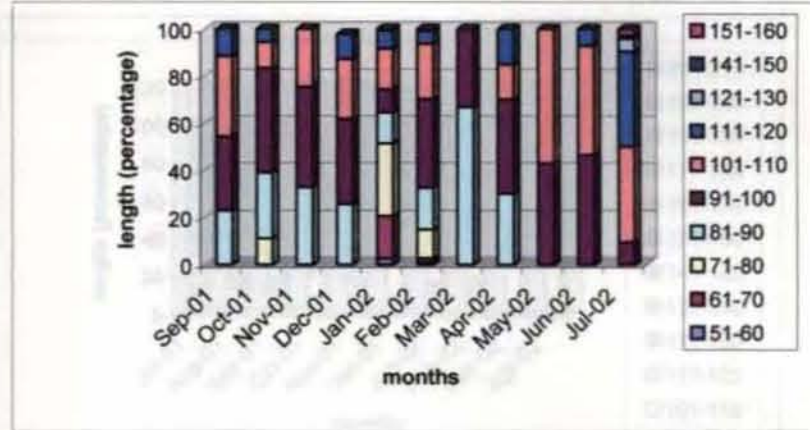
**Fig. 6.30 Length frequency distribution of *M.andamanensis* (Male ) in the exploited stock (in mm)**



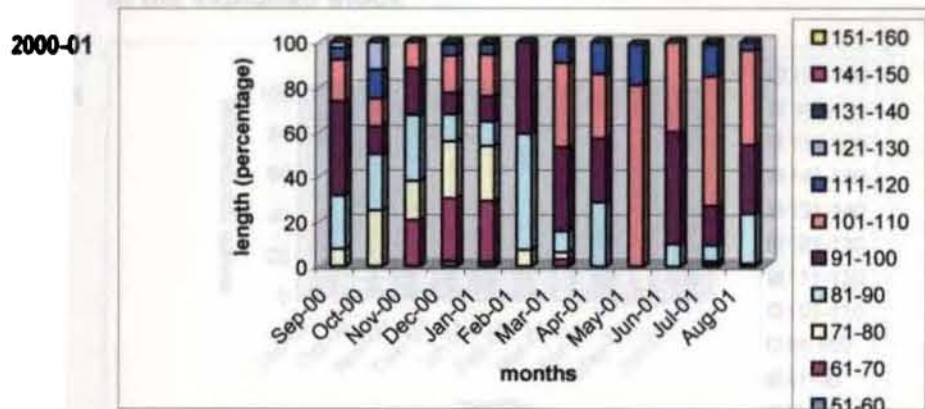
**Fig. 6.31 Length frequency distribution of *P.spinipes* (female) in the exploited stock (in mm)**



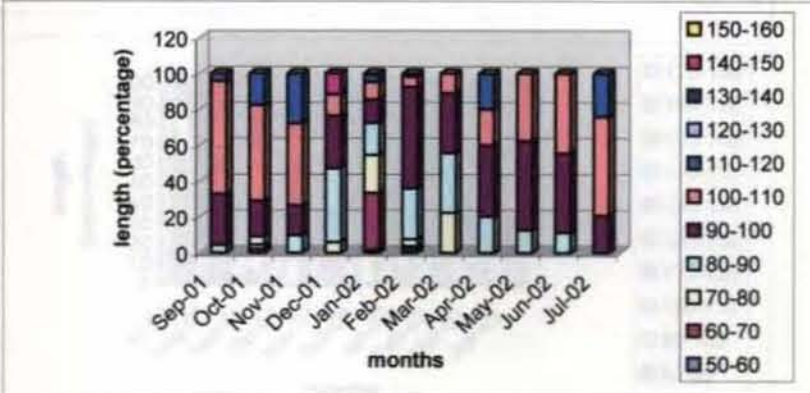
**2001-02**



**Fig. 6.32 Length frequency distribution of *P.spinipes* (Male) in the exploited stock**

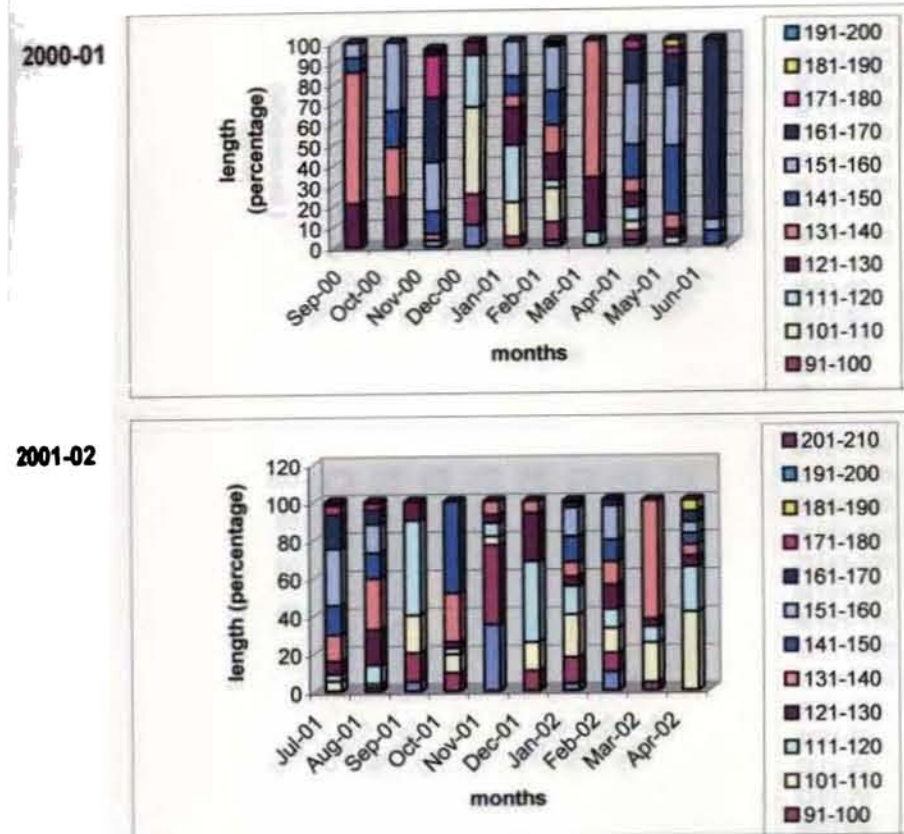


**2001-02**

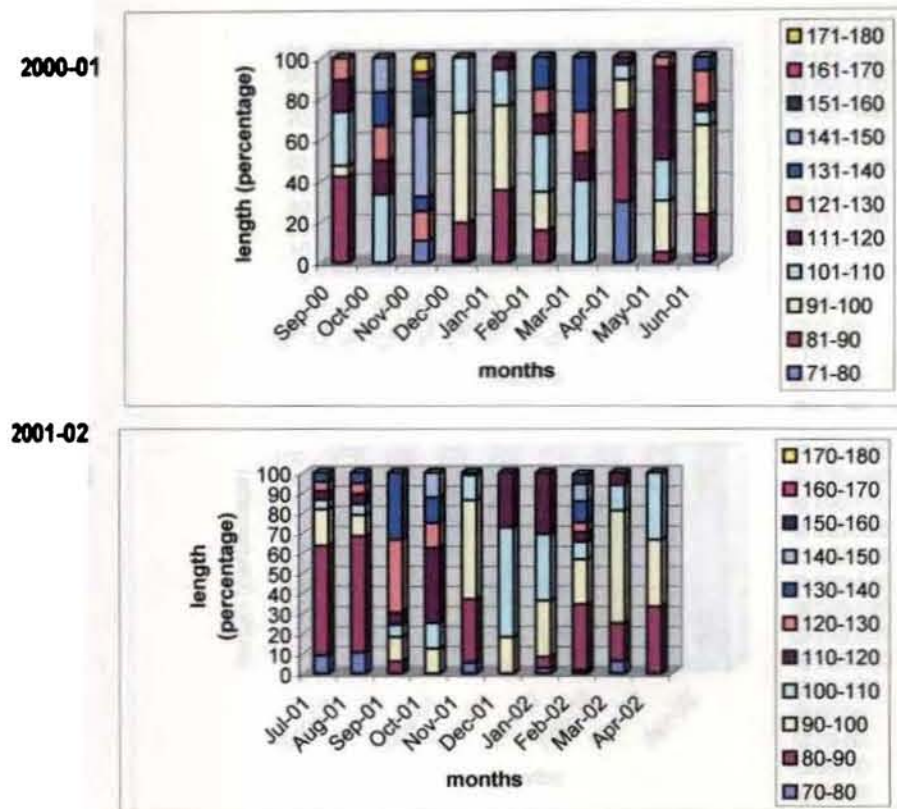




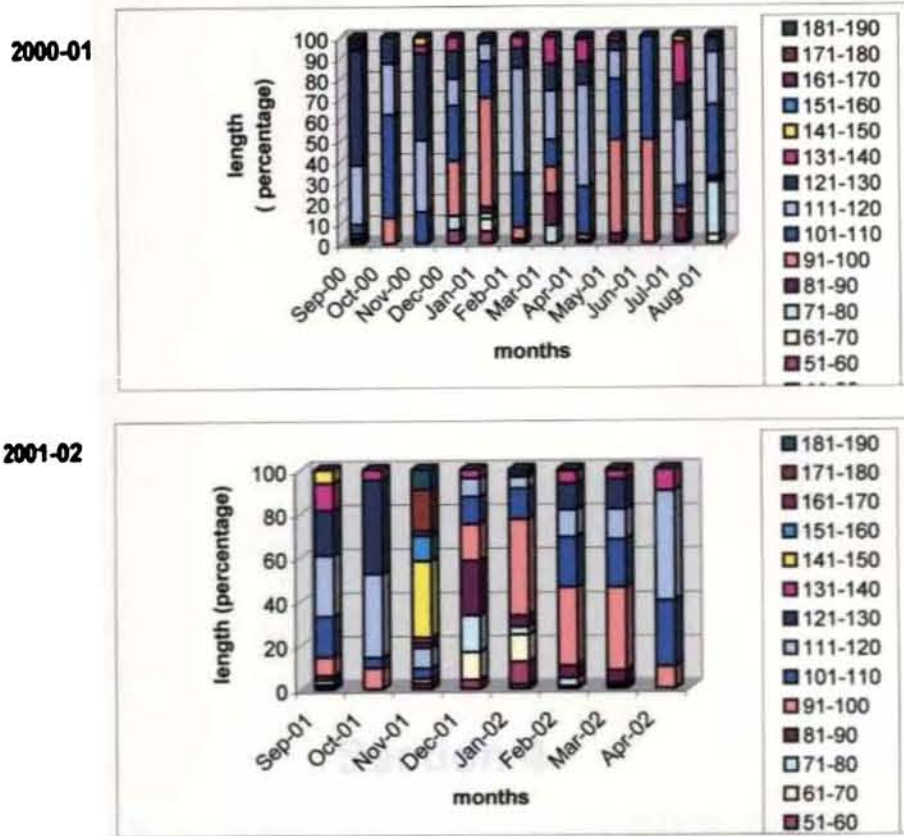
**Fig. 6.33 Length frequency distribution of *A.alcocki* (Female) in the exploited stock (in mm)**



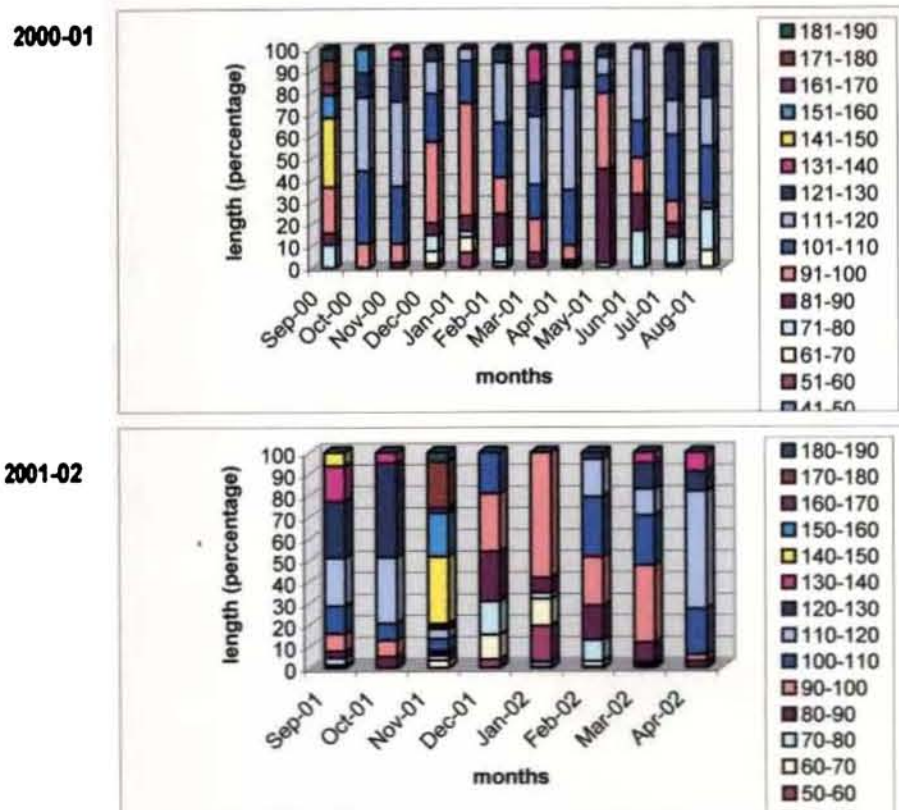
**Fig. 6.34 Length frequency distribution of *A.alcocki* (Male) in the exploited stock**



**Fig. 6.35 Length frequency distribution of *H.gibbosus* (Female) in the exploited stock (in mm)**



**Fig. 6.36 Length frequency distribution of *H.gibbosus* (Male) in the exploited stock (mm)**



## **Section 4**

# **BIONOMICS OF DEEP SEA PRAWNS**



**Chapter 7**

**FOOD AND FEEDING HABITS OF  
*HETEROCARPUS GIBBOSUS* AND**

***H.WOODMASONI***

## 7.1. INTRODUCTION

The study of food and feeding habits of an animal is very essential in understanding the various aspects of biology namely growth, development, reproduction, migration and seasonal variation in the body condition. Further, knowledge on natural diet of an animal is important in fundamental community analysis for studies of food webs, trophodynamics, resource partitioning and ecological energetics (Ivlev, 1961; Landenberger, 1968). An understanding of the relationship between animals and food organism especially the favourite food items and their seasonal distribution may help to locate the potential feeding grounds *per se* provide clue for the prediction and exploitation of the resources (Muthiah, 1994).

As food being the major factor regulating the abundance, growth and movement of animals, any information in this regard will add to the existing knowledge needed for better management of prawn stock. Many authors have discussed the food and feeding habits of deep sea prawns in many parts of the world ever since exploratory/ commercial fishing began for these crustaceans. One of the earliest works on feeding habits of deep sea prawns was by Murie (1903) on the Pink shrimp *Pandalus montagui*. The most significant contributions in the food and feeding on the pandalid prawn *Pandalus borealis* Kroyer, the principal species

supporting the cold-water fisheries of Northern Atlantic and Northern Pacific waters were that of Allen (1959), Turpaeva (1948,1953), Butler (1964,1968), Berenboim (1981,1992) and Weinberg (1980). Burukovsky (1992) studied the feeding habits of shrimps from western Africa. Food and feeding habits of *Plesionika ensis*, *Polycheles typhlops*, *Parapenaeus longirostris* and *Plesionika heterocarpus* were studied by Mary and Ioannis (1999). Cartes (1993) studied the diets of deep water pandalid shrimps *Plesionika edwardsi*, *P.martia* and *P.acanthonotus* of the western Mediterranean slope. Mistakidis (1957) and Allen (1963) examined the gut contents *Pandalus montagui* , while Kubo (1951) and Omori(1971) studied the feeding habit of *Pandalus kessleri* Czeriavsky and *Plesionika zumiae* Omori respectively.

Notable contribution on the food and feeding habits were made by Bullis (1956), Bullis and Rathjen (1959), Bullis and Thompson (1959), Thompson (1967), Klima (1969) and Anderson and Lindner (1971) on the Royal red shrimp *Hymenopenaeus robustus* Smith from the south east coast of United States and of Burukovsky (1978) on *Aristeus varidens* Holthuis from the west coast of Africa.

Nevertheless, in the Indian Ocean, only very little is known on the food and feeding habits of deep sea prawns, though similar information on coastal Penaeid prawns are aplenty (Gopalakrishnan, 1952; Panikkar, 1952; George, 1959; Kuttyamma, 1974;Kunju, 1967). The pioneer study

on the food of deep sea prawns *Penaeopsis jerryi* from India was made by Kurian (1965) who studied the gut contents and compared its feeding habits with those of littoral penaeids. Suseelan (1985) conducted a preliminary study on the gut contents of *Heterocarpus gibbosus* and *H.woodmasoni* collected during the exploratory surveys off south west coast of India, however, information on their food preference pertaining to season, sex, maturity stage and size class are still lacking. Therefore, the present study is aimed at to unravel the seasonal variations if any in sex wise, maturity stage wise, size group wise food preference and stomach conditions of males and females of *H.gibbosus* and *H.woodmasoni* inhabiting off Kerala coast.

Various methods are employed in the stomach content analysis of prawns and these were critically discussed by Haynes (1950) and Pillay (1952). The method employed for the study of food and feeding habits of animals should suit the nature of diet of the fish to be investigated. It appears that the quantity of food in the stomach of prawns is very little, and therefore, instead of volumetric method, the points (volumetric) method (Pillay, 1952) was employed for studying the food and feeding habits of *H.gibbosus* and *H.woodmasoni*. In order to get a summary picture of frequency of occurrence as well as volume of various food items, index of preponderance method (Natarajan and Jhingran, 1961) was employed. For studying the dynamics of feeding habits of marine animals a combination of numerical and volumetric methods would give

better picture of food item when each of these methods is applied in isolation (Qasim , 1972). As this method is suitable for studying the food and feeding habits of prawns, this method is extensively employed.

## 7.2. MATERIALS AND METHODS

Samples of *H.gibbosus* and *H.woodmasoni* were collected regularly on a weekly interval from the deep sea trawl landings of Sakthikulangara, Cochin, Munambum and Murikkumpadam harbours between September 2000 and August 2002. In the laboratory, the specimens so collected were washed, segregated sex wise and maturity stage wise and preserved in 5 % formalin, after making some perforations on the carapace for better preservation of gut, gonads and hepatopancrease. Each prawn was measured for its total length (TL) and weight (TW) to the nearest mm and g respectively. After cutting open the carapaceal wall, the stomach was dissected out, weighed and stomach fullness was recorded. The intensity of feeding was determined by observing the degree of distension of the stomach due to the quantity of food inside the anterior and posterior chambers of the proventriculus and this is further expressed by computing the gastro somatic index, as the percentage weight of stomach to the total body weight. The condition of feeding was expressed as full,  $\frac{3}{4}$  full,  $\frac{1}{2}$  full,  $\frac{1}{4}$  full, trace and empty and

each one was assigned 100,75, 50, 25,10 and 0 points respectively (Nandakumar,1997).

A preliminary qualitative analysis of gut contents showed that *H.gibbosus* and *H.woodmasoni* are carnivores and detritus feeders and therefore the Index of Preponderance method (Natarajan and Jhingran, 1962) suitable for carnivore animals was adopted in this study. The Index of Preponderance was worked out by the formula:

$$I_i = \frac{V_i O_i \times 100}{\sum V_i O_i}$$

Where  $V_i O_i$  represent the percentage of volume and percentage of occurrence indices of each food item respectively.

Food items of prawns were identified up to generic level wherever possible, counted and measured volumetrically. All identifiable and partially digested food remains were grouped under semi-digested matter. A total of 407 specimens of *H.woodmasoni* and 596 specimens of *H.gibbosus* were used in the present study. Food analysis was done in relation to months, sexes, maturity stages and size groups. The prawns were grouped with a class interval of 10 mm. For maturity stage wise analysis, three stages in males and seven stages in females were employed. The specimens collected from Cochin, Munambum and Sakthikulangara were pooled for gut content analysis.

### 7.3. RESULTS

Analysis of stomach contents of *H.gibbosus* showed that the food comprised of four major groups; euphausids, detritus, foraminifers and echinoderms. These four groups together formed 91% of the diet while miscellaneous items represented by semi digested matter, nematodes, sand and fish scales constituted the remaining 9% (Fig. 7.1). In *H.woodmasoni*, the above four major items contributed to the tune of 81.71% while the miscellaneous items formed a meager 18.29%(Fig. 7.2).

Following food items were encountered in the stomach contents of both the species.

1. **Euphausids** was the most predominant among the food items and could be easily identified by the presence of appendages, broken bright orange colored shells and antennae. In *H.gibbosus* they formed 40% of the diet whereas it was 27.8% in *H.woodmasoni*.
2. **Detritus** formed 16% and 14% to the diets of *H.gibbosus* and *H.woodmasoni* respectively and were identified by their black and brown colour.

3. **Foraminifera** constituted 13% and 22.87% to the diets of *H.gibbosus* and *H.woodmasoni* respectively. Among the foraminifers encountered from the stomachs *Globigerina* species showed its predominance. In most cases, this was represented as whole organisms. This was followed by *Lagena vulgaris* , *Protonina fusiformes* , *Entosolenia marginata* , *Rotalina mammalia* , *Redobolivina mexicana* while *Cristellaria calcar* was found only very occasionally in the diet.
4. **Echinoderms and sponge spicules** were present as spicules of glass sponges and skeletal rests of echinoderms, contributed significantly in the stomach contents of *H.gibbosus* (11%)and *H.woodmasoni* (16.67%).
5. **Fish scales** were mainly belonged to species of the family Gadidae encountered in the stomach of *H.gibbosus* (4%)and *H.woodmasoni* (5.13%) in appreciable quantities.
6. **Other crustaceans** comprising of mostly amphipods and rarely isopods were encountered in the stomach of *H.gibbosus* in significant quantities (11%). On the contrary, in *H.woodmasoni*, it was not regularly represented and if present, was only in traces (3%).



7. **Polychaetes** consisting of mostly *Paramphinome* species and aphrodites were rarely encountered from the stomach of *H.woodmasoni* (0.5%). These groups can easily be identified by the presence of setae, jaws and occasional body fragments in the proventriculus.
8. **Molluscan shells** were present in the stomachs of both the species in quite negligible quantities. Among them, thecostomata (*Cavolina trispinosa* ) and gastropoda (*Gapulus ungaricus* ) were the dominant items . Crushed unidentified items were also often met with.
9. **Nematode worms** were sparsely seen .
10. **Copepods** were present in many of the guts examined.
11. **Semi digested matter** and unidentifiable items were occasionally found mixed with sand particles in all the stomachs.

### 7.3.1. Preference to food items

Index of preponderance of various food items worked out in males and females of *H.gibbosus* and *H.woodmasoni* are given in Table 7.1 and 7.2. Euphausids and foraminifers showed a regular occurrence in moderate quantity in males and females of *H.gibbosus* where as both

the sexes of *H.woodmasoni* showed preference towards euphausids, sponges, detritus and foraminifers. Fish remnants, semi-digested food and polychaetes were also observed in minor quantities in the guts of both males and females of *H.woodmasoni*.

Monthly variation in the Index of preponderance of various food items encountered from the guts of males and females of *H.gibbosus* and *H.woodmasoni* are given in Table 7.3 and Table 7.4 respectively.

Euphausids appeared as the most preferred food in most of the months in both the sexes of *H.gibbosus*. Highest preference for this item in females was observed during February and in males during September. Detritus turned out to be the major food items in November in females and September in males. Foraminifers were found aplenty in the female diet during September, May, January and August. In males, significant quantities were found in most of the months. Other crustaceans occurred as an important diet in February and April in females and January in males. Sponges and echinoderms were found in the diet in appreciable numbers in males and females during February and November. Fish scales were found in appreciable quantities during March 2001 and January 2002 in females and February 2001 in males. Molluscan food items were found only in minor quantities in males and females.

Monthly variation in the diet preference of *H.woodmasoni* showed the predominance of euphausiids in some of the months in the gut contents of females (September, January, February, March, April, August, March) whereas the foraminifers showed its preponderance in October, December, January, July, January and February. In males, euphausiids and foraminifers were found equally in most of the months. Detritus was found in significant quantities during September, November and February in females but found in less quantity in males. Echinoderms showed its regular occurrence during most of the months in both the sexes especially during May.

In *H.gibbosus*, immature females preferred detritus as the major component (50%), however, with the progression of maturity, the presence of euphausiids was very regular. The foraminifera were mostly preferred by grey berried (53.33) and spent females (Fig. 7.4). In males, the euphausiids and detritus showed a regular occurrence in all the maturity stages (Fig. 7.3). The presence of foraminifera was encountered only in maturing males while sand, molluscs and fish remains were preferred by maturing and spent males.

In females of *H.woodmasoni* (Fig. 7.5), the maturity stages immature, maturing, head roes and spent showed a strong preference towards euphausiids while in other maturity stages detritus also showed equal preference .The foraminifera were found in relatively higher

quantities in immature, maturing and spent females whereas the diet of orange berries was mostly comprised of glass sponges (33.33%). Copepods and fish remnants were observed in appreciable quantities in the diets of maturing females (10.19%) and black berries (34.62%), whereas molluscan shells showed a regular occurrence in all the maturity stages. The polychaetes were present in black berries and spent stages only. In males, euphausids and detritus dominated the diets of immature males (50%) whereas matured males showed preference towards foraminifera, detritus and echinoderms (Fig. 7.6).

In females of *H.woodmasoni*, besides euphausids (47.06), foraminifera, detritus, echinoderms, fish remains, molluscs and semi-digested matter showed regular occurrence up to 80-89mm length groups. From 90mm onwards euphausids formed the principal food item followed by detritus and copepods (Fig. 7.7). Small males of *H.woodmasoni* (Fig. 7.8) preferred detritus and euphausids as the major food items and with growth the preference got shifted to detritus (53.3%) and sponge spicules (66.7%).

Euphausids, detritus and foraminifers were the most favored food item in females of *H.gibbosus* in 70-79mm length group (Fig. 7.9). From 80mm onwards females of *H.gibbosus* fed on sponge spicules, echinoderms, molluscs. Euphausids was the most preferred food item in males of *H.gibbosus* of 60-139mm length group (Fig. 7.10).

### 7.3.2. Stomach conditions

Percentage occurrence of various stomach conditions in different maturity stages of *H.gibbosus* and *H.woodmasoni* during September 2000 to August 2002 is presented in the Fig. 7.11 to 7.14. In female *H.woodmasoni*, the percentage occurrence of empty stomachs increased from 8.7% in immature to 20% in head roes where as in males the 'empty' stomach was observed only in immature animals (10%). Higher percentage of '¾ full' stomachs was observed in orange (75%) and grey berries (60%) due to the voracious feeding during spawning while 'full' stomachs could be discernible only in black berries (20%) (Fig. 7.11). Among male maturity stages of *H.woodmasoni*, highest percentage of '¾ full' stomachs were observed in spent animals (Fig. 7.12) .

The presence of 'empty' and '1/4<sup>th</sup>' stomach conditions were predominant in females of different maturity stages of *H.gibbosus* viz., immature females (50%) and head roes (51.52) whereas higher numbers of 'full' stomachs were noticed in spent females (21.43) as well as orange berries (18.75). In orange, black and grey berries, high occurrence of '½ full' stomach was observed which would manifest their voracious feeding habits after the gonadal maturation process (Fig. 7.13). In males of *H.gibbosus*, high percentage of 'full' stomachs was observed in spent males (17.24) in contrast to the high percentage of 'empty' stomachs seen in mature males (33.33) (Fig. 7.14).

In males of *H.woodmasoni*, empty stomachs were noticed in the length groups 80-89mm, 90-99mm, 110-119mm and 120-129mm while in female *H.woodmasoni* the empty stomachs were more in 80-89mm, 90-99mm and 100-109mm length groups. Active feeding was noticed in 130-139mm and 140-149mm length groups as manifested by the occurrence of '¾ full' and '½ full' stomachs in these prawns (Fig.7.15 & 7.16).

Incidence of empty stomachs was less in 60-69 and 70-79 length group in males and females of *H.gibbosus* (Fig.7.16 & 7.17). In male *H.gibbosus*, the number of full stomachs were invariably high from 120-129 to 150-159mm, showing highest percentage in 140-149mm (50%) length group .

### **7.3.3.Gastro somatic index (GSI)**

Variations in the gastro somatic index observed from males and females of *H.woodmasoni* commensurate with ovarian maturation process during September 2000 to August 2002 are depicted in Fig.7.18 & 7.19. The feeding intensity was high in immature females (1.59) and orange berries (3.8) as evidenced by higher GSI, while it was low in head roes (1.00) and grey berries (0.94). Among the three maturity stages of males of *H.woodmasoni*, the lowest GSI values were recorded in immature males (1.20) in contrast to the high GSI values observed in spent males (3.56).

Gastro somatic indices recorded in different maturity stages of *H.gibbosus* are depicted in Fig. 7.20 & 7.21. Among various maturity stages of *H.gibbosus*, the highest GSI values were observed in immature and spent of both females and males while it was lowest in matured males and head roe females.

#### 7.4. DISCUSSION

The results of stomach content analysis have shown that the food of pandalid shrimp *H.woodmasoni* consisted of two major groups viz. euphausiids and foraminifera whereas *H.gibbosus* feeds mainly on euphausiids. This observation agrees with that of Belogradov (1981) that the most preferable food component of pandalids from Ohotsk Sea and in Bay of Alaska (Bering Sea) were crustaceans whereas polychaetes and molluscs were less preferred by these prawns.

Even though the diets of the two species were found to be almost similar, however, *H.gibbosus* showed strong preference towards detritus, echinoderms and other crustaceans, which together contributed to 51.22% of the diet. The presence of detritus, euphausiids and mixture of bottom and planktonic organisms in the food of *H.woodmasoni* and *H.gibbosus* suggests their greater inclination of bottom feeding habits. Similar observations have been reported by a number of workers in other

pandalids. Turpaeva (1948,1953) reported dominance of flakes like detritus mainly composed of fragments of crustacean chitin, foraminifera, Polychaetes and planktonic copepods in the gut contents of *P. borealis*'s from Barents Sea.

Berenboim (1981,1992) reported that *P.borealis* of Barents Sea fed chiefly on Polychaeta, Euphausiacea, early adults of bivalves and foraminifera. According to Weinberg (1980), the diets of pandalids collected from Northern Sea and Skagerrak Strait were predominated in their food by detritus (70%), sand, Polychaetes, *Paramphinome* species, nematodes, echinodermata, euphausiacea and representatives of macro plankton.

Though there exists inter specific dietary overlap between two species, *H.woodmasoni* exhibits highly diverse preference for diets, on the contrary, *H.gibbosus* has a restricted dietary preference as the number of taxa observed in their diet is lesser than that of *H.woodmasoni*. Though *H.woodmasoni* and *H.gibbosus* exhibit nektobenthic behaviour, the depths of inhabitation of both the species differ significantly and this may be attributed to the variation in the dietary preference. *H.woodmasoni* inhabits comparatively shallower depth zones in the range 200 and 300m while the distribution of *H.gibbosus* is recorded from 300 to 600m (Suseelan, 1985). Although displaying a wide range of feeding, demersal fauna ultimately depend on the transfer of food item from the



productive epi pelagic zone to near bottom zones, while moving to deeper waters, the productivity of the overlying surface water becomes substantially very less and the benthic fauna has to change their feeding habits (Berenboim, 1981). As a result of inhabitation in deeper waters and less productive zone, the animals exhibit scavenging behaviour and become more detritophagous (Mary and Ioannis, 1999). The diet of *H. gibbosus* is predominated by high concentration of euphausiids (40.75%), detritus (16.91%), other crustacean carcasses (10.84%) and semi-digested matter (2.55%). Sporadic presence of carapaceal remnants and chewed muscle tissue of pandalid shrimps indicate its cannibalistic behaviour due to lack of food items in its place of inhabitation (Turpaeva, 1953). From the presence of copepods, polychaetes and nematodes in *H. woodmasoni* and their total absence in the diets of *H. gibbosus*, it can reasonably be inferred that *H. woodmasoni* prefers more to the shallower depth zones. This is further confirmed by the presence of trace quantities of euphausiids (27.79%) and detritus (4.38%) and predominance of shallow water foraminifers (22.87%) in the gut contents. Mary and Ioannis (1999) reported that there exist strong differences in the dietary behaviour *Plesionika ensis* and *Polychaetes typhlops* inhabiting at greater depths than *Parapenaeus longirostris* and *Plesionika heterocarpus* from Eastern Mediterranean Sea. According to Cartes (1993), the diets of deep-water pandalids *Pandalopsis edwardsi* and *P. martia* consisted primarily of benthic pelagic eucarid crustaceans

(*Pasiphea* spp.) where as *P.acanthonotus* preferred siphonophores, hyperiids and *euphausiids*.

Suseelan (1985) reported that 73% of the stomachs of *H.woodmasoni* are empty while the crustacean remnants predominated followed by foraminifers, fish remnants and sand particles in the remaining 27%. Whereas in *H.gibbosus*, crustaceans constituted the major element (54%) and foraminifers (37%) appeared as the second major component. From the nature of food consumed and the presence of high proportion of detritus and crustacean remnants though in varying quantities, it can well be inferred that both the species are typical bottom feeders.

The qualitative analysis of food in relation to size showed that there exist significant variation in the diet composition of juveniles and adults of both the species. In *H.gibbosus*, immature male and female devoured more actively on other crustaceans, sponges and echinoderms, the former up to 80-89 mm and latter up to 100-109 mm where as in adults of both the sexes, a glaring shift in the diet composition was observed towards molluscs, fish scales and nematodes. The percentage composition of foraminifers declined steadily with the increase of length groups and in adults, foraminifera was rarely observed in males and females of *H.gibbosus*.

In *H.woodmasoni*, juveniles devoured less detritus and more foraminifers than adults and with progression of length groups, the amount of detritus in the diet also showed an increase thus exhibiting more and more detritophagus behaviour with increasing stages of growth. Ivanova (2000) also reported similar findings in the diets of *P.borealis* from Flemish Cap. According to Lebour (1922) the food preferences of pandalid larvae from British waters were calcareous fragments, molluscan shells, echinoderm spines, coccoliths, and diatoms. Alden and Herbert (1981) reported similar observations in juvenile pandalids from the Gulf of Maine wherein crustacean remnants formed principal diets of adults followed by sand and debris.

Sex wise analysis of food preference in various length groups showed that in females of *H.gibbosus* and *H.woodmasoni* the higher length groups showed more selectivity in comparison with their males. Females of *H.woodmasoni* showed preference to detritus, euphausids and other crustaceans where as males preferred euphausids, detritus, foraminifers, other crustaceans, echinoderms, sponges, nematodes and semi digested matter. In *H.gibbosus*, females preferred euphausids, nematodes semi digested matter and sand particles whereas non-selective feeding was observed in males by the occurrence of diverse number of diets than females. Ivanova (2000) noticed slight difference in the diets of both the sexes of *P.borealis* where main food items of males were comprised of detritus, amphipods, crustaceans, foraminifers,

molluscs, crustacean and fish remnants, gastropods etc. thus exhibiting rich diversity of dietary preference, however, in females, the diets were predominated by amphipod and detritus, there by exhibiting only a narrow range of dietary variation.

Maturity wise feeding intensity of *H.gibbosus* and *H.woodmasoni* indicated that in both the species, highest number of empty stomachs were observed in head roes of females and matured males. The voracious feeding habits in females after the oviposition was observed as evidenced by the occurrence of highest number of 'full stomachs' and '3/4full' stomachs in the orange berry, grey berry and black berry stages. This finding strongly corroborates with that of Suseelan (1985) who reported highest frequency of empty stomachs in ovigerous females. The feeding intensity studies also showed that occurrence of 'trace' stomachs were high in all the months. This might be due to the faster digestive rates of carnivores (Qasim, 1972) or may be due to regurgitation while removing from deeper waters (Job, 1940).

Low feeding intensity of head roes and matured males are further explained on the basis of their lower gastro somatic index. In *H.woodmasoni* and *H.gibbosus* , higher GSI values were observed in spent males whereas in females the GSI values were maximum in orange berries and spent females. The lowest values recorded in head roe females have been attributed to less space in the cephalic region due to

the fully developed ovaries thus affecting food intake (Weinberg, 1980). Length group wise stomach condition indicated that *H.gibbosus* showed greatest influx in stomach condition from 80-89mm to 110-119 mm in males and 80-89mm to 120-129mm in females. Similarly, in *H.woodmasoni*, the empty stomachs were more from 80-89mm and 90 to 109 mm in males and females respectively. The low feeding condition in the above size groups would manifest about the spawner size groups, which are indiscriminately exploited by the commercial deep sea trawlers. This was also further confirmed by the highest occurrences of berried prawns (Ref. chapter 5 for details). Based on the results, it may be concluded that:

1. *H.gibbosus* and *H.woodmasoni* are bottom feeders.
2. *H.gibbosus* is a detritophagus scavenger feeder, feeding mainly on euphausiids remnants and detritus where as *H.woodmasoni* is a carnivore combining with necrophagus and detritophagus.
3. There exists significant variation in the diets of juveniles to adults both in *H.gibbosus* and in *H.woodmasoni*.
4. In both the species, females exhibit selective feeding habits in contrast to the non-selective feeding seen in males.
5. Depth of inhabitation is greatly influencing the feeding habits of pandalid prawns.

**Table 7.1** Index of preponderance of various food items in males and females of *Heterocarpus gibbosus*

|    | FOOD ITEMS            | MALES | FEMALES |
|----|-----------------------|-------|---------|
| 1  | Euphausids            | 52.27 | 48.05   |
| 2  | Detritus              | 22.23 | 20.59   |
| 3  | Foraminifera          | 11.96 | 16.27   |
| 4  | Other crustaceans     | 0.40  | 0.57    |
| 5  | Semi digested matter  | 1.58  | 2.29    |
| 6  | Echinoderms & sponges | 4.84  | 6.35    |
| 7  | Nematodes             | 0.89  | 0.57    |
| 8  | Sand                  | 2.47  | 0.14    |
| 9  | Fish scales           | 2.47  | 4.59    |
| 10 | Molluscs              | 0.89  | 0.57    |

**Table 7.2** Index of preponderance of various food items in males and females of *Heterocarpus woodmasoni*

|    | FOOD ITEMS            | MALES | FEMALES |
|----|-----------------------|-------|---------|
| 1  | Euphausids            | 29.86 | 25.72   |
| 2  | Foraminifera          | 22.41 | 23.33   |
| 3  | Debris & detritus     | 18.75 | 10      |
| 4  | Echinoderms & sponges | 14.15 | 19.18   |
| 5  | Copepods              | 0.52  | 1.65    |
| 6  | Fish remnants         | 2.88  | 7.37    |
| 7  | Molluscan shells      | 4.85  | 2.74    |
| 8  | Polychaetes           | 0.08  | 1.01    |
| 9  | Nematoda              | 0.08  | 5.42    |
| 10 | Other crustaceans     | 4.85  | 2.37    |
| 11 | Semi digested matter  | 1.55  | 1.21    |

TABLE 1.4. Monthly water volume and percentage of volume from various food sources for rainbow trout and brown trout in the Klamath River estuary during September 1990 to August 1992.

| Month                | Sep-90 | Oct   | Nov   | Dec   | Jan-91 | Feb   | Mar   | Apr   | May   | Jun   | Jul   | Aug   | Sep   | Oct   | Nov   | Dec   | Jan-92 | Feb   | Mar   | Apr   | May   | Jun   | Jul | Aug |  |
|----------------------|--------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-----|-----|--|
| <b>Food Items</b>    |        |       |       |       |        |       |       |       |       |       |       |       |       |       |       |       |        |       |       |       |       |       |     |     |  |
| Euphausiids          | 36.00  | 22.94 | 23.47 | 24.26 | 41.12  | 33.90 | 31.59 | 32.47 | 45.27 | 32.70 | 36.00 | 48.24 | 36.54 | 28.00 | 37.00 | 45.21 | 31.25  | 46.58 | 32.00 | 36.33 | 37.44 | 41.02 |     |     |  |
| Debris               | 43.58  | 18.46 | 22.84 | 16.46 | 9.10   | 11.98 | 19.58 | 15.60 | 19.74 | 18.80 | 31.00 | 23.58 | 6.44  | 15.41 | 14.52 | 9.91  | 9.85   | 16.25 | 16.00 | 31.00 | 26.37 | 27.00 |     |     |  |
| Foraminifera         | 15.70  | 26.85 | 16.80 | 25.09 | 23.15  | 20.04 | 24.50 | 18.45 | 33.99 | 19.34 | 24.00 | 9.75  | 19.71 | 21.78 | 26.21 | 32.06 | 16.69  | 19.29 | 33.00 | 23.00 | 18.25 | 28.00 |     |     |  |
| Other crustaceans    | 0.00   | 4.20  | 4.52  | 14.25 | 15.16  | 4.86  | 0.99  | 5.21  | 0.00  | 2.74  | 9.00  | 7.50  | 17.50 | 4.52  | 5.41  | 6.23  | 2.01   | 5.29  | 5.20  | 3.25  | 3.71  | 0.26  |     |     |  |
| Semi digested matter | 0.00   | 1.20  | 8.70  | 0.21  | 2.60   | 0.00  | 17.41 | 3.59  | 1.00  | 12.98 | 0.00  | 3.58  | 2.51  | 9.00  | 6.71  | 4.33  | 3.36   | 5.85  | 6.41  | 1.20  | 0.00  | 0.00  |     |     |  |
| Sponges              | 4.20   | 8.92  | 13.84 | 0.22  | 3.41   | 12.70 | 5.00  | 8.41  | 0.00  | 0.77  | 0.00  | 5.48  | 3.14  | 0.29  | 9.00  | 0.00  | 6.41   | 2.09  | 2.43  | 0.00  | 0.87  | 0.00  |     |     |  |
| Nematodes            | 0.00   | 2.23  | 2.14  | 2.59  | 0.00   | 0.58  | 0.00  | 0.98  | 0.00  | 12.00 | 0.00  | 0.00  | 2.80  | 9.00  | 0.85  | 2.10  | 8.10   | 3.35  | 3.20  | 0.00  | 1.59  | 1.02  |     |     |  |
| Sand                 | 0.52   | 0.80  | 4.73  | 16.71 | 2.40   | 0.90  | 0.00  | 2.10  | 0.00  | 0.00  | 0.00  | 1.36  | 6.41  | 8.00  | 0.30  | 0.16  | 4.13   | 0.78  | 0.00  | 4.20  | 5.50  | 1.20  |     |     |  |
| Fish scales          | 0.00   | 0.40  | 2.89  | 0.21  | 2.19   | 11.02 | 0.93  | 7.21  | 0.00  | 0.00  | 0.00  | 0.51  | 2.00  | 2.00  | 0.00  | 0.00  | 15.30  | 0.22  | 0.47  | 0.80  | 6.27  | 0.00  |     |     |  |
| Molluscs             | 0.00   | 14.00 | 0.07  | 0.00  | 0.87   | 4.00  | 0.00  | 6.00  | 0.00  | 2.67  | 0.00  | 0.00  | 3.25  | 3.00  | 0.00  | 0.00  | 3.00   | 0.32  | 1.29  | 0.22  | 0.00  | 1.50  |     |     |  |
| <b>Females</b>       |        |       |       |       |        |       |       |       |       |       |       |       |       |       |       |       |        |       |       |       |       |       |     |     |  |
| <b>Food Items</b>    |        |       |       |       |        |       |       |       |       |       |       |       |       |       |       |       |        |       |       |       |       |       |     |     |  |
| Euphausiids          | 33.34  | 32.00 | 24.00 | 21.00 | 26.25  | 15.83 | 25.00 | 21.50 | 30.00 | 30.00 | 28.00 | 32.59 | 40.52 | 36.78 | 28.57 | 46.72 | 58.70  | 43.21 | 29.02 | 28.00 | 32.76 | 19.75 |     |     |  |
| Debris               | 33.36  | 29.62 | 38.26 | 19.69 | 14.40  | 19.00 | 8.34  | 28.00 | 29.00 | 40    | 28.00 | 31.33 | 19.90 | 25.85 | 7.14  | 6.57  | 14.67  | 5.70  | 26.00 | 19.70 | 26.44 | 28.98 |     |     |  |
| Foraminifera         | 33.30  | 13.21 | 12.41 | 18.00 | 25.79  | 13.67 | 12.50 | 25.39 | 26.00 | 0.00  | 15.00 | 26.74 | 13.00 | 16.71 | 28.57 | 35.77 | 18.12  | 14.70 | 27.12 | 28.41 | 13.00 | 39.72 |     |     |  |
| Other crustaceans    | 0.00   | 10.00 | 0.00  | 8.31  | 7.00   | 16.25 | 0.00  | 16.43 | 15.00 | 0.00  | 1.02  | 1.50  | 16.72 | 2.55  | 0.00  | 0.00  | 0.00   | 2.00  | 9.00  | 9.25  | 2.00  | 1.55  |     |     |  |
| Semi digested matter | 0.00   | 2.41  | 7.06  | 11.00 | 4.00   | 12.50 | 12.50 | 0.59  | 0.00  | 10.00 | 2.51  | 2.00  | 0.00  | 12.68 | 7.14  | 0.00  | 0.18   | 11.39 | 0.00  | 1.00  | 21.51 | 0.00  |     |     |  |
| Sponges              | 0.00   | 12.74 | 18.27 | 19.00 | 0.00   | 14.01 | 12.50 | 1.58  | 0.00  | 16.47 | 0.00  | 2.51  | 1.87  | 5.62  | 0.00  | 6.57  | 4.53   | 12.00 | 0.99  | 5.21  | 0.00  | 10.00 |     |     |  |
| Nematodes            | 0.00   | 0.00  | 0.00  | 0.00  | 0.67   | 3.16  | 0.00  | 2.98  | 0.00  | 0.00  | 2.00  | 0.55  | 0.50  | 0.00  | 7.14  | 0.00  | 0.72   | 0.00  | 1.85  | 6.01  | 0.00  | 0.00  |     |     |  |
| Sand                 | 0.00   | 0.02  | 0.00  | 0.00  | 19.51  | 2.51  | 0.00  | 0.55  | 0.00  | 0.00  | 4.00  | 0.52  | 0.28  | 0.00  | 0.00  | 0.73  | 0.16   | 0.00  | 0.58  | 1.00  | 1.91  | 0.00  |     |     |  |
| Fish scales          | 0.00   | 0.00  | 0.00  | 2.00  | 0.00   | 2.41  | 20.83 | 0.98  | 0.00  | 20.00 | 5.00  | 1.99  | 7.21  | 0.00  | 14.29 | 0.73  | 2.80   | 11.00 | 2.11  | 0.71  | 2.35  | 0.00  |     |     |  |
| Molluscs             | 0.00   | 0.00  | 0.00  | 0.00  | 2.38   | 0.68  | 8.33  | 1.99  | 0.00  | 0.00  | 0.00  | 0.27  | 0.00  | 0.00  | 7.15  | 2.92  | 0.00   | 0.00  | 3.33  | 0.71  | 0.03  | 0.00  |     |     |  |

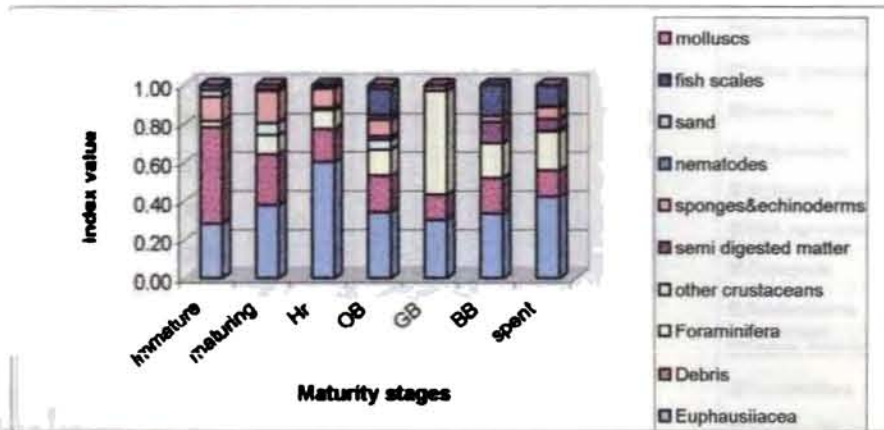
Table 7.4. Monthly variation in the abundance of zooplankton and detritus in the stomachs of female *Parachanna obscura* during the dry season (July-September) in Lake Tanganyika. Values are expressed as mean ± standard deviation.

| Food Items                       | Month         |            |            |            |               |            |            |            |            |            |            |            |            |            |            |            |               |            |            |            |            |            |            |            |  |
|----------------------------------|---------------|------------|------------|------------|---------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|---------------|------------|------------|------------|------------|------------|------------|------------|--|
|                                  | Sep-00        | Oct        | Nov        | Dec        | Jan-01        | Feb        | Mar        | Apr        | May        | Jun        | Jul        | Aug        |            |            |            |            |               |            |            |            |            |            |            |            |  |
| <b>Euphausiids</b>               | 13.20         | 25.99      | 31.99      | 15.16      | 15.98         | 19.94      | 26.47      | 18.92      | 14.70      | 8.47       | 14.30      | 23.92      | 34.71      | 26.41      | 23.29      | 22.67      | 28.54         | 23.93      | 17.50      | 43.02      | 17.51      | 19.90      |            |            |  |
| <b>Foraminifera</b>              | 23.00         | 21.54      | 5.24       | 14.56      | 22.43         | 38.54      | 24.17      | 29.98      | 20.29      | 31.56      | 27.02      | 19.66      | 20.51      | 24.98      | 17.81      | 15.43      | 19.10         | 26.41      | 20.81      | 7.09       | 28.09      | 23.00      |            |            |  |
| <b>Detritus &amp; detritus</b>   | 9.62          | 18.45      | 14.11      | 12.88      | 8.25          | 8.76       | 6.58       | 21.39      | 24.56      | 12.30      | 10.57      | 8.52       | 7.17       | 13.83      | 18.72      | 24.64      | 6.25          | 10.96      | 19.15      | 9.24       | 18.00      | 16.00      |            |            |  |
| <b>Echinozoans &amp; sponges</b> | 41.00         | 24.99      | 8.22       | 31.49      | 11.35         | 19.99      | 18.24      | 18.55      | 28.42      | 4.37       | 14.75      | 21.62      | 20.51      | 14.04      | 4.32       | 16.09      | 9.20          | 18.54      | 21.00      | 8.41       | 18.00      | 19.99      |            |            |  |
| <b>Copepoda</b>                  | 0.02          | 0.00       | 0.16       | 0.00       | 20.00         | 0.84       | 0.00       | 0.14       | 0.87       | 1.61       | 8.56       | 0.00       | 3.54       | 0.00       | 0.00       | 1.92       | 0.00          | 0.90       | 0.00       | 4.80       | 0.65       | 1.50       |            |            |  |
| <b>Fish remnants</b>             | 4.05          | 2.66       | 20.04      | 5.21       | 0.00          | 3.40       | 4.58       | 12.88      | 8.80       | 8.24       | 4.00       | 9.21       | 1.00       | 16.71      | 18.12      | 11.94      | 6.59          | 11.07      | 14.28      | 12.00      | 7.41       | 13.65      |            |            |  |
| <b>Molluscan shells</b>          | 0.60          | 0.23       | 0.00       | 16.25      | 0.00          | 9.64       | 4.92       | 8.45       | 0.00       | 6.72       | 6.00       | 7.25       | 11.21      | 6.91       | 0.00       | 0.00       | 11.00         | 4.00       | 3.00       | 0.99       | 9.20       | 1.55       |            |            |  |
| <b>Polychaetes</b>               | 1.00          | 0.00       | 0.00       | 0.00       | 2.67          | 0.54       | 0.00       | 0.74       | 0.00       | 1.01       | 0.06       | 0.02       | 0.00       | 2.00       | 12.39      | 0.29       | 0.93          | 2.58       | 2.70       | 2.00       | 0.00       | 1.00       |            |            |  |
| <b>Nematoda</b>                  | 0.00          | 4.09       | 14.57      | 0.00       | 7.55          | 9.11       | 3.41       | 6.36       | 0.00       | 4.62       | 0.00       | 0.05       | 0.00       | 0.00       | 4.05       | 2.38       | 0.00          | 3.00       | 7.44       | 3.21       | 5.00       | 6.44       |            |            |  |
| <b>Other crustaceans</b>         | 2.82          | 2.14       | 0.00       | 4.29       | 4.21          | 3.52       | 0.89       | 0.00       | 5.26       | 2.98       | 12.80      | 5.20       | 0.00       | 0.00       | 3.19       | 4.86       | 0.00          | 2.17       | 1.90       | 0.33       | 2.79       | 0.99       |            |            |  |
| <b>Semi digested matter</b>      | 4.79          | 0.00       | 0.00       | 0.34       | 7.86          | 0.38       | 11.86      | 0.00       | 4.27       | 6.24       | 0.21       | 2.50       | 0.00       | 2.88       | 2.00       | 8.00       | 0.00          | 1.15       | 1.11       | 1.00       | 5.21       | 1.98       |            |            |  |
| <b>Females</b>                   |               |            |            |            |               |            |            |            |            |            |            |            |            |            |            |            |               |            |            |            |            |            |            |            |  |
| <b>Food Items</b>                | <b>Sep-00</b> | <b>Oct</b> | <b>Nov</b> | <b>Dec</b> | <b>Jan-01</b> | <b>Feb</b> | <b>Mar</b> | <b>Apr</b> | <b>May</b> | <b>Jun</b> | <b>Jul</b> | <b>Aug</b> | <b>Sep</b> | <b>Oct</b> | <b>Nov</b> | <b>Dec</b> | <b>Jan-02</b> | <b>Feb</b> | <b>Mar</b> | <b>Apr</b> | <b>May</b> | <b>Jun</b> | <b>Jul</b> | <b>Aug</b> |  |
| <b>Euphausiids</b>               | 90.00         | 27.24      | 25.00      | 23.52      | 31.00         | 28.00      | 31.58      | 36.00      | 13.00      | 18.60      | 32.60      | 28.90      | 25.88      | 24.91      | 28.56      | 13.30      | 57.4          | 7.71       | 14.01      | 29.90      | 23.92      | 15.16      | 23.42      |            |  |
| <b>Foraminifera</b>              | 16.00         | 27.63      | 25.00      | 35.75      | 27.63         | 5.56       | 27.61      | 28.25      | 5.79       | 32.47      | 9.85       | 15.68      | 3.50       | 25.01      | 5.51       | 57.4       | 24.00         | 5.31       | 27.63      | 12.47      | 28.75      | 22.02      |            |            |  |
| <b>Detritus &amp; detritus</b>   | 32.00         | 19.72      | 25.00      | 13.41      | 19.00         | 33.11      | 15.44      | 22.70      | 11.00      | 11.30      | 23.60      | 14.56      | 7.00       | 23.71      | 32.75      | 23.0       | 45.72         | 13.27      | 20.00      | 19.26      | 36.21      | 11.47      |            |            |  |
| <b>Echinozoans &amp; sponges</b> | 0.00          | 19.79      | 25.00      | 0.56       | 15.78         | 22.22      | 18.79      | 6.71       | 24.12      | 8.24       | 8.53       | 16.25      | 3.50       | 9.02       | 13.66      | 0.00       | 0.00          | 2.86       | 42.48      | 15.79      | 19.98      | 4.03       |            |            |  |
| <b>Copepoda</b>                  | 0.00          | 1.02       | 0.00       | 1.12       | 0.00          | 0.00       | 0.00       | 0.08       | 0.02       | 5.24       | 0.00       | 0.25       | 0.00       | 0.35       | 0.00       | 0.00       | 0.00          | 0.00       | 1.77       | 0.00       | 0.00       | 7.34       | 0.06       |            |  |
| <b>Fish remnants</b>             | 0.00          | 0.66       | 0.00       | 3.30       | 0.66          | 0.00       | 0.66       | 2.10       | 9.82       | 6.54       | 2.47       | 0.17       | 10.66      | 6.50       | 0.00       | 0.00       | 0.00          | 8.57       | 7.96       | 8.56       | 8.56       | 0.58       | 0.26       |            |  |
| <b>Molluscan shells</b>          | 2.00          | 1.70       | 0.00       | 8.91       | 2.63          | 5.56       | 2.63       | 2.58       | 18.72      | 0.00       | 4.56       | 20.15      | 28.64      | 0.00       | 0.30       | 0.00       | 0.00          | 5.71       | 1.75       | 2.63       | 12.47      | 1.20       | 12.48      |            |  |
| <b>Polychaetes</b>               | 0.00          | 0.00       | 0.00       | 0.00       | 0.00          | 0.00       | 0.00       | 0.05       | 4.00       | 6.52       | 0.00       | 1.00       | 2.94       | 0.00       | 2          | 0.00       | 0.00          | 0.00       | 0.88       | 0.10       | 0.00       | 2.28       | 0.80       |            |  |
| <b>Nematoda</b>                  | 0.00          | 2.65       | 0.00       | 3.20       | 0.00          | 0.00       | 0.00       | 0.01       | 1.21       | 1.00       | 18.18      | 0.50       | 0.00       | 0.00       | 1          | 0.00       | 0.00          | 0.00       | 7.98       | 0.00       | 0.00       | 1.25       | 0.00       |            |  |
| <b>Other crustaceans</b>         | 0.00          | 0.96       | 0.00       | 2.23       | 0.66          | 0.00       | 0.66       | 1.25       | 7.62       | 11.09      | 0.21       | 2.54       | 12.78      | 4.00       | 16         | 0.00       | 0.00          | 4.62       | 1.77       | 0.66       | 0.11       | 0.30       | 16.47      |            |  |
| <b>Semi digested matter</b>      | 0.00          | 2.63       | 0.00       | 8.00       | 2.83          | 5.56       | 2.63       | 0.27       | 5.00       | 0.00       | 0.00       | 0.00       | 5.00       | 7.50       | 0.30       | 6.3        | 5.71          | 2.82       | 2.63       | 3.55       | 3.55       | 0.04       | 9.21       |            |  |

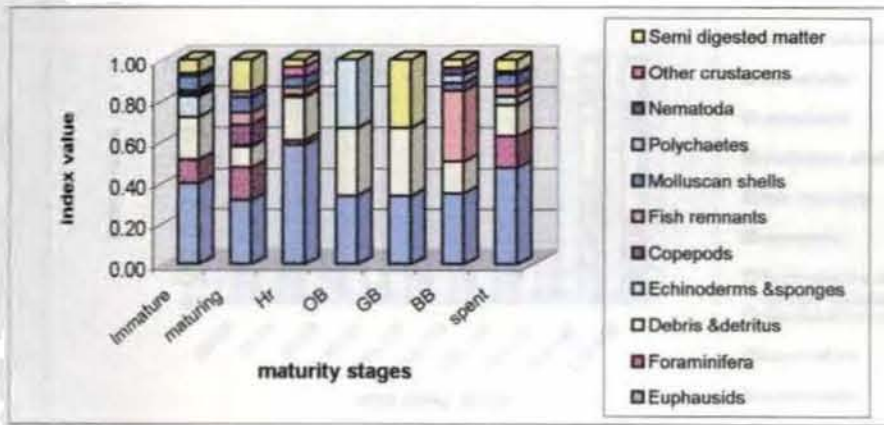




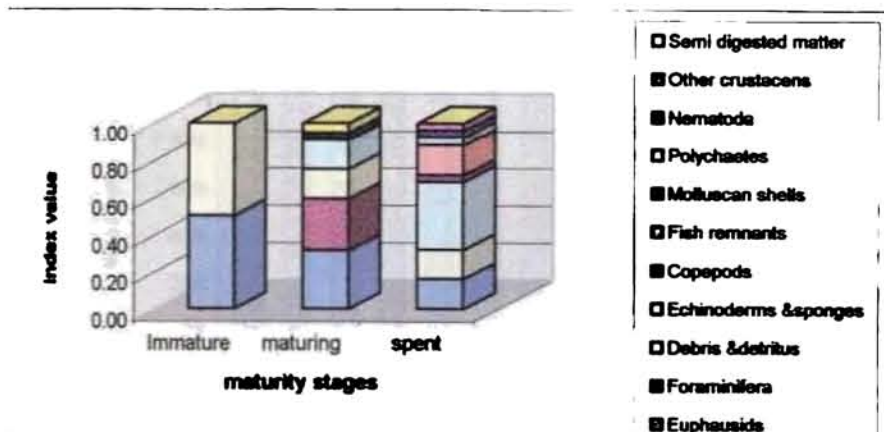
**Fig.7.4** Index of preponderance of various food items in different maturity stages of female *Heterocarpus gibbosus*



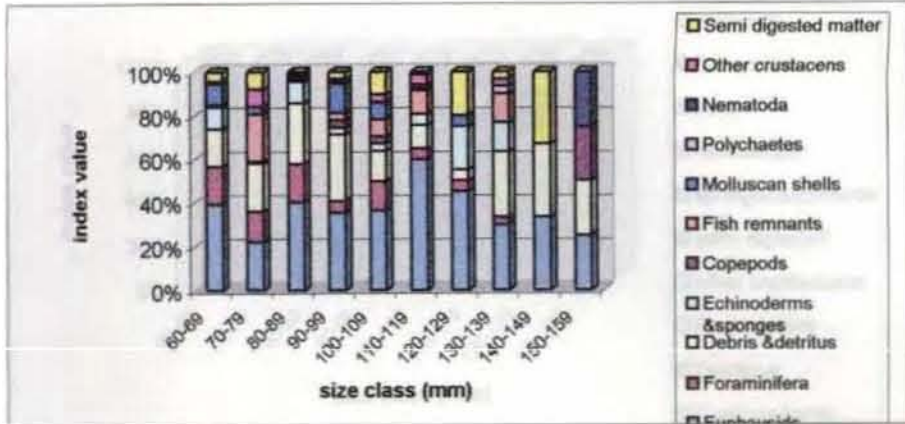
**Fig.7.5** Index of preponderance of various food items in different maturity stages of female *Heterocarpus woodmasoni*



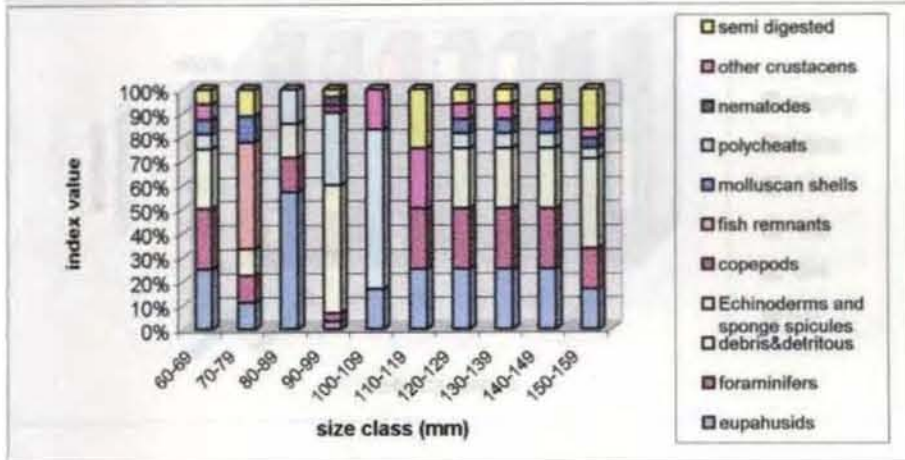
**Fig.7.6** Index of preponderance of various food items in different maturity stages of male *Heterocarpus woodmasoni*



**Fig.7.7** Size wise index of preponderance of different food items in females of *Heterocarpus woodmasoni*

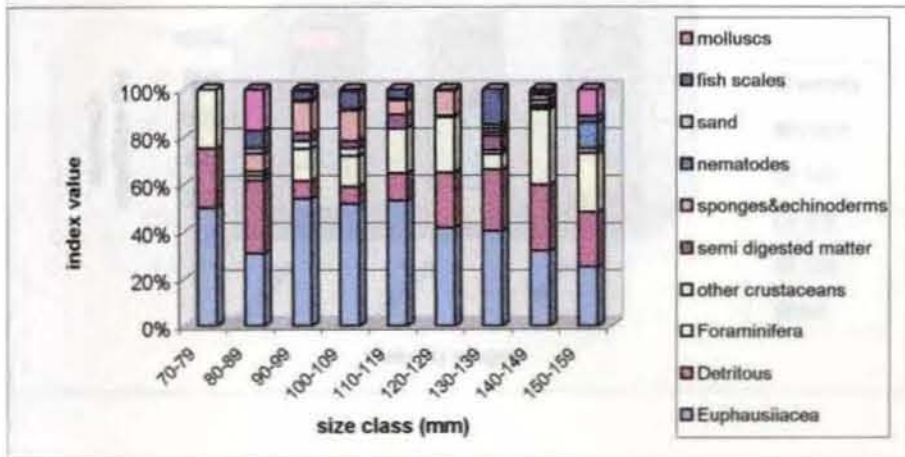


**Fig.7.8** Size wise index of preponderance of different food items in males of *Heterocarpus woodmasoni*



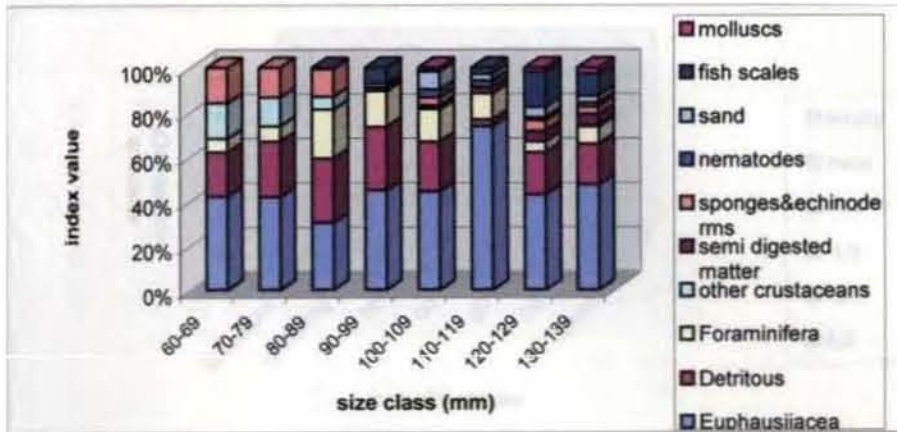
**Fig.7.9** Variations of stomach condition in male fish of different size classes of *Heterocarpus gibbosus*

**Fig.7.9** Size wise index of preponderance of different food items in females of *Heterocarpus gibbosus*

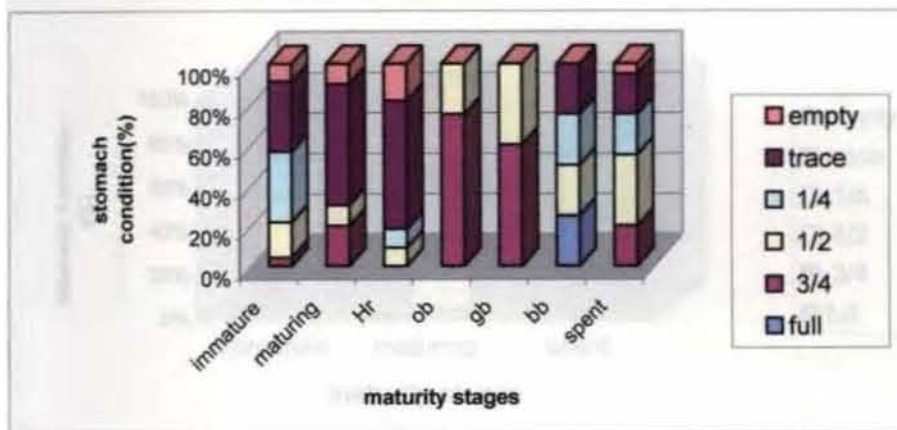




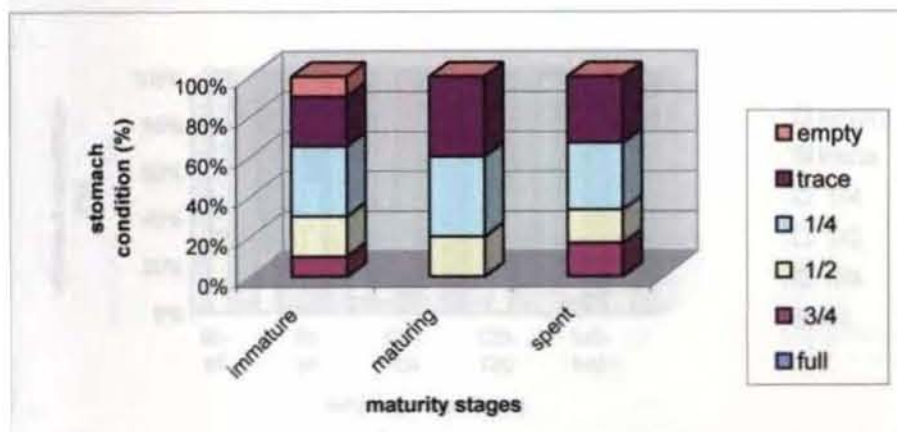
**Fig.7.10 Size wise index of preponderance of different food items in males of *Heterocarpus gibbosus***



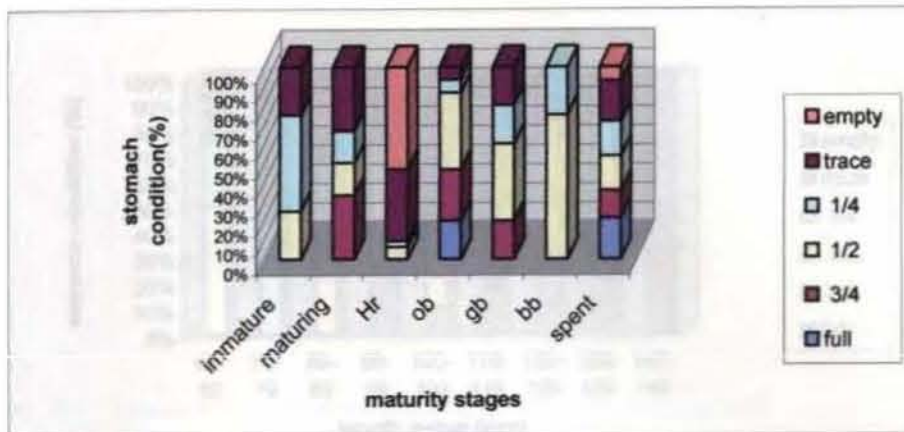
**Fig.7.11 Variations of stomach condition in female maturity stages of *Heterocarpus woodmasoni***



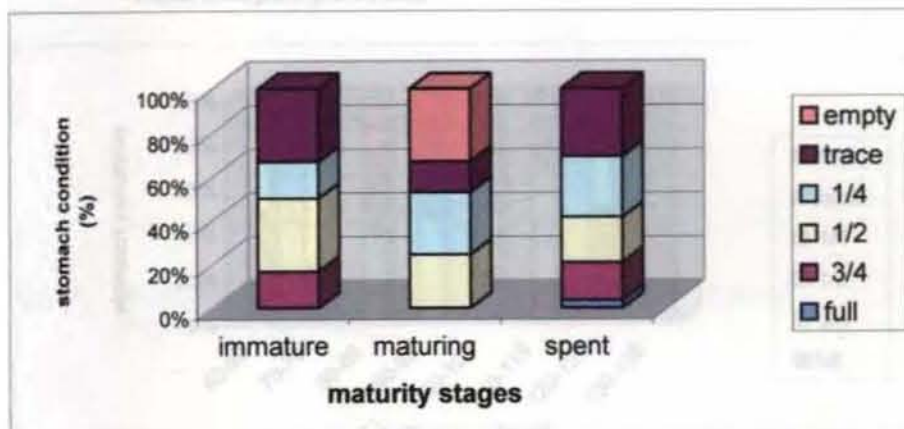
**Fig.7.12 Variations of stomach condition in male maturity stages of *Heterocarpus woodmasoni***



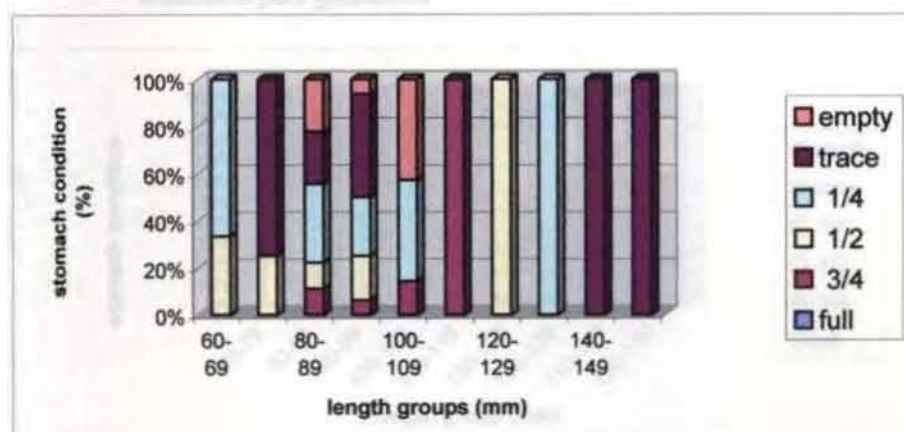
**Fig.7.13 Variations of stomach condition in female maturity stages of *Heterocarpus gibbosus***



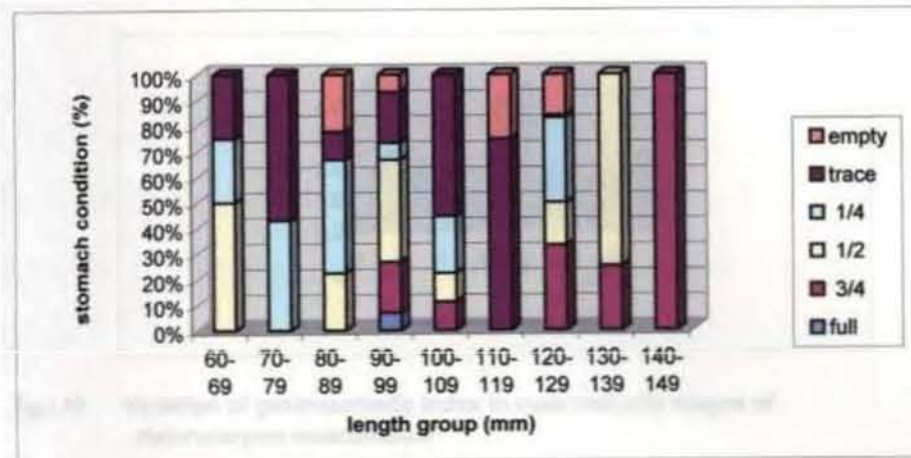
**Fig.7.14 Variations of stomach condition in male maturity stages of *Heterocarpus gibbosus***



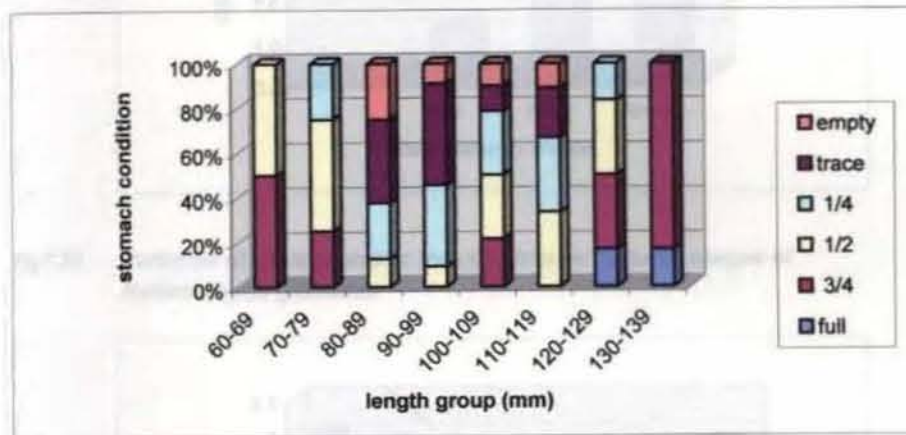
**Fig.7.15 Variations of stomach condition in female length groups of *Heterocarpus woodmasoni***



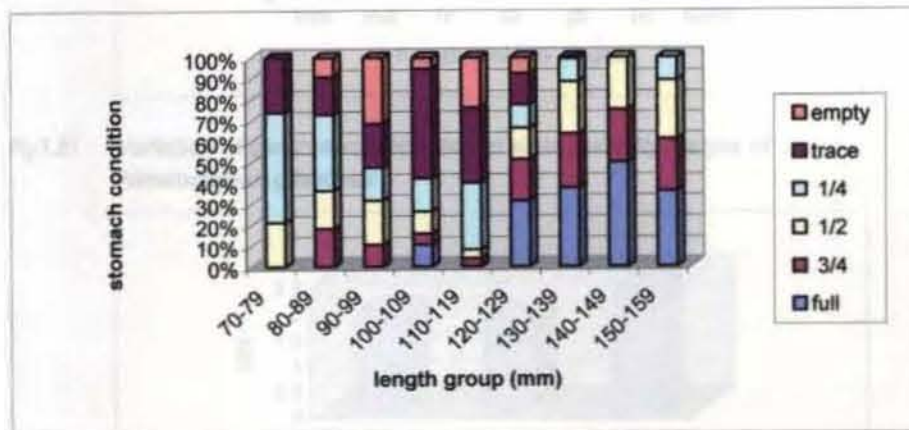
**Fig.7.16 Variations of stomach condition in male length groups of *Heterocarpus woodmasoni***



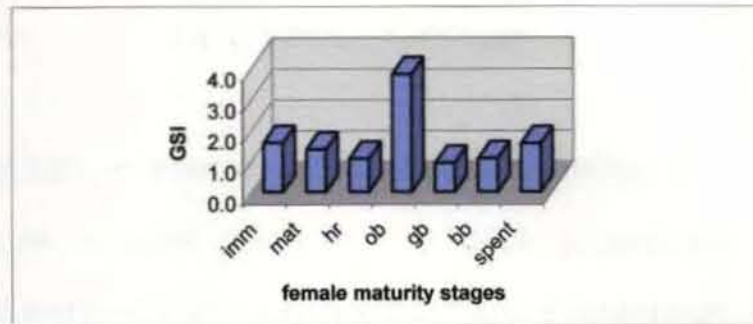
**Fig.7.16 Variations of stomach condition in male length groups of *Heterocarpus gibbosus***



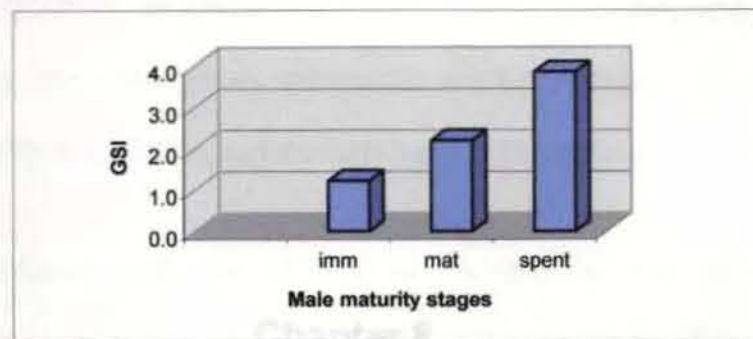
**Fig.7.17 Variations of stomach condition in female length groups of *Heterocarpus gibbosus***



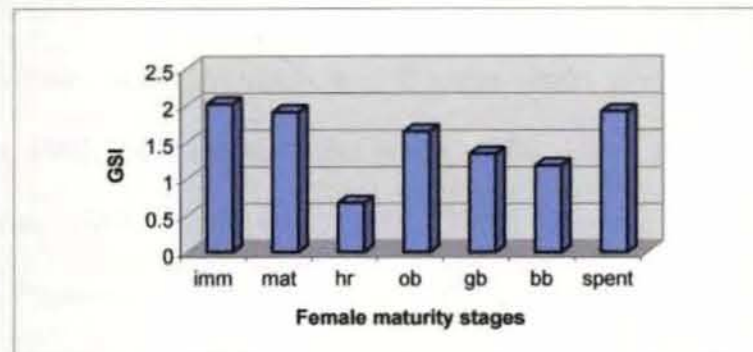
**Fig.7.18** Variation of gastroscopic index in female maturity stages of *Heterocarpus woodmasoni*



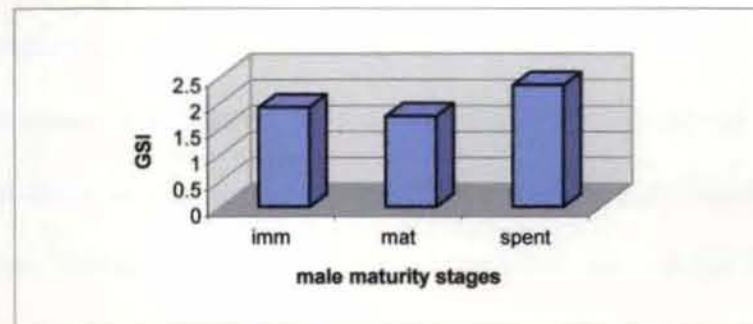
**Fig.7.19** Variation of gastroscopic index in male maturity stages of *Heterocarpus woodamsoni*



**Fig.7.20** Variation of gastroscopic index in female maturity stages of *Heterocarpus gibbosus*



**Fig.7.21** Variation of gastroscopic index in male maturity stages of *Heterocarpus gibbosus*



**Chapter 8**

**REPRODUCTIVE BIOLOGY**



## 8.1 INTRODUCTION

A thorough knowledge of the reproductive biology of any given species is an essential prerequisite for stock assessment of wild populations, sustainable exploitation and successful fishery management. The reproductive traits include aspects such as size at first maturity, size dependent fecundity, sex ratio, nature of gonads, frequency and season of spawning (Wootton, 1984). Information on these aspects is essential for sustainable exploitation and management of fish stocks.

Reproductive biology of several pandalid prawns have been subjected to detailed investigation from different parts of the world, among them *Pandalus borealis* Krøyer, the principal species supporting the fisheries of Atlantic and Pacific waters was studied by a number of researchers from North America and Europe (Hjort and Ruud, 1938; Rasmussen, 1953, 1967; Horsted and Smidt, 1956; Allen, 1959; Hoglund, 1962; Jensen, 1965, 1967; Dow, 1966, 1967; Squires, 1968; Butler, 1964, 1968; Pontaine, 1979; Balsiger, 1981). Shumway *et al.* (1985) investigated the life cycle of *P.jordani* Rathbun in the Pacific where as the biology of *P.montagui* Leach, another commercial important species in the North Atlantic have been investigated by Mistakidis (1957), Allen (1963), Stevenson and Pierce (1985). Reproductive biology of several pandalids shrimps of Japan and adjacent waters have been studied, viz. *P.nipponensis* Yokoya by Tamura (1950), *P.kessleri* Czerniavski by Kubo

(1951), Aoto (1952), Kurata (1955), Kashiwagi (1974); *P.hypsinotus* Brandt by Kurata (1957), *Pandalopsis coccinata* Urita by Abe (1965), *P.japonica* Balss by Ito (1978) and *Plesionika izumiae* Omori by Omori (1971). Larval development of pandalid shrimps have been investigated by Modin and Cox (1967), Wickins (1972), Haynes (1976,1978, 1979), Rothlisberg (1980), Weinberg (1982), Mikulich and Ivanov (1983), Needler (1938), Lebour (1940) and Hiroshi (1978). Schultze and Anger (1997) assessed the larval growth pattern in *P.montagui* from North Sea. The life history traits of commercially important pandalid shrimps of North America viz. *Pandalus platyceros* Brandt, *P.danae* Stimpson, *P.goniurus* Stimpson, *P.stenolepis* Rathbun and *P.hypsinotus* Brandt have been studied by Berkeley (1929), Tegelberg and Smith (1957), Butler (1964, 1970) and Dahlstrom (1970). Clark *et al.* (1991) reported the egg size and reproductive output of *P.borealis* off Sweden while Qunitio *et al.* (1991) assessed the changes in GSI and HSI of *P.kessleri* during annual reproductive cycle. Ohtomi (1997) described the reproductive biology of *Plesionika semilaevis* from Kagoshima Bay while Company and Sardá (1997) gave a comprehensive account on the comparative reproductive biology of 5 deep water pandalids shrimps *Plesionika hetrocarpus*, *P.edwardsii*, *P.gigliolii*, *P.martia* and *P.acanthonotus* inhabiting a depth gradient 150-1100m off western Mediterranean. Legaki (1992) and Colloca (2002) made comparative reproductive studies in *Parapandalus narwal* and *P.edwardsii* from Central Mediterranean Sea.

Investigations on the reproductive biology of pandalid shrimps *Heterocarpus gibbosus* and *H.woodmasoni* are limited in spite of the fact that these species are widely preferred in the export market due to their bigger size and therefore, a regular commercial fishery has been developed in the deeper waters off Kerala. Though *Heterocarpus spp.* inhabiting Pacific and Atlantic waters were studied for their reproductive biology (Wilder, 1974; Moffit, 1983; King, 1984; King and Butler, 1985) similar information with regard to Indian Ocean population are scanty. Rao and Suseelan (1967) made preliminary observations on the pre zoea stage of *H.woodmasoni* collected from the exploratory surveys, while Menon (1972) reported the larval development of the genus *Heterocarpus* collected from International Indian Ocean Expedition surveys. Suseelan (1985) made a preliminary account on the general life history traits of deep sea prawns collected from the exploratory surveys off South West coast of India, however, the information generated are too inadequate for making decision on fishery regulatory activities. Against this background, an attempt was made to investigate the reproductive characteristics of both *H.gibbosus* and *H.woodmasoni* inhabiting off Kerala coast.

## 8.2 MATERIALS AND METHODS

Weekly samples of *H.gibbosus* and *H.woodmasoni* were collected from the commercial deep sea trawl landings at

Sakthikulangara, Cochin, Munambum and Murikkumpadam Fisheries harbours of Kerala during September to April 2000-02. Samples were not available during May - August due to the suspension of commercial fishing activities. However, during the closed fishing season (May - August), the specimens were collected from the cruise surveys of the exploratory research vessel FORV Sagar Sampada carried out off south west coast of India.

In the laboratory individuals were sorted by species level following Alcock (1906) and were sexed by morphological examination according to the shape of the endopod of the first pleopod and the presence or absence of appendix masculina on the endopod of the second pleopod (King and Moffitt, 1984). Total length was measured from the tip of rostrum to the extremity of telson up to nearest millimeter with the abdomen keeping fully stretched. The total weight of the individual prawn was taken to the nearest 0.1g using an electronic balance.

Animals were segregated maturity stage wise following Ceccaldi (1966) and Company and Sardá (1997) based on colour and dimension both of gonads and embryos. The specimens were then dissected out to remove gonad and hepatopancreas after recording total weight to the nearest 0.1 g. The gonads and hepatopancreas were then dissected out and their weights were recorded to nearest 0.01g after removing excess moisture using filter paper.

Gonado somatic (GSI) and hepato somatic indices (HSI) were calculated as the percentage weight of gonad and hepatopancreas respectively to the total body weight (June, 1953). Monthly average of GSI and HSI were sequentially arranged in time series in order to delineate spawning season (King, 1995). Length at first maturity was calculated for males and females from the length at which 50% of the individuals showed maturity.

To determine fecundity, 55 berried females of *H.gibbosus* and 24 berried females of *H.woodmasoni* were sorted based on length and embryonic development. Eggs were carefully removed from the brood pouch and fixed in modified Gilson's fluid. After four to five days, the eggs were weighed after removing the adhered water and absolute fecundity was estimated following standard procedures (Kurup and Kuriakose, 1994). Absolute fecundity so arrived at was regressed to 25 morphometric measurements by least square method (Snedecor and Cochran, 1967) to establish the relationship of various body dimensions to fecundity. The diameter of 300 ova each was taken at different embryonic stages to measure the diameter of eggs using ocular micrometer where each micro divisions equal to 0.015 mm.

In order to identify various developmental stages of ovary, histological studies were carried out following Anekutty (2003). For this purpose, fresh ovarian tissue was fixed in 20 volumes of Bouin's

paraformal for 12 to 24 hrs. Afterwards the tissue was dehydrated in different graded strengths of alcohol, cleared in xylene and embedded in paraffin. The blocks were then sectioned at 6-8  $\mu\text{m}$ . Sections were later stained with Delafield's haematoxyline, counterstained with Alcoholic Eosin, and mounted permanently for microscopic analysis. Oocytes were measured with an ocular micrometer to the nearest 0.01mm.

## 8.3 RESULTS

### 8.3.1 Description of maturity stages

There were glaring differences in the colour and shape of the ovaries in *H.gibbosus* and *H.woodmasoni*, though the variation in gonad structure was not prominent in males of both the species. In females, seven stage maturity were identified of which four stages (immature, maturing, head roe, spent) were defined according to the relative intensity of colour and dimension of ovary in the cephalothorax while the later three stages of maturity were defined on the basis of the color of embryo in ovigerous females. In males also, the maturity stages could be assigned to three stages based on external macroscopic examination.

### **8.3.1.1 *H.gibbosus***

#### **Females**

##### **1. Immature stage**

Ovaries very thin, translucent ill developed thread like tissue and confined to more than  $\frac{1}{2}$  length of cephalothorax; Ovary not visible through carapace. Total weight of the ovary varied between 0.01 and 0.03 g while the total length of the animal was below 60 mm.

##### **2. Maturing stage**

Size of the ovary increases, becomes creamy white in colour, not visible through carapace and the weight varied between 0.03 and 0.05g. The lobes extend forwards in the cephalothorax and girth increases. Size of the maturing females was in the range 70-90 mm in total length.

##### **3. Head roe stage**

The ovary is very clearly visible through the exoskeleton, bright yellow mostly and in a few cases greenish yellow. Ovary very well developed and due to its fullness, the ovary occupies the entire space available in the cephalothorax, which seems bulged due to the swollen ovary. The posterior end of the ovary extends up to lower portion of the

1<sup>st</sup> abdominal segment and can be visible through the base of the rostrum.

**4. Ovigerous females with orange eggs (Orange berry)**

Females with eggs of immediate spawning with intense colour and no embryo pigmentation visible. Yolk fills most of the egg volume. Colour of the eggs bright orange.

**5. Ovigerous females with grey eggs (Grey berry)**

Appearance of a ventral cleft and slightly pigmented eyespot. Colour of the egg mass turns grey.

**6. Ovigerous females with black eggs (Black berry)**

Eye spots fully pigmented and clearly visible. Segmentation completed and ready to hatch. Eggs mass brownish black in colour.

**7. Spent recovering stage**

Females after liberating one brood retains ovigerous setae, remnants of immature eggs and mucous threads, may or may not having another set of ripening ovaries for the subsequent spawning.



**Males****1. Immature stage**

Small males with testis narrow thread-like and transparent; extend  $\frac{3}{4}$ <sup>th</sup> length of cephalothorax and having not more than 0.02 g in total weight. Prawns invariably belong to less than 60 mm.

**2. Mature stage**

Broader than immature stage, thicker leaf like and occupies entire length of cephalothorax; creamy white in colour. Animals more than 60mm in total length. Weight of testes ranged between 0.04 to 0.22 g.

**3. Spent males**

Gonads appear like white threads having less than 0.02g in total weight. This stage is distinguishable from immature males on the basis of relative size of the prawn.

**8.3.1.2 *H.woodmasoni*****Females****1. Immature stage**

Ovary thin, ribbon like, glassy transparent and thread like. Pale white, occupy more than ½ length of cephalothorax. Ovary having less than 0.02g in total weight.

## **2. Maturing stage**

Size of the ovary increases and colour turns to milky white with a weight in the range 0.02 and 0.09 g.

## **3. Head roe**

Ovary clearly visible through exoskeleton and occupies entire cephalothorax; granulated appearance; generally light yellow, sometimes light green and weighed in the range 0.20 to 0.90 g.

## **4. Ovigerous females with orange eggs (Orange berry)**

Ovigerous females with newly spawned bright orange colored eggs. Some possessing fully developed ovaries in the cephalothorax.

## **5. Ovigerous females with grey eggs (Grey berry)**

Egg mass grayish in colour. Eyespot clearly visible and pigmented.

## **6. Ovigerous females with black eggs (Black berry)**

Egg mass turns pinkish brown to black and ready for hatching.

## **7. Spent recovering females**

Ovary loose, shrunken. Females after extrusion of embryos, possessing another brood in the cephalo thorax. Pleopods with ovigerous setae and mucous threads.

### **Males**

#### **1. Immature stage**

Small males with translucent body; testes appeared as a thin thread like and weighed in the range 0.01 to 0.02g.

#### **2. Mature stage**

Testis milky white in colour, broad thread like appearance and weighed in the range 0.03 to 0.07 g).

#### **3. Spent stage**

Large males, testes transparent thread like with weight of 0.01 g.

### **8.3.2 Histology of ovarian tissues at different stages**

Histological examination of the ovaries of *H.gibbosus* and *H.woodmasoni* showed the presence of oocytes having different stages of development (Plate 8.1 A). During differentiation, in *H.gibbosus* and

*H. woodmasoni* four stages were identified as oogonial cells, developing oocytes, early vitellogenic and late vitellogenic cells (Table 8.1). The differentiation of these stages was made based on their cytoplasmic content and the size of the oocytes. The germinal zone was found on the ventro lateral region of the ovary (Plate 8.1 B). The ventro lateral position of the ovary in the cephalic region would be advantageous for the growth of oocytes in the opposite direction due to the tubular nature of the body cavity of the prawn and the availability of more space in the dorso -lateral regions (Adiyodi and Subramaniam , 1982). The oogonial cells were found in clusters near germinal zone. These cells were basophilic with large round nuclei surrounded by a thin rim of oocortex, which lack sustainable yolk materials (Victor and Sarojini, 1985). By rapid mitotic divisions, the oogonial cells increased in number and size in *H.gibbosus* and *H.woodmasoni*.

Developing oocytes organized themselves in to tubule like structural units (ie. ovarian parenchyma). Each tubule, with wall composed of a thin layer of developing follicular cells, packed with developing oocytes in a row. These developing oocytes becoming semi spherical with diameter 1.5 to 3 $\mu$ m in *H.gibbosus* (Plate 8.2 A) and 3 to 5 $\mu$ m in *H.woodmasoni* (Plate 8.5 A); nucleus bearing 2-9 nucleoli and cytoplasm composed of basophilic mass (colour bluish pink under H-E stain). At the end of early vitellogenic phase, the nucleus of the primary oocytes swelled in to germinal vesicle and possessed granular cytoplasm.

Vitellogenic oocytes measured between 20- 47  $\mu\text{m}$  in *H.woodmasoni* and 25-64  $\mu\text{m}$  in *H.gibbosus*. During vitellogenic phase, the yolk granules started accumulating in the oocortex. Eosinophilic granules were observed in the perinuclear cytoplasm (Plate 8.2 B & 8.5B).

The perinuclear ring disappeared with the advancement of vitellogenesis. Generally yolk was formed from both extraoocyte sources (haemolymph) by diffusion through follicular cell layer in collaboration with nuclear extrusion granules (Beams and Kessel, 1963; Hinsch and Cone, 1969) (Plate 8.3 & 8.6A). The oval, non germinative, accessory, follicular cells were also helpful in the uptake of extraoocytic yolk protein because they were always found attached themselves around the early vitellogenic oocytes. As the oocyte grows in size, the yolk droplets became strongly eosinophilic and increased in size and number (Plate 8.4 & 8.6B). After maturation, the ova were ovulated and oviposited in the brood pouch of the females. The presence of more than one size range of oocytes in the ovaries of *H.gibbosus* and *H.woodmasoni* provided evidence for the continuous breeding pattern of these prawns.

### **8.3.3 Seasonal occurrence of maturity stages**

Percentage occurrences of various maturity stages in the female population of *H.woodmasoni* are presented in Fig. 8.1 & 8.2. Females with different stages of maturity were observed in all the seasons of the

year which would indicate the possibility of a prolonged breeding. The percentage occurrence of various stages, however, showed marked variations in different months. Non-berried immature and maturing females were predominant from February to April and July to August and thenceforth a dominance of head roe females could be discernible during October, November, December and January. Ovigerous females with Orange Berry (OB), Grey Berry (GB) and Black Berry (BB) were encountered in highest numbers during March, April and May (Plates 8.8 B). In contrast, the percentage occurrence of spent females showed an increasing trend from July to August and December (Plate 8.9 B).

Monthly variations in the occurrence of female maturity stages of *H.gibbosus* are presented in Fig. 8.3 & 8.4. Immature and maturing females were encountered in all the months with varying degrees but were absent during March to May (Plate 8.7 A). The head roe females were predominated from October to April but were absent during May to September (Plate 8.7 B). The ovigerous females also showed a distinct predominance in all the months except from July to August with peak occurrence registered in December, March and April (Plates 8.8 A, 8.9 A & 8.10).

In males of *H.woodmasoni*, gonads with different stages of maturity were encountered in most of the months during 2000-02. Highest number of immature and maturing males could be registered during July

- September (Fig. 8.5& 8.6) while the peak occurrence of spent males was registered during March to May and December.

Immature males of *H.gibbosus* (Fig. 8.7 & 8.8) were encountered in all the months observed except during February to May in both the years. Highest abundance of immature males could be registered in September 2000, January 2002 and July 2002. During May, towards the end of breeding season, a higher percentage of spent males could also be registered.

#### **8.3.4 Seasonal variation in Gonado Somatic Index (GSI)**

Monthly variation of GSI in males of *H.woodmasoni* during September 2000 to August 2002 is depicted in Fig. 8.9. The GSI values showed a gradual increase from 0.50 in September to 0.68 in October, and thereafter an inflexion was observed up to December. A sharp increase was discernible during January to April 2001 with peak in February (0.97). Almost similar pattern was seen during 2nd year also, showing peak GSI in January 2002(1.24).

GSI of females of *H.woodmasoni* showed similar trend when compared to that of males (Fig. 8.10). A steady increase in GSI of females from 0.58 to 2.35 was noticed during September 2000 to January 2001. Thereafter gradual descend was noticed with lowest GSI value in March (0.56). During the second year also a rapid increase could be

noticed from November (0.41) and attained peak in January (1.98), and thenceforth it declined glaringly up to May 02 (0.01).

In males of *H.gibbosus* (Fig. 8.11), GSI showed lowest value in the months of July, August and December and increased thereafter, showed an upward trend from January to April 2001. Similar trend could also be seen in the 2<sup>nd</sup> year. In females of *H.gibbosus* (Fig. 8.12) two distinct peaks in GSI were observed, the former in October and the later in March during both the years. The values were found invariably very low during June and July.

### **8.3.5 Variation of GSI among various maturity stages**

In females of *H.woodmasoni*, an increase in GSI could be noticed during ovarian development from immature (0.55) to head roe stage (5.09), in contrast, a decline could be discernible in orange berries (0.41). Again, a slow progression in GSI commensurate with the embryonic development was seen in females as ripe ovaries were encountered in the ovigerous females. In these prawns, the ovary and the incubating eggs have been developing simultaneously at the same rate, so that when the attached eggs were hatched and shed, the ova will get ready for another spawning. This was evidenced from higher GSI values of spent females (Fig. 8.13).



Among males of *H.woodmasoni*, an increase in GSI was observed with progression of maturity from immature to head roe, however, the values showed a decline in spent males (0.41) (Fig. 8.14).

In females of *H.gibbosus*, the pattern of GSI in different female maturity stages were found to be more or less similar to that of *H.woodmasoni*, however, the decrease in GSI value of ovigerous females were more pronounced when compared to *H.woodmasoni* (Fig. 8.15). In males of *H.gibbosus*, GSI showed an increase from immature to maturing but a sharp decline could be discernible in spent stage (Fig. 8.16).

### **8.3.6 Seasonal variation in Hepato Somatic Index (HSI)**

In females of *H.woodmasoni*, HSI values showed distinct peak and trough during both the years of study (Fig. 8.17). High HSI values could be discernible in December during both the years, with 5.64 and 4.93 respectively. HSI of females were lowest in January with 1.46 and 1.24 respectively for 2001 and 2002.

In males of *H.woodmasoni*, HSI showed a gradual increase during September to January 2001 and thereafter it declined during May (2.98) (Fig. 8.18). In the second year also, similar pattern could be recorded with the highest and lowest HSI values during February 2002 (7.85) and September 2001 (1.64) respectively.

In males of *H.gibbosus*, an increase in the HSI was recorded from November to January during both the years followed by a decrease during February to March. Highest HSI was encountered in December 2000 (0.20) and January 2002 (0.21) respectively (Fig .8.19). HSI of females of *H.gibbosus* was highest (0.42) during January 2001, and it gradually decreased, showing lowest (0.09) in October 2000. In the 2<sup>nd</sup> year, highest (0.79) and lowest (0.09) HSI values could be discernible in December 2001 and March 2002 respectively (Fig. 8.20).

### **8.3.7 Variation in HSI among maturity stages**

Among female maturity stages of *H.woodmasoni*, an increasing pattern of HSI could be noticed from immature (2.95) to maturing stage (3.84) but declined in the head roe stage (2.87), however, it started increasing in the subsequent ovigerous stages (Fig. 8.21). In males of *H.woodmasoni*, highest HSI value (5.18) was encountered in spent stage (Fig. 8.22).

In males of *H.gibbosus*, an increase in HSI from 0.10 in immature to 0.35 in mature males was registered coinciding with the gonadal maturation (Fig. 8.23). The HSI values of female of *H.gibbosus* showed a decrease from maturing (0.21) to head roe (0.19) where as in ovigerous stages such as orange berry, black berry and grey berry, the HSI was distinctly on a higher side when compared to head roe and spent female (Fig. 8. 24).

### 8.3.8 Size at first maturity

Percentage occurrence of matured males and females of *H.woodmasoni* is shown in Fig. 8.25. The size at first maturity of *H.woodmasoni* was estimated to be 96.75mm and 100mm for males and females respectively and that of *H.gibbosus* were 98.5 mm for females and 97mm for males (Fig. 8.26).

### 8.3.9 Ova diameter

Ova diameter of *H.gibbosus* and *H.woodmasoni* at different stages of larval development is shown in Fig. 8.26 to 8.32. In *H.woodmasoni*, the diameter of orange berries (Fig. 8.27) ranged from 180-240 $\mu$ m while the diameter of gray berries ranged between 195 and 270  $\mu$ m (Fig. 8.28). The black berries were measured between 270 to 345  $\mu$ m (Fig.8.29). In *H.gibbosus*, the diameter of orange berries varied between 150 to 210 $\mu$ m (Fig.8.30) where as in gray berries it was ranged between 225 and 285  $\mu$ m (Fig.8.31). Ova diameter of black berries of *H.gibbosus* varied from 255 to 330 $\mu$ m with peak at 300 $\mu$ m (Fig. 8.32).

### 8.3.10 Fecundity

Minimum, maximum, mean and standard deviation of fecundity and various morphometric characters studied in *H.gibbosus* are presented in Table 8.2. Mean absolute fecundity of *H.gibbosus* was

estimated as 20672 eggs. Fecundity varied between 5670 and 33962 eggs in berried females having the total length ranged between 94mm (7.88g) and 136mm (25.51g). Fecundity per unit measurement of body dimension was estimated directly from the mean of observations as well as from the logarithmic equations derived (Table 8.2). Number of eggs per unit dimension of total length, carapace length and total weight recorded from *H.gibbosus* was found to be 173,618 and 1261 respectively (Fig. 8.33 to 8.36)

Results of regression analysis of fecundity with various morphometric measurements are also presented in Table 8.2. Relative fecundity of orange, grey and black berried females of *H.gibbosus* showed a gradual decrease commensurate with the embryonic development (Table 8.3) though the variation was not found significant ( $P>0.05$ ). Difference noticed in the relative fecundity in various length groups of *H.gibbosus* are presented in Table 8.4. Average absolute fecundity showed a gradual increase with increase in length groups where as the relative fecundity showed a gradual increase in 91-100,101-110,111-120 and 121-130mm length groups and a sharp decrease in 131-140mm length group are worth reporting.

Details of various morphometric measurements and the fecundity stages in *H.woodmasoni* and results of regression analysis are presented in Table 8.5. Highest fecundity enumerated in *H.woodmasoni*

was 17472 eggs (total length 118mm, weight 8.53g) while lowest were 564 eggs (total length 98mm, weight 4.75g). The mean absolute fecundity was worked out to be 6585 eggs. Number of eggs per unit dimension of total length, carapace length and total weight recorded from *H. woodmasoni* was estimated to be 61, 219 and 1051 respectively (Fig. 8.37 to 8.39).

Variation in fecundity in different length groups of *H. woodmasoni* is presented in Table 8.7. Relative fecundity of ovigerous females at different stages of embryonic development showed a gradual reduction from OB to BB stages (Table 8.6).

#### 8.4 DISCUSSION

Head roes and matured males of *H. woodmasoni* showed a regular occurrence in commercial landings from September onwards and subsequently berried females also started appearing from November with peak availability during January – March periods. By examining the pattern of availability of male and female *H. woodmasoni*, it appears that November to April is the peak-breeding season of *H. woodmasoni* with intense spawning activity in January. Presence of head roes and berries in almost all months of observation except during July shows the prolonged reproductive activity of this species. Suseelan (1985) also

reported similar findings with peak period of breeding during October to April in *H.woodmasoni*. Similarly, in *H.gibbosus* also, the occurrence of head roes and berried females were recorded in all the months except during August indicating the possibility of a prolonged breeding of this species. However, intense spawning activity was observed during October to March with peak in February. The seasonal breeding nature of *H.gibbosus* reported by Suseelan (1985) do not match with the present results as the presence of head roes and berries were seen in almost all the months except August due to suspension of both exploratory as well as commercial fishing for deep sea prawns.

In the present study, higher Kn values recorded from November to March for both the species also suggest their peak spawning period during January to March. The highest percentage of berried females encountered in the population of *H.woodmasoni* and *H.gibbosus* during October to March also suggest the peak period of spawning activity of the two pandalid prawns (Refer Chapter 5 for details).

King and Butler (1985) also reported on the prolonged breeding behaviour of *H.laevigatus* and *H.sibogae* from northern Chile. Present findings corroborate with Hancock and Henriques (1968) in Chilean shrimp *H.reedi*, which showed intense reproductive activity during December to January while very low reproductive activity was reported during May to June . Further, Anderson and Lindner (1971) also reported

the peak spawning season of *H.robustus* as January to May along US coasts and Company and Sardá (1997) observed the peak reproductive season of *Plesionika Heterocarpus* during winter in the Mediterranean Sea. The peak reproductive behaviour of deep sea prawns during winter might be due to the increase of water temperature.

Omori (1974) observed continuous reproductive pattern for lower meso and bathypelagic decapod with fewer eggs. Although seasonal reproduction has been observed in different deep sea taxa, the most predominant reproductive pattern generally reported in deep sea crustaceans is the continuous reproduction (Tyler, 1986,1988; George and Menzies, 1967; Harrison, 1988, Gage and Tyler, 1991; Bishop and Shella, 1994). However, the reason for continuous reproduction was not yet fully unraveled due to the difficulty in performing experimental studies, which faithfully reproduce the conditions of the deep sea environment (Company and Sardá, 1997). Several workers suggested the possibility of larval food availability, sinking organic matter originating from surface and primary production as reasons for the continuous reproductive activity of deep sea prawns. Maximum abundance of both the species were registered around 250-350m depth range in the neritic zone. The neritic zone is more productive through out the year than the adjacent oceanic zone, in relation to both phytoplankton biomass and zooplankton biomass (Estrada *et al.* , 1985; Estrada and Salat ,1989) . This is one of the main factors which would allow both *H.woodmasoni* and *H.gibbosus* to have an

extended breeding season in contrast to the deepest dwelling species such as *Plesionika acanthonotus* (Company and Sardá, 1997) and *Aristeus antennatus* (Relini Orsi and Relini, 1979). Colocca (2002) and Company and Sardá (1997) also reported the occurrence of ovigerous females of pandalid shrimps through out the year from the central Mediterranean.

In aquatic animals, variation in the gonado somatic index can be taken as a useful criterion for determining the duration and intensity of spawning (June, 1953; Erdman, 1968). An increase of GSI was noticed in head roes and again during the later stages of embryonic development, both in grey and black berries. This would suggest the possibility of a continuous development of immature ovary to mature head roe stage along with the embryonic development. Higher GSI values in spent animals also lend to support the possibility of more than one spawning of the individual in a single breeding season. This finding is well in agreement with that of Ohtomi (1997) and Omori (1971) who reported multiple broods with in a single prolonged reproductive period in *Plesionika semilaevis* and *P. izumiae* in Japanese waters.

Hepatopancreas plays a major role in the food assimilation (Dhall and Moriarty, 1983) and its relative weight probably manifests the provision for energy utilization for growth and metabolism. An increase in HSI was discernible with the progression of gonadal development in both



*H.woodmasoni* and *H.gibbosus*. However, it showed a drastic decline during breeding season as the fully ripe ovaries may occupy the major portion of the cephalothorax. Qunitio *et al.* (1991) reported similar observation in *Pandalus kessleri*, which showed a sharp decrease in HSI with the increase in GSI during the spawning season.

Seven maturity stages in females and three maturity stages in males were identified in *H.gibbosus* and *H.woodmasoni* during the present study based on colour and dimensions of both gonads and embryos. The results from the histology of ovarian tissues showed that changes in colour and size of the ova match very well with the development of oocytes and size of the ovary. In the immature stage, only primary oocytes were present with no sign of development. In maturing females the ovarian tissues possessing high number of nucleoli indicate that these oocytes have become very active. The enlargement of oocytes during development is due to expansion of cytoplasm which then becomes acidophilic. The presence of yolk granules in vitellogenic oocytes might be due to the presence of glycoprotein for the growth of ovarian cells (Relini and Semeria, 1982). Similar observation on the occurrence of numerous yolk granules have been reported in deep sea aristeid prawn *Aristeomorpha foliacea* Risso by Hui-Chen *et al.* (1999), *Caridina rajadhari* (Bouvier) by Victor and Sarojini (1985), *Chirocephalus bundyi* by Linder (1959) and *Palaemon paucidens* by Kamiguchi (1971). In head roes, oocytes with different stages of development were present

and therefore it can be inferred that the changes in the oocyte size and morphology observed in the ovary can truly reflect the different developing stages of the ovarian tissue of *H.gibbosus* and *H.woodmasoni*.

The size at first maturity of *H.gibbosus* was 96.75 mm in males and 100mm in females while in *H.woodmasoni* size at first maturity of males was observed to be 97 and 98.5 mm in females, which is in close agreement with that of Suseelan (1985). According to him, the females attained maturity at 103.2mm in *H.woodmasoni* and 104mm in *H.gibbosus* collected during exploratory surveys off south west coast of India.

The result of fecundity estimation showed that in *H.gibbosus* the average absolute fecundity was 20672 eggs, which varied from 5670 to 33962 in females having total length of 94 to 136mm. According to Suseelan (1985) *H.gibbosus* with the size range from 105 to 125 mm total length, the absolute fecundity varied from 10732 to 31822 eggs with an average absolute fecundity of 19745. It would thus appear that the absolute fecundity arrived at in the present study agrees with that of Suseelan (1985). Whereas King and Butler (1985) observed a slightly higher value of 28312 eggs in *H.gibbosus*, followed by 23292 in *H.sibogae* and 34461eggs in *H.laevigatus* from British Columbia. The fecundity of *H.woodmasoni* was estimated as 6586 eggs, and this is well

comparable with that of Suseelan (1985), however, when compared to *H.gibbosus* it is very low. The absolute fecundity of *H.gibbosus* was found to be high when compared to other deep sea prawns viz. *P.spinipes*, *P.martia* and *P.ensis* which are characterized by an absolute fecundity of 3972, 2733 and 2655 eggs respectively (Suseelan, 1985). However, these form only 2.29% of the regeneration capability of their counter parts inhabiting in coastal waters (Hall, 1962; Rao, 1968; Nalini, 1976; Rao, 1989).

In the present study, a strong correlation could be established between total weight and fecundity of *H.gibbosus* followed by carapace length and rostral length where as in *H.woodmasoni*, fecundity showed a strong correlation with total length, total weight and rostral length. The exponential values (regression coefficient) between total length and fecundity was found to be higher than the cube in *H.gibbosus* which showed a positive deviation and this is in disagreement with the generally accepted view about fecundity and the total length (Bagenal, 1978). However, exponential values greater than 6 have been reported in the case of fecundity – length relationship of *Penaeus indicus* and 3.45 in *Parapenaeopsis stylifera* (Rao, 1968). Similar values greater than 4 have been reported in fishes by Selvaraj *et al.* (1972), Siddiqui *et al.* (1975) and Pathak and Jhingran (1977).

The fecundity in *H.gibbosus* showed a strong correlation with total weight than the total length. Positive relationship between fecundity and body weight have been reported Siddhiqui *et al.* (1975) and Kurup and Kuriakose (1994) lend support to the present findings. The exponential values of total length, total weight, carapace length and rostral length were found to be 4.34, 2.09, 2.32 and 2.81 mm respectively. In respect of the short and long second chelipeds are 1.14 and 1.08 respectively. The relative fecundity of the first four length groups showed a gradual increase, commensurate with the progression of size. In 130-140mm length group, a decreasing trend in relative fecundity was observed which might be attributed to the significant loss of eggs due to advancement of maturity stages in *H.gibbosus*.

The relative fecundity of orange berry, grey berry and black berry both in *H.gibbosus* and *H.woodmasoni* showed a gradual decrease commensurate with the progression of maturation though the difference is not found to be significant. This might due to the embryo loss as a function of the mortality of embryos during the incubation of females. King and Butler (1985) and Ohtomi (1997) also reported the egg loss during embryonic development in *H.sibogae* and *P.semilaevis* while Haynes (1979) reported 36% in embryo loss in ovigerous females of *P.borealis* during larval development.

Of the twenty five fecundity indices established in the present study, the indices in respect of total weight, carapace length and rostral length can be taken as most reliable morphometric characters as the measurement of these parameters are very easy and therefore be useful for the indirect enumeration of the number of eggs carried by the berried females. Indirect estimation of fecundity by resorting to reliable indices is found immensely useful in assessing the regeneration capacity of these emerging resources. The result of the present study showed that the eggs per gram body weight of *H.gibbosus* varied from 502 to 1690 and the same in respect of millimeter carapace length ranged from 252.46 to 737.44 while in the case of rostral length it ranged from 272.39 to 880.29 eggs. It would thus worked out to be an average egg per gram body as 1317 while the same per mm of carapace length and rostral length were 658 and 578 respectively. In the case of *H.woodmasoni*, the average number of eggs computed per gram body weight was 1051.92, while in unit millimeter of total length and carapace length were 61 and 219 eggs respectively.

| Oocyte size classes | Oocyte diameter range (µm) |                      | Stage of the Oocytes |
|---------------------|----------------------------|----------------------|----------------------|
|                     | <i>H. gibbosus</i>         | <i>H. woodhousei</i> |                      |
| I                   | 1                          | 1-2                  | Oogonial cells       |
| II                  | 1.5-3                      | 3-5                  | Developing oocytes   |
| III                 | 4-25                       | 6-20                 | Early vitellogenic   |
| IV                  | 25-64                      | 20-47                | Vitellogenic         |

Table 8.3 Average values of morphometric measurements and relative fecundity in different stages of embryonic development of *Heterocarpus gibbosus*

| No. | Berry colour | Number of observations | Mean total length (mm) | Mean total weight (g) | Mean carapace length (mm) | Mean rostral length (mm) | Mean absolute fecundity (no.) | Relative fecundity Fec./TW (no.) | Relative fecundity Fec./TL (no.) | Relative fecundity Fec./CL (no.) |
|-----|--------------|------------------------|------------------------|-----------------------|---------------------------|--------------------------|-------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 1   | orange       | 25                     | 103.25                 | 11.73                 | 28                        | 28.51                    | 7248.00                       | 617.90                           | 70.19855                         | 258.8571                         |
| 2   | grey         | 16                     | 115.69                 | 14.18                 | 30.25                     | 34.96                    | 16218.00                      | 1143.72                          | 140.18498                        | 536.1322                         |
| 3   | black        | 9                      | 119.42                 | 21.52                 | 34.51                     | 36.73                    | 17121.00                      | 796.59                           | 143.36795                        | 486.1171                         |

Table 8.4 Average values of morphometric measurements and relative fecundity in different length groups of *Heterocarpus gibbosus*

| No. | Berry colour | Number of observations | Mean total length (mm) | Mean total weight (g) | Mean carapace length (mm) | Mean rostral length (mm) | Mean absolute fecundity (no.) | Relative fecundity Fec./TW (no.) |
|-----|--------------|------------------------|------------------------|-----------------------|---------------------------|--------------------------|-------------------------------|----------------------------------|
| 1   | 90-100       | 6                      | 96.00                  | 9.05                  | 25.50                     | 31.50                    | 6555.00                       | 724.12                           |
| 2   | 100-110      | 5                      | 106.00                 | 12.18                 | 27.20                     | 31.60                    | 9477.60                       | 781.72                           |
| 3   | 110-120      | 18                     | 115.72                 | 13.99                 | 30.50                     | 35.50                    | 15918.67                      | 1125.58                          |
| 4   | 120-130      | 18                     | 124.61                 | 18.26                 | 35.61                     | 40.33                    | 29460.13                      | 6566.00                          |
| 5   | 130-140      | 8                      | 132.25                 | 22.06                 | 41.05                     | 45.63                    | 571.72                        | 1324.66                          |

Table 2. Results of regression analysis of morphometric variables of *Microgaster* species and their fecundity per unit body dimension.

| No | Morphometric Variable                | Results of regression analysis with fecundity |         |         |         |                         |                            | Fecundity per unit body dimension |                             |
|----|--------------------------------------|---|---------|---------|---------|-------------------------|----------------------------|-----------------------------------|-----------------------------|
|    |                                      | Minimum                                       | Maximum | Mean    | SD      | Regression constant (a) | Regression coefficient (b) |                                   | Correlation coefficient (r) |
| 1  | Total length(mm)                     | 84  | 136     | 119.73  | 9.26    | -3.8194                 | 4.0426                     | 0.8790*                           | 172.86                      |
| 2  | Total weight(g)                      | 7.88  | 25.51   | 16.39   | 3.94    | 2.2460                  | 2.3900                     | 0.7419*                           | 1261.26                     |
| 3  | Carpus length (mm)                   | 23  | 44      | 33.44   | 5.23    | 0.7442                  | 2.3264                     | 0.7611*                           | 618.20                      |
| 4  | Rostral length(mm)                   | 27  | 49      | 38.25   | 5.00    | -0.1721                 | 2.8173                     | 0.7707*                           | 540.44                      |
| 5  | II. Iechium(mm)                      | 6   | 16      | 11.63   | 1.77    | 1.8926                  | 2.2467                     | 0.7605*                           | 1777.86                     |
| 6  | Merus(mm)                            | 7   | 19      | 12.12   | 2.57    | 2.4193                  | 1.7293                     | 0.7553*                           | 1705.81                     |
| 7  | Carpus(mm)                           | 10  | 25      | 17.78   | 4.06    | 3.0301                  | 1.6062                     | 0.5853*                           | 1162.37                     |
| 8  | Propodus(mm)                         | 1   | 4       | 2       | 0.63    | 4.1612                  | 0.4146                     | 0.2910*                           | 10336                       |
| 9  | Dactylus(mm)                         | 1   | 4       | 1.67    | 0.77    | 4.1479                  | 0.7134                     | 0.6410*                           | 12378.44                    |
| 10 | second long cheiliped length(mm)     | 33  | 67      | 46.37   | 8.12    | 2.4657                  | 1.1432                     | 0.7963*                           | 445.81                      |
| 11 | II. Iechium(mm)                      | 5   | 14      | 9.16    | 2.06    | 2.7552                  | 1.6007                     | 0.7706*                           | 2256.77                     |
| 12 | Merus(mm)                            | 3   | 9       | 5.14    | 1.58    | 3.7751                  | 1.7241                     | 0.7432*                           | 4021.79                     |
| 13 | carpus(mm)                           | 7   | 13      | 9.65    | 1.16    | 2.7260                  | 1.5801                     | 0.3983*                           | 2142.16                     |
| 14 | Propodus(mm)                         | 1   | 8       | 2.12    | 2.30    | 4.2865                  | 0.0561                     | 0.0875*                           | 9750.94                     |
| 15 | Dactylus(mm)                         | 1   | 3       | 1.33    | 0.74    | 4.2967                  | 0.2518                     | 0.2121*                           | 15542.86                    |
| 16 | second short cheiliped length(mm)    | 21  | 42      | 28.05   | 6.34    | 3.2280                  | 0.8035                     | 0.6628*                           | 736.97                      |
| 17 | I. Abdominal segment(mm)             | 56  | 75      | 54.53   | 24.16   | 1.9679                  | 1.2658                     | 0.2669*                           | 379.09                      |
| 18 | V. Abdominal segment(mm)             | 30  | 45      | 30.12   | 13.49   | 4.5061                  | 1.4730                     | 0.5144*                           | 686.32                      |
| 19 | II Pleural width(mm)                 | 8   | 17      | 12.69   | 2.35    | 2.6140                  | 1.5178                     | 0.6226*                           | 1629.00                     |
| 20 | Brood pouch Width(mm)                | 3   | 15      | 10.65   | 2.16    | 2.1476                  | 1.9654                     | 0.6564*                           | 1941.03                     |
| 21 | Brood pouch depth(mm)                | 7   | 15      | 11.8    | 1.76    | 3.2521                  | 1.0068                     | 0.5403*                           | 1751.86                     |
| 22 | Brood pouch length(mm)               | 28  | 59      | 46.04   | 5.72    | 0.6697                  | 2.1731                     | 0.5736*                           | 449.00                      |
| 23 | Telson length(mm)                    | 9   | 18      | 12.53   | 2.23    | 3.0403                  | 1.8323                     | 0.6927*                           | 1649.80                     |
| 24 | Brood Pouch Area (mm) <sup>2</sup>   | 252   | 662     | 546.55  | 120.29  | -0.0427                 | 1.5941                     | 0.7629*                           | 37.82                       |
| 25 | Brood Pouch volume (mm) <sup>3</sup> | 882   | 10736   | 6006.06 | 2210.15 | 1.5026                  | 0.7413                     | 0.6976*                           | 3.44                        |
|    | Absolute Fecundity                   | 5670  | 33662   | 20672   | 6617.93 |                         |                            |                                   |                             |

\* Significant at 1% level (P<0.01)

TABLE 10. Regression analysis of morphometric variables of *Uca* spp. (Decapoda, Crustacea) with fecundity. The regression equation is:  $Y = a + bX$ , where  $Y$  is fecundity (unit body diameter) and  $X$  is morphometric variable. The regression coefficient ( $b$ ) and correlation coefficient ( $r$ ) are given. The regression constant ( $a$ ) and standard deviation ( $SD$ ) are also given. The regression equation is:  $Y = a + bX$ , where  $Y$  is fecundity (unit body diameter) and  $X$  is morphometric variable. The regression coefficient ( $b$ ) and correlation coefficient ( $r$ ) are given. The regression constant ( $a$ ) and standard deviation ( $SD$ ) are also given.

| No | Morphometric Variable                | Results of regression analysis with fecundity |         |         |         |                        | Results of regression analysis with fecundity |                            |                                  |
|----|--------------------------------------|---|---------|---------|---------|------------------------|---|----------------------------|----------------------------------|
|    |                                      | Minimum                                       | Maximum | Mean    | SD      | Regression constant(a) | Regression coefficient(b)                     | Correlation coefficient(r) | Fecundity per unit body diameter |
| 1  | Total length(mm)                     | 98  | 118     | 107.67  | 7.87    | -0.3650                | 0.9402  | 0.8953*                    | 61.16                            |
| 2  | Total weight(g)                      | 4.75  | 8.53    | 6.26    | 1.44    | -0.2253                | 0.8761  | 0.7549*                    | 1051.93                          |
| 3  | Carepace length (mm)                 | 27  | 98      | 30.00   | 2.37    | 0.5289                 | 0.4612  | 0.5816*                    | 219.50                           |
| 4  | Rostral length(mm)                   | 26  | 32      | 28.00   | 2.10    | -0.4031                | 1.1782  | 0.5963*                    | 235.18                           |
| 5  | II. Ischium(mm)                      | 6   | 7       | 6.67    | 0.52    | 0.5068                 | 0.6966  | 0.5078*                    | 987.76                           |
| 6  | Merus(mm)                            | 7   | 8       | 7.83    | 0.41    | -0.7011                | 0.7777  | 0.4279                     | 840.65                           |
| 7  | Carpus(mm)                           | 12  | 15      | 13.17   | 1.17    | -2.6649                | 1.6454  | 0.7211*                    | 500.13                           |
| 8  | Propodus(mm)                         | 1   | 2       | 1.67    | 0.52    | 0.9813                 | 0.3168  | 0.2313                     | 3951.036                         |
| 9  | Dactylus(mm)                         | 0.5   | 1       | 0.83    | 0.26    | 0.8453                 | 0.2091  | 0.0660                     | 7902.07                          |
| 10 | second long cheliped length(mm)      | 27  | 33      | 30.17   | 2.38    | 1.0576                 | 0.4101  | 0.6032                     | 218.29                           |
| 11 | II. Ischium(mm)                      | 3   | 6       | 5.33    | 1.21    | 0.2949                 | 0.9888  | 0.5853                     | 1234.70                          |
| 12 | Merus(mm)                            | 4   | 6       | 4.83    | 0.98    | 0.2269                 | 0.8280  | 0.8370*                    | 1362.43                          |
| 13 | carpus(mm)                           | 2   | 7       | 5.50    | 1.76    | 0.4285                 | 0.8172  | 0.9164*                    | 1197.28                          |
| 14 | Propodus(mm)                         | 2   | 6       | 3.83    | 1.33    | 0.1619                 | 0.5988  | 0.1318                     | 1717.84                          |
| 15 | Dactylus(mm)                         | 1.5   | 3       | 2.08    | 0.49    | 0.2920                 | 0.5767  | 0.0694                     | 3160.83                          |
| 16 | second short cheliped length(mm)     | 14.5  | 27      | 21.58   | 4.10    | 0.8429                 | 0.6320  | 0.4700                     | 305.10                           |
| 17 | I. Abdominal segment(mm)             | 23  | 29      | 24.83   | 2.32    | 0.9761                 | 0.5195  | 0.3971                     | 265.17                           |
| 18 | V. Abdominal segment(mm)             | 33  | 37      | 35.17   | 1.83    | 1.4317                 | 0.1445  | 0.2730                     | 187.25                           |
| 19 | II Pleural width(mm)                 | 5   | 10      | 7.67    | 1.97    | 0.6923                 | 0.1638  | 0.0754                     | 858.92                           |
| 20 | Brood pouch Width(mm)                | 8   | 12      | 10.17   | 1.33    | -0.6121                | 1.1360  | 0.2485                     | 647.71                           |
| 21 | Brood pouch depth(mm)                | 4   | 11      | 7.17    | 2.79    | 0.6640                 | 0.7179  | 0.8586*                    | 918.85                           |
| 22 | Brood pouch length(mm)               | 29  | 34      | 32.50   | 1.87    | 1.0217                 | 0.5010  | 0.5555                     | 202.62                           |
| 23 | Telson length(mm)                    | 15  | 19      | 17.17   | 1.47    | 0.4783                 | 1.2414  | 0.7460*                    | 383.60                           |
| 24 | Brood Pouch Area (mm) <sup>2</sup>   | 116   | 352     | 234.00  | 92.80   | 0.3584                 | 0.8069  | 0.5465                     | 28.14                            |
| 25 | Brood Pouch volume (mm) <sup>3</sup> | 952   | 3168    | 1803.50 | 940.72  | 0.4934                 | 0.7212  | 0.5459                     | 3.65                             |
|    | Absolute Fecundity                   | 564.4   | 17472   | 6585.06 | 5556.95 |                        |   |                            |                                  |

\* Significant at 1% level(P<0.01)



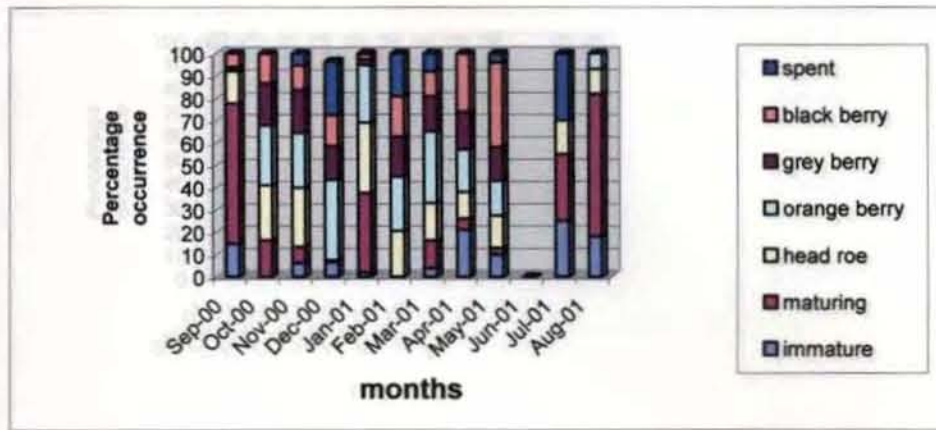
**Table 8.6** Average values of morphometric measurements and relative fecundity in different colors of embryonic development of *Heterocarpus woodmasoni*

| No. | Berry colour | Number of observations | Mean total length (mm) | Mean total weight (mg) | Mean carapace length (mm) | Mean rostral length (mm) | Mean absolute fecundity (no.) | Relative fecundity Fec./TW (no.) | Relative fecundity Fec./TL (no.) | Relative fecundity Fec./CL (no.) |
|-----|--------------|------------------------|------------------------|------------------------|---------------------------|--------------------------|-------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 1   | orange       | 11                     | 101.83                 | 5.42                   | 28.41                     | 24.65                    | 8143.69                       | 690.25                           | 92.07                            | 340.51                           |
| 2   | grey         | 7                      | 114.51                 | 6.73                   | 29.95                     | 26.61                    | 8250.31                       | 891.41                           | 96.12                            | 339.96                           |
| 3   | black        | 6                      | 113.29                 | 6.01                   | 29.01                     | 25.37                    | 5899.95                       | 761.51                           | 88.75                            | 216.81                           |

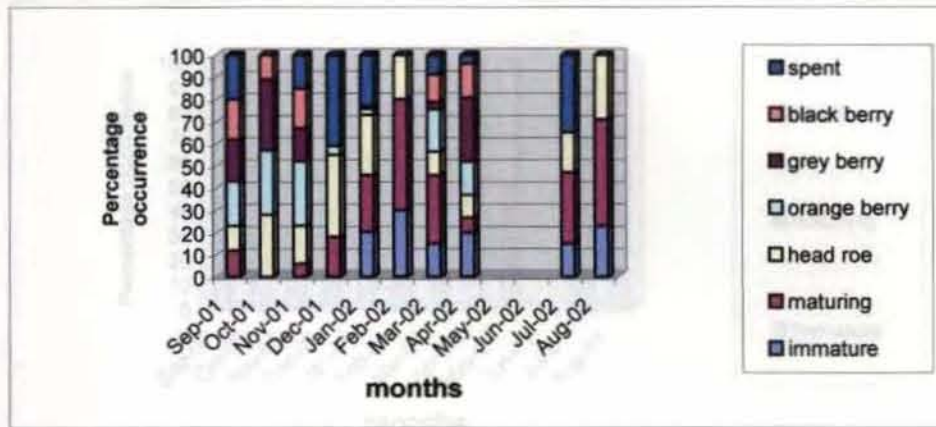
**Table 8.7** Average values of morphometric measurements and relative fecundity in different length groups of *Heterocarpus woodmasoni*

| No. | Berry colour | Number of observations | Mean total length (mm) | Mean total weight (mg) | Mean carapace length (mm) | Mean rostral length (mm) | Mean absolute fecundity (no.) | Relative fecundity Fec./TW (no.) | Relative fecundity Fec./TL (no.) | Relative fecundity Fec./CL (no.) |
|-----|--------------|------------------------|------------------------|------------------------|---------------------------|--------------------------|-------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 1   | 90-100       | 6                      | 95                     | 4.87                   | 27                        | 22.5                     | 4369.50                       | 899.72                           | 45.91                            | 161.83                           |
| 2   | 100-110      | 13                     | 104.67                 | 5.53                   | 29.33                     | 29                       | 5668.13                       | 1033.23                          | 54.54                            | 191.23                           |
| 3   | 110-120      | 5                      | 117                    | 7.77                   | 32.5                      | 27.5                     | 10146.00                      | 1411.52                          | 89.91                            | 323.28                           |

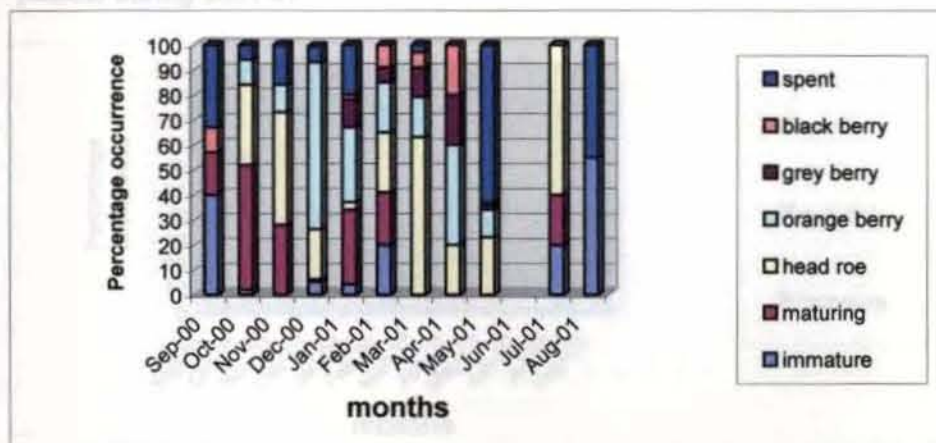
**Fig. 8.1** Seasonal variation of maturity stages in *Heterocarpus woodmasoni* (Females) during 2000-01



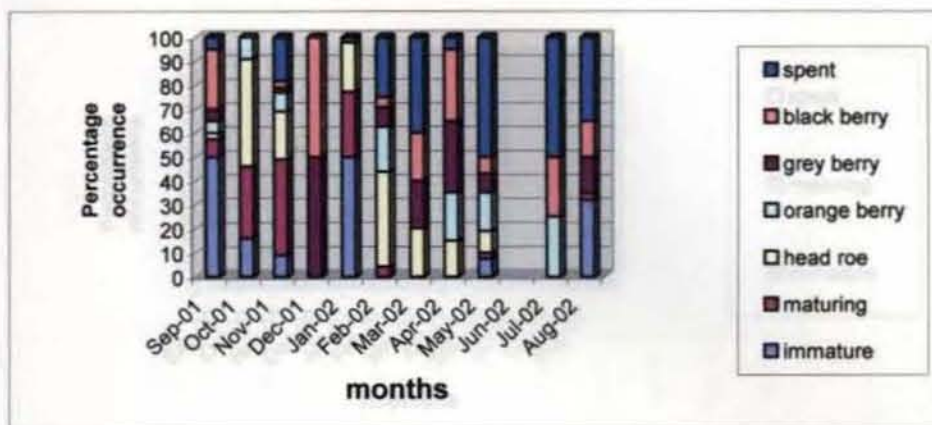
**Fig. 8.2** Seasonal variation of maturity stages in *Heterocarpus woodmasoni* (Females) during 2001-02



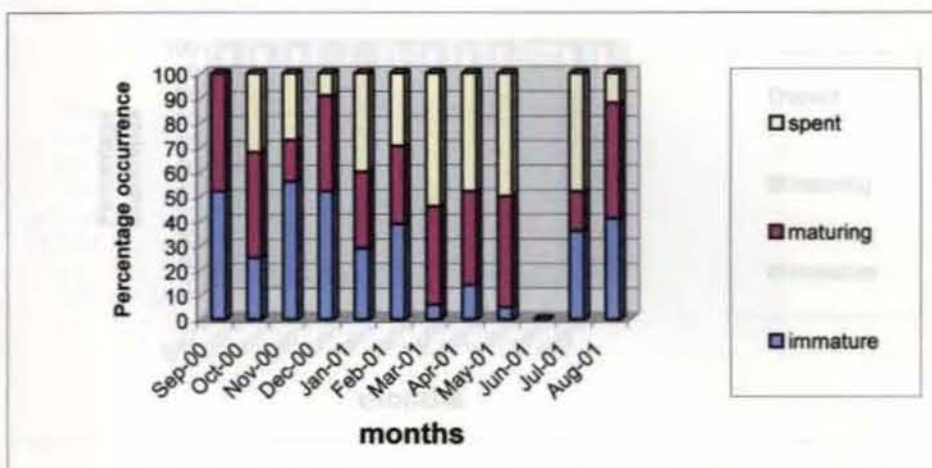
**Fig. 8.3** Seasonal variation of maturity stages in *Heterocarpus gibbosus* (Females) during 2000-01



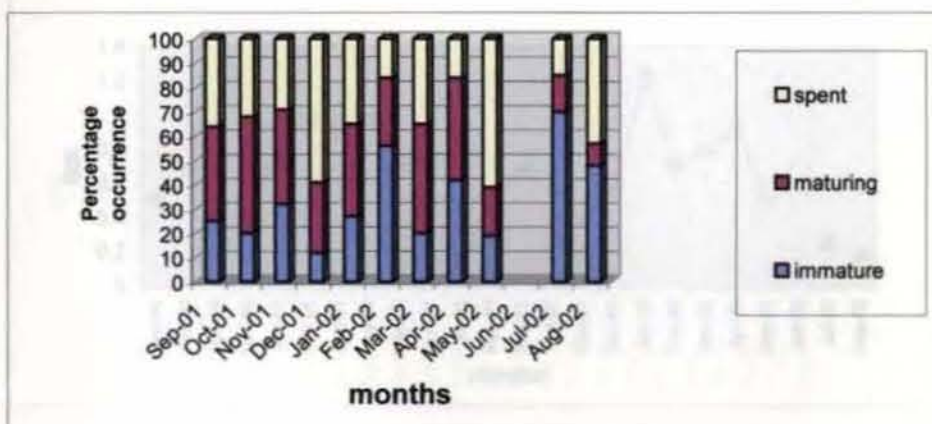
**Fig. 8.4** Seasonal variation of maturity stages in *Heterocarpus gibbosus* (Females) during 2001-02



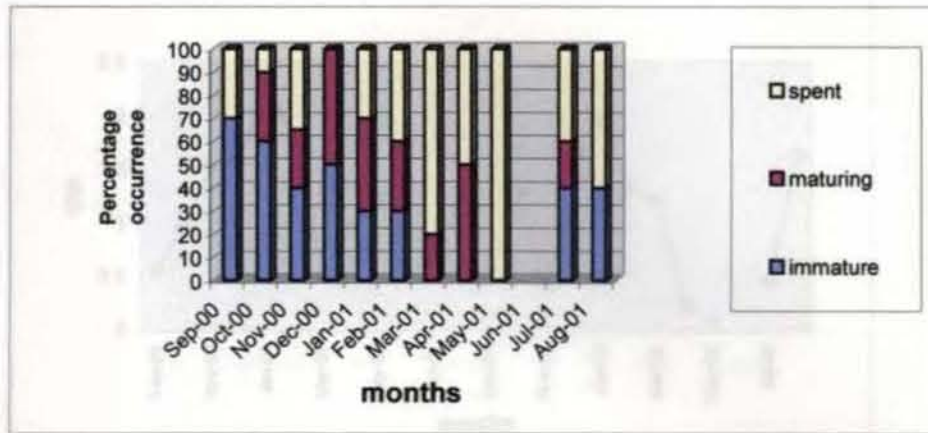
**Fig. 8.5** Seasonal variation of maturity stages in *Heterocarpus woodmasoni* (Males) during 2000-01



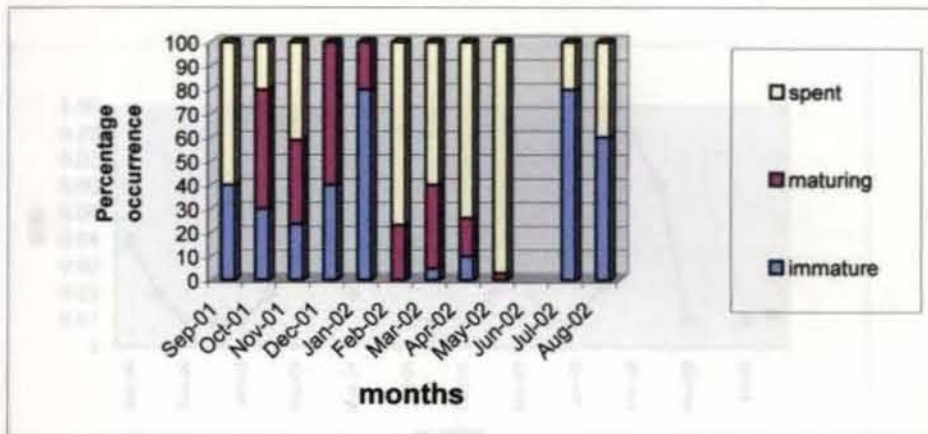
**Fig. 8.6** Seasonal variation of maturity stages in *Heterocarpus woodmasoni* (Males) during 2001-02



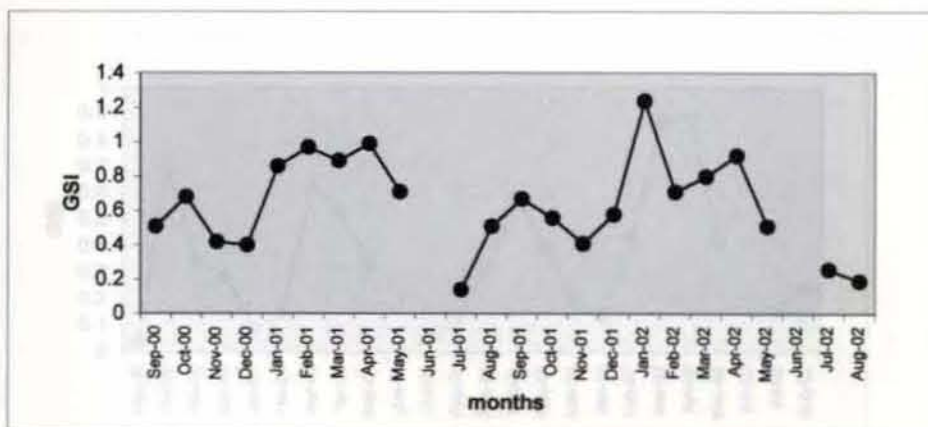
**Fig. 8.7** Seasonal variation of maturity stages in *Heterocarpus gibbosus* (Males) during 2000-01



**Fig. 8.8** Seasonal variation of maturity stages in *Heterocarpus gibbosus* (Males) during 2001-02

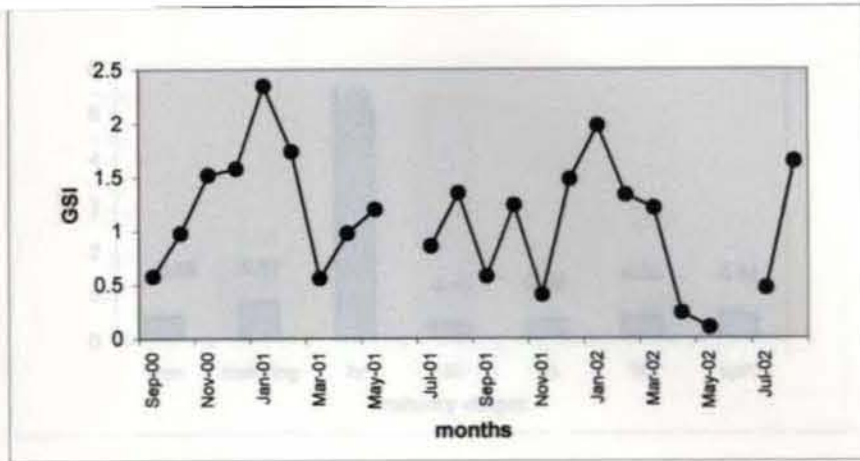


**Fig. 8.9** Variation in the gonadosomatic index of *Heterocarpus woodmasoni* (Male)

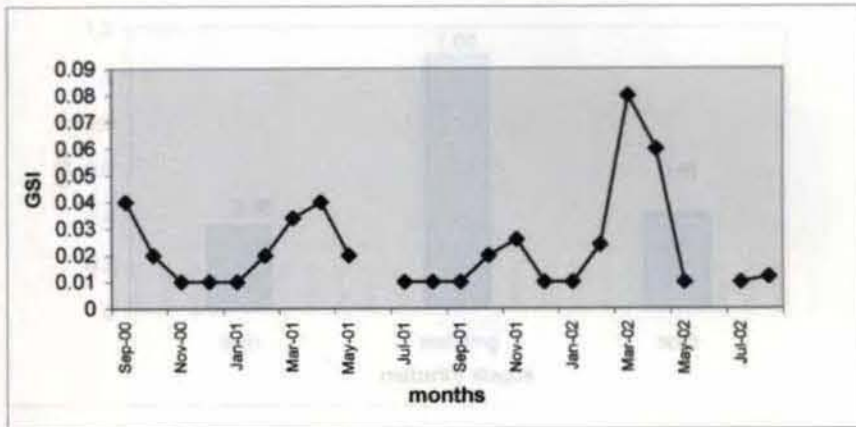




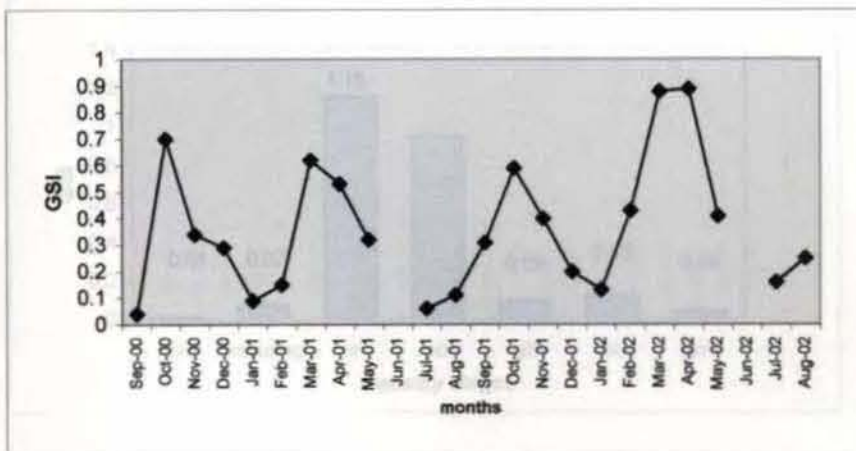
**Fig. 8.10** Variation in the gonadosomatic index of *Heterocarpus woodmasoni* (Female)



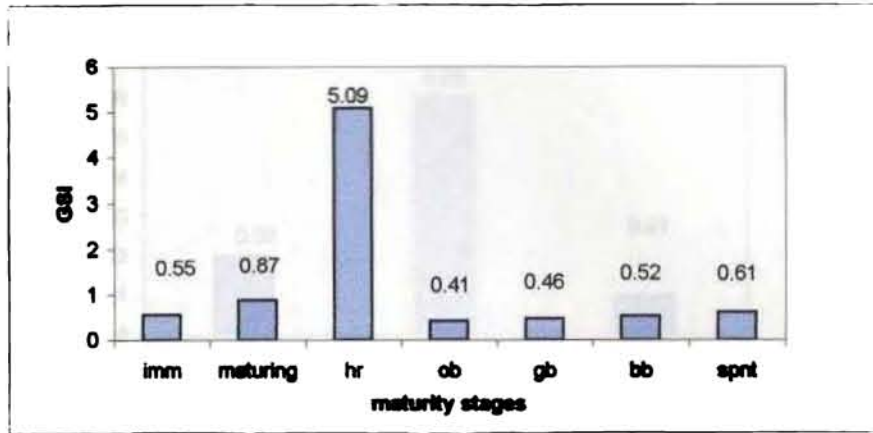
**Fig. 8.11** Variation in the gonadosomatic index of *Heterocarpus gibbosus* (Male)



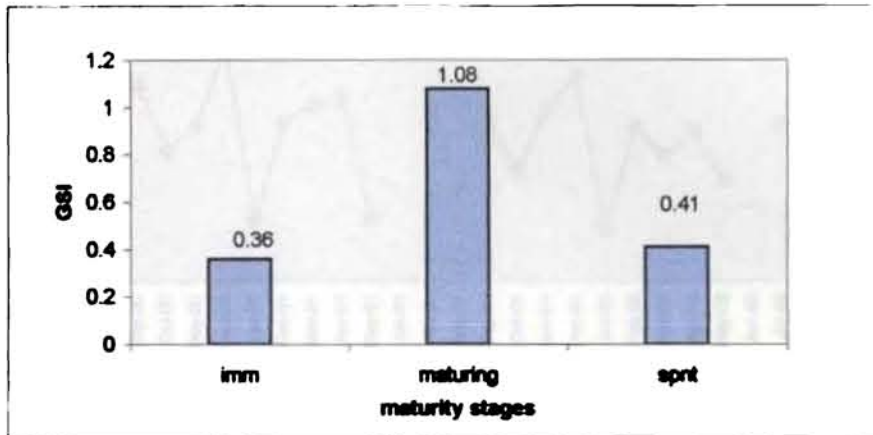
**Fig. 8.12** Variation in the gonadosomatic index of *Heterocarpus gibbosus* (Female)



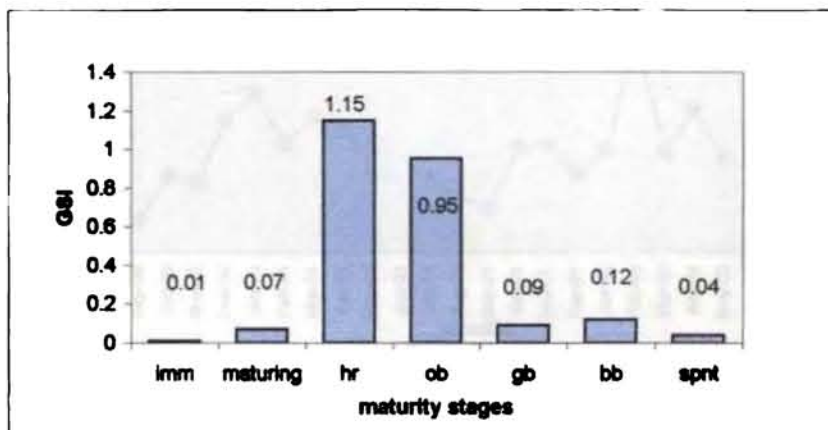
**Fig. 8.13** Variation in the gonadosomatic index in various maturity stages of *Heterocarpus woodmasoni* (Female)



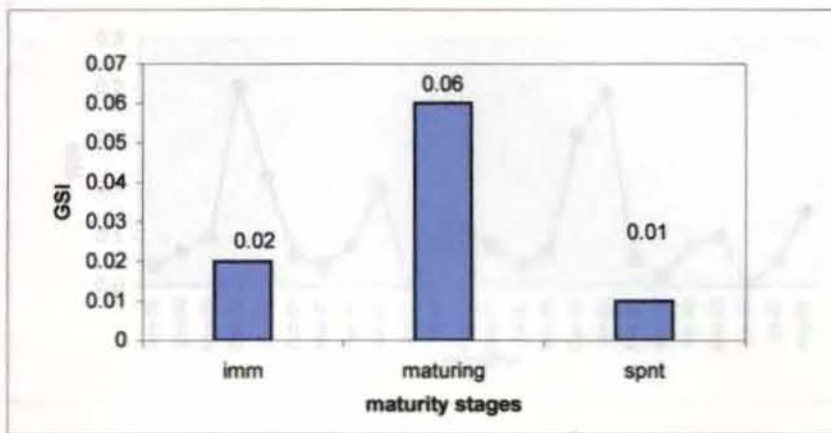
**Fig. 8.14** Variation in the gonadosomatic index in various maturity stages of *Heterocarpus woodmasoni* (Male)



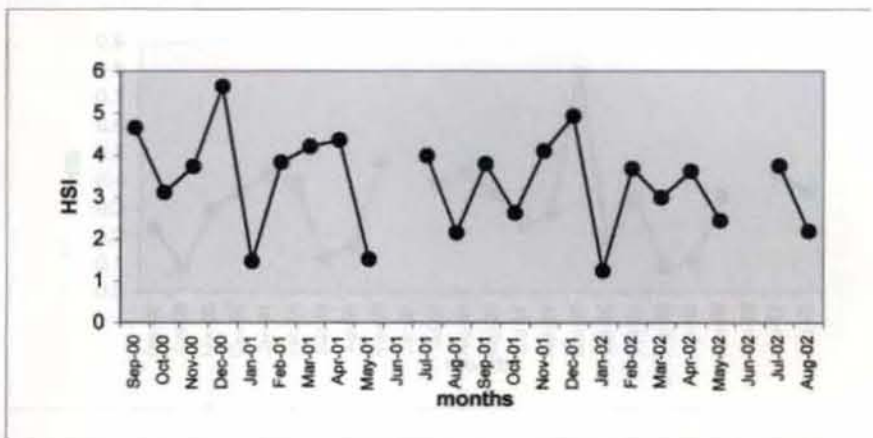
**Fig. 8.15** Variation in the gonadosomatic index in various maturity stages of *Heterocarpus gibbosus* (Female)



**Fig. 8.16** Variation in the gonadosomatic index in various maturity stages of *Heterocarpus gibbosus* (Male)



**Fig. 8.17** Variation in the hepatosomatic index of *Heterocarpus woodmasoni* (Female)



**Fig. 8.18** Variation in the hepatosomatic index of *Heterocarpus woodmasoni* (Male)

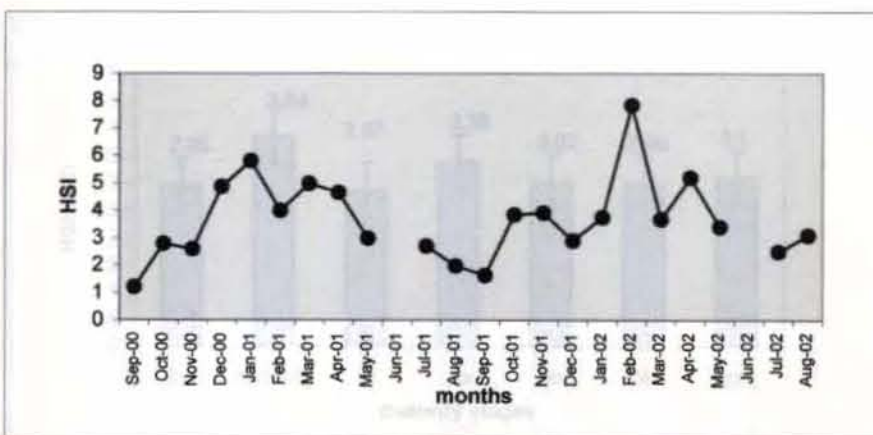


Fig. 8.19 Variation in the hepatosomatic index of *Heterocarpus gibbosus* (Male)

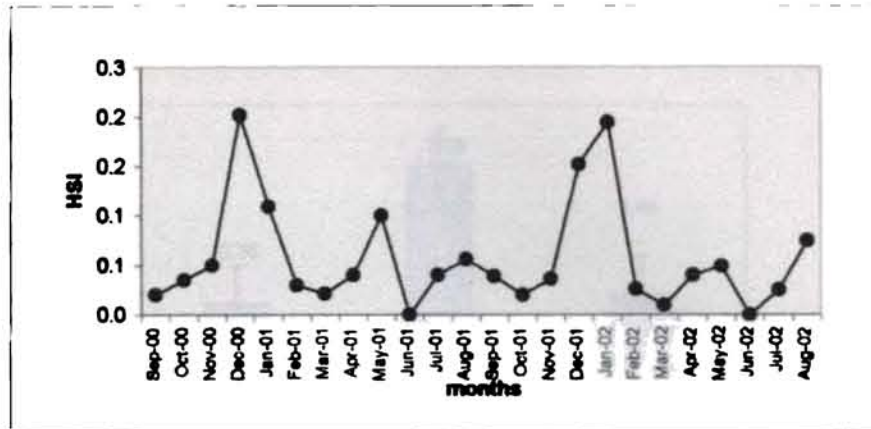


Fig. 8.20 Variation in the hepatosomatic index of *Heterocarpus gibbosus* (Female)

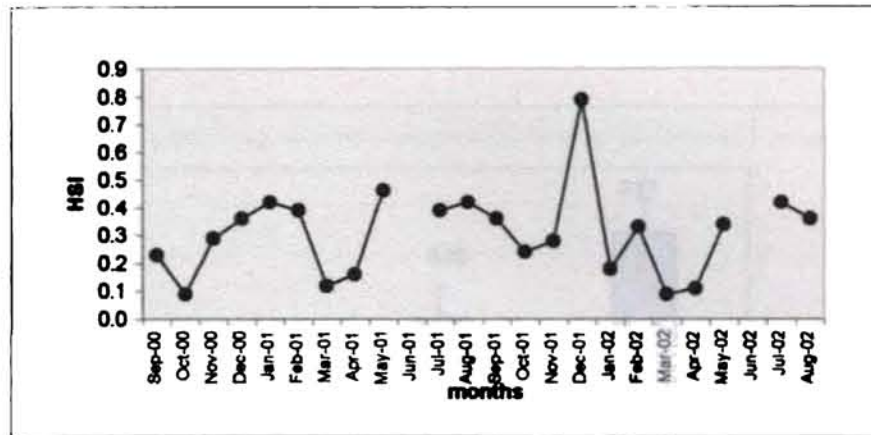
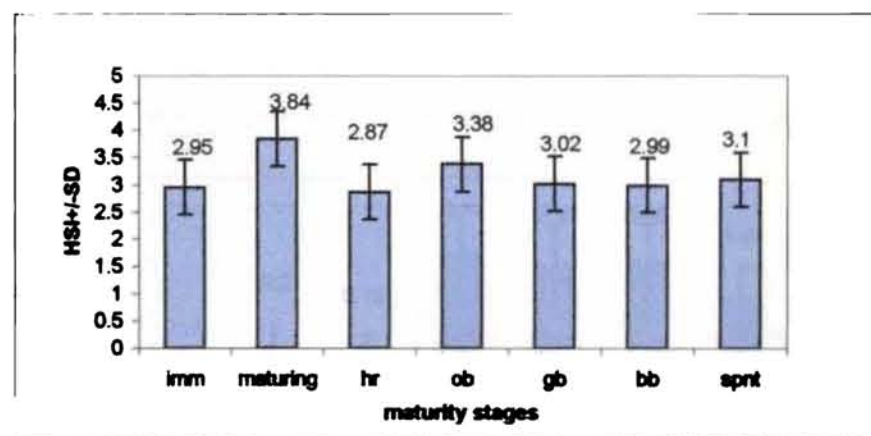
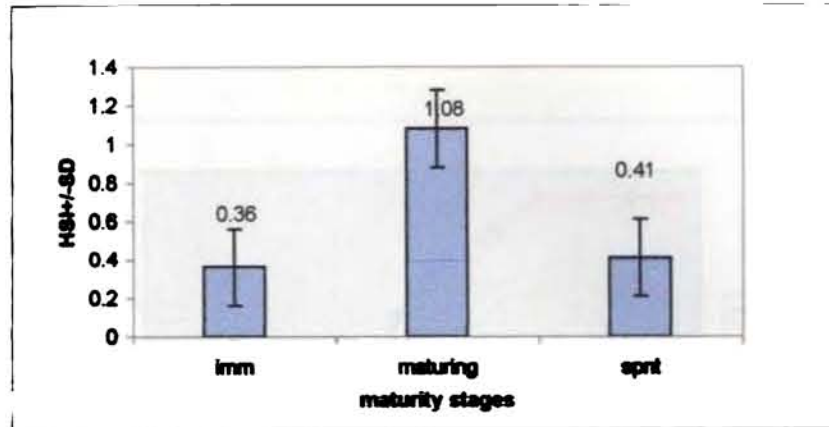


Fig. 8.21 Variation in the hepatosomatic index in various maturity stages of *Heterocarpus woodmasoni* (Female)

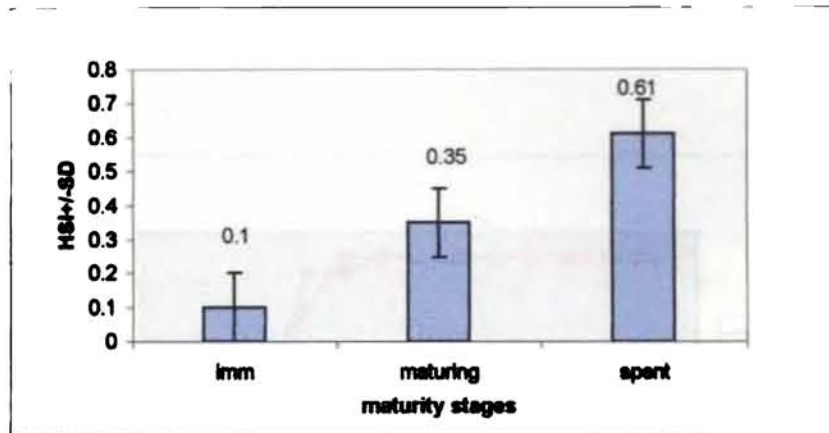




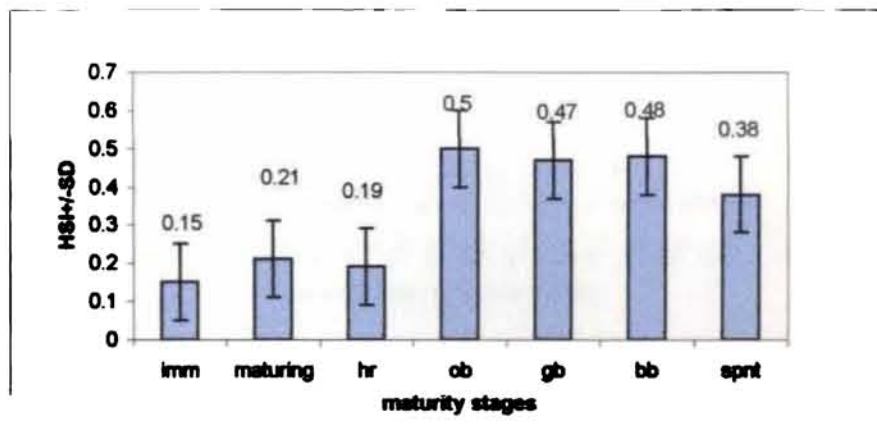
**Fig.8. 22 Variation in the hepatosomatic index in various maturity stages of *Heterocarpus woodmasoni* (Male)**



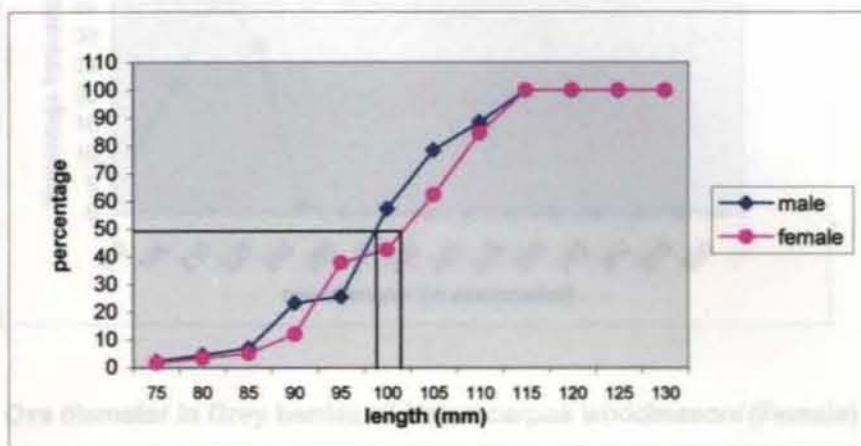
**Fig.8. 23 Variation in the hepatosomatic index in various maturity stages of *Heterocarpus gibbosus* (Male)**



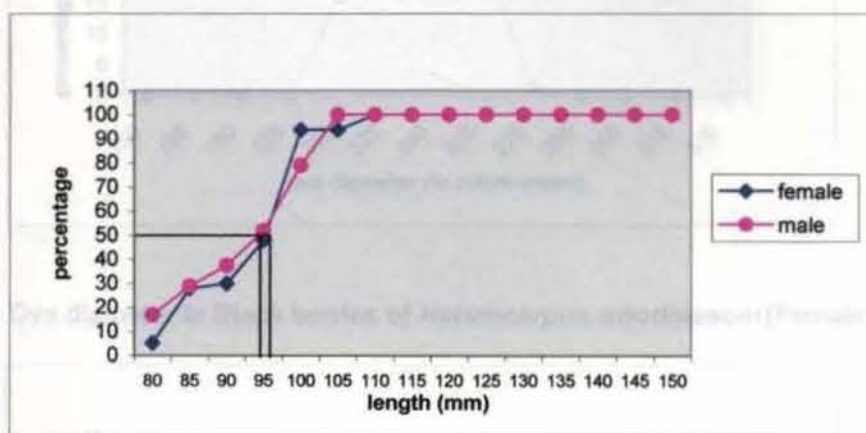
**Fig.8. 24 Variation in the hepatosomatic index in various maturity stages of *Heterocarpus gibbosus* (Female)**



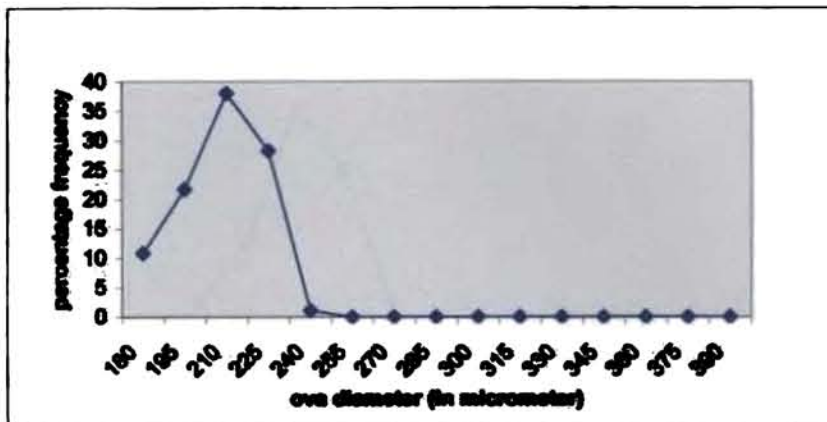
**Fig. 8.25** Size at first maturity of *Heterocarpus woodmasoni* (Male and Female)



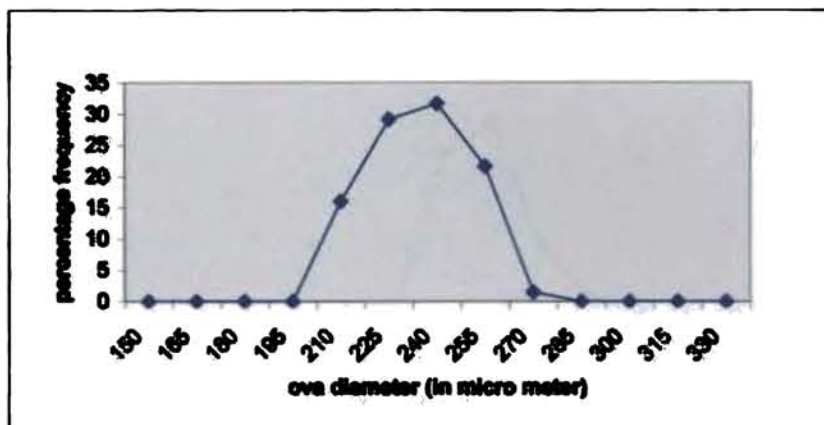
**Fig. 8.26** Size at first maturity of *Heterocarpus gibbosus* (Male and Female)



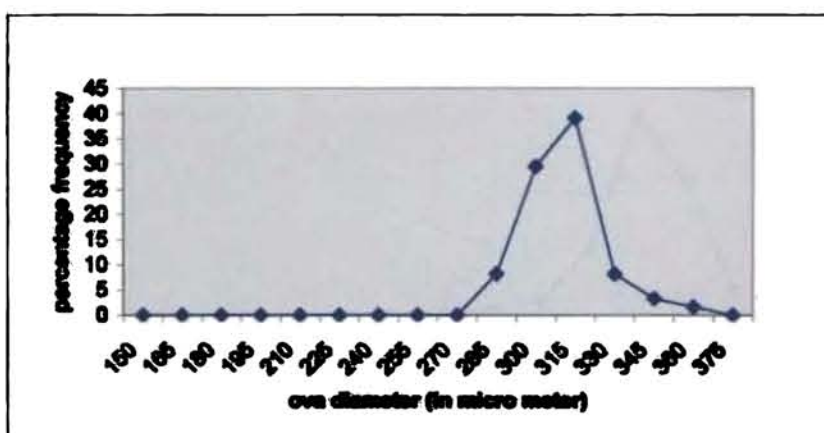
**Fig. 8.27 Ova diameter in Orange berries of *Heterocarpus woodmasoni* (Female)**



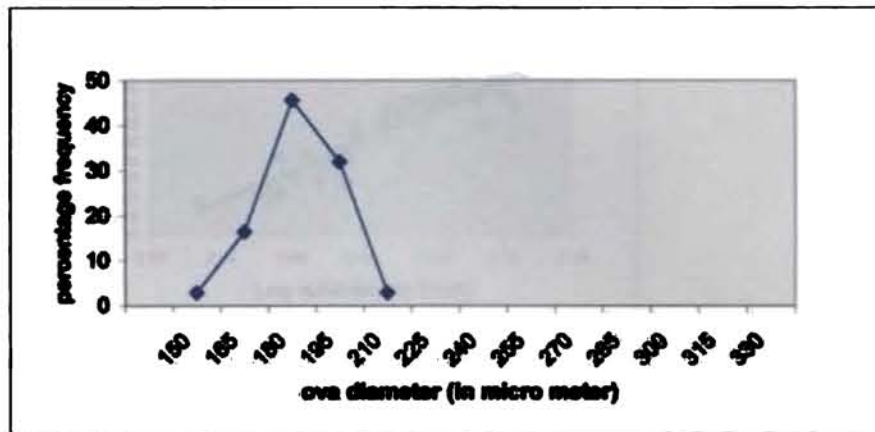
**Fig. 8.28 Ova diameter in Grey berries of *Heterocarpus woodmasoni* (Female)**



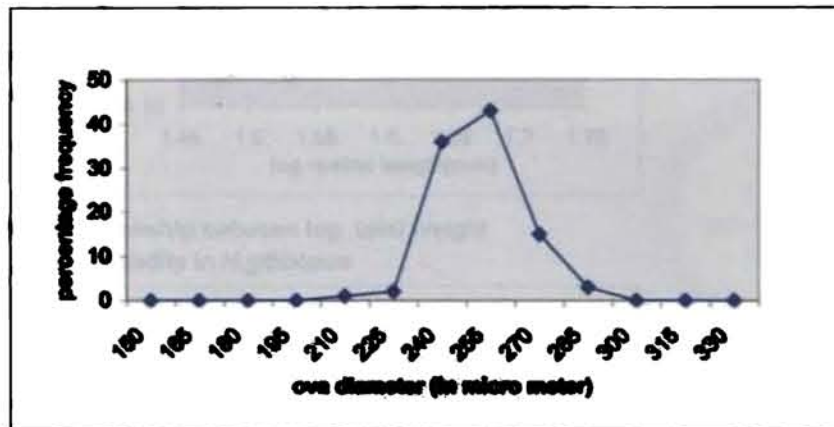
**Fig. 8.29 Ova diameter in Black berries of *Heterocarpus woodmasoni* (Female)**



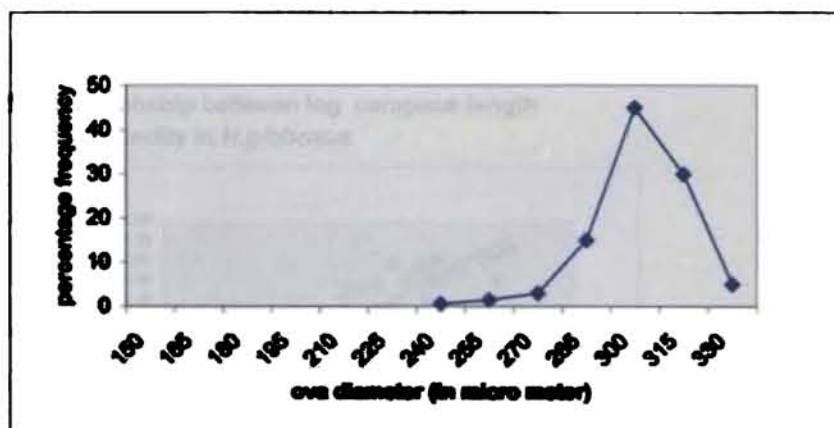
**Fig. 8.30 Ova diameter in Orange berries of *Heterocarpus gibbosus* (Female)**



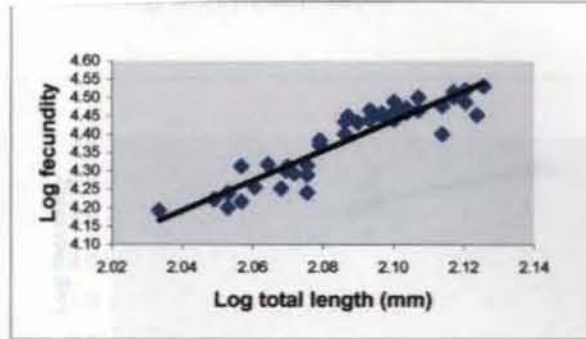
**Fig. 8.31 Ova diameter in Grey berries of *Heterocarpus gibbosus* (Female)**



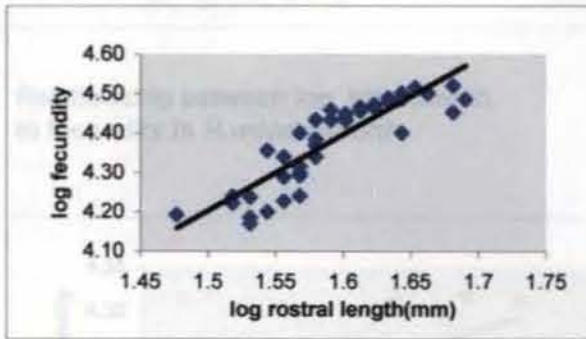
**Fig. 8.32 Ova diameter in Black berries of *Heterocarpus woodmasoni* (Female)**



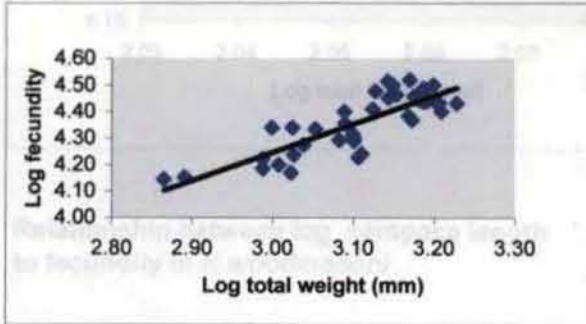
**Fig. 8.33** Relationship between log total length to fecundity in *H.gibbosus*



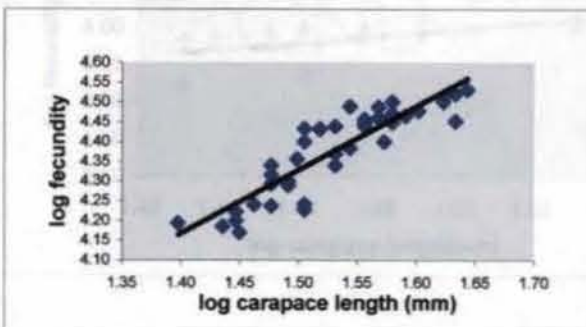
**Fig. 8.34** Relationship between log rostral length to fecundity in *H.gibbosus*



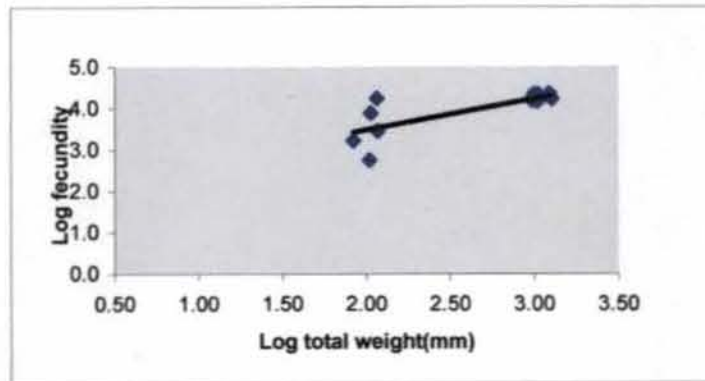
**Fig. 8.35** Relationship between log total weight to fecundity in *H.gibbosus*



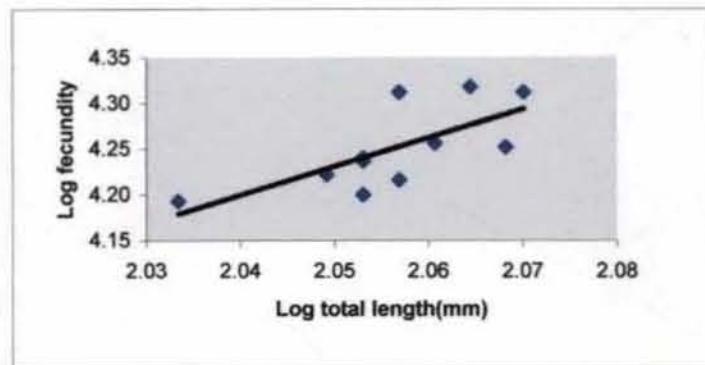
**Fig. 8.36** Relationship between log carapace length to fecundity in *H.gibbosus*



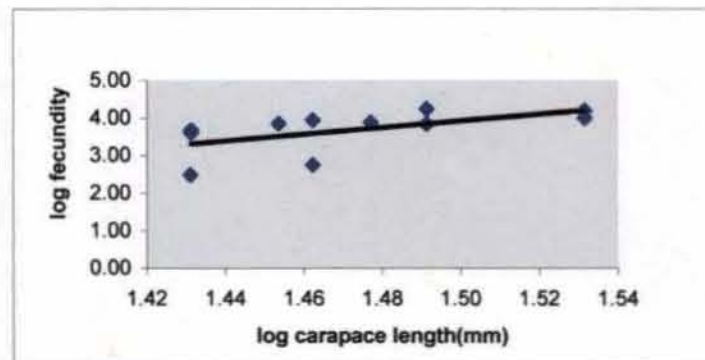
**Fig. 8.37** Relationship between log total weight to fecundity in *H.woodmasoni*



**Fig. 8.38** Relationship between log total length to fecundity in *H.woodmasoni*



**Fig. 8.39** Relationship between log carapace length to fecundity in *H.woodmasoni*





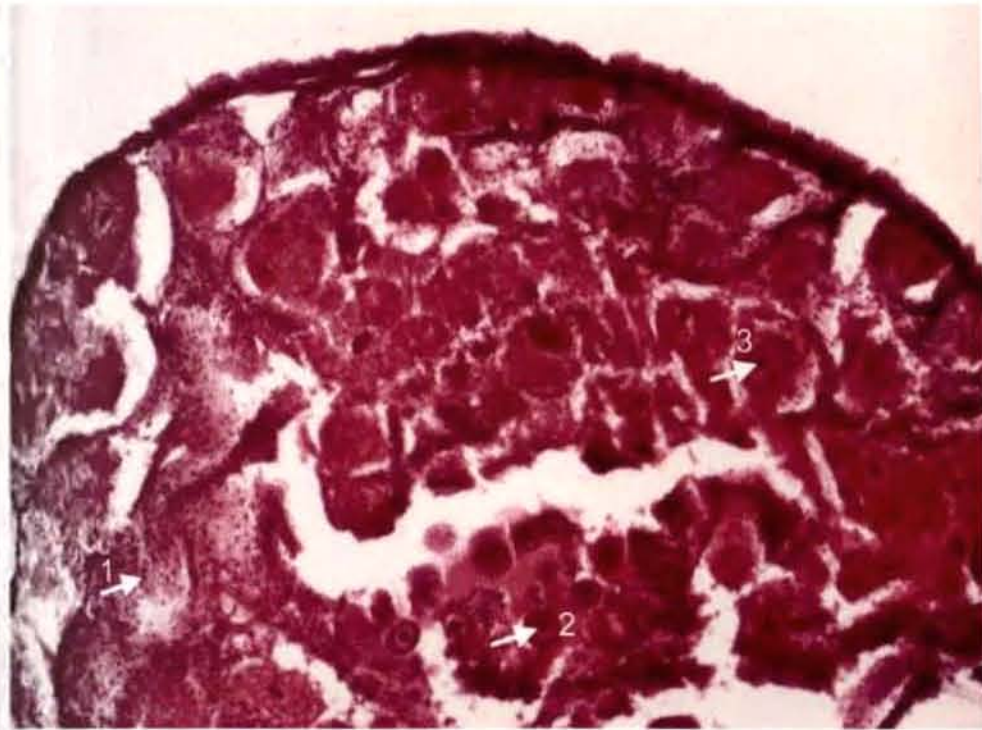


Plate 8.1 A: Sectional view of ovary of *H.gibbosus* showing oocytes in different stages of development (X 40) (1-follicular cells, 2 - oocytes , 3- oogonial cells).

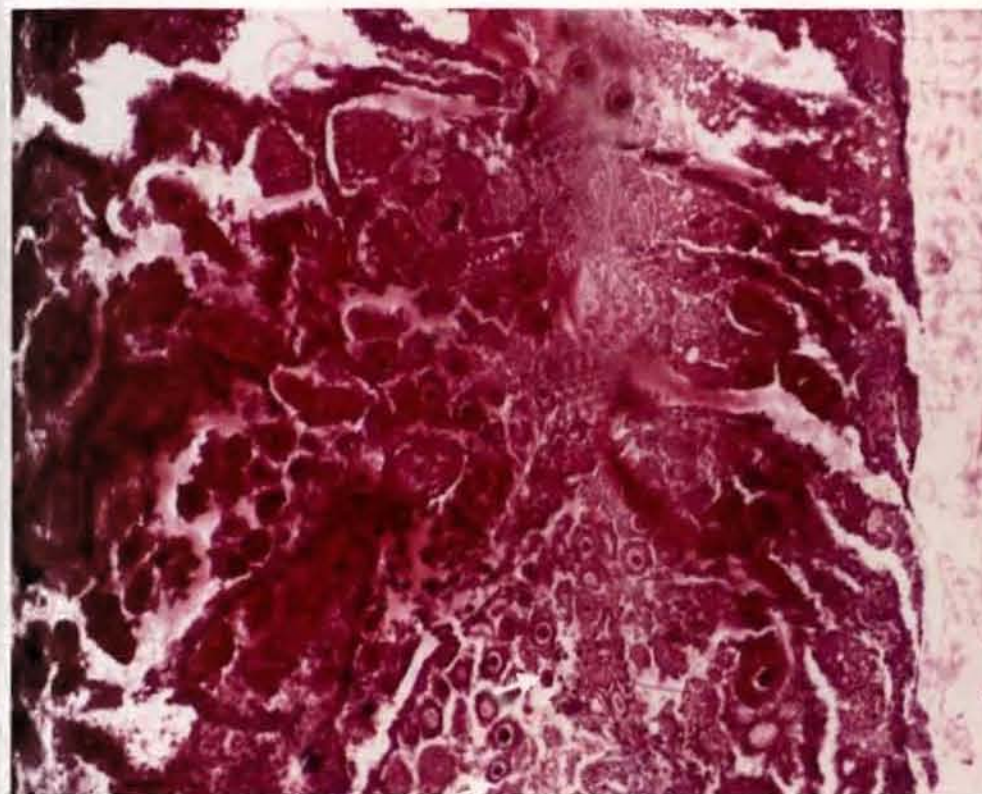
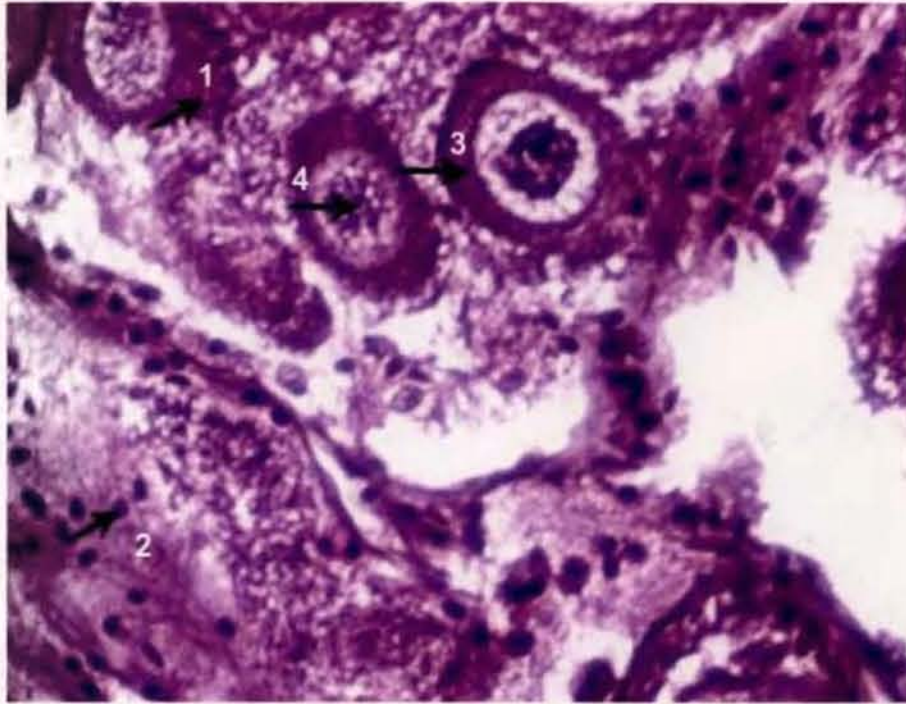
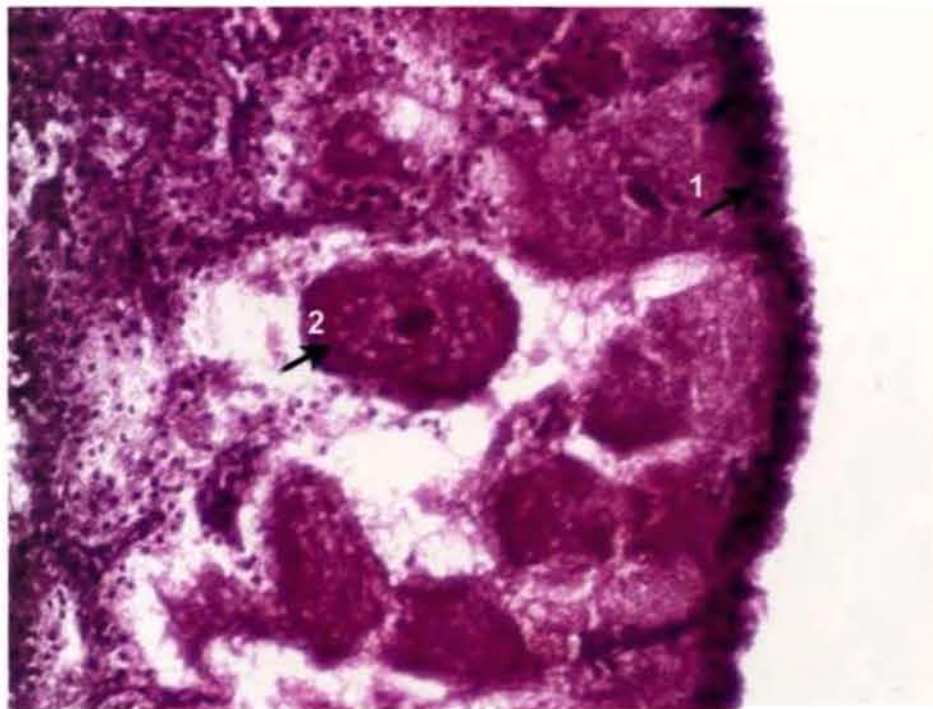


Plate 8.1 B: Germinal zone showing clusters of oogonial cells in the ovary of *H.gibbosus* ( X 40) . (1- oogonial cells ,2- nucleus )

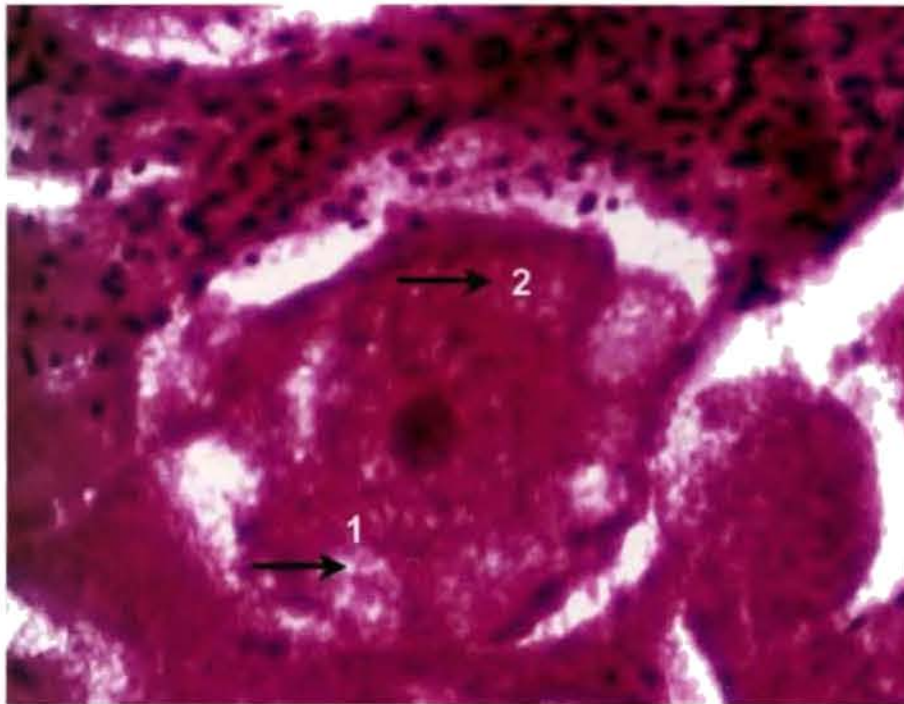


**Plate 8.2 A: Early vitellogenic oocytes with central nuclei and granular oocortex in the ovary of *H.gibbosus* ( X 100) (1- vitellogenic oocytes,2-Follicular cells ,3- Germinal vesicle,4 - nucleoli )**

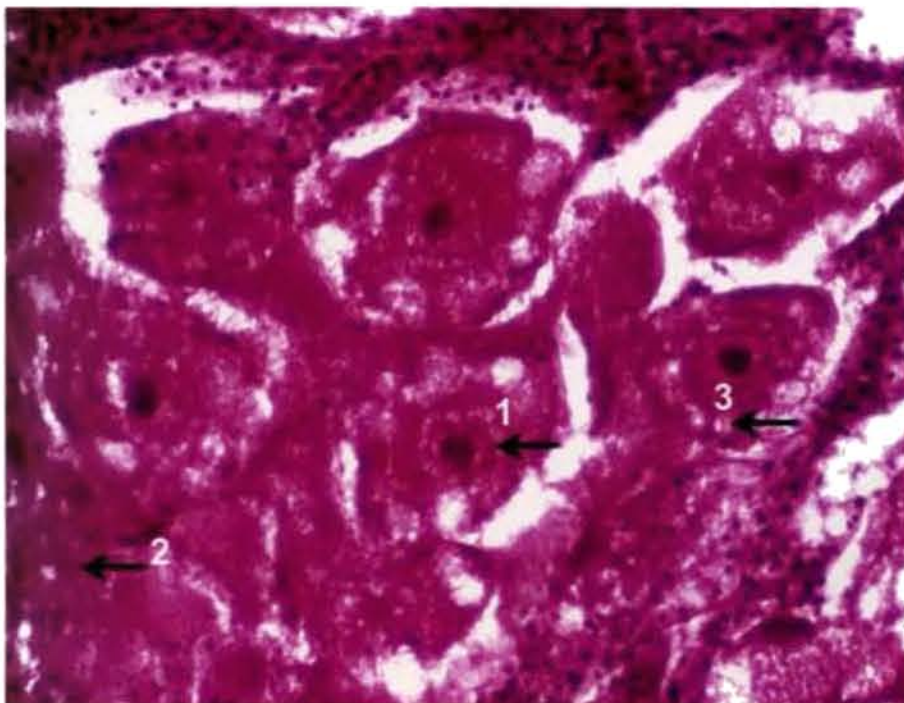


**Plate 8.2 B : Vitellogenic oocytes showing perinuclear eosinophilic granules ( X 100) in the ovary of *H.gibbosus*. ( 1-Perinuclear ring,2-ovarian wall)**

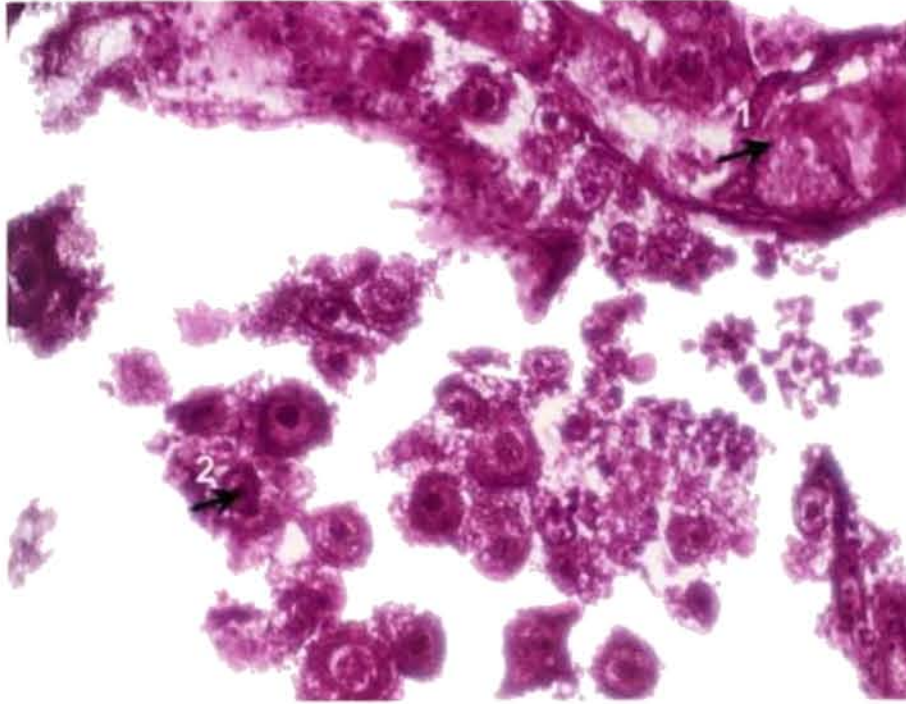




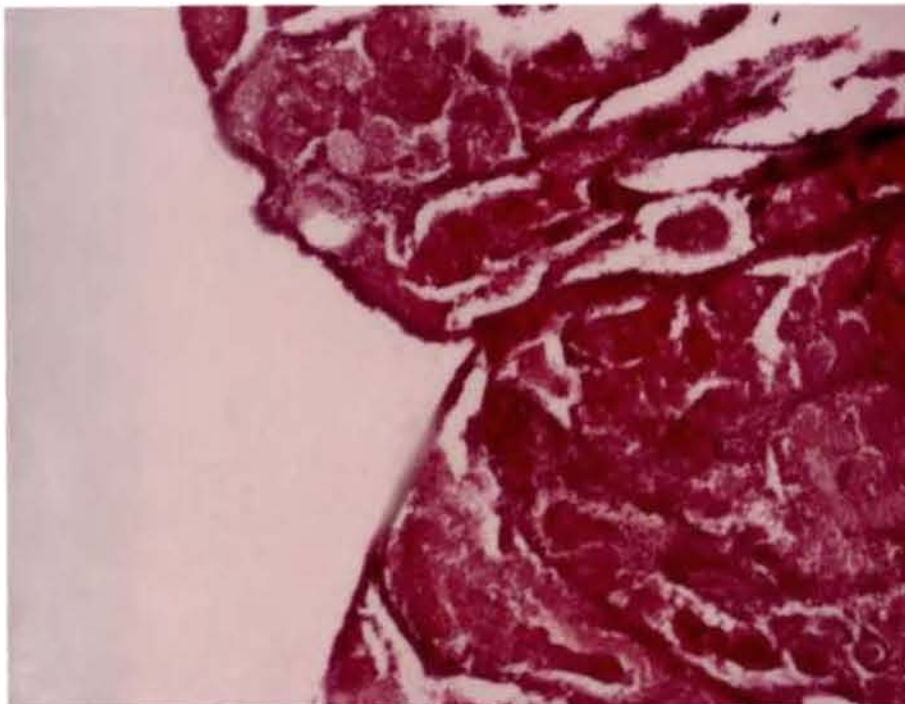
**Plate 8.3 : Oocytes showing yolk droplets (X 100) in the ovary of *H.gibbosus*. (1- Yolk droplets, 2 – germinal vesicle)**



**Plate 8.4 : Matured oocytes showing eosinophilic yolk droplets, ( X 100 ) in the ovary of *H.gibbosus*. (1- matured oocytes ,2- degenerative oocytes , 3- yolk droplets )**



**Plate 8.5 A: Oocytes with central nuclei and granular oocortex ( X 10 ) in the ovary of *H.woodmasoni*. (1- oocortex , 2- nucleus )**



**Plate 8.5 B: Bilobed ovary of *H.woodmasoni* showing clusters of vitellogenic and matured oocytes ( X 10 ) in the germinal zone**



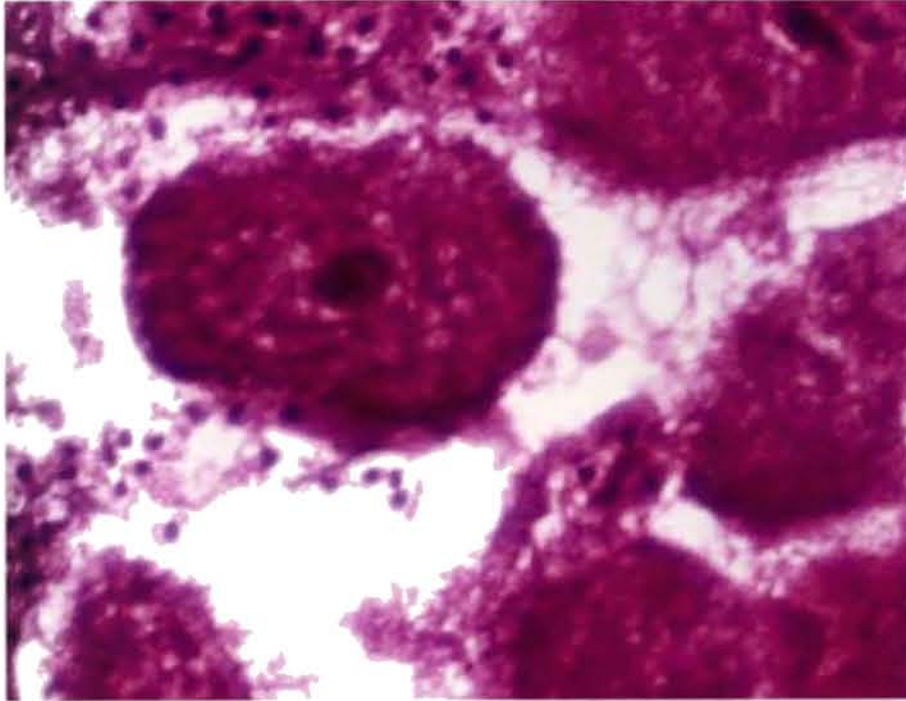


Plate 8.6 A: vitellogenic oocytes in the ovary of *H.woodmasoni*

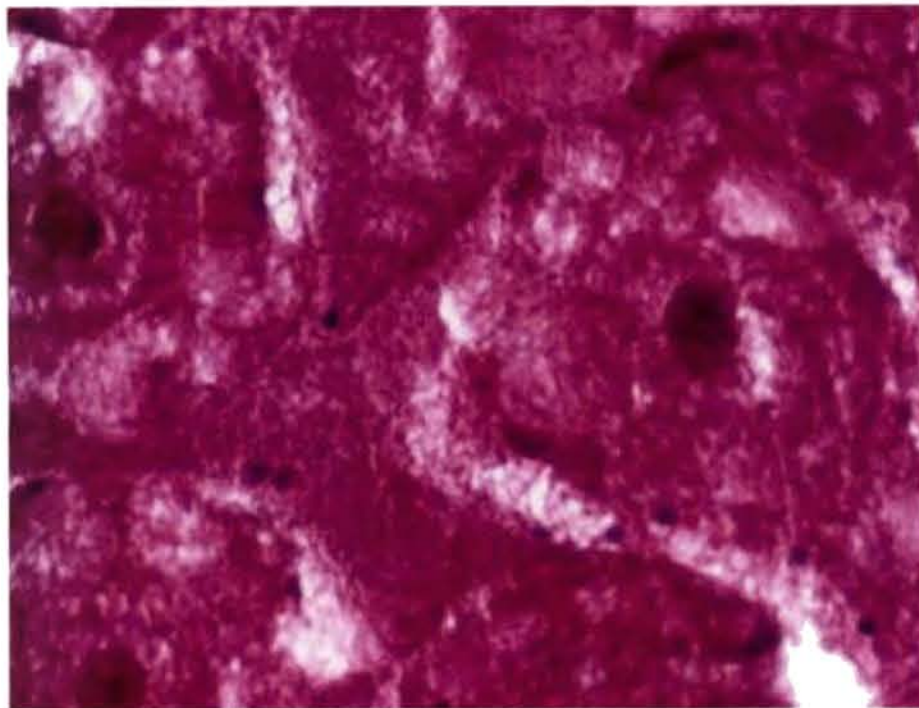


Plate 8.6 B: Matured oocytes in the ovary of *H.woodmasoni*



Plate 8.7 A: Dorsal view of male *Heterocarpus gibbosus* (carapace removed) showing immature gonad



Plate 8.7 B: Dorsal view of female *Heterocarpus gibbosus* showing head roe through carapace



Plate 8. 8 A: Ventral view of grey berried female of *Heterocarpus gibbosus* showing eggs with advanced embryonic stages.



Plate 8.8 B : Lateral view of black berried *H.woodmasoni* showing extruded eggs.





Plate 8.9 A: Lateral view of female black-berried *Heterocarpus gibbosus* showing extruded eggs attached to pleopodal setae.



Plate 8.9 B : Dorsal view of female *Heterocarpus woodmasoni* with spent ovaries



Plate 8.10 : Dorsal view of female *Heterocarpus gibbosus* showing spent ovaries through carapace.

**Chapter 9**

**CAROTENOID ESTIMATION AND PROXIMATE  
ANALYSIS**



## 9.1. INTRODUCTION

Deep water prawns are characterized by very distinct life history traits such as extreme longevity, late age of maturity, slow growth rate and low fecundity, very high lipid content and vibrant coloration (Company and Sardá, 1997). It is generally accepted that the colour of the deep sea prawns is considered as one of the most important quality parameters. From the point of taking decisions on purchase of deep sea shrimps and red salmons, the general consumers perception is that the reddish coloration of both the shrimps and salmons are considered as an index of freshness, better flavor, higher quality and higher price. Therefore, color plays a decisive role when evaluating the quality of the product at point of sale. The coloration, which is the resultant product of deposition of carotenoids, is considered to be of significant in behavioral importance of animals. Carotenoids in prawns are seen dissolved in fatty acid droplets present in the eggs, gonad and exoskeleton. These pigments ingested through the food is converted and deposited in tissues of muscle and hepatopancreas subsequently being mobilized to the gonad for maturation (Harrison, 1990).

A review of literature shows that no concerted attempt has so far been made to evaluate biochemical as well as carotenoid variation commensurate with the change in phases of reproduction in deep sea

prawns though detailed information on the lipid and carotenoid concentration of a variety of coastal decapod crustaceans are provided by Fisher (1962) and Fisher *et al.* (1952, 1953, 1954, 1957). The role of diet in imparting colouration to various organs in rainbow trouts was demonstrated by Hubbs and Stavenhagen (1958). It has been well documented that the diet is presumably responsible for differences in carotenoid pigmentation (Storebakken *et al.*, 1987; Choubert and Storebakken, 1989; Bjerkeng *et al.*, 1992). The ingested carotenoids accumulate in the liver and muscle during the breeding season and are mobilized to gonad as they ripen (Torrissen, 1989). The carotenoid pigment composition and distribution in decapods have also been the subject of separate investigation on species of both Natantia (Tsukuda, 1963; Larry and Salwin, 1966; Ishikawa *et al.*, 1966; Czerpak and Czczuga, 1969; Katayama *et al.*, 1972) and more frequently Reptantia (Goodwin and Srisukh, 1949; Wolfe and Cornwell, 1964; 1965). Most of these animals examined were shallow-water species while Herring (1973) studied the depth wise variation of carotenoid pigments and lipids in deep water decapod crustaceans *Acantheephyra pelagica*, *Systllaspis debilis* and *Gennadas brevirostris*. In Indian waters, Lethakutty (1993) studied the mobilization of total carotenoids in relation ovarian maturation in *Mdobsoni* while Krishnakumar *et al.* (1987) studied the carotenoid content of *Perna viridis*. Patnaik (2001) reported the mobilization pattern

of total carotenoids with the progress of maturation in the demersal fish *Pnacanthus hamrur* from Cochin coast.

Biochemical changes in relation to reproductive cycles and the sexual periodicities of invertebrates hailing from different parts of the world have been studied extensively by many workers. Seasonal variation in different organic constituents of oysters had been reported by Russel (1923), Okazaki and Kobayashi (1929), Sekine *et al.* (1930), Tully (1936) and Humphrey (1941). Castle and Lawrence (1989) reported the relationship between maturation and biochemical composition of gonad and digestive gland in *Penaeus aztecus* and *P.setiferus* while Teshima *et al.* (1989) investigated the variation in lipid profile of ovary and hepatopancreas during maturation in *P.japonicus*. Read and Caulton (1981) studied the changes in body composition in relation to moulting and ovarian development in *P.indicus* of South Africa while Lawrence *et al.* (1979) assessed the protein, carbohydrates and lipids in ovary and hepatopancreas of ablated and unablated females of *P.vannamei*, *P.stylirostris* and *P.setiferus*.

Literature on the variation in biochemical composition in relation to reproduction of pandalids is scanty. Quinitio *et al.* (1991) studied the profiles of progesterone and estradiol from haemolymph of *Pandalus kessleri* during the reproductive period while Hopkins *et al.* (1993) assessed the total lipid content and fatty acid composition of *P.borealis*.

Olsen *et al.* (1991) extracted phosphatase from the hepatopancreas of *P.borealis* while Ikeda (1991) and Anderson (1991) studied its dry weight and elemental composition from the cast moults and percentage composition of extractable and non-extractable proteins.

In India, very few studies were carried out on the biochemical changes in relation to reproductive cycles in penaeid prawns (Mohamed and Diwan, 1992; Sherief and Xavier, 1994). George and Patel (1956) studied the seasonal variation in the fat content of liver and gonad in marine decapods. Pillai and Nair (1973) examined the variation in biochemical composition of ovary and hepatopancreas in relation to reproductive phases in *Metapenaeus affinis*. Kulkarni and Nagabhushanam (1979) reported similar findings in *Parapenaeus hardwickii* while Achuthankutty and Parulekar (1984) made biochemical comparison in *M. affinis*, *M.dobsoni*, *P. merguensis* and *Parapenaeus stylifera*.

*Aristeus alcocki*, *Heterocarpus gibbosus*, *H.woodmasoni*, *Solenocera hextii* and *Metapenaeopsis andamanensis* are major commercially important deep-water shrimps, which are fetching very high price at par with major coastal shrimps by virtue of their attractive colouration and size. Despite the fact that these species inhabit deeper waters at various depth zones, and characterised by deep reddish

exoskeleton, however, these species were not investigated for their pigmentation aspects.

The present work is, therefore, undertaken with the following objectives:

1. To evaluate the proximate composition in the muscle tissue and hepatopancreas in *H.gibbosus* and *H.woodmasoni* and to bring out variations, if any, in both sex wise and maturity stage wise.
2. Studying the distribution and mobilization pattern of total carotenoids in various tissues like exoskeleton, muscle, hepatopancreas and gonad in *H.gibbosus* during different stages of gonadal maturation.
3. To delineate depth linked variation in total carotenoids, if any, among important species of deep sea prawns.

## **9.2. MATERIALS AND METHODS**

Samples for the present study were collected from deep sea trawl landings from Cochin and Munambum fisheries harbours of Kerala during September 2000 to August 2002. The specimens were brought to the laboratory in fresh conditions. Identification of sexes was done following

King and Moffitt (1984). The total length and weight were observed and the maturity stages were determined following Ceccaldi (1966).

For proximate composition analysis, muscle and hepatopancreas were taken. A weighed portion of the sample was kept in the hot air oven at 70°C (Sherief *et al.*, 1992) and dried to constant weight in order to determine the moisture content. The fat content was extracted from a known volume of dried tissue in Soxhlet Apparatus and the percentage fat was estimated (Folsch *et al.*, 1957). The nitrogen was estimated by Micro-Kjeldahl's method (Hawk *et al.*, 1954) and the amount of total protein was calculated by multiplying nitrogen value by 6.25 (Giese *et al.*, 1958). The ash content was estimated by igniting the known volume of over dried samples in a porcelain crucible kept in the muffle furnace at 550°C to 600°C for about 10 hours. The ignited residue thus obtained was reckoned as the ash content. The Nitrogen Free Extract (NFE) was estimated on dry weight basis following Hastings (1976) using the following formula

$$\text{NFE} = 100 - (\text{protein} + \text{lipid} + \text{moisture} + \text{ash})$$

The results of proximate composition were analysed statistically using ANOVA (Snedecor and Cochran, 1967).

For the estimation of total carotenoids, fresh samples of the selected species were collected from the same harbours. Total

carotenoids in exoskeleton, muscle, hepatopancreas and gonad of *H.gibbosus* and exoskeleton and muscle tissue of *Acanthephyra sanguinea*, *Aristeus alcocki*, *Metapenaeopsis andamanensis*, *Solenocera hextii* and *Parapandalus spinipes* were estimated following Olson (1979).

1g of fresh tissue was weighed and placed in 25ml screw cap clear test tubes. To this 2.5g of anhydrous sodium sulphate was added and the sample was gently macerated with a glass rod against the walls of test tube until it mixes thoroughly with sodium sulphate. 5ml chloroform was added and the test tube was sealed and placed at 0°C overnight after covering each test tube with aluminum foils. When the chloroform formed a clear layer of 1 to 2cm height above the caked residue, optical density was read at 475nm and 500nm, taking 0.3ml aliquots of chloroform diluted to a column of 3ml with absolute ethanol.

A blank prepared in a similar manner was used for comparison. A wavelength of 475nm at which maximum absorption obtained was used for calculation. The total carotenoid content was calculated as µg carotenoid /g wet weight of tissue as follows:

$$\text{Carotenoid content} = \frac{\text{Absorption at 475nm} \times 10}{0.25 \times \text{sample weight (g)}}$$

Where,            10 = dilution factor  
                       0.25 = extinction coefficient

Analysis was done repeatedly for more than five times in each maturity stages and average was computed with standard deviation. The results of carotenoid estimation were subjected to statistical treatments using ANOVA (Snedecor and Cochran, 1967).

### **9.3. RESULTS**

#### **9.3.1. Proximate composition**

##### **9.3.1.1. Muscle tissue**

The average values of moisture, protein, fat, ash and NFE content of muscle tissue estimated from various maturity stages of *H. woodmasoni* are given in Table 9.1. The moisture content found varied between 75.82 to 82.93 % while the protein ranged between 13.86 and 16.82 %. The fat content was comparatively high in all the maturity stages; however, it showed an increase with the progression of maturity stages with peak in head roe stage ( $2.97 \pm 0.05$ ) but decreased thereafter. Results of analysis of variance showed significant difference in fat and NFE value ( $P < 0.01$ ), on the contrary, no such difference was seen in the muscle protein and ash content. Among the males, the moisture content was high in spent males while it was lowest in maturing males, however, the fat content was very high in the latter. NFE content showed a gradual increase from



immature to maturing males and it was statistically significant ( $P < 0.01$ ) (Table 9.2).

Mean values of various proximate constituents estimated from the muscle tissue of females of *H.gibbosus* are presented in Table 9.3. Moisture content of the muscle tissue varied between 77.90 and 80.71% and there was a decreasing trend from immature to head roes while the protein and fat content showed an increasing trend. The protein, ash and NFE were found to differ significantly among maturity stages while no such difference was discernible in fat and moisture contents in muscle tissue.

The moisture content in males of *H.gibbosus* did not show significant difference among the maturity stages. The protein and fat content showed a reduction in head roes in contrast to the high NFE content. The NFE value showed significant variation among male maturity stages ( $P < 0.01$ ) (Table 9.4).

#### 9.3.1.2. Hepatopancreas

Average values of various biochemical components of hepatopancreas in various maturity stages of female *H.woodmasoni* is given in Table 9.5. The fat content in the hepatopancreas were found to be invariably high in all the maturity stages when compared to the muscle while the protein and moisture content were on a lower level. A

decreasing trend could be apparent in the moisture content from 57.42% in immature female to 56% in head roes, however, it increased thereafter in the successive stages. Results of ANOVA showed significant variation in moisture, fat and NFE content at 1% level ( $P < 0.01$ ) while no such variation could be seen in protein and ash content.

In males of *H. woodmasoni* also, high fat content was observed in all the stages with low moisture and protein content, however, the difference was insignificant among the maturity stages ( $P > 0.01$ ) (Table 9.6).

In females of *H. gibbosus*, the moisture content varied from 56.23% in spent males to 59.09 % in berried females, thus showing a higher fat content (Table 9.7). Results of ANOVA showed significant variation in fat and NFE values. The proximate composition values in males were more or less comparable with that of females (Table 9.8).

### **9.3.2. Total carotenoid estimation**

#### **9.3.2.1. Total carotenoids in exoskeleton**

Table 9.9 shows the total carotenoid content in the exoskeleton of females of *H. gibbosus* during different maturity stages. In the tissue of *H. gibbosus*, total carotenoids of exoskeleton in females ( $32.47 \mu\text{g/g}$ ) was slightly higher than the males ( $30.87 \mu\text{g/g}$ ). In females, the carotenoids

showed a sharp increase from immature ( $31.19 \mu\text{g/g} \pm 5.73$ ) to spent stages ( $38.30 \mu\text{g/g} \pm 1.70$ ) thus manifesting that the pigmentation of the exoskeleton increased during the process of maturation (Fig. 9.1). Results of ANOVA showed significant variation among maturity stages ( $P < 0.05$ ) (Table 9.10).

The carotenoid content of males (Table 9.11) showed a gradual increase from immature stage ( $26.32 \pm 1.29$ ) to maturing stage ( $33.32 \pm 2.39$ ), while in spent stages a slight reduction was apparent ( $32.97 \pm 1.52$ ) (Fig 9.2). The values were highly significant among various maturity stages at 5% level ( $P < 0.05$ ) (Table 9.12).

#### **9.3.2.2. Total carotenoids in muscle tissue**

The total carotenoids in muscle tissue were found to be very low when compared to exoskeleton, the average value being  $4.2 \mu\text{g/g}$  of tissue (Table 9.13) (Plate 9.1. A). Though it was very low, the total carotenoid concentration showed a gradual increase from immature ( $2.80 \pm 0.21$ ) to head roe stage ( $5.23 \pm 1.63$ ) but declined during oviposition in orange berry stage, thereafter showed an increase during subsequent maturity stages, thus indicating mobilization of total carotenoids during maturation process (Fig. 9.3). The variation in the carotenoid concentration of muscle tissue was found to be significant among various maturity stages ( $P < 0.05$ ) (Table 9.14).

The mean total carotenoids in muscle tissue of *H.gibbosus* males were estimated as 2.95µg/g showing a very low value than females (Table 9.15). The muscle carotenoid decreased from maturing ( $3.04 \pm 0.41$ ) to spent stages ( $52.80 \pm 0.75$ ). (Fig. 9.4) Results of ANOVA showed no significant variation among maturity stages ( $P>0.05$ ) (Table 9.16).

### 9.3.2.3. Total carotenoids in hepatopancreas

The mean carotenoid content in hepatopancreas of females of *H.gibbosus* was estimated to be 5.84 µg/g which showed a sharp increase from immature ( $2.56 \pm 0.34$ ) to head roe ( $9.87 \pm 1.06$ ), however, a reduction after oviposition was observed in grey berry ( $5.46 \pm 1.14$ ) (Table 9.17) (Plate 9.1.B). The values increased thereafter in black berry and spent stages (Fig. 9.5). The results of ANOVA showed significant variation among various maturity stages ( $P<0.05$ ) (Table 9.18).

In males, the mean carotenoid concentration of hepatopancreas was estimated to be 2.87µg/g (Table 9.19). The values showed an increase from immature ( $2.93\mu\text{g/g} \pm 0.16$ ) to maturing males ( $3.09 \pm 0.26$ ) however, in spent males, it showed a reduction ( $2.60\mu\text{g/g} \pm 0.53$ ) (Fig. 9.6). There exist significant variation between maturity stages ( $P<0.05$ ). (Table 9.20) .

#### **9.3.2.4. Total carotenoids in gonads**

The total carotenoids in the ovary of *H.gibbosus* (12.77 $\mu$ g/g) were found to be higher than the carotenoid concentration of muscle and hepatopancreas (Table 9.21) (Plate 9.1.C). The total carotenoids in females showed a sharp increase from immature (7.93  $\pm$  0.90) to head røe stage (27.88  $\pm$  1.30), and then decreased gradually thereafter in the subsequent maturity stages (Fig. 9.7). Highly significant difference was observed between maturity stages at 5% level ( $P < 0.05$ ) (Table 9.22).

Total carotenoid concentration of gonad of males of *H.gibbosus* was on a lower side than ovary of females (4.29 $\mu$ g/g) (Table 9.23). The values showed a gradual increase from immature (4.09  $\pm$  0.45) to maturing stage (4.96  $\pm$  0.75); on the other hand, in spent males it declined (3.84  $\pm$  0.97) (Fig.9.8). No significant variation was found in the carotenoid concentration among male maturity stages ( $P > 0.05$ ) (Table 9.24).

### **9.3.3. Depth linked variation in carotenoid content**

#### **9.3.3.1. Exoskeleton**

The deep sea prawns showed glaring variations in the total carotenoid content commensurate with the depth at which they are inhabiting (Table 9.25). The depth of occurrence of five species of *A.sanguinea*, *A. alcocki*, *M.andamanensis*, *S.hextii* and *P.spinipes* are shown in Fig.9.9. Among the various prawns studied, *A. sanguinea* (51.98 $\mu$ g/g) and *A. alcocki* (40.02 $\mu$ g/g), which usually inhabit at high depths of 450-650m (Fig.9.9) , the total carotenoids in the exoskeleton were highest. Next in order of carotenoid content were that of *P. spinipes* and *H.gibbosus* which are occupying at 250-350m depth zones (Fig. 9.9). On the other hand, *M. andamanensis* which inhabits at 150-250 m showed the lowest concentration of carotenoids in the exoskeleton while *S. hextii* which is a relatively deep water species when compared to *M.andamanensis* and inhabits 250-350 m, the carotenoid values were relatively higher when compared to the former species (25.93 $\mu$ g/g) .

Results of ANOVA showed that there exists significant difference ( $P < 0.05$ ) in the carotenoids of exoskeleton in deep sea prawns inhabiting different depth zones (Table 9.26).

#### **9.3.3.2. Muscle tissue**

Total carotenoid content in the muscle tissue of six species of deep sea prawns are given in Table 9.27. There exist very wide variation in the

muscle carotenoids commensurate with the depth of inhabitation. The muscle tissue carotenoid was highest in the deepest dwelling species *A.sanguinea* (9.30µg/g) while it was lowest in *M.andamanensis* (2.71µg/g), a shallow water species which inhabits at 150-200m depth. Fig. 9.10 shows difference in muscle carotenoid content in various species of deep sea prawns inhabiting at various depths from 150-650m. Results of ANOVA showed that there exists significant difference in the total carotenoids among various deep sea prawns studied which are distributed at different depth zones ( $P<0.05$ ) (Table 9.28).

#### 9.4. DISCUSSION

Results of the present study showed that in *H.woodmasoni* and *H.gibbosus* moisture formed the major constituent in all the tissues, which ranged between 78-82%. This in comparison with those of coastal prawns was on a higher side in contrast to the low protein content (Gopakumar, 1997). Both the species are having very high fat content, which ranged between 2.33 to 2.97% and 2.19 to 2.41% in *H.woodmasoni* females and males respectively whereas in *H.gibbosus* it ranged from 1.55 to 2.38 in males and 1.57 to 1.82 in females. Morris (1972) reported a fat content of 2.5 % and 3.5% in the epibenthic species *H.grimaldii* and *H.ensifer* respectively from northeastern Atlantic. The high lipid content in both the species studied can be correlated with their deep sea life history characteristics. According to Childress and Nygaard (1974), the very high

lipid content of mesopelagic and nektobenthic deep sea crustaceans may be useful in attaining neutral buoyancy in the water column. Herring (1973) also expressed similar views on the high fat content of deep sea prawns, and reasoned that the attached eggs in the pleopods and mobilization of wax esters reduces the stability of carideans in the deeper waters and the center of buoyancy of females would change considerably with resulting changes in the stability of animals in waters. The maintenance of high wax ester levels in females is very useful in sustaining the buoyancy. Inogradov (1970) found very high lipid concentration in deep macroplanktonic crustaceans whereas Lee *et al.* (1971) reported that the lipid content of deep-water species is consistently higher than that of shallower species. Morris (1972) made an attempt to establish the relationship between depth and wax ester component in deep sea crustaceans and reported that benthic decapods showed fat content in the range 14.2 to 29.6% while it was 1.9-6.3% in epibenthic and nektobenthic species. Gopakumar (1997) observed very high lipid content ranging from 2.59 % in *Chlorophthalmus agassizi* to 12.10 % in lantern fish *Benthosoma pterotaa* collected from south west coast of India.

The total fat content in the muscle was high during the ripening stages of the gonads in both the species except in males of *H.gibbosus* . In *H.woodmasoni*, highest of 2.97% was observed in head roes and 2.41% in maturing males while in females *H.gibbosus*, the fat content was



high in orange berries though the difference was not significant. After oviposition, the fat level in the muscle showed a reduction. Similar changes in fat content in relation to reproductive activity have been reported by Clarke (1977,1979) in the shrimps *Chorismus antarticus* and *Pandalus montagui* ,wherein there was an increase in total lipid content from 6 to 20% and 4 to 24% on dry weight basis respectively in the muscle tissue during peak reproductive period . The fat appeared to be one of the important sources of energy metabolism during the breeding season. With greater catabolism of fat during the spawning period, there was a reduction in the fat content significantly. The levels of fat content of both the species were also similar to those reported by Hopkins *et al.* (1993) in *P.borealis* .

Carbohydrate level probably represents the storage level of food in tissues and might be expected to vary during the reproductive stages. A striking change in the nitrogen free extract level was seen during the various reproductive stages in testis and ovary of *H.gibbosus* and *H.woodmasoni* . In females of both the species, the NFE level decreased in muscle tissue towards the fully maturing stages and after oviposition the level showed an increase. It may be inferred that the accumulated glycogen might be utilized for reproductive activities and this attributes for the reduction of NFE levels during the fully maturing periods. Giese (1969) observed similar changes in the gonads of the mollusc *Kathorina tunicata* which showed a low level of glycogen during spawning period, on

the other hand, the level increased again after spawning period. Okazaki and Kobayashi (1929) also stated that the glycogen levels become low in the oyster *Ostrea circumpecta* during breeding season. It would thus appear that the NFE levels in muscle tissue showed significant changes in connection with the sexual maturation and metabolic activity.

In females of *H.gibbous*, the protein content of muscle tissue showed significant difference among various maturity stages and this can be taken as an index of high cellular activity (Lemmens, 1959). Among them, peak value was observed in orange berries while low level of protein was observed in immature females. Though the protein levels did not show any remarkable difference among various maturity stages of *H.woodmasoni*, the values were highest in head roes while it was lowest in spent females. From the results, it may be inferred that there exist significant differences in the metabolic activity of both the species.

Hepatopancreas plays a significant role in the food assimilation and mobilization of energy during moulting, pigmentation, gluconeogenesis and carbohydrate storage (Dhall and Moriarty, 1983; Skinner, 1985; Ghidalia, 1985). The fat content of hepatopancreas was found to be very higher when compared to muscle tissue, however, showed an inverse relation with moisture and protein content. The fat content in females of both *H.woodmasoni* and *H.gibbosus* showed an increasing trend with the progression of maturity, oviposition and

thereafter decreased drastically during the spent stage. Commensurate with this, the moisture content showed a decreasing trend during spawning period. It may, therefore be inferred that as in other marine shrimps (Jeckel *et al.*, 1989; Teshima *et al.*, 1989; Mourente and Rodrigues, 1991; Allen *et al.*, 2000), the accumulation of total fat in the hepatopancreas of *H.gibbosus* and *H.woodmasoni* takes place during the period of peak reproductive development. Present results also corroborate with Pillai and Nair (1973) who established an antagonistic relationship between moisture and protein or lipid content in gonad and hepatopancreas of crustaceans. Hence, the hepatopancreas act as a storage organ for the principal storage nutrients such as fat and glycogen (Yonge, 1924). Significant variation noticed in the moisture, fat and NFE of the hepatopancreas in females of both *H.woodmasoni* and *H.gibbosus* in the present study would lend support to the observations on the difference in growth and relative size of hepatopancreas among various maturity stages of both the species.

#### **9.4.1. Total carotenoids**

Carotenoids are a group of pigments that cannot be biosynthesized by animals. They are taken up from the diet and can be transformed afterwards from one carotenoid to other. The bright coloration of the deep sea prawns might be attributed to the type of diet consumed by the individual groups. The levels of pigment in the

exoskeleton, muscle, gonad and hepatopancreas are determined both by the pigment content of the feed and uptake efficiency which in turn is dependent on the carotenoid requirement of each species. The food and feeding habits of *H.gibbosus* showed that it feeds mainly on euphausiids (50%), foraminifers (16%) and detritus (21%) as the major food items. Similarly, other deep sea crustaceans inhabiting the same habitat are also characterized by the presence of similar type of food items in their gut content (Suseelan, 1985). Fisher *et al.* (1952) could extract carotenoid content as high as 50 to 88 $\mu$ g/g from euphausiids. The total amount of carotenoid in the carapace, flesh and eye of Antarctic krill *Euphausia superba* was found to be 1.13mg, 1.06mg and 90.82 mg/100g respectively (Maoka *et al.*, 1985). Gillam *et al.* (1939) estimated high concentration of carotenoids in zooplanktons from North Sea.

Highest concentration of total carotenoids was observed in the exoskeleton of deep sea prawns. In addition, the pigment concentration was more in female than males. Tsukuda (1963) found more than 90% of the pigment of *P.borealis* in the exoskeleton while Mc Beth (1970) found 94% of astaxanthin and its esters in the total pigments in *Betaeus harfordi*. A comparison of carotenoids in the exoskeleton of females *H.gibbosus* showed a sharp increase up to head roe stage but declined during orange berry after which the values increased up to spent stage. An increase in the carotenoid content would manifest the possibility of accumulation of pigments in the exoskeleton during ripening stage of

females. While during oviposition the pigments were been transferred to eggs from hepatopancreas. The increased carotenoids in spent stage may be ascribed to the increased size of female prawn since the animals tend to store pigments in the exoskeleton until mortality (Patnaik, 2001).

In males also, the carotenoid showed a sharp increase during the advancement of maturing stage, on the other hand, it showed a reduction in spent stages. The low value recorded in spent males can be explained as a result of lesser mobilization of carotenoids from hepatopancreas after spawning possibly because of the minor utilization of cuticular pigments as mating gesture. Patnaik (2001) reported similar findings in *Princanthus hamrur* wherein high carotenoid values were observed in spent males in contrast to the low values in mature males. A similar observation was also made by Kithara (1985) in Masu salmon *Onchorhynchus masu*.

The role of skin pigmentation as breeding stimulation has been well established by Tin Bergen (1953). Dall *et al.* (1995) conducted biochemical studies in *Penaeus esculantus* and found out that astaxanthin and its esters are the principal carotenoids. A comparison with carotenoid of the natural diet of *P.esculantus* indicated that, after ingestion, dietary carotenoids were converted to astaxanthin.

Among the various tissues examined in *H.gibbosus* for total carotenoids, the lowest pigment values were observed from muscle

tissues with highest content in females when compared to that of males. Fisher *et al.* (1964) and Goodwin (1950) reported similar low values of muscle carotenoids in fishes and decapod crustaceans while Ando *et al.* (1985) reported that the change in muscle composition brought about during spawning season was closely related to their physiological state. The reason for the low carotenoid in the muscle tissue might be due to the deposition of very high content in the exoskeleton and corroborated with the results of Storebakken *et al.* (1987) who reported a very low carotene in the flesh of Atlantic salmon in contrast to high content in the skin. Torrissen (1989) correlated the deposition carotenoids in the muscle to feeding time, individual body weight and individual growth.

The carotenoids in muscles of both the sexes of *H.gibbosus* showed an increasing trend towards maturation but declined during oviposition, thus manifesting certain degree of mobilization from muscle tissue to exoskeleton. Crozier (1970) and Kithara (1983) also reported the mobilization of carotenoids in Salmons from the flesh to the skin and gonads during progress of maturation.

The highest concentration of carotenoids next to body tissue was reported in hepatopancreas of other decapod crustaceans (Lenel, 1965; Establier, 1966; Gilchrist & Lee, 1967; Mokhtar & Lenel, 1971) and the present findings strongly corroborates with the above view. In females of *H.gibbosus*, the carotenoids in hepatopancreas was found to be

increasing from immature to head roes, thenceforth showed a reduction, reaching a very low level in grey berry stage. However, from the spent stage onwards, the values showed a further increase. According to Vincent (1988) and Harrison (1990), during the early maturation stages, free and esterified carotenoids accumulate in the hepatopancreas and during the period of secondary vitellogenesis they are getting mobilized from hepatopancreas via the haemolymph to the ovaries. This pattern of accumulation of carotenoids in the ovaries during maturation results in their darkening based on which the quantification of maturity stages in females is usually taking place. Takashima *et al.* (1972) also reported on the synthesis of lipoprotein in the liver of rainbow trout under the influence of the ovary steroid hormones. Leger (1985) and Hardy *et al.* (1990) reported the mid gut gland as the site of lipoprotein synthesis and metabolization of canthaxanthin in fishes. Results of the proximate analysis in the present study also showed an increasing level of total fat during the maturation period in the hepato pancreas of *H.gibbosus*. Therefore, taking in to account the significant role of hepatopancreas in the synthesis and mobilization of carotenoids, it can reasonably be concluded that in *H.gibbosus*, high amounts of carotenoids was stored in the form of lipoproteins and vitamin-A up to head roe stage which was transferred subsequently to the ovaries until spawning, which decreased to a lower level during oviposition up to grey berry stage. Again, the carotenoids started accumulation in the hepatopancreas for the next

spawning activity as evidenced from high carotenoid content in the spent stage. Correspondingly, the carotenoid values in the ovary also showed an increasing trend from immature to head roe and a decline thereafter as evidenced from the low colouration of spent ovaries. The present findings are corroborative with those of Herring (1973). Love (1970) and Turuk (1972) also observed a high lipid content in liver during gonad development in *Salmo trutta* and *Gadus morhua*.

Other than pigmentation, available reports suggest that (Wouters *et al.*, 2003) carotenoids also have a biological function responsible for growth and reproduction. In the males and female gonads of *H.gibbosus*, the carotenoid level showed an increase with the maturation of gonads. Similar findings were reported by Herring (1973) in 14 decapod crustaceans and correlated the carotenoid content to total lipid content. According to Herring (1973) , the pigments in the gonads and eggs of the decapods have a role in the synthesis of the visual pigments in the developing larva. Reports on the variation in carotenoid content commensurate with the gonadal maturation are plenty, notably by Wolfe & Cornwell (1965) , Lenel (1965) , Establier (1966) , Gilchirst & Lee (1967) and Mokhtar & Lenel (1971). In *Metapenaeus dobsoni* , an increase in carotenoid content was observed by Lethakutty (1993) from immature to mature ovary. So there may be the possibility of establishing a positive correlation on the increased ovary weight and carotenoid content. In the testis, the carotenoid value was found to be less than half



of ovary in females. Such low levels of carotenoid might be due to the lesser materials of males to be transported when compared to the ovary to the developing larvae (Love, 1970).

A comparison on the total carotenoids among various species of deep sea prawns inhabiting in different depth zones showed that there exists glaring differences in the total carotenoid content both in exoskeleton as well as muscle tissue in species inhabiting different depth zones. Since carotenoids cannot be biosynthesized by the animals, and are only assimilated from the diets (Wouters *et al.*, 2003), it can reasonably be inferred that the variations encountered in carotenoids of prawns inhabiting different depth zones might be due to the variation in the diet consumed by these organisms, which is governed by the food availability in their different depth of inhabitation. Foxton (1970a, 1970b, 1972) also reported the depth wise carotene distribution in decapods from Fuerteventura area, North Atlantic.

The present database on the carotenoid content in the deep sea prawns demonstrate that they are cheap and abundant source of carotenoids and the dried chitin can be used as a better food for a number of ornamental fish species for gaining attractive colouration. Experiments (Wouters *et al.*, 2003) already indicated that the koi carps are more vibrant and fascinating when it is fed with the natural compounds than synthetic zeaxanthin and canthaxanthin. The

performance of natural carotenoids are much better in comparison to their synthetic counterparts; the former may get preferentially absorbed and can contribute to a number of additional carotenoids with beneficial effects than the latter. Further investigations on the pigmentation of these prawns will be a promising area of research.

**Asteroborus woodmassoni (Females)**

| Maturity stages    | Moisture (%)        | protein (%)          | Fat (%)            | Ash (%)            | NFE (%)            |
|--------------------|---------------------|----------------------|--------------------|--------------------|--------------------|
| immature           | 78.80+/-1.12<br>(7) | 15.70 +/-0.04<br>(7) | 2.56+/-0.03<br>(7) | 1.52+/-0.04<br>(7) | 0.90+/-0.14<br>(7) |
| maturing           | 80.27+/-0.69<br>(7) | 15.04+/-0.16<br>(7)  | 2.82+/-0.02<br>(7) | 1.45+/-0.16<br>(7) | 0.62+/-0.21<br>(7) |
| Head roe           | 75.8+/-0.99<br>(7)  | 16.21+/-0.43<br>(7)  | 2.97+/-0.05<br>(7) | 1.54+/-0.04<br>(7) | 1.39+/-0.07<br>(7) |
| Orange Berry       | 78.13+/-1.28<br>(7) | 14.60+/-0.43<br>(7)  | 2.92<br>(7)        | 1.47+/-1.02<br>(7) | 1.37+/-0.16<br>(7) |
| Black Berry        | 81.22+/-0.54<br>(7) | 14.11+/-0.42<br>(8)  | 2.57+/-0.06<br>(7) | 1.30+/-0.54<br>(7) | 0.62+/-0.09<br>(7) |
| Grey Berry         | 80.85+/-2.34<br>(7) | 14.81+/-0.25<br>(7)  | 2.39+/-0.18<br>(7) | 1.32+/-0.11<br>(7) | 0.38+/-0.08<br>(7) |
| Spent              | 82.93+/-2.46<br>(7) | 13.86+/-0.15<br>(7)  | 2.33+/-0.10<br>(7) | 1.20+/-0.13<br>(7) | 0.40+/-0.02<br>(7) |
| MSS                | 110.24<br>df= 6     | 8.97<br>df= 6        | 0.46<br>df= 6      | 520.84<br>df= 6    | 1.06<br>df= 6      |
| MSS within samples | 132.33<br>df= 6     | 4.03<br>df= 6        | 0.01<br>df= 6      | 518.39<br>df= 6    | 0.10<br>df= 6      |
| F-ratio            | 0.8314<br>NS        | 2.2341<br>NS         | 62.2880<br>S       | 1.0047<br>NS       | 261.28<br>S        |

Values are presented as AVG+/-SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level(P<0.01)

NS = Not significant (P>0.05)

**Table 6.2**

**Proximate composition of muscle tissue of various maturity stages of *Heterobranchius woodmasoni* (Male)**

| <b>Maturity stages</b> | <b>Moisture (%)</b> | <b>protein (%)</b>  | <b>Fat (%)</b>     | <b>Ash (%)</b>     | <b>NFE (%)</b>     |
|------------------------|---------------------|---------------------|--------------------|--------------------|--------------------|
| immature               | 80.12+/-0.66<br>(6) | 15.18+/-0.65<br>(6) | 2.14+/-0.26<br>(6) | 1.23+/-0.17<br>(6) | 0.59+/-0.13        |
| maturing               | 79.02+/-1.34<br>(6) | 15.82+/-0.76<br>(6) | 2.41+/-0.25<br>(5) | 1.21+/-0.19<br>(6) | 1.28+/-0.34<br>(6) |
| spent                  | 81.19+/-2.05<br>(6) | 15.04+/-0.41<br>(6) | 2.19+/-0.41<br>(5) | 1.19+/-0.09<br>(6) | 0.56+/-0.18<br>(6) |
| <b>MSS</b>             | 1.75                | 1.03                | 0.11               | 0.002              | 0.91               |
| <b>Bet.samples</b>     | df= 2               | df= 2               | df= 2              | df= 2              | df= 2              |
| <b>MSS</b>             | 7.83                | 0.38                | 0.09               | 0.02               | 0.05               |
| <b>within samples</b>  | df= 15              | df= 15              | df= 15             | df= 15             | df= 15             |
| <b>F-value</b>         | 0.2200<br>NS        | 2.6400<br>NS        | 1.1500<br>NS       | 0.0849<br>NS       | 15.38<br>S         |

Values are presented as AVG+/-SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level(P<0.01)

NS = Not significant (P>0.05)

| Maturity stages | Moisture (%)        | protein (%)          | Fat (%)            | Ash (%)            | NiFe (%)           |
|-----------------|---------------------|----------------------|--------------------|--------------------|--------------------|
| immature        | 80.71+/-1.85<br>(7) | 14.35 +/-0.33<br>(7) | 1.55+/-0.27<br>(7) | 1.65+/-0.15<br>(7) | 1.70+/-0.14<br>(7) |
| maturing        | 79.43+/-2.07<br>(7) | 14.60+/-0.30<br>(7)  | 2.04+/-0.10<br>(7) | 1.45+/-0.13<br>(7) | 1.50+/-0.18<br>(7) |
| Head roe        | 77.90+/-1.89<br>(7) | 14.70+/-0.35<br>(7)  | 2.09+/-0.09<br>(7) | 1.71+/-0.11<br>(7) | 0.98+/-0.18<br>(7) |
| Orange Berry    | 80.36+/-1.03<br>(7) | 15.28 +/-0.41<br>(7) | 2.34+/-0.25<br>(7) | 1.76+/-0.08<br>(7) | 1.37+/-0.16<br>(7) |
| Black Berry     | 79.57+/-2.23<br>(7) | 15.06+/-0.40<br>(8)  | 1.96+/-0.14<br>(7) | 1.65+/-0.14<br>(7) | 0.76+/-0.09<br>(7) |
| Grey Berry      | 79.43+/-1.72<br>(7) | 14.09+/-0.40<br>(7)  | 2.38+/-0.26<br>(7) | 1.59+/-0.15<br>(7) | 0.84+/-0.18<br>(7) |
| Spent           | 79.71+/-1.11<br>(7) | 14.70+/-0.44<br>(7)  | 2.25+/-0.19<br>(7) | 1.65+/-0.08<br>(7) | 0.50+/-0.02<br>(7) |
| MSS             | 5.57<br>df= 6       | 0.97<br>df= 6        | 0.46<br>df= 6      | 0.06<br>df= 6      | 1.06<br>df= 6      |
| Bet. samples    |                     |                      |                    |                    |                    |
| MSS             | 3.06<br>df= 35      | 0.14<br>df= 35       | 0.01<br>df= 35     | 0.01<br>df= 35     | 0.10<br>df= 35     |
| within samples  |                     |                      |                    |                    |                    |
| F-value         | 1.8100<br>NS        | 6.8300<br>S          | 0.9195<br>NS       | 3.8700<br>S        | 261.28<br>S        |

Values are presented as AVG+/-SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level(P<0.01)

NS = Not significant (P>0.05)

Table 9.4

Proximate composition of muscle tissue of various maturity stages of *Heterocarpus gibbosus* (Male)

| Maturity stages | Moisture (%)        | protein (%)         | Fat (%)            | Ash (%)            | NFE (%)            |
|-----------------|---------------------|---------------------|--------------------|--------------------|--------------------|
| immature        | 80.40+/-0.55<br>(6) | 15.31+/-0.50<br>(6) | 1.52+/-0.17<br>(6) | 1.61+/-0.17<br>(6) | 0.07+/-0.13        |
| maturing        | 80.56+/-0.44<br>(6) | 15.24+/-0.52<br>(6) | 1.44+/-0.19<br>(6) | 1.49+/-0.19<br>(6) | 1.25+/-0.34<br>(6) |
| spent           | 80.40+/-0.55<br>(6) | 15.54+/-0.50<br>(6) | 1.50+/-0.09<br>(6) | 1.37+/-0.09<br>(6) | 0.50+/-0.18<br>(6) |
| MSS             | 0.05                | 1.03                | 0.13               | 0.002              | 0.91               |
| Between samples | df= 2               | df= 2               | df= 2              | df= 2              | df= 2              |
| MSS             | 0.26                | 0.38                | 0.85               | 0.02               | 0.05               |
| within samples  | df= 12              | df= 15              | df= 15             | df= 15             | df= 15             |
| F-value         | 0.17                | 2.64                | 0.51               | 0.08               | 15.38              |
|                 | NS                  | NS                  | NS                 | NS                 | S                  |

Values are presented as AVG+/-SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level (P<0.01)

NS = Not significant (P>0.05)

PROLIFERATION OF *Heterocarpus woodmasoni* (Female) AT VARIOUS MATURITY STAGES

| Maturity stages | Moisture (%)        | protein (%)         | Fat (%)             | Ash (%)            | NFE (%)            |
|-----------------|---------------------|---------------------|---------------------|--------------------|--------------------|
| immature        | 57.42+/-0.75<br>(7) | 9.61 +/-0.12<br>(6) | 29.24+/-0.52<br>(6) | 1.79+/-0.07<br>(5) | 1.57+/-0.19<br>(5) |
| maturing        | 57.42+/-0.78<br>(7) | 9.81+/-0.32<br>(6)  | 30.20+/-0.40<br>(6) | 1.85+/-0.04<br>(5) | 0.92+/-0.34<br>(5) |
| Head roe        | 56.00+/-0.93<br>(7) | 9.77+/-0.49<br>(6)  | 31.30+/-0.55<br>(6) | 1.89+/-0.08<br>(5) | 0.98+/-0.02<br>(5) |
| Orange Berry    | 57.96+/-0.43<br>(7) | 9.21+/-0.43<br>(6)  | 29.34+/-0.41<br>(6) | 1.82+/-0.07<br>(5) | 1.47+/-0.34<br>(5) |
| Black Berry     | 57.74+/-0.77<br>(7) | 9.66+/-0.42<br>(6)  | 28.52+/-0.57<br>(6) | 1.84+/-0.05<br>(5) | 0.91+/-0.34<br>(5) |
| Grey Berry      | 58.88+/-0.17<br>(7) | 8.64+/-0.25<br>(6)  | 29.54+/-0.43<br>(6) | 1.79+/-0.06<br>(5) | 0.98+/-0.02<br>(5) |
| Spent           | 59.21+/-0.74<br>(7) | 9.51+/-0.15<br>(6)  | 27.75+/-0.88<br>(6) | 1.81+/-0.12<br>(5) | 1.08+/-0.21<br>(5) |
| MSS             | 8.36<br>df= 6       | 0.11<br>df= 6       | 7.79<br>df= 6       | 520.84<br>df= 6    | 1.06<br>df= 6      |
| within samples  | 0.48<br>df=43       | 0.10<br>df= 35      | 0.31<br>df= 35      | 518.39<br>df= 34   | 0.10<br>df= 35     |
| F-value         | 17.37<br>S          | 1.1680<br>NS        | 24.8584<br>S        | 1.2300<br>NS       | 7.53<br>S          |

Values are presented as AVG+/-SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level(P<0.01)

NS = Not significant (P>0.05)

**Table 9.9**

**Proximate composition of hepatopancreas of various maturity stages of *Heterocarpus woodmasoni* (Male)**

| <b>Maturity stages</b> | <b>Moisture (%)</b> | <b>protein (%)</b> | <b>Fat (%)</b>     | <b>Ash (%)</b>    | <b>NFE (%)</b>    |
|------------------------|---------------------|--------------------|--------------------|-------------------|-------------------|
| immature               | 57.40±/0.38<br>(6)  | 9.64±/0.23<br>(5)  | 29.35±/0.14<br>(6) | 1.64±/0.17<br>(6) | 1.86±/0.13        |
| maturing               | 57.36±/0.13<br>(6)  | 9.60±/0.12<br>(5)  | 29.73±/0.25<br>(5) | 1.57±/0.19<br>(6) | 1.73±/0.34<br>(6) |
| spent                  | 57.04±/0.04<br>(6)  | 9.65±/0.21<br>(5)  | 29.87±/0.41<br>(5) | 1.82±/0.09<br>(6) | 1.65±/0.09<br>(6) |
| <b>MSS</b>             | <b>0.2015</b>       | <b>0.004</b>       | <b>0.01</b>        | <b>0.002</b>      | <b>0.91</b>       |
| <b>Bet.samples</b>     | <b>df= 2</b>        | <b>df= 2</b>       | <b>df= 2</b>       | <b>df= 2</b>      | <b>df= 2</b>      |
| <b>MSS</b>             | <b>0.05</b>         | <b>0.036</b>       | <b>0.09</b>        | <b>0.02</b>       | <b>0.05</b>       |
| <b>within samples</b>  | <b>df= 12</b>       | <b>df= 12</b>      | <b>df= 15</b>      | <b>df= 15</b>     | <b>df= 15</b>     |
| <b>F-value</b>         | <b>3.7073</b>       | <b>0.1094</b>      | <b>1.1600</b>      | <b>1.2540</b>     | <b>2.1034</b>     |
|                        | <b>NS</b>           | <b>NS</b>          | <b>NS</b>          | <b>NS</b>         | <b>NS</b>         |

Values are presented as AVG±/SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level(P<0.01)

NS = Not significant (P>0.05)



Table 9.7

Proximate composition of hepatopancreas of various maturity stages of *Heterocarpus gibbosus* (Female)

| Maturity stages       | Moisture (%)        | protein (%)         | Fat (%)             | Ash (%)            | NFE (%)            |
|-----------------------|---------------------|---------------------|---------------------|--------------------|--------------------|
| immature              | 59.24+/-0.15<br>(7) | 9.60 +/-0.12<br>(6) | 26.89+/-0.52<br>(6) | 2.01+/-0.87<br>(5) | 2.50+/-0.10<br>(5) |
| maturing              | 57.29+/-0.71<br>(7) | 10.76+/-0.32<br>(6) | 27.10+/-0.27<br>(6) | 1.86+/-0.15<br>(5) | 1.99+/-0.41<br>(5) |
| Head roe              | 58.00+/-0.39<br>(7) | 10.39+/-0.90<br>(6) | 28.04+/-0.05<br>(6) | 1.92+/-0.81<br>(5) | 1.65+/-0.21<br>(5) |
| Orange Berry          | 59.69+/-0.34<br>(7) | 9.05+/-0.20<br>(6)  | 29.00+/-0.11<br>(6) | 1.87+/-0.07<br>(5) | 1.08+/-0.40<br>(5) |
| Black Berry           | 58.40+/-0.70<br>(7) | 9.79+/-0.40<br>(6)  | 29.08+/-0.54<br>(6) | 1.85+/-0.05<br>(5) | 1.28+/-0.40<br>(5) |
| Grey Berry            | 59.36+/-0.15<br>(7) | 8.67+/-0.41<br>(6)  | 28.51+/-0.25<br>(6) | 1.73+/-0.06<br>(5) | 1.77+/-0.27<br>(5) |
| Spent                 | 56.23+/-0.04<br>(7) | 10.40+/-0.15<br>(6) | 29.87+/-0.09<br>(6) | 1.64+/-0.12<br>(5) | 2.09+/-0.18<br>(5) |
| MSS                   | 0.961<br>df= 6      | 0.11<br>df= 6       | 7.79<br>df= 6       | 520.84<br>df= 6    | 1.06<br>df= 6      |
| MSS<br>within samples | 0.682<br>df=67      | 0.10<br>df= 35      | 0.31<br>df= 35      | 518.39<br>df= 34   | 0.10<br>df= 35     |
| F-ratio               | 1.9439<br>NS        | 1.1680<br>NS        | 24.8584<br>S        | 1.2300<br>NS       | 7.53<br>S          |

Values are presented as AVG+/-SD

Values in parenthesis denotes the number of observations

S = Significant at 1% level(P&lt;0.01)

NS = Not significant (P&gt;0.05)

**Table 9.3** Proximate composition of hepatopancreases of various maturity stages of *Heterocarpus gibbosus* (Male)

| Maturity stages    | Moisture (%)       | protein (%)       | Fat (%)            | Ash (%)           | NFE (%)           |
|--------------------|--------------------|-------------------|--------------------|-------------------|-------------------|
| immature           | 58.32±/0.57<br>(6) | 9.43±/0.41<br>(5) | 29.35±/0.14<br>(6) | 1.64±/0.17<br>(6) | 1.86±/0.13        |
| maturing           | 57.80±/0.97<br>(6) | 9.60±/0.25<br>(5) | 29.73±/0.25<br>(5) | 1.57±/0.19<br>(6) | 1.73±/0.34<br>(6) |
| spent              | 57.76±/0.70<br>(6) | 9.49±/0.30<br>(5) | 29.87±/0.41<br>(5) | 1.82±/0.09<br>(6) | 1.85±/0.09<br>(6) |
| MSS                | 0.004<br>df= 2     | 0.004<br>df= 2    | 0.01<br>df= 2      | 0.002<br>df= 2    | 0.91<br>df= 2     |
| MSS within samples | 0.036<br>df= 12    | df= 12            | 0.09<br>df= 15     | 0.02<br>df= 15    | 0.05<br>df= 15    |
| F-value            | 0.1094<br>NS       | NS                | 1.1500<br>NS       | 1.2540<br>NS      | 2.1034<br>NS      |

Values are presented as AVG±/SD

Values in parenthesis denotes the number of observations

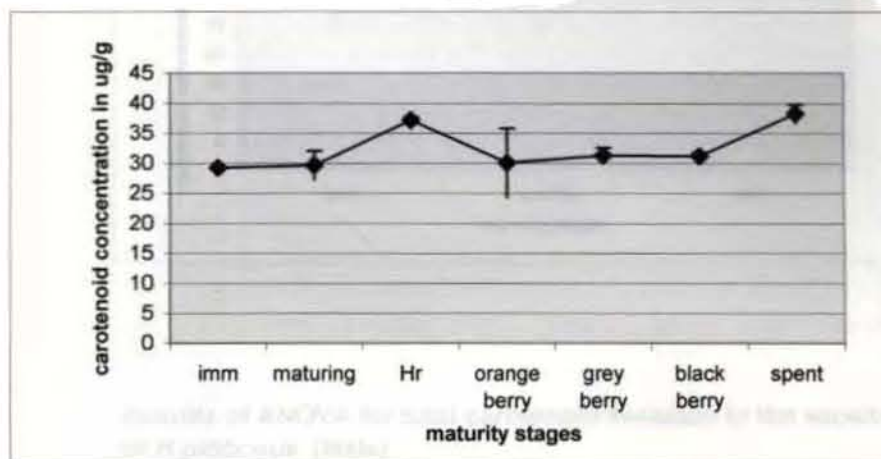
S = Significant at 1% level(P<0.01)

NS = Not significant (P>0.05)

**Table 9.9** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the exoskeleton of *Heterocarpus gibbosus* (Female)

| Replications | Maturity stages |          |          |              |            |             |       |
|--------------|-----------------|----------|----------|--------------|------------|-------------|-------|
|              | immature        | maturing | Head roe | orange berry | grey berry | black berry | Spent |
| 1            | 33.16           | 29.52    | 40.42    | 29.58        | 31.25      | 36.51       | 38.02 |
| 2            | 29.53           | 28.99    | 26.74    | 32.14        | 32.58      | 37.52       | 37.02 |
| 3            | 27.85           | 29.56    | 29.82    | 30.52        | 31.79      | 35.41       | 39.51 |
| 4            | 28.52           | 30.21    | 26.42    | 28.64        | 31.25      | 37.01       | 40.51 |
| 5            | 27.01           | 30.01    | 32.57    | 29.56        | 31.12      | 39.58       | 36.43 |
| Mean         | 29.21           | 29.66    | 37.21    | 30.09        | 31.60      | 31.19       | 38.30 |
| S.D          | 2.39            | 0.48     | 5.73     | 1.33         | 0.61       | 1.54        | 1.70  |

**Fig. 9.1** Total carotenoid variation in the exoskeleton of female *Heterocarpus gibbosus* in the different maturity stages



**Table 9.10** Results of ANOVA for total carotenoid variation in the exoskeleton of *H.gibbosus* (Female)

| Source of Variation | SS         | df | MS       | F        | P-value | F crit |
|---------------------|------------|----|----------|----------|---------|--------|
| Between Groups      | 414.812889 | 6  | 69.13548 | 10.4708* | 4.3E-06 | 2.4453 |
| Within Groups       | 184.874763 | 28 | 6.60267  |          |         |        |
| Total               | 599.687652 | 34 |          |          |         |        |

\*significant at 5 % level.

Table 9.11

Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the exoskeleton of *Heterocarpus gibbosus* (Male)

| Replications | Maturity stages |              |              |
|--------------|-----------------|--------------|--------------|
|              | immature        | maturing     | spent        |
| 1            | 27.48           | 36.51        | 33.56        |
| 2            | 25.55           | 30.2         | 32.46        |
| 3            | 26.51           | 34.61        | 33.71        |
| 4            | 27.52           | 33.12        | 30.59        |
| 5            | 24.53           | 32.18        | 34.53        |
| <b>Mean</b>  | <b>26.32</b>    | <b>33.32</b> | <b>32.97</b> |
| <b>S.D</b>   | <b>1.29</b>     | <b>2.39</b>  | <b>1.52</b>  |

Fig. 9.2

Total carotenoid variation in the exoskeleton of male *Heterocarpus gibbosus* in the different maturity stages

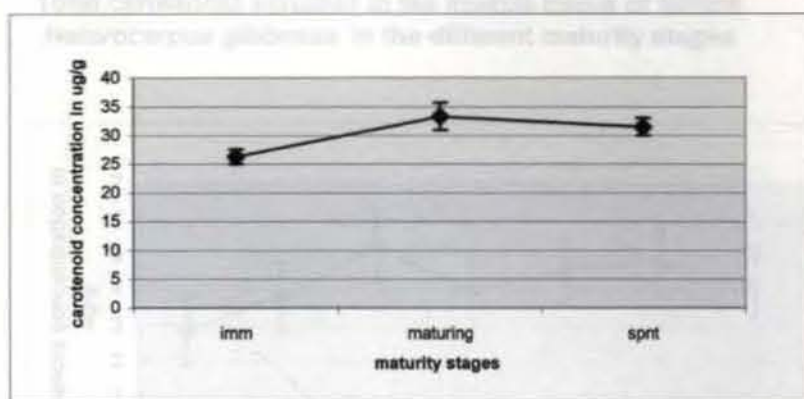


Table 9.12

Results of ANOVA for total carotenoid variation in the exoskeleton of *H.gibbosus* (Male)

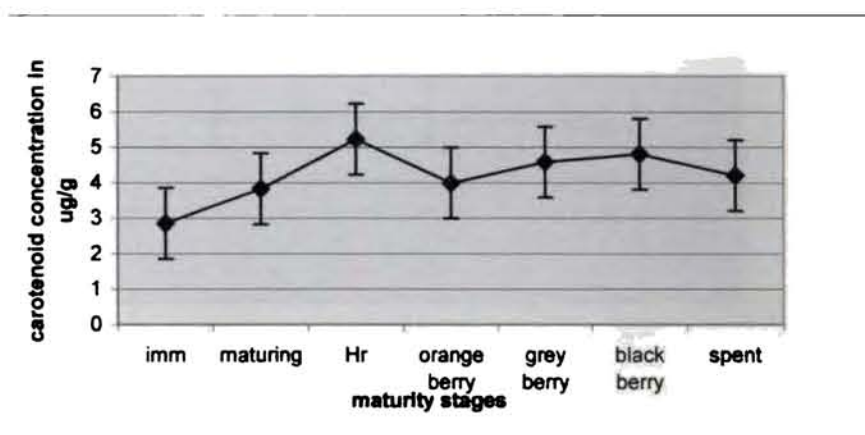
| Source of Variation | SS                 | df        | MS       | F       | P-value | F crit |
|---------------------|--------------------|-----------|----------|---------|---------|--------|
| Bet. Groups         | 155.7640933        | 2         | 77.88205 | 24.095* | 6.3E-05 | 3.8853 |
| Within Groups       | 38.7866            | 12        | 3.232217 |         |         |        |
| <b>Total</b>        | <b>194.5506933</b> | <b>14</b> |          |         |         |        |

\*significant at 5 % level

**Table 9.13** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the muscle tissue of *Heterocarpus gibbosus* (Female)

| Replications | Maturity stages |          |      |              |            |             |       |
|--------------|-----------------|----------|------|--------------|------------|-------------|-------|
|              | immature        | maturing | Hr   | orange berry | grey berry | black berry | Spent |
| 1            | 2.96            | 3.70     | 2.50 | 3.71         | 4.231      | 4.70        | 3.95  |
| 2            | 3               | 3.71     | 6.56 | 5.06         | 4.3        | 5.02        | 4.07  |
| 3            | 2.51            | 4.02     | 6.17 | 3.89         | 4.58       | 4.79        | 4.81  |
| 4            | 3               | 3.91     | 5.92 | 3.19         | 4.61       | 5.36        | 5.01  |
| 5            | 2.81            | 3.78     | 4.98 | 4.1          | 5.2        | 4.18        | 3.17  |
| Mean         | 2.86            | 3.82     | 5.23 | 3.99         | 4.58       | 4.81        | 4.20  |
| S.D          | 0.21            | 0.14     | 1.63 | 0.69         | 0.38       | 0.43        | 0.74  |

**Fig. 9.3** Total carotenoid variation in the muscle tissue of female *Heterocarpus gibbosus* in the different maturity stages



**Table 9.14** Results of ANOVA for total carotenoid variation in the muscle tissue of *H.gibbosus* (Female)

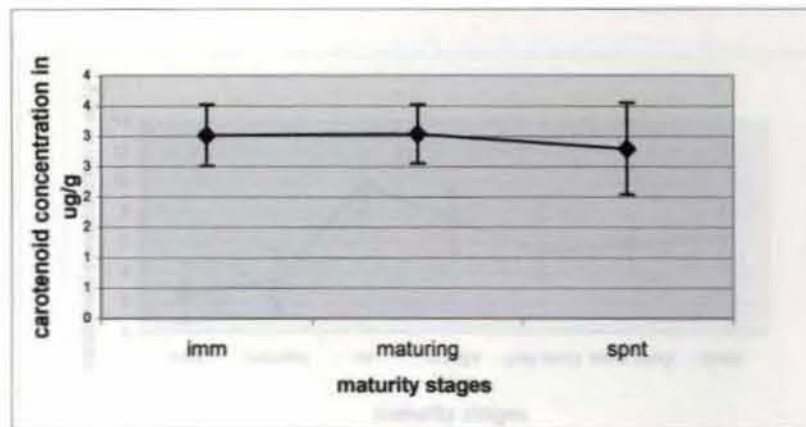
| Source of Variation | SS     | df | MS    | F      | P-value | F crit |
|---------------------|--------|----|-------|--------|---------|--------|
| Between Groups      | 17.819 | 6  | 2.970 | 5.102* | 0.001   | 2.4453 |
| Within Groups       | 16.299 | 28 | 0.582 |        |         |        |
| Total               | 34.119 | 34 |       |        |         |        |

\*significant at 5 % level.

**Table 9.15** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the muscle of *Heterocarpus gibbosus* (Male)

| Replications | Maturity stages |          |      |
|--------------|-----------------|----------|------|
|              | imm             | maturing | spnt |
| 1            | 2.51            | 2.79     | 1.98 |
| 2            | 2.93            | 2.89     | 2.52 |
| 3            | 2.91            | 3.76     | 2.91 |
| 4            | 3.72            | 2.71     | 3.77 |
| Mean         | 3.02            | 3.04     | 2.80 |
| S.D          | 0.51            | 0.49     | 0.75 |

**Fig. 9.4** Total carotenoid variation in the muscle of male *Heterocarpus gibbosus* in the different maturity stages



**Table 9.16** Results of ANOVA for total carotenoid variation in the muscle tissue of *H.gibbosus* (Male)

| Source of Variation | SS      | df | MS       | F       | P-value | F crit |
|---------------------|---------|----|----------|---------|---------|--------|
| Between Groups      | 0.14495 | 2  | 0.072475 | 0.2047* | 0.81857 | 4.2565 |
| Within Groups       | 3.18625 | 9  | 0.354028 |         |         |        |
| Total               | 3.3312  | 11 |          |         |         |        |

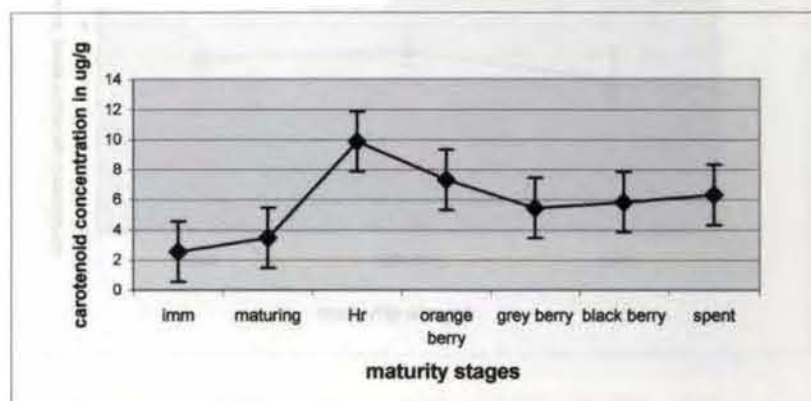
\*Not significant ( $P > 0.05$ )



**Table 9.17** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the hepatopancrease of *Heterocarpus gibbosus* (Female)

| Replications | Maturity stages |          |       |              |            |             |       |
|--------------|-----------------|----------|-------|--------------|------------|-------------|-------|
|              | immature        | maturing | Hr    | orange berry | grey berry | black berry | Spent |
| 1            | 2.00            | 2.70     | 11.78 | 6.10         | 5.980      | 5.84        | 5.31  |
| 2            | 2.55            | 3        | 8.77  | 9.26         | 4.63       | 4.91        | 7.05  |
| 3            | 2.89            | 3.5      | 9.26  | 5.99         | 5.96       | 7.26        | 6.51  |
| 4            | 2.76            | 4.26     | 9.54  | 7.26         | 6.78       | 6.94        | 6.74  |
| 5            | 2.61            | 3.89     | 10.01 | 8.01         | 3.97       | 4.29        | 6.04  |
| Mean         | 2.56            | 3.47     | 9.87  | 7.32         | 5.46       | 5.85        | 6.33  |
| S.D          | 0.34            | 0.64     | 1.16  | 1.37         | 1.14       | 1.27        | 0.68  |

**Fig. 9.5** Total carotenoid variation in the hepatopancrease of female *Heterocarpus gibbosus* in the different maturity stages



**Table 9.18** Results of ANOVA for total carotenoid variation in the hepatopancrease of *H.gibbosus* (Female)

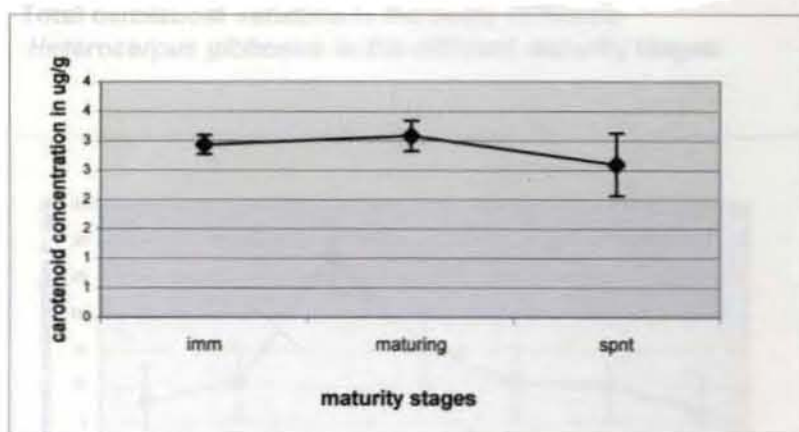
| Source of Variation | SS          | df | MS       | F       | P-value | F crit |
|---------------------|-------------|----|----------|---------|---------|--------|
| Between Groups      | 176.0080403 | 6  | 29.33467 | 28.877* | 9.2E-11 | 2.4453 |
| Within Groups       | 28.44318967 | 28 | 1.015828 |         |         |        |
| Total               | 204.45123   | 34 |          |         |         |        |

\*significant at 5 % level.

**Table 9.19** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the hepatopancreas of *Heterocarpus gibbosus* (Male)

| Replications | Maturity stages |          |       |
|--------------|-----------------|----------|-------|
|              | immature        | maturing | spent |
| 1            | 2.90            | 3.09     | 1.87  |
| 2            | 2.79            | 3.43     | 2.56  |
| 3            | 3.17            | 2.81     | 3.11  |
| 4            | 2.87            | 3.01     | 2.84  |
| Mean         | 2.93            | 3.09     | 2.60  |
| S.D          | 0.16            | 0.26     | 0.53  |

**Fig. 9.6** Total carotenoid variation in the hepatopancreas of male *Heterocarpus gibbosus* in the different maturity stages



**Table 9.20** Results of ANOVA for total carotenoid variation in the hepatopancreas of *H.gibbosus* (Male)

| Source of Variation | SS          | df | MS       | F      | P-value | F crit |
|---------------------|-------------|----|----------|--------|---------|--------|
| Between Groups      | 0.503016667 | 2  | 0.251508 | 1.995* | 0.19167 | 4.2565 |
| Within Groups       | 1.134075    | 9  | 0.126008 |        |         |        |
| Total               | 1.637091667 | 11 |          |        |         |        |

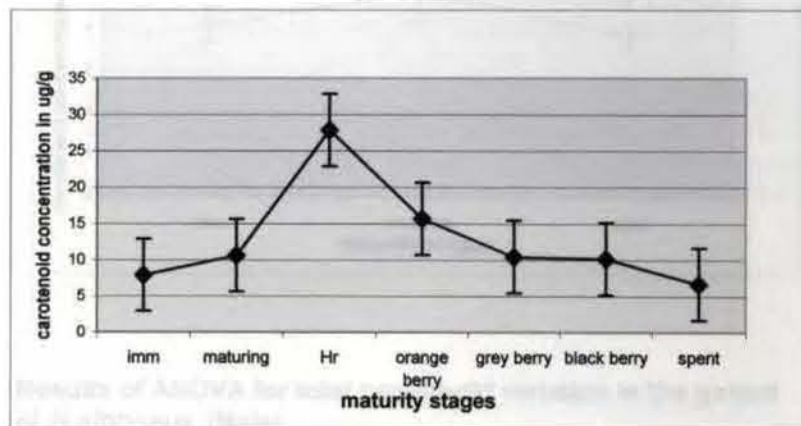
\*Not significant ( $P > 0.05$ )



**Table 9.21** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the ovary of *Heterocarpus gibbosus* (Female)

| Replications | Maturity stages |          |       |              |            |             |       |
|--------------|-----------------|----------|-------|--------------|------------|-------------|-------|
|              | immature        | maturing | Hr    | orange berry | grey berry | black berry | Spent |
| 1            | 7.16            | 11.01    | 28.89 | 16.24        | 11.530     | 10.98       | 5.19  |
| 2            | 6.85            | 10.79    | 26.53 | 16.73        | 9.67       | 9.88        | 6.17  |
| 3            | 9.24            | 9.53     | 26.42 | 15.42        | 10.53      | 11.52       | 8.42  |
| 4            | 8.37            | 10.27    | 29.01 | 15.98        | 7.98       | 6.42        | 6.59  |
| 5            | 8.01            | 11.51    | 28.56 | 14.11        | 12.54      | 12          | 7.03  |
| Mean         | 7.93            | 10.62    | 27.88 | 15.70        | 10.45      | 10.16       | 6.68  |
| S.D          | 0.96            | 0.76     | 1.30  | 1.00         | 1.75       | 2.23        | 1.19  |

**Fig. 9.7** Total carotenoid variation in the ovary of female *Heterocarpus gibbosus* in the different maturity stages



**Table 9.22** Results of ANOVA for total carotenoid variation in the ovary of *H.gibbosus* (Female)

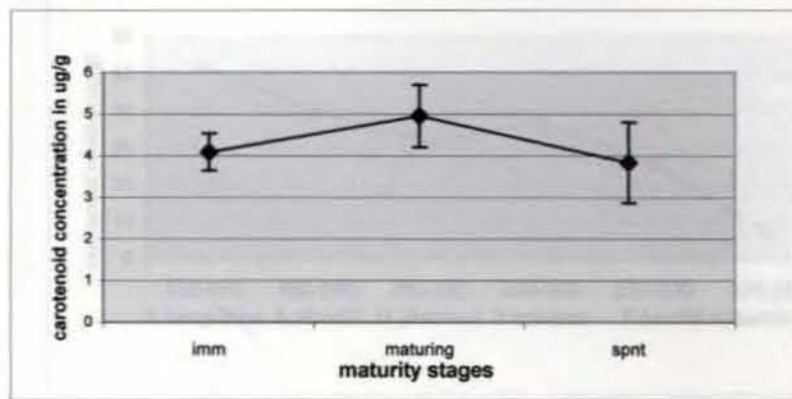
| Source of Variation | SS          | df | MS       | F       | P-value | F crit |
|---------------------|-------------|----|----------|---------|---------|--------|
| Between Groups      | 1571.440243 | 6  | 261.9067 | 134.38* | 2.6E-19 | 2.4453 |
| Within Groups       | 54.56976099 | 28 | 1.94892  |         |         |        |
| Total               | 1626.010004 | 34 |          |         |         |        |

\*Significant at 5 % level.

**Table 9.23** Total carotenoid variation ( $\mu\text{g/g}$  wet wt ) in the gonad of *Heterocarpus gibbosus* (Male)

| Replications | Maturity stages |          |       |
|--------------|-----------------|----------|-------|
|              | immature        | maturing | spent |
| 1            | 4.10            | 5.18     | 4.01  |
| 2            | 3.71            | 5.71     | 4.85  |
| 3            | 3.83            | 3.92     | 3.97  |
| 4            | 4.71            | 5.02     | 2.51  |
| Mean         | 4.09            | 4.96     | 3.84  |
| S.D          | 0.45            | 0.75     | 0.97  |

**Fig. 9.8** Total carotenoid variation in the gonad of male *Heterocarpus gibbosus* in the different maturity stages



**Table 9.24** Results of ANOVA for total carotenoid variation in the gonad of *H.gibbosus* (Male)

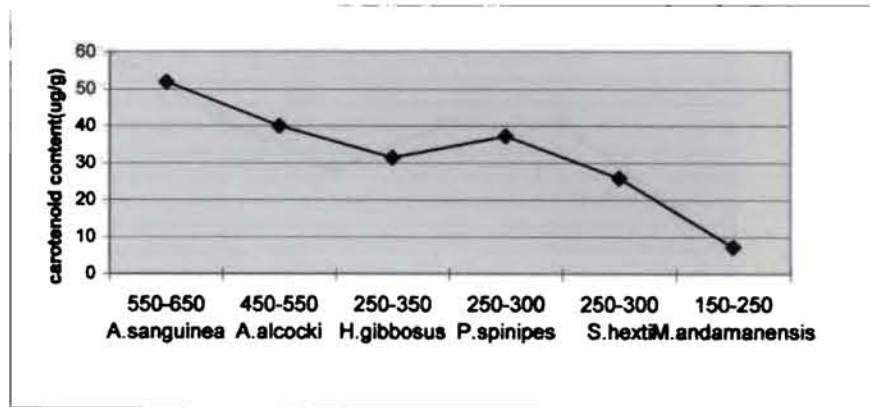
| Source of Variation | SS    | df | MS       | F      | P-value | F crit |
|---------------------|-------|----|----------|--------|---------|--------|
| Between Groups      | 2.774 | 2  | 1.387108 | 2.434* | 0.14282 | 4.2565 |
| Within Groups       | 5.127 | 9  | 0.569694 |        |         |        |
| Total               | 7.901 | 11 |          |        |         |        |

\*Not significant ( $P > 0.05$ )

**Table 9.25** Carotenoid concentration in exoskeleton of important species of deep sea prawns inhabiting at various depths

| Replications | species          |                    |                   |                       |                   |                 |
|--------------|------------------|--------------------|-------------------|-----------------------|-------------------|-----------------|
|              | <i>A.alcocki</i> | <i>A.sanguinea</i> | <i>P.spinipes</i> | <i>M.andamanensis</i> | <i>H.gibbosus</i> | <i>S.hextii</i> |
| 1            | 38.90            | 74.93              | 22.18             | 7.57                  | 33.02             | 32.28           |
| 2            | 41.82            | 40.77              | 29.50             | 8.02                  | 28.89             | 35.74           |
| 3            | 32.57            | 32.38              | 25.19             | 7.41                  | 31.38             | 32.00           |
| 4            | 46.79            | 59.82              | 26.85             | 6.02                  | 32.28             | 35.00           |
| Mean         | 40.02            | 51.98              | 37.21             | 7.26                  | 31.39             | 25.93           |
| S.D          | 5.94             | 19.13              | 3.07              | 0.86                  | 1.80              | 1.89            |

**Fig. 9.9** Carotenoid variation in the exoskeleton of different deep sea prawns



**Table 9.26** Results of ANOVA for total carotenoid variation in the exoskeleton of deep sea prawns

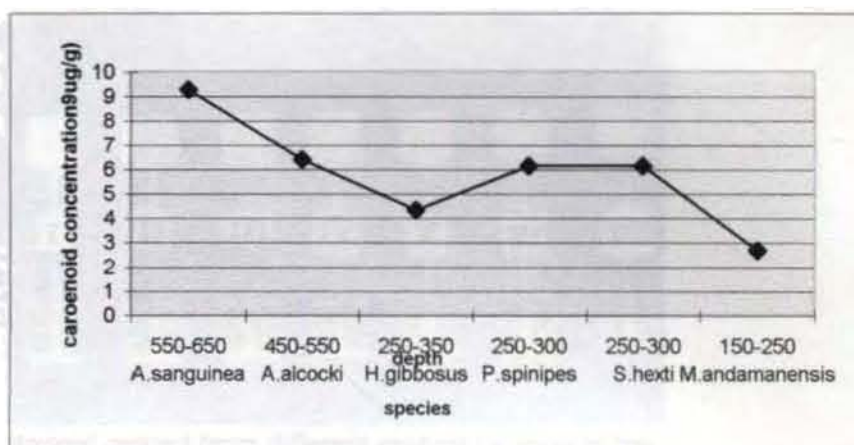
| Source of Variation | SS         | df | MS       | F      | P-value   | F crit |
|---------------------|------------|----|----------|--------|-----------|--------|
| Between Groups      | 258628.476 | 1  | 258628.5 | 20.55* | 0.0019158 | 5.3176 |
| Within Groups       | 100674.816 | 8  | 12584.35 |        |           |        |
| Total               | 359303.291 | 9  |          |        |           |        |

\*Significant at 5%

**Table 9.27** Carotenoid concentration in the muscle tissue of of deep sea prawns inhabiting at various depths

| Replications | species   |             |            |                     |            |          |
|--------------|-----------|-------------|------------|---------------------|------------|----------|
|              | A.alcocki | A.sanguinea | P.spinipes | M.andaman-<br>ensis | H.gibbosus | S.hextii |
| 1            | 5.60      | 8.92        | 5.373      | 2.1                 | 2.50       | 3.26     |
| 2            | 6.00      | 9.07        | 7.47       | 3.24                | 6.56       | 2.8      |
| 3            | 7.52      | 8.21        | 5.9        | 2.78                | 4.23       | 4.75     |
| 4            | 6.50      | 11          | 5.87       | 2.78                | 4.70       | 3.99     |
| 5            | 7.52      | 9.07        | 5.9        | 2.78                | 3.70       | 3.99     |
| Mean         | 6.63      | 9.25        | 6.15       | 2.74                | 4.34       | 6.10     |
| S.D          | 0.87      | 1.04        | 0.80       | 0.41                | 1.49       | 0.75     |

**Fig. 9.10** Carotenoid variation in the muscle of different deep sea prawns



**Table 9.28** Results of ANOVA for total carotenoid variation in the muscle tissue of deep sea prawns

| Source of Variation | SS         | df | MS       | F       | P-value   | F crit |
|---------------------|------------|----|----------|---------|-----------|--------|
| Between Groups      | 338332.639 | 1  | 338332.6 | 33.135* | 0.0001838 | 4.9646 |
| Within Groups       | 102107.888 | 10 | 10210.79 |         |           |        |
| Total               | 440440.527 | 11 |          |         |           |        |

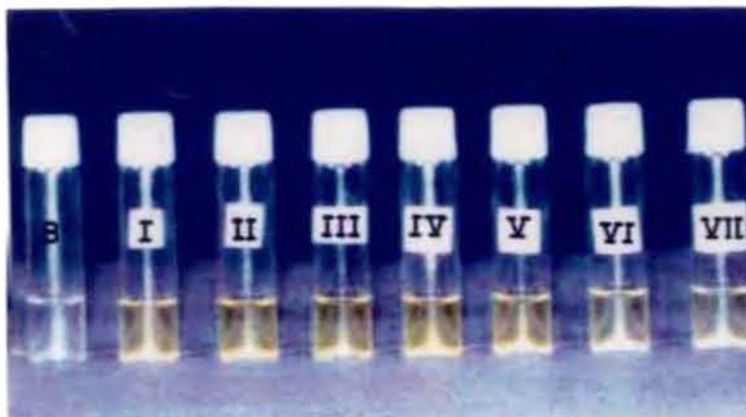
\*Significant at 5%



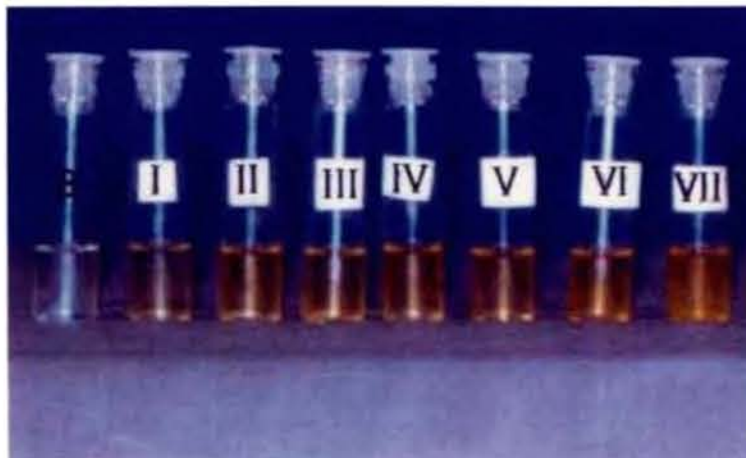
## Plate 9.1



A. Carotenoid extract from different maturity stages in the muscle of *Heterocarpus gibbosus* (female)



B. Carotenoid extract from different maturity stages in the hepatopancreas of *Heterocarpus gibbosus* (female)



C. Carotenoid extract from different maturity stages in the ovary of *Heterocarpus gibbosus*.

**Chapter 10**

**AGE AND GROWTH**

## 10.1 INTRODUCTION

Age and growth estimation form the most fundamental and vital aspects in the life history traits of a fish species. Knowledge of these parameters are essential to understand the major positive dynamic forces acting on the population and forms the basic key to determine the rate of addition to a fish population over time. The analysis of age structure with reference to time in aquatic animals provides information on the methods of assessment of exploited populations (Mergrey, 1989) and as a tool in studying age and time dependent processes such as growth, mortality and recruitment variability (Roa and Ernst, 1996). Aquatic vertebrates can be aged directly with the help of age marks on the vertebrae and other such permanent hard structures, however, for organisms with out hard body structures, indirect methods are widely employed.

The growth of crustaceans, as in fishes, vary with sex and commensurate with the variation of other extrinsic factors such as food quality, quantity, population density, light, temperature and salinity (Nandakumar, 1997). Since crustaceans do not possess a bony structure to mark imprints according to environmental or internal variations to read age directly, the number of moults and the increase in size determines the size at any age at each moult. Owing to the difficulty in incorporating

such phenomena in mathematical models, growth is considered as a continuous process and it is measured directly as size at age. Hence, all conclusion on growth presented by various authors represent overall increments in dimensions in a given period of time which are summations of individual spurts of growth that have taken place at different moultings (Dall *et al.*, 1990).

Crustaceans can also be aged by keeping organisms in captivity (Plaut and Fishelson, 1991; Hill, 1992), by mark recapture experiments (Campbell, 1988; Taylor and Hoenig, 1990; Fitz and Weigert, 1991; Somers and Kirkwood, 1991), by physiological correlates of age and by using mixture distribution analysis of length frequency data (Macdonald and Pitcher, 1979; Fournier *et al.* 1991; France *et al.*, 1991; Bergström, 1992). Determination of age in deeper water species is not possible in captivity, whereas tagging and recapturing methods are unreliable owing to their discontinuous growth and seasonal shedding of exoskeleton (Garcia and Le Reste, 1981; Hartnoll, 1983). Hence, reliance has perforce to be placed on methods of analysis of length frequency distributions suggested by Peterson (1892) in age determination (Bhimachar, 1965). Indirect estimation of age in crustaceans has been attempted by a number of researchers from temperate waters. Ettershank (1983) and Sheehy (1990) correlated the concentration of the pigment lipofuscin to age by image analysis while Allen and Landry (1984) used



the ratio of nucleic acid for age determination. Yano and Kobayashi (1969) and Farmer (1973) reported the increase in the number of lamellae in endocuticle with age in the deep sea crabs *Gaetice depressus* and *Nephrops norvegicus*.

Moult cycles, synchronization between moulting and reproduction, berrying in some species and size related growth rates are the main intrinsic factors introducing uncertainty into estimates of growth parameters in deep water crustaceans (Drach, 1939; Passano, 1960; Aiken, 1980; Hartnoll, 1983 ; Caddy , 1987) . External parameters such as temperature, hours of day light and food availability may also stimulate or inhibit growth processes (Venner, 1985). All these aspects have received considerable attention in species maintained in captive conditions and in coastal water penaeids grown in pounds (Descouturelle, 1976; Richard, 1978; Emmerson , 1980) and in spiny and clawed lobsters (Aiken, 1980; Morgan, 1980; Conan, 1985). Nevertheless, individual growth studies using cultured specimens and free living animals have added a substantial contribution to the present state of knowledge of specific growth processes in shallow water crustaceans (Cobb and Phillips, 1980; Bliss, 1983) and in mid water species (Childress *et al.*, 1980 ; Childress and Price, 1983) .

Modal progressions in time series of size frequency distributions compiled from random samples of research vessels have proved to be one of the most useful methods of estimating growth parameters in crustaceans (Sparre *et al.*, 1989). This type of research is extensively carried out in coastal penaeids (Garcia and Le Reste, 1981), however, in species dwelling at greater depths, the work is confined to a limited number of species of commercial interest inhabiting temperate waters, such as the nektobenthic shrimp *Pandalus borealis* and the benthic Norway lobster *Nephrops norvegicus* (Cessay, 2000; Anderson, 1991; Stefansson *et al.*, 1994) . Growth of deep-water crustaceans is generally considered to be slow, chiefly because of the lower temperature and low productivity of deeper waters (Mauchline, 1972; Gage and Tyler ,1991). *N.norvegicus* (Sardá 1985; Mytilineou *et al.*, 1998), *Aristeus antennatus* (Orsi and Relini, 1985; Sardá and Demestre, 1987; Demestre, 1990) and *A.foliacea* (D'onghia *et al.*, 1994) which are inhabiting beyond 400 m and *Liocarcineus depurator* (Abelló, 1986), *Plesionika edwardsii* (Colloca, 2002) and *Solenocera membranacea* (Demestre and Abelló, 1993) whose distribution is confined to below 400 m, are some of the most important commercial species in the western Mediterranean Sea which were subjected to growth studies . Company and Sardá (2000) estimated comparative growth patterns of 17 deep-water decapod crustaceans from the Northwestern Mediterranean Sea. Ohtomi and Irieda (1997) assessed

the growth structure of *Solenocera melantho* while Ohtomi (1997) studied the growth of pandalid shrimp *Plesionika semilaevis* from Kagoshima Bay. Roa and Ernst (1996) studied the age structure of pandalid shrimp *Heterocarpus reedi* from Central Chile where as Dailey and Ralston (1986) assessed the reproductive biology, growth and mortality of *H. laevigatus* in Hawaii.

Though a number of studies on age and growth of penaeid prawns have been reported from Indian waters (George *et al.* ,1963; Banerji and George , 1967; Kurup and Rao ,1974; Thomas ,1975,Nandakumar,1997) similar information on pandalid shrimps is hitherto not available.

Due to the absence of regular commercial deep sea prawn landings from Indian coasts and *inter alia* the lack of regular samples, studies on age and growth of deep sea prawns of this country became a very difficult task. However, for the first time in the history of Indian fisheries, the trawlers of Kerala started deep sea fishing off Kerala coast since 1999 with an endurance of 5 to 7 days. With the materialization of commercial deep sea prawn fishery, heavy landings were recorded along the Kerala coast with dominance of *Heterocarpus* spp. It is against this background that an attempt has been made to study the age and growth of *Heterocarpus gibbosus* and *H. woodmasoni* off Kerala based on the deep sea prawn landings from 250 to 450 m off Kerala coast .

## 10.2 MATERIALS AND METHODS

The materials for the study were collected during 2000-2002, from the commercial deep sea landings at Sakthikulangara, Cochin and Munambum, the three important harbours of Kerala. Length measurements of the specimens collected randomly were taken in the field itself at weekly intervals. There was a data gap from commercial landings during monsoon months due to the imposition of a ban on trawling in the EEZ of Kerala and another self-imposed ban due to inclement weather conditions. However, the specimens collected from the cruise surveys of the research vessel FORV Sagar Sampada off South West coast of India in the same period were utilized to bridge the gap. A total of 2925 males in the size range from 11 to 180mm and 2272 females having 43 to 189 mm TL were used in *H.gibbosus* while in *H.woodmasoni*, 2114 males with 52 to 143 mm TL and 2641 females having 41 and 176 mm were utilized for the present study. Total length was measured from the tip of rostrum to the extremity of telson (Nandakumar, 1997). Length measurements were grouped into 10mm class intervals, separately for males and females. As the trawlers from the three harbours invariably operate in same depth and area along Kerala coast using similar trawl nets having 16-18 mm cod end mesh size and since there was no significant difference in the size composition of

the landings observed at three harbours, the data was pooled and sequentially arranged for age and growth studies of the two species.

Age and growth of *H.gibbosus* and *H.woodmasoni* were estimated following Von Bertalanffy Growth Formula (Bertalanffy, 1938), which can be expressed as

$$L_t = L_\alpha [ 1 - e^{-K(t-t_0)} ]$$

Where  $L_t$  is the length of fish at age  $t$ ,  $L_\alpha$  the average asymptotic length to which the individual grows,  $K$  is the growth coefficient which determines how fast length of the fish approaches  $L_\alpha$  and  $t_0$  is the theoretical age of the animal at zero length if it always had growth according to the above equation. The growth parameters for both sexes were estimated using ELEFAN 1 (Gayanilo *et al.*, 1996). Age length key at three month interval were computed from ELEFAN 1 and the estimates of  $t_0$  was made using von Bertalanffy (1934) plot in which the results of regression of  $-\ln(1-L_t/L_\alpha)$  against '  $t$  ' was used to calculate  $t_0$  as :

$$t_0 = -a/b .$$

The estimates of  $L_\alpha$  and  $K$  were done using Ford – Walford method (Ford ,1933; Walford ,1946) which in linear form is given by

$$L_{t+1} = L_{\alpha} (1 - e^{-k}) + e^{-k} L_t$$

Or

$$L_{t+1} = a + b L_t$$

The lengths at age derived were subjected to linear regression and the results so obtained were used to calculate the growth parameters.  $L_{\alpha}$  and  $K$  were estimated from the regression equation as follows:

$$L_{\alpha} = a / (1 - b)$$

$$K = -\log_e b$$

The time interval used was one quarter (3 months) and therefore, the  $K$  value obtained was multiplied by 4 to get the annual growth coefficient ( $K$ ) or curvature parameter.

The growth performance index  $\phi'$  (phi prime) of both the species of *H.gibbosus* and *H.woodmasoni* were used to compare the growth performance of sexes following Pauly and Munro (1984) which is expressed by the equation:

$$\phi' = \log_{10} K + 2 \log_{10} L_{\alpha}$$

Where  $K$  is the growth constant expressed in annual basis ( $\text{yr}^{-1}$ ) and  $L_{\infty}$  is the asymptotic length in cm. The equation has proved that the quantity of phi prime approximately normally distributed within the family members and generally, its values are around 3 ( Muthiah, 1994) .

### 10.3 RESULTS

#### ***H.woodmasoni***

The growth parameters  $L_{\infty}$  and  $K$  estimated in male and female population of *H.woodmasoni* by applying ELEFAN 1 Programme is presented in Table 10.1. The length frequency data with superimposed growth curve fitted at highest levels of  $R_n$  values in the response surfaces of males and females of *H.woodmasoni* are depicted in Fig.10.1 and 10.2 respectively. Appearance of growth curve during October to February corroborates the possibility of recruitment of a major brood to the commercial fishery.

The highest  $R_n$  values obtained through response surface analysis was 0.265 for males and the corresponding  $L_{\infty}$  and  $K$  are 160.59 and 0.82 while the  $R_n$  values estimated for females was 0.343 along with the

$L_{\infty}$  and  $K$  188 and 0.60 respectively. Length at maximum of *H.woodmasoni* was estimated as 158 mm for males and 177mm for females.

Based on the growth parameters, the von Bertalanffy Growth equations of *H.woodmasoni* can be expressed as follows:

$$\text{Male: } L_t = 160.59 \left( 1 - \exp^{-0.82(t-0.97)} \right)$$

$$\text{Female: } L_t = 188 \left( 1 - \exp^{-0.60(t-0.96)} \right)$$

The total length of *H.woodmasoni* worked out (in mm) at trimonthly age based on the growth parameter arrived at from ELEFAN are given in Table 10.2 . It was observed that initially the males showed a faster growth rate than females but the growth slows down after attaining maturity. By the end of 21<sup>st</sup> month the length at age of both males and females were found almost similar in the population, thereafter, the females grow larger than males.

On applying the Von Bertalanffy Growth Formula in *H.woodmasoni* , the males and females attained  $L_{\infty}$  at the age of 7years . However, the  $L_{\text{max}}$  observed during the present study is reached at the age of 5 years in both the sexes and therefore, the average life span of *H.woodmasoni* is



estimated as 5 years at which the males and females attain 157.99mm and 178.98mm respectively (Table 10.2) .

The phi prime values ( $\phi'$ ) used to compare the growth performance of *H.woodmasoni* male and female was estimated as 4.33 each respectively.

### ***H.gibbosus***

The restructured length frequency data with super imposed growth curve fitted at highest levels of  $R_n$  values in males and females of *H.gibbosus* are depicted in Fig. 10.3 & 10.4 .

The highest  $R_n$  values obtained through response surface analysis was 0.218 for males with corresponding  $L_\infty$  and  $K$  are 200mm and 0.73 while the  $R_n$  values estimated for females was 0.230 with corresponding  $L_\infty$  and  $K$  as 203mm and 0.53 respectively.  $L_{max}$  of *H.gibbosus* was estimated as 198 mm for males and 197.89 mm for females.

The growth parameters estimated in male and female population of *H.gibbosus* by applying ELEFAN 1 Programme is given in Table 10.3. In

*H.gibbosus*, the growth curve shows a prolonged recruitment from November to March as discernible from the data.

Based on the growth parameters, the von Bertalanffy growth equations of *H.gibbosus* can be expressed as follows :

$$\text{Male: } L_t = 200 \left( 1 - \exp^{-0.73(t-0.98)} \right)$$

$$\text{Female: } L_t = 203 \left( 1 - \exp^{-0.53(t-0.86)} \right)$$

The total length (in mm) at different age (in months) calculated for *H.gibbosus* based on tri monthly age length are given in Table 10.4. The males and females attained 104.75 and 85.63 mm during the first year while during second year they attained 154.56 and 133.91 mm respectively, thus showing a slower growth rate in females when compared to their male counterparts.

Length (in mm) at age (in years) as computed for males and females of *H.gibbosus* are given in Table 10.4. The average life span of males was estimated as 5 years during when the animals reached  $L_{\max}$  of 195.44mm. Females showed a greater longevity than males, attained  $L_{\max}$  at the age of 7years with a length of 198.60mm. The  $L_{\infty}$  was observed at the age of 8 years when the animal reaches 200.53mm. The

phi prime values ( $\phi'$ ) of *H.gibbosus* was found to be 4.47 for male and 4.34 for females.

#### 10.4 DISCUSSION

*H.gibbosus* and *H.woodmasoni* belonging to the pandalid shrimps constitute the major component of the exploited deep-water fisheries of Kerala in recent years. These shrimps have attracted considerable scientific interest mainly because of their export demand and reproductive strategy. Information on resource characteristics of these stocks, such as growth and age structure are of paramount importance in conservation and management of stock and also for their sustainable exploitation. Knowledge on the age structure enables us to see the age composition of the individuals constituting the exploited stock, thereby imposing corrective measures if required for their rational exploitation .

In the present study, a preliminary attempt is made to estimate the growth parameters and age structure of both male and female population of *H.gibbosus* and *H.woodmasoni*. The results of this study would give some idea about the rate at which the new recruits are added to the exploited stock, whereby the fishing effort can be regulated at sustainable levels. Though voluminous studies on age and growth of wild population of penaeid prawns have been carried out in the Indian waters (Menon ,

1955; George *et al.*, 1963; Banerji and George , 1967; Kurup and Rao 1974; Thomas ,1975; Ramamurthy *et al.*,1978 ; Lalitha Devi , 1986; Rao *et al.*,1993) based on length frequency, no such studies on pandalid shrimps have ever been attempted in the Indian context.

Fitting the von Bertalanffy Growth equation based on ELEFAN I (Gayanilo *et al.*, 1996) showed that the  $L_{\infty}$  values arrived at in males of both the species were on a lower side when compared to their female counterparts. High values of asymptotic length arrived at in females when compared to males has already been reported in other pandalid shrimps and this is in agreement with Dailey and Ralston (1986), Ohtomi(1997) and Colloca (2002) . In contrast, the K values of males were on a higher side than females in both the species. In the present study , K values worked out in males and females of *H.woodmasoni* were 0.82 and 0.60 respectively while the same in *H.gibbosus* were 0.73 and 0.53 respectively. Roa and Ernst (1996) observed a low  $CL_{\infty}$  value in males ( $CL_{\infty}=40.68\text{mm}$ ) than females ( $CL_{\infty}=48.34\text{mm}$ ) based on the carapace length whereas the  $k$  ( $\text{yr}^{-1}$ ) was found to be higher in reported that in the pandalid shrimp *H.laevigatus* from Hawaii Islands ,  $CL_{\infty}$  of male was 17 while that of female was 19.20mm . According to Company and Sardá (2000), the growth coefficient values were in the range between 0.40 and

0.94 in 5 pandalid species *Plesionika heterocarpus*, *P.edwardsii*, *P.giglioli*, *P.martia* and *P. acanthonotus* from the Western Mediterranean.

The  $L_{max}$  recorded with regard to both the sexes of *H.woodmasoni* were far below when compared to the corresponding  $L_{\infty}$  values. In *H.gibbosus* also, lower  $L_{max}$  values were arrived at than the  $L_{\infty}$ , and present findings are well conforming with the equation  $L_{\infty} = L_{max} / 0.95$  (Pauly, 1982).

The results of the present study revealed that there exist differential growth between males and females, especially from second year onwards during when females growing faster than males, thus attaining larger length at age. Length attained by males and females of *H.gibbosus* in the present study are 90.52 mm and 80.37mm respectively at the end of 12 months while the same in *H.woodmasoni* are 104.75mm and 85.63mm respectively. In the females of *H.gibbosus*, the growth is found to be slower than males in the lower age groups, but attains more weight in higher age groups. In *H.woodmasoni* also, after the initial retarded growth, the females become more massive than males at later ages, attained 132.61mm by the end of 2<sup>nd</sup> year while the males attained only 130.16mm during the same period. The difference between sexes is counterintuitive in the sense that females are expected to be smaller due to the need to allocate energy for reproductive purpose except for

protandric hermaphrodites. However, both *H.woodmasoni* and *H.gibbosus* are exceptions to this situation.

In both the species, there is the possibility a single prolonged recruitment pulse every year starting from October to February for *H.woodmasoni* and November to March for *H.gibbosus*, suggesting that they are continuous breeders. However, lack of adequate data during monsoon months poses great difficulty to ascertain the exact duration of spawning of this species .

The length at maximum of *H.woodmasoni* observed was 157.99 mm in males and 178.95 mm in females when they completed longevity of around 5 yrs. The  $L_{max}$  of *H.gibbosus* was estimated as 195.44 mm at the age of 6 yrs for males and 198.60 mm at 7 yrs for females, thus showing a higher longevity in females. Based on the above data, the longevity of the above two deep sea prawn species was found to be two times more than the coastal shrimps. In view of their slow growth rate, it can reasonably be inferred that the time required for their recruitment to the usable stock will be at least two times more than their counterparts in the coastal waters. Roa and Ernst (1996) estimated the average life span of *H.reedi* as 5 to 7 years with the females growing massive in size than males of the same length at late ages. Present findings show very strong agreement with the above observations. Slower growth rates were also

reported in other deeper water prawns as well. Rasmussen (1953) observed the longevity of *P.borealis* as more than 6 years in which the sex change of animals takes place after one to three years of life span depending upon the water temperature whereas Anderson (1991) reported the complete transformation of the species from males to females at the age of 6.4years in Alaskan waters. The life span of deep aristeid shrimp *Aristaeomorpha foliacea* was estimated to be about 7-8 years in females and 5-6 years in males from the north western Ionian sea ( D'onghia *et al.*,1998) and they showed a faster growth rate for the first two years, but decreases sharply thereafter, registering very low growth rates in subsequent years. Ohtomi and Irieda (1997) studied the growth rates in the deeper water prawn *Solenocera melantho* from Kagoshima Bay wherein the females grow faster and reach larger size than males of the same age group. Omori (1974) reported both greater longevity and lower growth rates in the bathypelagic decapod crustaceans *Acanthephyra sanguinea* and *A.quadrspinosa* based on the length frequency data. Massuti *et al.* (1995) also reported similar pattern of growth and longevity in the deep sea fishes of the family Macrouridae from Western Mediterranean Sea.

The growth performance index in the present study was worked out to be 4.3 for both the sexes of *H.woodmasoni* and 4.47 for males and 4.34 for females of *H.gibbosus*, thus showing a significant skewness from

the ideal value of three as reported by Muthiah (1994). Nevertheless, the Growth Performance Index was very similar for females and males of both the species, which indicates that the two sexes follow more or less the same growth model (Pauly and Munro, 1984). Available report (Childress *et al.*, 1980) suggested that in deep sea shrimps *Sergia robusta* and *Pasiphea multidentata*, despite of their larger size and longer life span, these deepest dwelling meso pelagic species showed higher phi prime values than the shallower dwelling species.

Annual growth rates of deep sea organisms have largely been considered to be slower than those of their shallow water counterparts and low water temperature and low food availability are attributed as the major factor responsible for slow growth rates (Mauchline 1972; Gage and Tyler, 1991). Availability of food and prevailing water temperature are the two main environmental factors affecting growth rates of deep sea prawns (Venner, 1985). In crustaceans, the amount or quality of food and the water temperature influence the duration of the inter moult period and the moult size increment and these extraneous factors cause either increase or decrease in growth rates (Hartnoll, 1983). Rich food supply and water temperature seems to be the factors mainly responsible for the higher growth rates of tropical penaeids in the coastal waters (Nandakumar, 1997). According to Suseelan (1985), the abundance of *H.woodmasoni* and *H.gibbosus* in Arabian Sea are strongly related to the



prevailing water temperatures, temperature of 10.5<sup>0</sup>C to 14<sup>0</sup>C to the former and 10.5<sup>0</sup>C to 13.5<sup>0</sup>C to the latter. The slower growth rates observed in two deep sea prawn species when compared to that of coastal penaeid shrimps can well be attributed to the low water temperature prevailing in the deeper waters (Refer chapter 3 for details).

The present findings have immense application in the management of the fishery of deep sea prawns, which need to be done on a regional basis. The new deep-water resources must be exploited by exercising utmost care, giving due emphasis to their slow growth rate. While designing a strategy for regulated exploitation, it should be remembered that deep water species generally have low levels of tolerance towards exploitation in terms of long term sustainable fishery. In this context, it is fundamental to establish and impose critical measures to reduce the risk of over exploitation.

**10.1 Growth parameters of males and females of *Heterocarpus woodmasoni* by the method of ELEFAN I**

| Sex    | $L_{max}(mm)$ | $L_{\infty}(mm)$ | K    | Rn    | to   | $\theta$ |
|--------|---------------|------------------|------|-------|------|----------|
| Male   | 158           | 160.592          | 0.82 | 0.265 | 0.97 | 4.33     |
| Female | 177           | 188              | 0.60 | 0.343 | 0.96 | 4.33     |

**10.2 Length at age of *Heterocarpus woodmasoni***

| Age in months | Mean total length (mm) |         |
|---------------|------------------------|---------|
|               | Males                  | Females |
| 0             | 0.66                   | 0.99    |
| 3             | 29.86                  | 26.71   |
| 6             | 54.43                  | 49.12   |
| 9             | 74.36                  | 68.61   |
| 12            | 90.52                  | 85.37   |
| 15            | 103.25                 | 99.49   |
| 18            | 113.94                 | 111.78  |
| 21            | 122.66                 | 122.48  |

| Age in years | Mean total length (mm) |         |
|--------------|------------------------|---------|
|              | Males                  | Females |
| 1            | 91.51                  | 87.19   |
| 2            | 130.16                 | 132.61  |
| 3            | 147.19                 | 157.62  |
| 4            | 154.69                 | 171.39  |
| 5            | 157.99                 | 178.98  |
| 6            | 159.45                 | 183.16  |
| 7            | 160.08                 | 185.45  |

**10.3 Growth parameters of males and females of *Heterocarpus gibbosus* by the method of ELEFAN I**

| Sex    | $L_{max}$ (mm) | $L_{\infty}$ (mm) | K    | Rn    | to   | $\theta$ |
|--------|----------------|-------------------|------|-------|------|----------|
| Male   | 193            | 200               | 0.73 | 0.218 | 0.98 | 4.47     |
| Female | 197.89         | 203               | 0.53 | 0.230 | 0.86 | 4.34     |

**10.4 Length at age of *Heterocarpus gibbosus***

| Age in months | Mean total length (mm) |         |
|---------------|------------------------|---------|
|               | Males                  | Females |
| 0             | 0.35                   | 0.58    |
| 3             | 33.31                  | 28.01   |
| 6             | 61.68                  | 49.68   |
| 9             | 85.22                  | 68.85   |
| 12            | 104.75                 | 85.63   |
| 15            | 120.47                 | 100     |
| 18            | 134.01                 | 112.75  |
| 21            | 145.24                 | 124.04  |
| 24            | 154.56                 | 133.91  |

| Age in years | Mean total length (mm) |         |
|--------------|------------------------|---------|
|              | Males                  | Females |
| 1            | 105.68                 | 91.78   |
| 2            | 154.94                 | 137.48  |
| 3            | 178.61                 | 164.46  |
| 4            | 189.98                 | 180.39  |
| 5            | 195.44                 | 189.78  |
| 6            | 198.07                 | 195.33  |
| 7            | 199.33                 | 198.6   |
| 8            |                        | 200.53  |

Month wise restructured Length Frequency Distribution for the males of *Heterocarpus woodmasoni*  
 Estimated using ELEFAN - 1 Programme

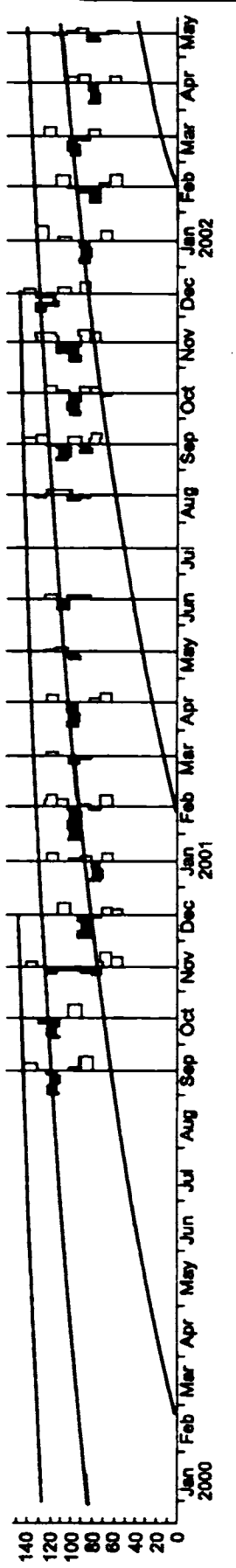


Fig. 10.2

Month wise restructured Length Frequency Distribution for the females of *Heterocarpus woodmasoni*  
 Estimated using ELEFAN - 1 Programme

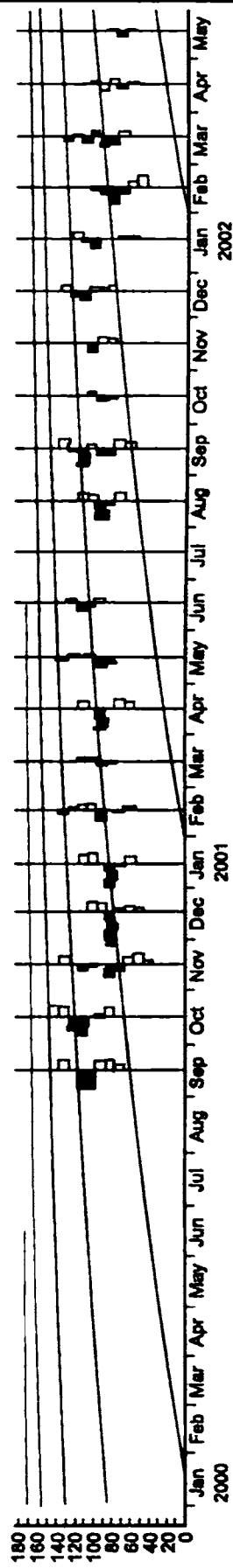


Fig. 10.3

Month wise restructured Length Frequency Distribution for the males of *Heterocarpus gibbosus*  
Estimated using ELEFAN - 1 Programme

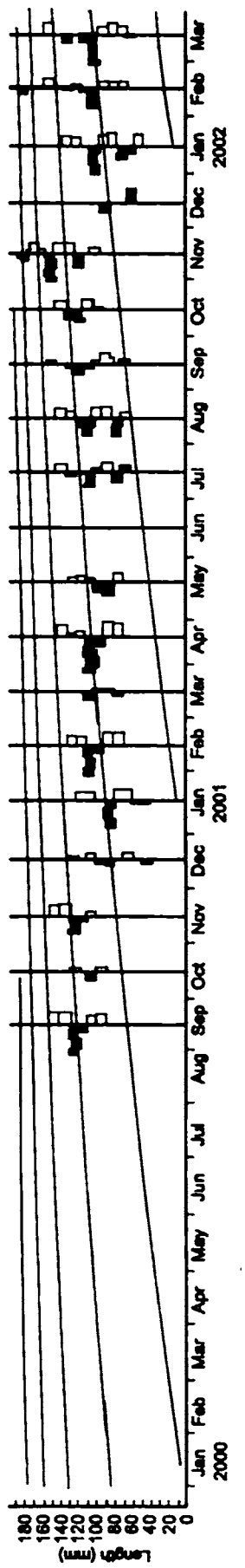
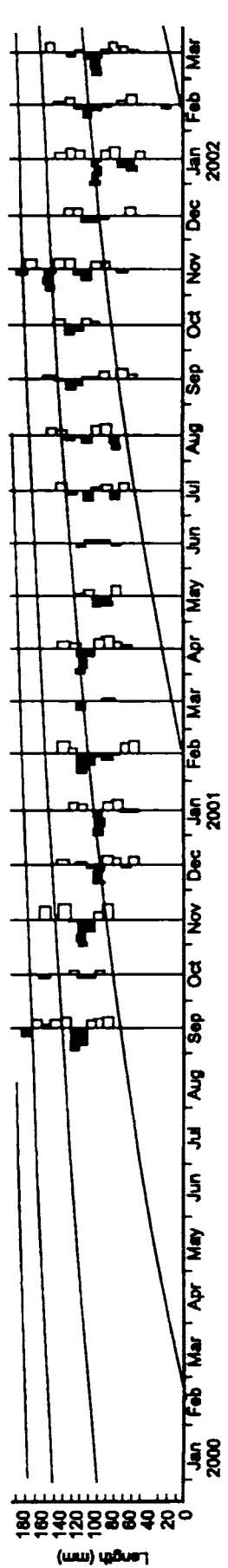


Fig. 10.4

Month wise restructured Length Frequency Distribution for the females of *Heterocarpus gibbosus*  
Estimated using ELEFAN - 1 Programme



**Chapter 11**

**POPULATION DYNAMICS**

## 11.1. INTRODUCTION

Owing to lucrative price, higher export value and heavy demand from the worlds major seafood markets, the deep sea prawns have gained a prime position among the exploited marine fishery resources of Kerala with in a short span of three years. Indiscriminate exploitation patterns such as exerting 80% of the total fishing efforts in the inshore waters coupled with over-dependence in shrimp trawlers have adversely affected the stocks of costal penaeid prawns, resulted in their stock depletion (Devaraj and Vivekanandan, 1999). This situation has tempted the shrimp trawlers to shift their area of operation to increasingly deeper parts of the oceans targeting deep sea prawns during late 90's. However, the shrimp trawlers carried out the fishing for deep sea prawns almost on par with the coastal shrimps, regardless of the stock size and regeneration capability of the former groups. Besides, their unique biological features such as low fecundity, sexual segregation and slow growth rates make them vulnerable to high and uncontrolled levels of fishing pressures in the deeper waters of Kerala. As a result, the total deep sea prawn landings showed a drastic decline from 48675t in 2000-01 to 19285 tonnes in 2001-02, thus registering a reduction to the tune of 60.35% in the total deep sea prawn landings of Kerala (refer chapter 5 for details) .

It would thus appear that enforcement of strict management measures is warranted for the sustenance of the stock of deep sea prawns. For adoption of successful management practices, knowledge on the dynamics of fish population is essential to understand the stock position from time to time, which is the net result of various dynamic forces acting on the population. This information is vital in regulating the exploitation level of the stock as a measure of conservation.

The earlier attempts to estimate stock assessment of crustaceans were mostly on penaeid prawns which restricted to the study of mortality rates based on tagging experiments (Lindner and Anderson , 1956; Klima , 1965; Kutkunh , 1966 ) and catch composition ( Neal , 1968; Berry , 1970; Garcia , 1977 ; Jones and Van Zalinge , 1981 ; Pauly *et al.*,1984) . Studies on the population dynamics of deep sea prawns are very scanty and are confined to a few species viz., *Aristeomorpha foliacea* and *Aristeus antennatus* (Yahiaoui, *et al.*, 1986; Orsi and Relini , 1988 ; Demestre and Martin , 1993; Yahiaoui , 1994; Ragonese and Bianchini , 1995; Ragonese *et al.* ,1994; Spedicato *et al.*,1994; Donghia *et al.* ,1998), *Pandalus borealis* (Anderson , 1991; Bergström ,1992 ; Cessay ,2000) and *Heterocarpus laevigatus* (Dailey and Ralston, 1986) .

Studies on the dynamics of population of marine prawns of Indian waters were confined to coastal Penaeid and Solenocerid prawns.



Notable works among them are on *Penaeus* spp. (Banerji and Geroge , 1967; Kurup and Rao ,1974; Lalitha Devi ,1986; Rao,1988;Rao *et al.*, 1993) *Metapenaeus dobsoni* ( Ramamurthy *et al.*, 1978; Alagaraja *et al.* , 1986; George *et al.*, 1988) , *Parapenaeopsis stylifera* ( Ramamurthy ,1980; Alagaraja *et al.* ,1986; Suseelan and Rajan , 1989; Geroge *et al.*, 1980) *M.monoceros* ( Lalitha Devi , 1987 , Rao , 1994) , *Solenocera crassicornis* ( Chakraborty *et al.*,1997) and *P.merguiensis* (Bhadra and Biradar, 2000).

Information on the dynamics of *Heterocarpus gibbosus* and *H.woodmasoni* from any part of the world is not available. Against this background, a maiden attempt is made to estimate the mortality parameters and stock assessment of two most commercially important species *Heterocarpus gibbosus* and *H.woodmasoni* off Kerala coast.

## 11.2. MATERIALS AND METHODS

The detailed methodology is described in chapter 10 on age and growth. The materials used for age and growth and population dynamics are same. For the estimation of total instantaneous rate of mortality

coefficient (Z), among the various methods available, the following four methods were employed in the present study.

1. **Beverton and Holt method (1957)**

$$Z = K \frac{\bar{L} - L'}{\bar{L} - L}$$

Where  $\bar{L}$  is the mean length of prawn of length  $L'$  and larger.  $L'$  is the lower limit of the size group from which length upwards, all lengths are under full exploitation.

2. **Ssentongo and Larkin method (1973)**

$$Z = K \frac{n}{n+1} \frac{1}{\bar{y} - y_c}$$

where  $y = -\log(1-l/l)$

$y_c = -\log(1-l_c/l)$

$\bar{y} = \sum y/f$  where  $n=f$ ,  $n+1 = f+1$

$y_c =$  corresponding  $l_c$  value

$n =$  number of prawn caught from  $y_c$

onwards

$l =$  mid length

**3. Length converted catch curve method (Gayaniilo *et al.*,1996)**

$$\ln (N_i/t_i) = a + b t_i$$

where N = number in length class i

t = time needed to grow through length class i

t = the age corresponding to the mid length class

i

( relative age computed with  $t_0 = 0$  )

b = estimate of Z when sign altered.

**4. Pauly's pile up method (1983)**

$$\text{Log } e (Nt / t) = a - bt^*$$

$$Z = -(-b) , t^* = t_1 + \frac{1}{2} t$$

$$t = 1/k \log_e \frac{(L-L_1)^{1/2}}{(L-L_2)}$$

$$t_1 = \frac{1}{k} \log_e \frac{(1-1/L)}{L}$$

where  $L$  = lower limit of length class

$t_1$  = relative age corresponding to lower limit of length class

$t^*$  = relative age corresponding to the mid length of length-class

Nt = Number of individual caught at time 't'.

To estimate natural mortality coefficients the following three methods are employed:

**1. Rickter and Effanov method**

$$M = 1.521(t_m^{-0.72}) - 0.155$$

Where  $t_m$  is the age at which 50% of the population is mature.

## 2. Sekharans' method ( $t_{max}$ method ) (1975)

$$M = \frac{-\ln 0.01}{t_{max}}$$

$$\text{Where } t_{max} \cong 3/K$$

$t_{max}$  is the age at  $l_{max}$  assuming that 99% of fish in the exploited population die when they reach  $t_{max}$  or the longevity of the prawn stock in question.

## 3. Pauly's empirical method

Pauly (1980) developed an empirical relationship between  $L_\alpha$ ,  $K$  and mean sea surface temperature ( $T$ ) and natural mortality as :

$$\text{Log}_{10}(M) = -0.0066 - 0.279 \log_{10} L_\alpha + 0.6543 \log_{10} K + 0.4653 \log_{10} T$$

$L_\alpha$  = asymptotic length (in cm)

$K$  = annual growth coefficient

$T$  = mean sea surface temperature in  $^{\circ}\text{C}$ .

The annual mean temperature of sea in which deep sea prawn stock lives is taken as  $12^{\circ}\text{C}$  based on the present study (refer Chapter 3)

### **Fishing mortality estimation**

Instantaneous rate of fishing mortality rate (F) was estimated by simple expression

$$F = Z - M$$

### **Stock assessment**

For the purpose of stock assessment studies, the following parameters are considered:

#### **Jones' (1984) length based cohort analysis**

In Jones' length cohort analysis, an assumption is made that the picture presented by all size (age) classes caught during one year reflects that of a cohort during its life span. This length based cohort analysis is written as

$$N(L_1) = [N(L_2) X(L_1, L_2) + C(L_1, L_2)] X(L_1, L_2)$$

Where  $N(L_1)$  = the number of fish that attains length  $L_1$

$N(L_2)$  = the number of fish that attains length  $L_2$

$C(L_1, L_2)$  = the number of fish caught of length between  $L_1$  and  $L_2$

$$X(L_1, L_2) = \left( \frac{L_\alpha - L_2}{L_\alpha - L_1} \right)^{M/2K}$$

The exploitation rate is determined from the relationship

$$F/Z = C(L_1, L_2) / (N(L_1) - N(L_2))$$

The fishing mortality was calculated using the formula  $F = M(F/Z)/(1-F/Z)$ . In above equations  $L_\alpha$  and  $K$  are growth parameters of VBGE,  $L_1$  and  $L_2$  are lower and upper limits of the length group considered,  $N$  is the stock number,  $C$  is the number caught,  $F$  and  $M$  are fishing and natural mortality coefficient respectively.

#### Exploitation rate (U)

The rate of exploitation (U) is defined as the fraction of fish present at the start of a year that is caught during the year (Ricker, 1975). It is estimated by the equation given by Beverton and Holt (1957) and Ricker (1975) as

$$U = \frac{F}{Z} (1 - e^{-Z})$$

### **Exploitation ratio (E)**

It refers to the ratio between fish caught and the total mortality (Ricker , 1975) or the exploitation rate or the fraction of deaths caused by fishing (Sparre and Venema , 1992) and estimated by the equation

$$E = \frac{F}{Z} = \frac{F}{M + F}$$

The ratio gives an indication whether a stock is over fished or not , under the assumption that the optimal value of E equals to 0.5 which in turn is under the assumption that the sustainable yield is optimized when  $F \approx M$  ( Gulland , 1971).

### **Recruitment patterns**

The method described by Pauly restructures the recruitment pulses from a time series of length frequency data to determine the relative strength and number of young ones per year. It involves backward projection of length frequency in time series as defined by Von Bertalanffy growth function( Bertalanffy , 1938) .

## 11.3. RESULTS

### 11.3.1. Mortality coefficients

The growth parameters of *H. woodmasoni* estimated are: males  $L_{\infty}$  -161mm,  $K$  - 0.82 yr<sup>-1</sup>,  $t_0$  - 0.97 ; females  $L_{\infty}$  - 188mm ,  $K$  - 0.60 yr<sup>-1</sup>,  $t_0$  - 0.96 ( refer chapter 10 for details). The total mortality coefficients of male and female population of *H. woodmasoni* are given in Table 11.1. The Z values calculated by different methods in males varied from 2.77 to 8.30 . Beverton and Holt method gave the lowest value while the estimate by Jones and Van Zalinge was the highest. In females, the lowest Z value was estimated by Pauly's pile up method while the highest was obtained by Jones Zalinge method . Since the Z values obtained were not closer to each other, the Z estimate was calculated from the average of the 3 methods, which were taken for further analysis.

The natural mortality coefficient values estimated by different methods in males and females of *H. woodmasoni* are given in Table 11.2. In females, the values were 1.37 by Rikhtor and Effanov method , 0.92 by Sekharan's method and 1.19 by Pauly's empirical formula . While in males, the estimated M value was maximum by Rikhtor and Effanov method (1.37), followed by 1.19 by Pauly's empirical formula and 0.92 by



Sekharan's method. The average values were taken in males and females for further analysis .

Between the two sexes studied, the total mortality was obviously high in females. On the contrary, the natural mortality was slightly higher in males than females. The mortality due to fishing (F) is estimated as 3.43 in females and 1.73 in males of *H.woodmasoni*, which were far exceeded the natural mortality, which is indicative of heavy exploitation level of *H.woodmasoni*, especially in female population.

The growth parameters of *H.gibbosus* used for stock assessment studies are : males  $L_{\infty}$  - 200mm ,  $K$  - 0.73 yr<sup>-1</sup> ,  $t_0$  - 0.98 ; females  $L_{\infty}$  - 203mm ,  $K$  - 0.53 yr<sup>-1</sup> ,  $t_0$  - 0.86 (refer Chapter 10 for details). The total mortality (Z) and natural mortality (M) of male and female population of *H.gibbosus* are given in Tables 11.3 and 11.4. Amongst the mortality rates , the M value obtained in females by Jones Zalinge method appeared as the highest (5.17) while it was lowest in Pauly's pile up method . In males also, the lowest M value was estimated by the same method (2.65) while it was highest while estimating with Beverton and Holt method (6.88). The natural mortality estimates based on Pauly's empirical formula were lower in males and females with 1.10 and 0.81 respectively. Whereas the highest M values were estimated based on Rikhtor and Effanov method. It would thus appear that the values of Z and

M estimated using different method for *H.gibbosus* were not closer, and therefore the average was computed and used for further analysis . Among the two sexes studied , the Z and M values were glaringly high in males and in compliance with this , the F value was also apparently high in male population when compared to their counterparts , being 3.91 in males against 2.47 for females.

#### 11.3.2. Exploitation rate (U) and Exploitation rate (E)

The exploitation rate (U) in males of *H.woodmasoni* was 0.5311 while the exploitation ratio (E) was 0.5563. Whereas in females, the U and E values were 0.7389 and 0.7468 for the period 2000 -02.

The exploitation rate of male *H.gibbosus* was estimated at 0.7483 while the exploitation ratio was 0.7527. In females, the U and E values were estimated to be 0.6747 and 0.6950 respectively during the study period.

#### 11.3.3. Recruitment patterns

By pooling the annual length frequency for the two years, the recruitment patterns were determined in males and females of *H.woodmasoni* separately as depicted in Fig. 11.1 and 11.2. The recruitment pattern in male *H.woodmasoni* showed the entry of two

distinct modes to the usable stock, one major mode added to the stock during March to April , contributed 33.29% of the recruitment to the fishery while the second minor mode was observed in September (16.57%) . Similarly, in females also, recruitment of two modes to fishery was evident, a major one in March and a minor one in July, contributed up to 11.25 and 20.03 % respectively. It is noteworthy to mention that though the species is characterized by a continuous reproductive activity, it exhibited a prolonged breeding peak starting from October to April when 60% of the females belonged to both mature and ripe stages (refer Chapter 8) .In *H.gibbosus* , a major mode was discernible during July and August followed by a smaller one in February in male while in female a minor mode was observed during December to February followed by a major mode in July (20.39%) (Fig. 11.3 & 11.4 ).

#### 11.3.4. The relative Yield /Recruitment Model ( Y'/R )

The  $L_c/L_\infty$  and  $M/K$  used for the Y'/R analysis of *H.woodmasoni* were 0.56 and 1.69 in males and 0.51 and 1.93 in females respectively. The yield per recruitment reached a maximum at an exploitation rate of 0.839 ( $E_{max}$ ) and with the further increase of exploitation rate the Y'/R decreases. Fig .11.5 showed that the present level of exploitation has exceeded the optimum exploitation rate (0.5) in male *H.woodmasoni* . The  $E_{-0.1}$  was estimated as 0.761 while  $E_{-0.5}$  was 0.382.

In females of *H.woodmasoni*,  $E_{max}$  was observed as 0.791. From Fig.11.6 , it appears that the present exploitation rate (0.74) has significantly exceeded the optimum exploitation rate (0.5). The females are subjected to overexploitation when compared to their male counterparts in the population. The  $E_{-0.1}$  in females was estimated as 0.713 and  $E_{-0.5}$  as 0.367 .

Results of the length converted cohort analysis revealed that in males and females, specimens in the length groups 50-60mm and above were vulnerable to exploitation, however, heavy exploitation of the length class 80-90 mm was quite discernible. The fishing mortality there after showed a steep increase in males. In females also, the exploitation started from the length group 50-60 mm onwards which attained peak at 70-100 mm length class. The fishing mortality showed a gradual increase up to 90-100 mm, however, it become steady henceforth (Fig. 11. 7 & 11. 8).

The  $L_c/L_\infty$  and  $M/K$  used for the  $Y'/R$  analysis of *H.gibbosus* were 0.57 and 1.73 in males and 0.57 and 2.05 in females respectively. In males and females,  $E_{max}$  was observed at 0.791 and 0.933 respectively. In the males, the present exploitation rate (0.748) has significantly exceeded the optimum exploitation rate (0.5) (Fig 11.9). Thus, it can be concluded that the males of *H.gibbosus* are subjected to overexploitation in the

population. The  $E_{-0.1}$  in males was estimated as 0.812 and  $E_{-0.5}$  as 0.386.

Fig.11. 10 shows the exploitation level of females, which indicates that the present exploitation rate,  $U$  (0.675) was higher than optimum exploitation level, 0.5. The  $E_{-0.1}$  was estimated as 0.852 and  $E_{-0.5}$  as 0.388.

Results of the length converted cohort analysis are depicted in Fig . 11. 11 & 11.12. In male population of *H.gibbosus* , specimens below 50mm are not vulnerable to exploitation, however, the exploitation above 60 mm showed a gradual increase attaining peak exploitation between 90 and 120 mm. The fishing mortality was invariably high in the size groups 90-130mm.

Among females, the specimens in the length group 70-80mm and above were vulnerable to exploitation; however, heavy exploitation was discernible at 90-110mm size groups. The fishing mortality was found to be increasing from 90mm onwards with peak in 100-110mm size groups.

#### 11.4. DISCUSSION

Even though very few studies on the stock assessment of pandalid shrimps had been attempted at temperate waters, the same with

reference to Indian Ocean region are totally lacking. Furthermore, no attempt has so far been made from any part of the world to estimate the stock assessment of *H.gibbosus* and *H.woodmasoni*. In India, the studies on population dynamics were done only on coastal water penaeid prawns, however, the recently started deep sea prawn fishery off Kerala enabled in carrying out a maiden study on the dynamics of the deep water pandalids of Indian waters.

In the present study, analytical models working with concepts such as mortality rates and individual growth rates have been used to get reliable assessment of *H.gibbosus* and *H.woodmasoni* stocks. The total instantaneous rate of mortality,  $Z$  was estimated with the help of four methods viz., Beverton and Holt method, Ssentongo and Larkin method, Length converted catch curve method and Pauly's pile up method using the length frequency data of two years (2000-02). In *H.woodmasoni*, the  $Z$  value was estimated to be 3.12 and 4.58 respectively for males and females while in *H.gibbosus*, it was high in males (5.18), in contrast, the value was low in female with 3.56.

For estimating natural mortality coefficient, Rickter and Effanov method, Sekharans' method and Pauly's empirical method were employed in the present study, however, the regression of  $Z$  against effort (Sparre and Venema, 1992) has not been attempted for mortality

estimation due to the practical difficulty in apportioning the fishing effort for a single species alone in the context of multi species complexity of deep sea prawns harvested off Kerala. Moreover, as natural mortality is influenced by several biological and environmental parameters, it is difficult to get an accurate estimate (Pauly, 1982; Cushing, 1981) . Further, it is also related to other growth parameters like  $L_{\infty}$  (Sparre and Venema , 1992) and maturity (Rikhtor and Effanov , 1976) .

The natural mortality (M) in *H.woodmasoni* and *H.gibbosus* can be explained following Gulland (1969) who related natural mortality to age and size, as larger fishes generally would have less rate of predation. Since M is linked to longevity and the latter to growth coefficient K, M/K ratio is found constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959). M/K ratio usually ranges from 1 to 2.5 ( Beverton and Holt , 1959).In males and females of *H.woodmasoni* , the M/K ratio arrived at by all the three methods were found to be within the known limits. It may, therefore , be inferred that the estimation of M following all the three methods in both the sexes were appeared to be reasonable in *H.woodmasoni*.

In the present study, the M/K ratio obtained for males *H.gibbosus* by the three methods were found to be with in known limits of 1-2.5 while in female also similar results could be apparent barring the method of

Pauly's empirical formula. It may, therefore, be inferred that the estimates of  $M$  following all the methods were appeared to be reasonable and acceptable in *H.gibbosus* with an exception as mentioned above.

The fishing mortality rate ( $F$ ) in the females of *H.woodmasoni* was found to be very high (3.42) when compared to males (1.73) . The exploitation rate and exploitation ratio were also found to be far higher in females when compared to their male counterparts. The sex ratio analysis of the exploited stock of *H.woodmasoni* indicated that the females were represented far in excess of males during 2000-01 and 2001-02 with a male to female ratio 1:1.62 and 1:2.04 for the first and second years respectively. In addition, the peak occurrence of berried females could also be encountered coinciding with the peak fishing season during when the percentage of ovigerous females in the total female population ranged from 74.11 in March to 86.01 % in January. As the exploitation ratio of both males and females are found to be more than the optimum levels in the present study, it is evident that the stock of *H.woodmasoni* is grossly over exploited beyond the sustainable limit and this is all the more pertinent in case of female population. The modal size group in the fishery revealed the dominance of size group 90-100mm in both the sexes of *H.woodmasoni* and the size at first maturity of male and female were worked out at 96.75mm and 100mm respectively. The length cohort analysis also showed the very high fishing mortality in 100-130mm



length groups. This finding clearly shows that, the entire population does not get a chance to reproduce even once during their lifetime.

In the case of *H.gibbosus*, the fishing mortality of males was found to be higher than their female counterparts in the population, thus suggesting that the males are subjected to more fishing pressure than their female counterparts. However, the exploitation ratio is more than 0.5 in both the sexes, there is every necessity to reduce the fishing effort to maintain the stock at optimal levels and also to avoid the stock from over exploitation .

In *H.gibbosus* , males dominated in the exploited stock during most of the months during the study period showing a male female ratio 1:0.85. The modal length group in both the sexes were observed to be 80-90mm while the size at first maturity calculated for males and females were 97mm and 98.5mm respectively. The fishing mortality was observed to be high in 90-110 mm size groups. Also the modal size group of ovigerous females in both the species were 90-110mm. Therefore, the results of the present study are indicative of the existence of gross over exploitation of spawning stock of *H. gibbosus* which can cause very serious impact on the sustainability of the stock. The percentage of ovigerous females was also found to be high during December to March (refer chapter 5 for details). It would thus appear that the stock of both *H.woodmasoni* and

*H.gibbosus* are prone to the threat of both growth and recruitment over fishing as defined by Pauly (1982) and may collapse in near future unless otherwise the fishing effort is judiciously regulated at optimal levels giving due emphasis to maximum sustainable yield. The exploitation of these new deeper water resources must be carefully developed, taking into consideration that deep water species can generally withstand only low levels of exploitation in terms of long term sustainable fishery (Colloca , 2002) . In this context, it is found imperative to do appropriate enactments as a conservation measure to protect the stock from the risk of over exploitation. In view of the fact that the smaller size classes were prone to intensive exploitation, a closed season during the recruitment period together with the enforcement of statutory mesh size of 35mm for bottom trawling shall be done as the immediate measure of conservation for the sustenance of the stock of deep sea prawns off Kerala Coast. However, the fishing grounds of deep sea prawns are located beyond the territorial waters of Kerala and therefore the Government of Kerala have no executive powers to enforce the above conservation measures in EEZ of Kerala. Therefore, it is recommended that Government of Kerala may initiate appropriate steps to get the above conservation measures implemented through Government of India at the earliest.

11.1 Instantaneous rate of total mortality (Z) for males and females of *Heterocarpus woodmasoni* during 2000-02

| Sex    | Pauly's pile up | Beverton & Holt | Ssentongo & Larkins | Length Catch curve | Jons Zalinge plot | Average |
|--------|-----------------|-----------------|---------------------|--------------------|-------------------|---------|
| Female | 4.2245          | 2.7658          | 2.8038              | 4.80               | 8.30              | 4.5828  |
| Male   | 2.84            | 3.04            | 2.98                | 3.82               | 4.38              | 3.1165  |

11.2 Instantaneous rate of natural mortality (M) and fishing mortality (F) for males and females of *Heterocarpus woodmasoni* during 2000-02

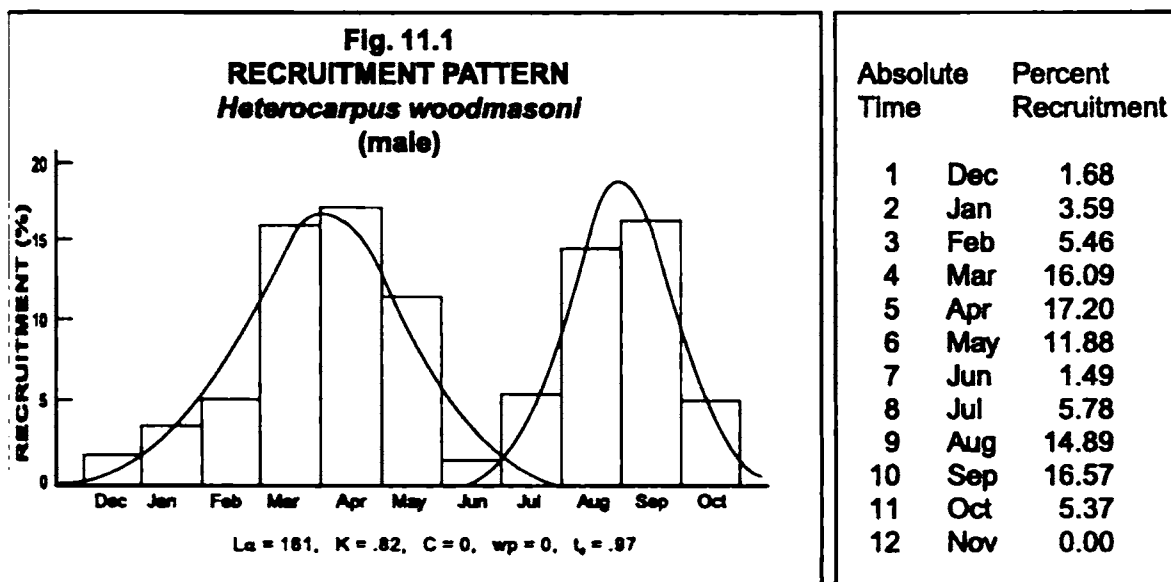
| Sex    | Rickter Effanov | Sekharan's Method | Pauly's Empirical | Average natural mortality | Average Fishing mortality |
|--------|-----------------|-------------------|-------------------|---------------------------|---------------------------|
| Female | 1.37            | 0.921             | 1.19              | 1.1603                    | 3.4225                    |
| Male   | 1.37            | 1.26              | 1.52              | 1.3829                    | 1.7336                    |

11.3 Instantaneous rate of total mortality (Z) for males and females of *Heterocarpus gibbosus* during 2000-02

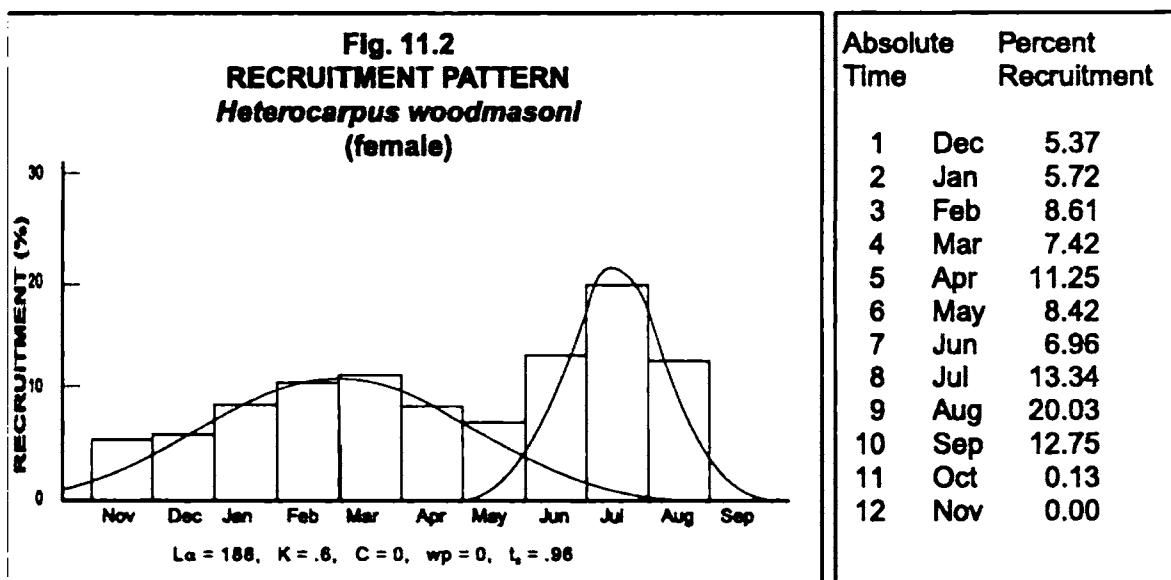
| Sex    | Pauly's pile up | Beverton & Holt | Ssentongo & Larkins | Length Catch curve | Jons Zalinge plot | Average |
|--------|-----------------|-----------------|---------------------|--------------------|-------------------|---------|
| Female | 2.0675          | 4.5179          | 4.0817              | 3.78               | 5.17              | 3.5557  |
| Male   | 2.6541          | 6.8818          | 6.015               | 3.76               | 4.386             | 5.1837  |

11.4 Instantaneous rate of natural mortality (M) and fishing mortality (F) for males and females of *Heterocarpus gibbosus* during 2000-02

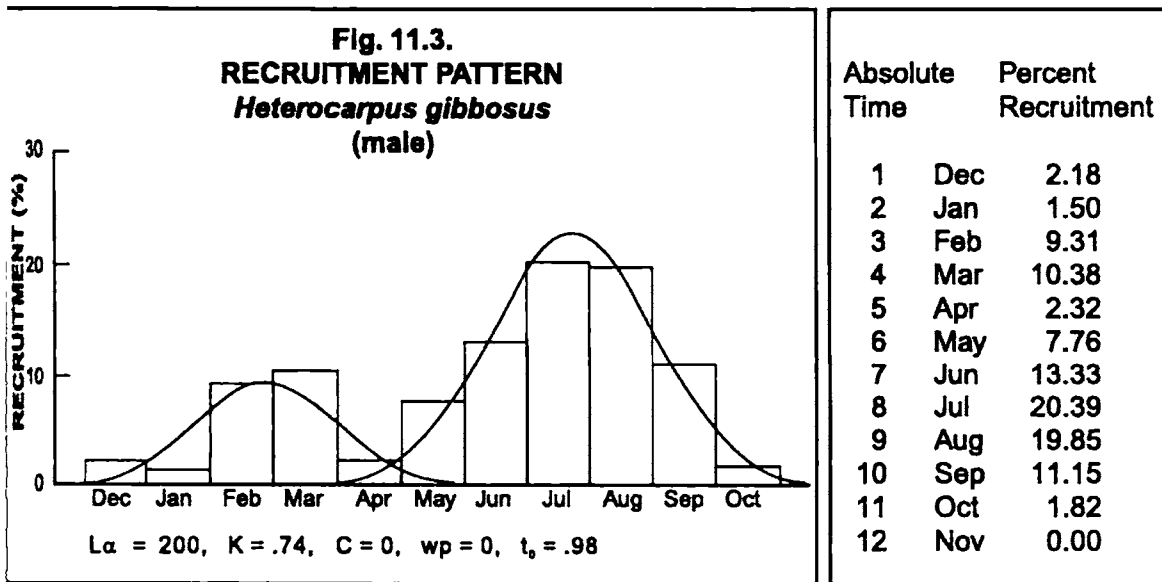
| Sex    | Rickter Effanov | Sekharan's Method | Pauly's Empirical | Average natural mortality | Average Fishing mortality |
|--------|-----------------|-------------------|-------------------|---------------------------|---------------------------|
| Female | 1.37            | 1.07              | 0.81              | 1.0845                    | 2.4712                    |
| Male   | 1.37            | 1.34              | 1.14              | 1.2819                    | 3.9017                    |



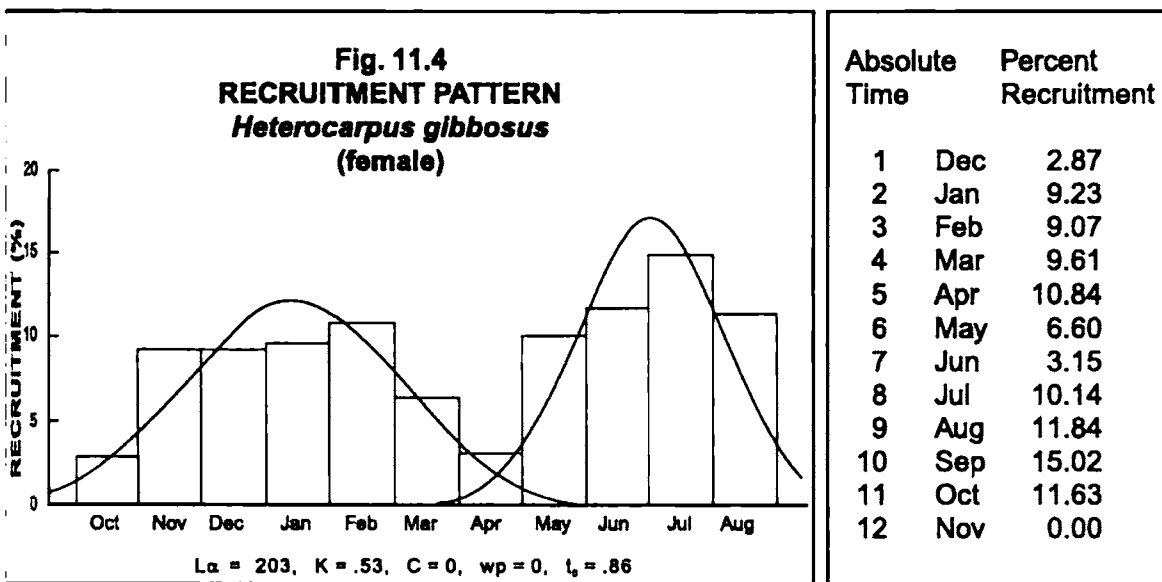
|                          |                   |                                  |
|--------------------------|-------------------|----------------------------------|
| <b>Group parameters:</b> |                   | <b>Species name</b>              |
| Mean (1) : 4.04          | Mean (2) : 9.03   | ▶ <i>Heterocarpus woodmasoni</i> |
| 3.ii. (1) : 1.38         | S.D. (2) : 0.87   | other file identifiers           |
| N (%) (1) : 58.28        | N (%) (2) : 41.74 | ▶ male                           |



|                          |                   |                                  |
|--------------------------|-------------------|----------------------------------|
| <b>Group parameters:</b> |                   | <b>Species name</b>              |
| Mean (1) : 4.04          | Mean (2) : 8.50   | ▶ <i>Heterocarpus woodmasoni</i> |
| 3.ii. (1) : 2.09         | S.D. (2) : 0.80   | other file identifiers           |
| N (%) (1) : 56.85        | N (%) (2) : 43.15 | ▶ female                         |

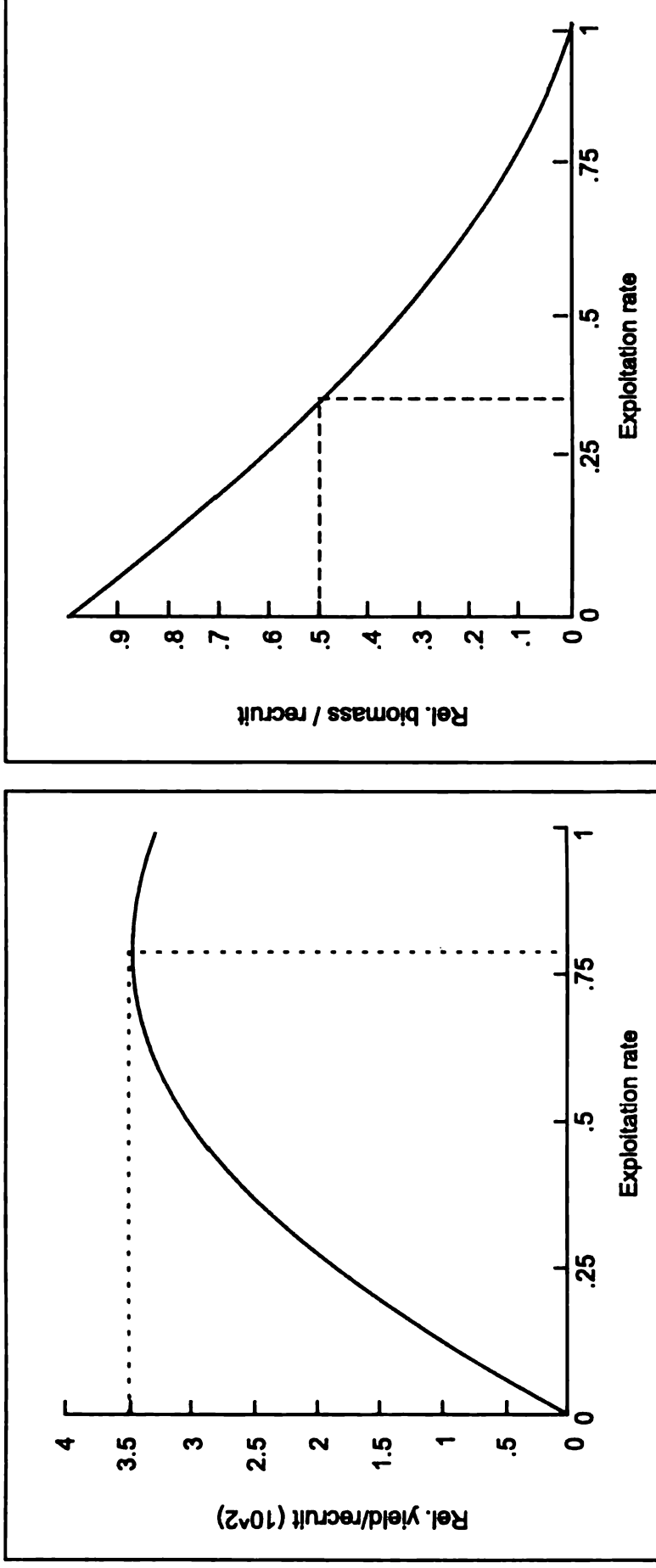


|                          |       |                                |       |
|--------------------------|-------|--------------------------------|-------|
| <b>Group parameters:</b> |       | <b>Species name</b>            |       |
| Mean (1) :               | 2.91  | Mean (2) :                     | 7.75  |
| 3.II. (1) :              | 1.10  | S.D. (2) :                     | 1.30  |
| N (%) (1) :              | 25.84 | N (%) (2) :                    | 74.16 |
|                          |       | ▶ <i>Heterocarpus gibbosus</i> |       |
|                          |       | other file identifiers         |       |
|                          |       | ▶ male                         |       |



|                          |       |                                |       |
|--------------------------|-------|--------------------------------|-------|
| <b>Group parameters:</b> |       | <b>Species name</b>            |       |
| Mean (1) :               | 3.45  | Mean (2) :                     | 9.03  |
| 3.II. (1) :              | 1.68  | S.D. (2) :                     | 1.13  |
| N (%) (1) :              | 51.01 | N (%) (2) :                    | 48.99 |
|                          |       | ▶ <i>Heterocarpus gibbosus</i> |       |
|                          |       | other file identifiers         |       |
|                          |       | ▶ female                       |       |

**Fig 11.5.**  
**Relative yield per recruit curve for the females of *Heterocarpus woodmasoni***

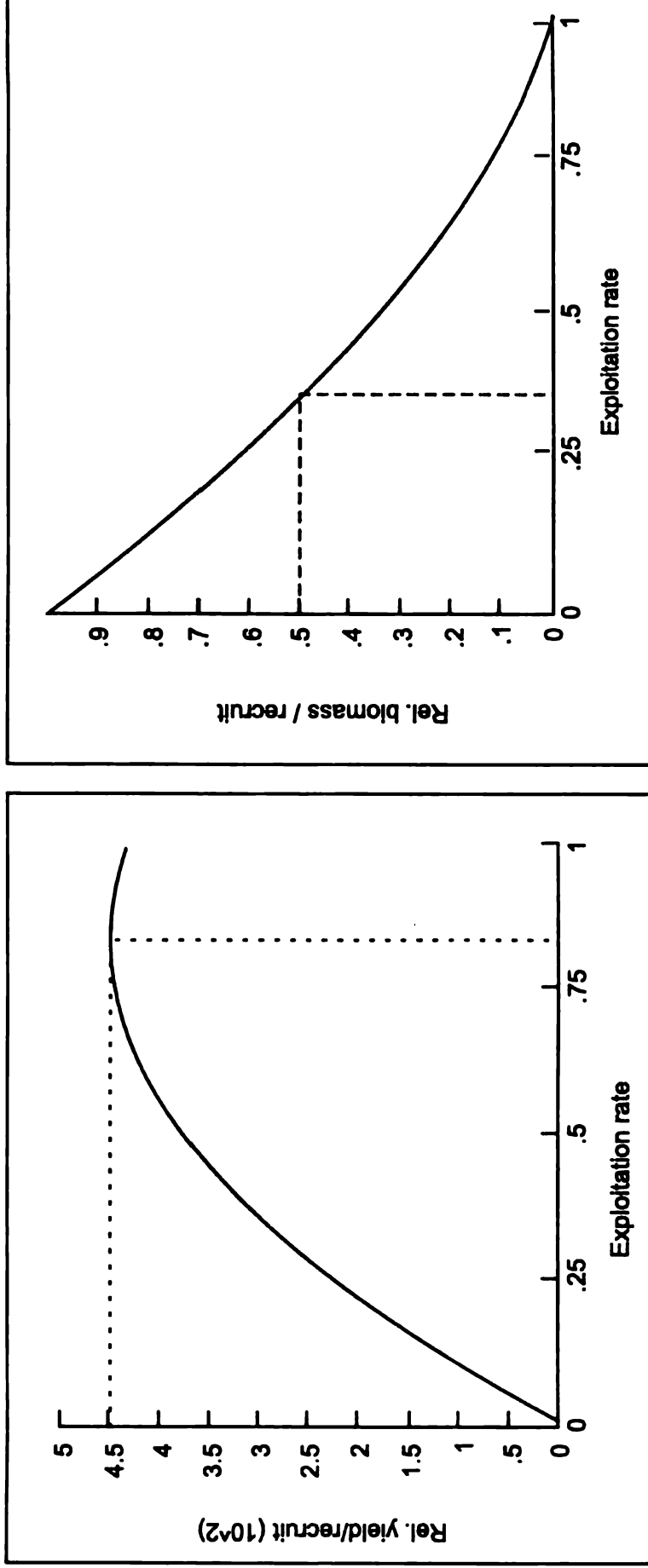


Optima : 0.7910  
 Exam : 0.7131  
 E-.1 : 0.3668

Lc / L $\alpha$  = 0.51  
 M.K = 1.93

Rel. yield / recruit  
 Knife-edge option

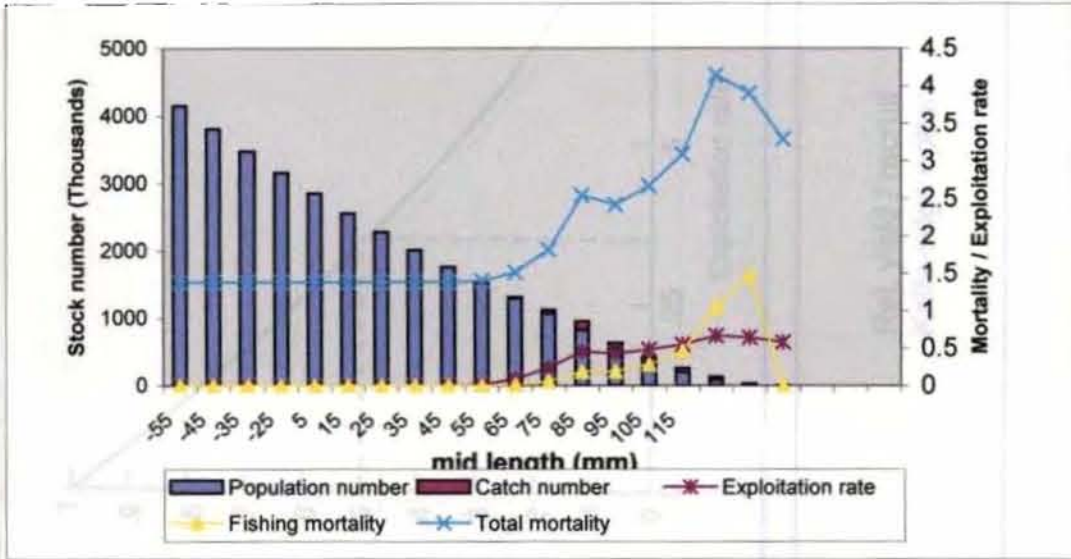
**Fig 11.6.**  
**Relative yield per recruit curve for the males of *Heterocarpus woodmasoni***



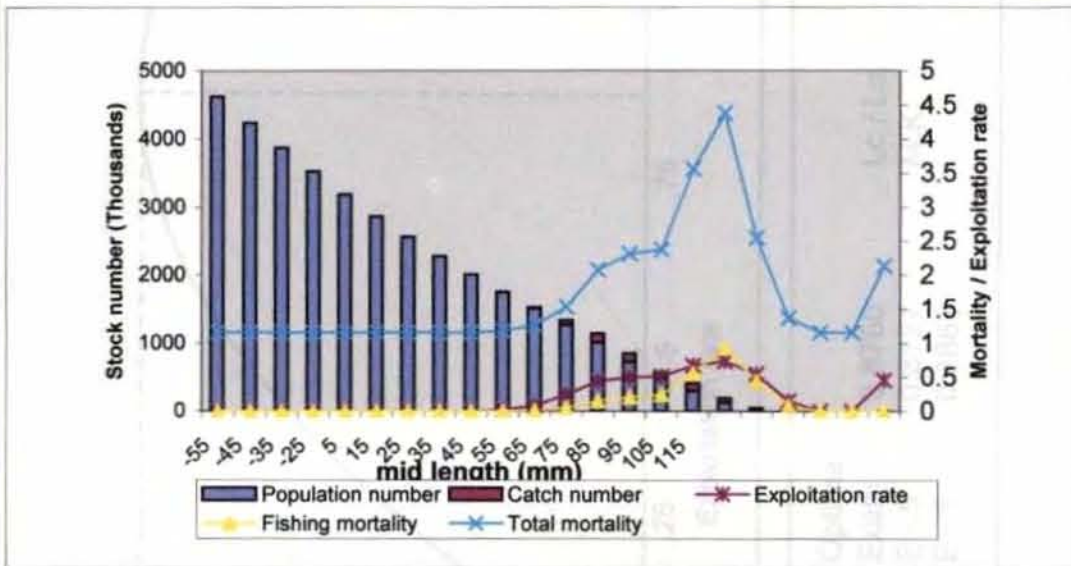
|        |          |                 |        |
|--------|----------|-----------------|--------|
| Optima |          |                 |        |
| Exam   | : 0.8390 | Lc / L $\alpha$ | = 0.56 |
| E -.1  | : 0.7613 | M.K             | = 1.69 |
| E -.5  | : 0.3820 |                 |        |

Rel. yiedl/recruit  
 Knife-edge option

**Fig. 11.7 Length cohort analysis of males of *Heterocarpus woodmasoni***

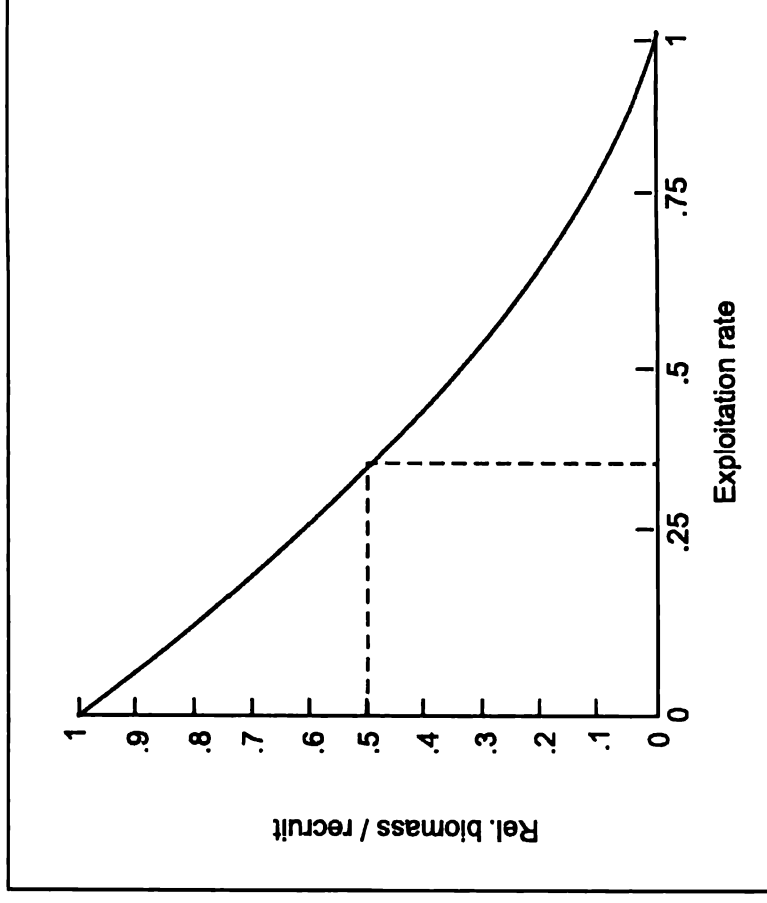
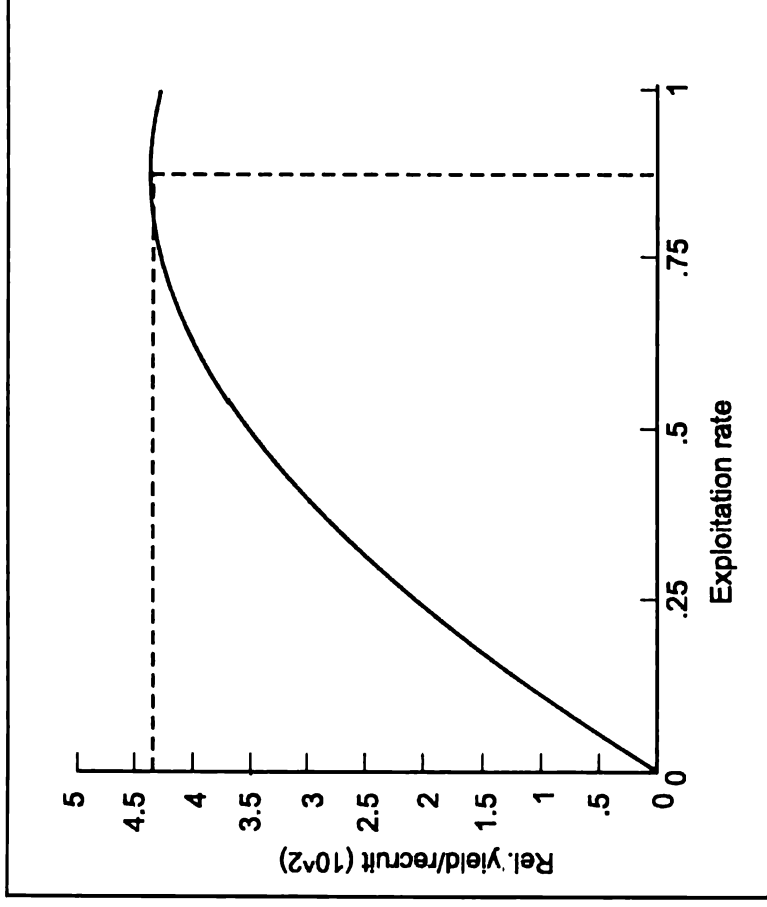


**Fig. 11.8 Length cohort analysis of females of *Heterocarpus woodmasoni***





Relative yield per recruit curve for the males of *Heterocarpus gibbosus*

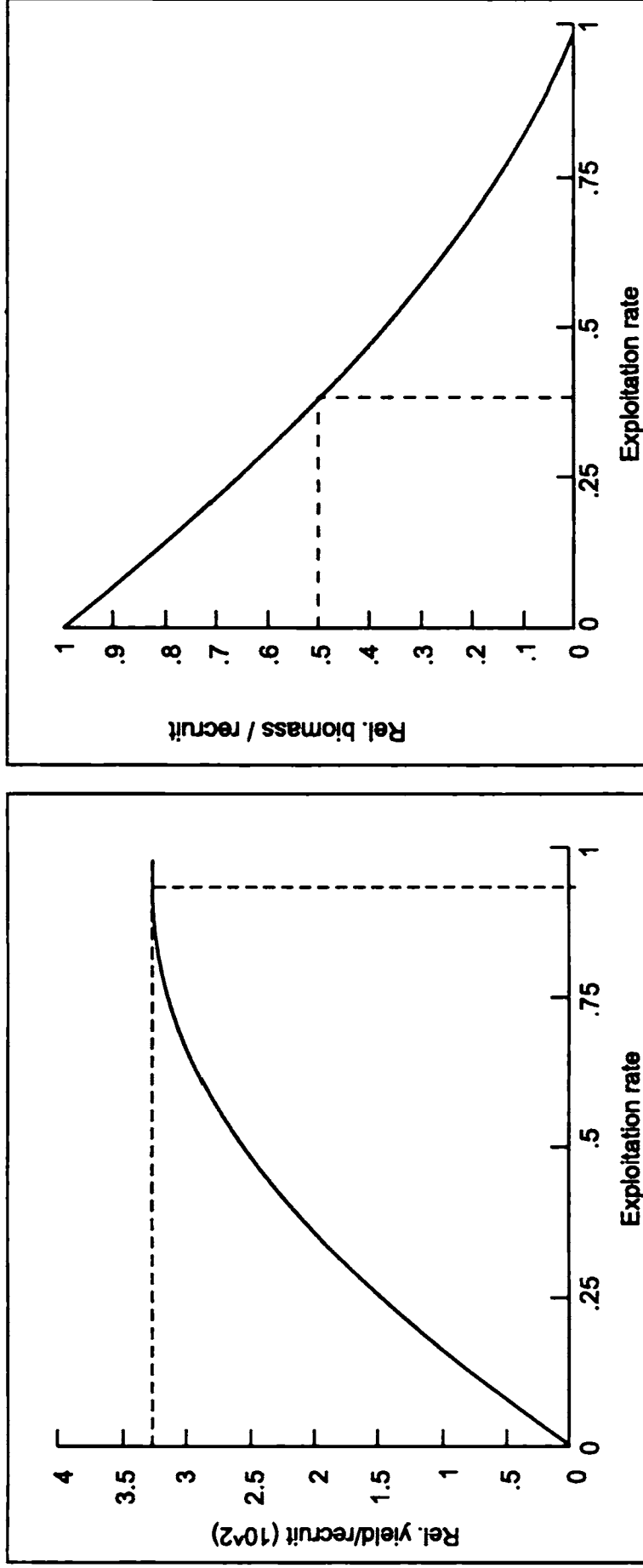


Optima : 0.8760  
 Exam : 0.8127  
 E -.5 : 0.3869

Lc / L $\alpha$  = 0.57  
 M.K = 1.73

Rel. yield / recruit  
 Knife-edge option

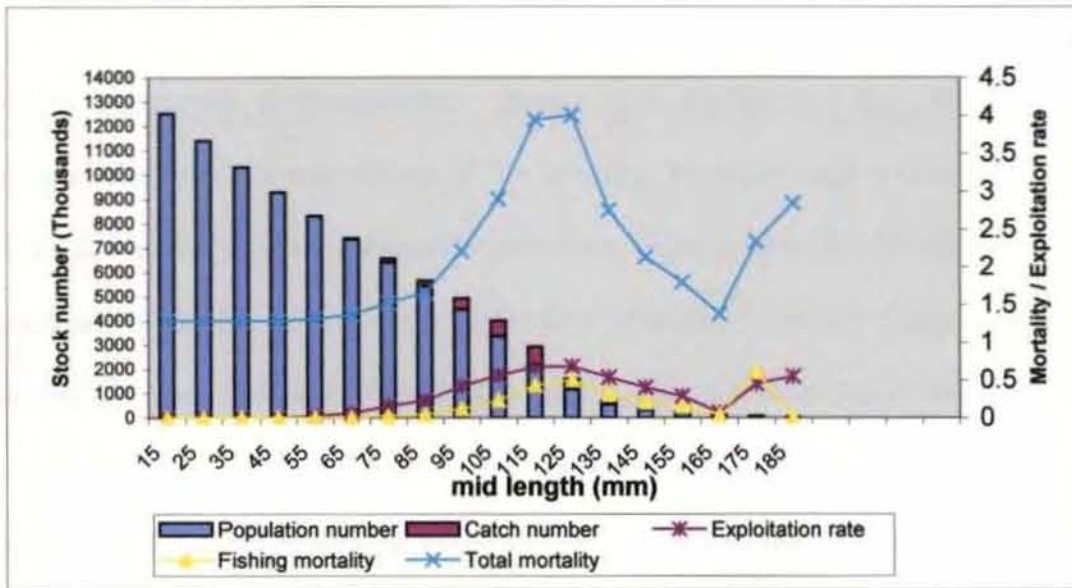
**Fig 11.10.**  
 Relative yield per recruit curve for the females of *Heterocarpus gibbosus*



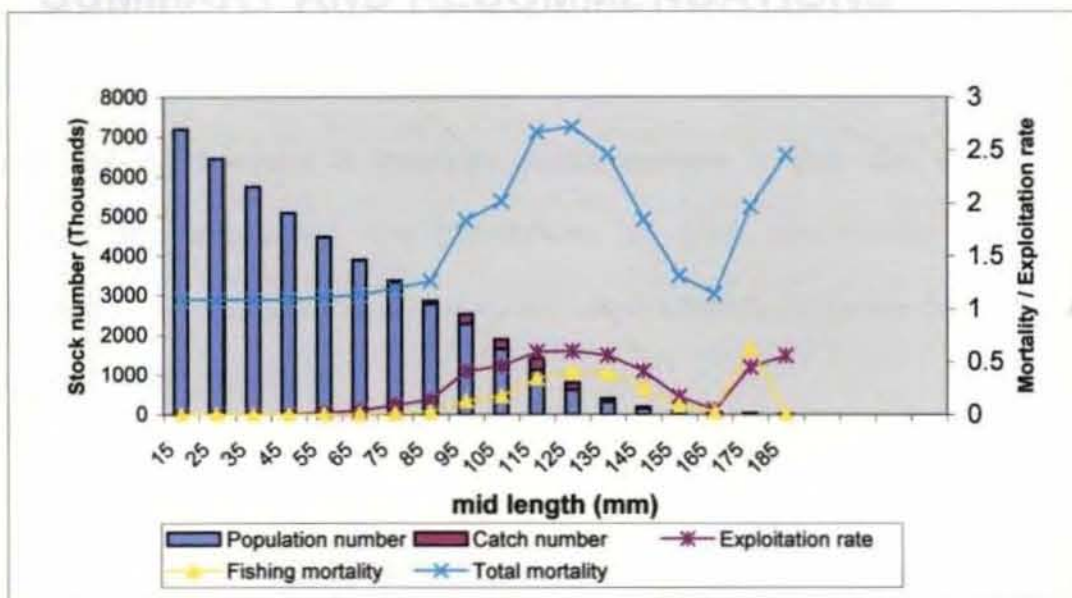
Optima : 0.9330       $L_c / L_\alpha = 0.57$   
 Exam : 0.8575      M.K = 2.05  
 E -.1 : 0.3875

Rel. yield / recruit  
 Knife-edge option

**Fig. 11.11 Length cohort analysis of males of *Heterocarpus gibbosus***



**Fig. 11.12 Length cohort analysis of females of *Heterocarpus gibbosus***



## **Chapter 12**

# **SUMMARY AND RECOMMENDATIONS**

Though a wealth of information is available on the distribution pattern, resource characteristics, fishery and biology of the shrimp resources of the inshore waters of the country, however, our knowledge on similar and or closely related resources beyond the above zone is practically inadequate. In India, scientific investigations on deep sea prawns are very few and fragmentary and dates back from the middle of the 19<sup>th</sup> century. During the past four decades, exploratory surveys had been carried out in the EEZ of India by various organizations and data so generated on deep sea prawns were mostly on the taxonomy and distribution. The exploratory shrimp trawling surveys carried out by the research vessels on the shelf-edge and upper continental slope along the south west coast of India during the period 1958 and 1965 had brought out very valuable information on the availability of commercially important deep sea crustaceans in trawlable concentrations in this part of the country and expressed the possibilities of their commercial level exploitation as one of the avenues for the enhancement of marine capture fisheries of the country.

The pioneer commercial exploitation of deep sea prawns off Kerala coast had started since 1999 and thus the deep sea prawn fishing became a reality in the history of marine fisheries of the country. Landings by large trawlers were focused mostly in three fisheries harbours of

Kerala and comprised of a wide assemblage of deep sea prawn species represented by both pandalid and penaeid prawns, and thus accounted for a substantial percentage in the total marine fisheries of Kerala.

While scanning the literature on the deep sea prawns both at national and global levels, it appeared that, no concerted attempt has so far been made to bring out a holistic account on the deep sea prawn wealth of the country giving due emphasis to systematics, bionomics, biodiversity, resource characteristics and stock size, although similar information are available in some other countries. Most importantly, virtually no information is also available on the population dynamics and stock recruitment relationships of this peculiar group of animals that inhabit mostly beyond 300m. Against these backgrounds, an in depth investigations on the systematics, biodiversity and fishery of deep sea prawns off Kerala was carried out. The bionomics of *H.gibbosus* and *H.woodmasoni* were also studied in detail while deep sea prawns inhabiting the depth zones of 150-650 m were screened for their carotenoid content of body muscle and exoskeleton whereas studies on maturity stage wise carotenoid concentration was attempted only in *H.gibbosus*.

Detailed systematic descriptions with complete synonymy, regional distribution and easily diagnostic features of 15 species of deep sea prawn collected and identified under 3 super families, 5 families and 10

genera from the exploited stock landed at 6 major and 4 minor harbors of Kerala are presented. A dichotomous taxonomic key was prepared based on easily measurable and clearly distinguishable morphological characters. Morphometric analysis was carried out in 15 species based on 24 different body parameters with a view to establish variations, if any, in the relative proportions of various morphometric measurements. The results of the morphometric ratios revealed that like coloration, morphological and meristic features, the morphometric ratios also exhibit meaningful clues depicting species-wise changes. When the morphometrics is applied individually to each of the 15 species with out taking in to account their generic affiliations, more than 50 ratios were found as non overlapping and therefore species specific and these ratios would be invaluable for species separation.

Of the total 1309 allometric relationships worked out, 216 were having high degree of correlation. Comparison of regression coefficients of relationship between rostral length, carapace length, 1<sup>st</sup> cheliped length, lengths of propodus, merus, 2<sup>nd</sup> total chelipeds to total length and carapace length revealed that there exists species specific variation in the growth of various body parts among the various species belonging to the super family Penaeoidea, Pandaloidea and Oplophoroidea inhabiting off Kerala coast.

Analysis of biodiversity indices of deep sea prawns off Kerala during different months of 2000-01 and 2001-02 revealed that the biodiversity indices were high at 150-250 and 251-350 m whereas in higher depth zones of 351-450, 451-550 and 551-650 m, the diversity is gradually declining. The species richness was also found maximum at relatively lower depth zones of 251-350 in contrast to the low values registered in higher depths. Off the Kerala coast, there is a marked faunal zonation along the bathymetric gradient. The present results strongly suggest that the species diversity as well as richness show a reduction with increase in depth. A strong correlation, however, exists between the richness and diversity of deep sea prawns, which are further correlated to the nature of bottom substratum and water temperature, both of these are showing variation in the different depth zones studied.

The results of the present study showed that the variation in species diversity, abundance and evenness of deep sea prawns observed at various depth zones off Kerala might be due to the combined effect of both nature of substratum and the prevailing water temperature, besides the impacts of deep sea trawling operations. Bray-Curtis Similarity Index and CLUSTER analysis used for the estimation of similarity between the exploited stocks showed that in 151-250 m depth zones, 94.73% similarity were observed between March and April 2001 while during the 2<sup>nd</sup> year, 98.45 % similarity was realized between March 2002 and October 2001. Similar observations were made at 251-350m,



351-450m, 451- 550m and 551-650m depth zones during the first and second years.

Based on the data compiled from the synoptic surveys it can reasonably be concluded that there is spatial variation in the species composition and stock availability of deep sea prawn resources along the Kerala coast. Interestingly, the species composition of deep sea prawns at 3 depth regions evinced very distinct region specific and depth specific distribution pattern. Depth wise prawn catch in relation trawling effort in different latitude zones showed that highest c/hr was observed in region-1 encompassing Lat.8<sup>o</sup> N (114kg/hr) and Lat9<sup>o</sup>N (144.83 kg/hr) at 251-300m depth zones followed by 301-350 m depth zones in Lat9<sup>o</sup>N (96.9kg/hr) which represents Quilon Bank, thus confirming this region as the most productive ground of deep sea prawns for the commercial fishery. This region was also demarcated as the most important ground for pandalid shrimps where the dominance of *H.woodmasoni*, *H.gibbosus*, *P.spinipes* and *P. ensis* was discernible.

The results of the catch composition in different latitudinal and bathymetric regions revealed that the deep sea prawn resources of Lat.9<sup>o</sup>N and Lat.10<sup>o</sup> N (Off Quilon to Off Cochin) are multi species in nature, available in varying proportions and constituted by 11 species viz. *Parapandalus spinipes*, *Heterocarpus woodmasoni*, *Heterocarpus gibbosus*, *Metapenaeopsis andamanensis*, *Aristeus alcocki*, *Plesionika*

*martia*, *Plesionika ensis*, *Heterocarpus alfonsi*, *Parapenaeus investigatoris*, *Penaeopsis jerryi* and *Solenocera hextii*. The patterns of catch composition in different latitude zones showed distinct variation in the species distribution at various depth zones. It was observed that the population of *H.woodmasoni* is well restricted between lat. 8° N and Lat 10° N in the Quilon Bank. The highest c/hr was observed at Lat.8° N (58.91) followed by Lat.9°N (55.92kg/hr) in 251-300m depth Zones. *Heterocarpus gibbous* is distributed between the latitude zones 8-12°N (off Quilon – off Ezhimala). The average c/hr in the area of its occurrence was 7.5kg. Bathymetrically, the highest catch rates were recorded from the depth ranges 301-350m(13.50kg/hr) followed by 351-400m(15.83kg). *Aristeus alcocki*, the principal species constituting the fishery, is distributed in the southern latitude zones 9-10°N (off Alleppey and Cochin) at 401-500m depth zones (12.05kg/hr). In the northern zones, off Ezhimala (lat.12°-13°N), where this species was predominately represented in commercial concentration at 401-600m, appeared to be a potential ground of *Aristeus alcocki*. *P.spinipes* appeared as the dominant species in the deep sea prawn catches leaving other species far behind in percentage composition and is distributed in the latitude zones 8-12 °N at 201-350 m depth range. The average c/hr in the area of its occurrence is 12.56kg/hr while in the area of abundance it was 72.92kg/hr. The distribution of *Metapenaeopsis andamanensis* was restricted to only lat. 10-12°N in the depth zones 201 to 350 m (4.45kg). In its area of

abundance, the highest c/hr recorded of this species was 11.21kg. Depth varying from 150-200m between the latitudes 7- 13<sup>0</sup>N was significantly unproductive and represented in traces by penaeids such as *P. jerryi* and *M.andamanensis* and solenocerid shrimps.

The deep sea prawn landings in Kerala during Sept-2000 to April 2001 have been quantified as 48675 tonnes which accounted for 9.35% of the exploited marine fisheries of Kerala during this year. In contrast, during 2001-02, it declined to 19285 tonnes, thus registering a reduction to the tune of 60.35% in the deep sea prawn landings. The harbour wise deep sea prawn landings also steadily declined during 2001-02 and the landings were limited to five harbours in contrast to ten harbours registered in the previous year. A 40% decline was reported at Sakthikulangara while it was 47% at Munambum and 31% at Cochin. A reduction in the catch per hour to the tune of 53.57% recorded during the 2<sup>nd</sup> year is also worth noticing. The month wise c/hr and CPU of deep sea prawns landed at various harbours were observed as 6.69kg and 31.20kg, which declined during the 2<sup>nd</sup> year to 5.67kg and 26.49kg respectively. Among the 15 species of deep sea prawns landed at various harbours of Kerala, *A.alcocki*, *H. woodmasoni*, *H. gibbosus*, *P. spinipes* and *M.andamanensis* constituted the commercial fishery in fairly significant quantities.

Among the deep sea prawns, *P. spinipes* appeared as the most dominant species (24.99%) followed by *H.woodmasoni* (15.09%). Percentage contribution of various species showed that in both the years *P. spinipes* appeared as the most dominant species contributing to 9208t (19%) and 7646t (40%) during 2000-01 and 2001-02 respectively. The 2<sup>nd</sup> and 3<sup>rd</sup> positions were occupied by *M. andamanensis* (17.5%) and *H.woodmasoni* (14.5%). Depth wise c/hr and CPU also showed a drastic decline during Aug-01 to Apr-02. Monthly variation in the c/hr and CPU of various species were also worked out and the results showed that c/hr of *H.gibbosus* declined from 6.69kg in the preceding year to 5.66kg during the succeeding year while in *H.woodmasoni*, the catch per hour remained more or less steady (12.75kg). The c/hr of *A. alcocki* showed a drastic decline in the second year from 9.72kg in the 1<sup>st</sup> year to 5.39kg. Similarly, in *P. spinipes* and *M. andamanensis*, a decline to the tune of 3.26kg and 3.15 kg each were observed in the 2<sup>nd</sup> year.

A comparison of catch per hour of deep sea prawns at various depths during 2000-02 showed a sharp decline in all the depth zones studied during the second year of study. Depth wise analysis of catch in relation to effort of deep sea prawns landed at various harbours were corroboratory with the results of exploratory surveys conducted during 1999-2000.

The life history traits such as length weight relationships, relative condition factor, percentage of berried pandalid prawns in the exploited stock and size groups constituting the fishery were studied. The results of length weight relationships indicated that the deep sea prawns show dissimilarities in their dimensional equalities commensurate with their habitats. In mesopelagic species, such as *M. andamanensis* (male  $b=2.78$ , female  $b=2.36$ ) and *S. hextii* (male  $b=2.32$ , female  $b=1.96$ ) the relationship between length and weight is strongly allometric in both the sexes. While in *H.gibbosus* (male  $b= 3.34$ , female  $b= 3.29$ ), *H. woodmasoni* (male  $b= 3.37$ , female  $b= 3.50$ ), *P. ensis* (male  $b=2.84$ , female  $b=2.60$ ), *P.martia* (female  $b=2.94$ ) and *P. spinipes* (male  $b=2.74$ , female  $b=2.95$ ), which are nektobenthic, an isometric growth pattern was observed through out the life stages. Again, in the benthic species such as *A.alcocki* ( $b=2.12$ ), the exponent values were very low, thus manifesting a poor body dimensional equality during their growth when compared to other groups.

Results of relative condition showed high  $K_n$  values during November – February and this manifests the possibility of spawning during this period. The results of month wise and lengthwise sex ratio analysis revealed the preponderance of females over males in *P. spinipes*, *H. woodmasoni*, *M. andamanensis* and *A. alcocki*. The skewness in the sex ratio suggested the possibility of differential migration of

male population from the fishing ground and this can be postulated as one of the reasons for the stock depletion.

Percentage of berried pandalid shrimps were very high during December to March, in the range 71.33 to 91.25% and a decline of the fishery registered during the second year can well be attributed to the indiscriminate exploitation of berried females in the commercial landings. From the results arrived at on the growth rates of deep sea prawns based on monthly distribution of length frequency, it appeared that the growth rate of deep sea prawns are very slow when compared to their counterparts inhabiting in the coastal waters. In the length frequency analysis carried out in 5 species of deep sea prawns showed an intra specific size segregation by season and inter specific size segregation among species. Seasonal analyses of modes showed that new individuals were continuously recruited into the usable stock, however, the progression in the mean sizes were found as very slow. Based on the occurrence of berried females in the total female population it appears that their breeding season is continuous or almost year round in the fishing grounds.

The diet of both the species were examined giving emphasis to variations with regard to months, size groups, sex and maturity stages. Stomach conditions in various maturity stages, length groups and gastro somatic index were also presented. Qualitative analysis of gut contents of

*H.gibbous* and *H.woodmasoni* showed that both the species are bottom feeders. *H.gibbosus* is a detritophagus scavenger feeding mainly on euphausiids remnants and detritus where as *H.woodmasoni* is a carnivore combining with necrophagus and detritophagus. In both the species, highest number of full stomachs were observed in orange berried females and spent males due to their voracious feeding after spawning. Highest number of empty stomachs was observed in head roes of female and maturing males, which would suggest poor food intake during breeding period. In both the species, females exhibit selective feeding habits in contrast to the non-selective feeding of males. The feeding habits of deep sea prawns were much influence by the depth of inhabitance. Variations in the GSI showed that there exist strong correlation between feeding intensity and breeding season of both the species.

The results of the quantification of maturity stages, histological examination of ovary, maturation and spawning seasons and size at first maturity of *H. gibbous* and *H. woodmasoni* are presented.

Seven maturity stages in females and three maturity stages in males were identified in *H.gibbosus* and *H.woodmasoni* based on colour and dimension of both of gonads and embryos. The results from the histology of ovarian tissues showed that changes in colour and size of the ova match very well with the development of oocytes and size of the ovary. In *H. woodmasoni*, the size at first maturity in males and females

were computed at 96.75mm and 100 mm respectively, where as in *H. gibbosus* 50% maturity is attained at 97mm and 98.5mm in males and females respectively.

Highest number of head roe females and peak GSI coincided with the spawning season from October to February in *H. woodmasoni* with intense spawning activity in January. The peak spawning season of *H. gibbosus* was observed during November to March with peak activity in February. The presence of immature, maturing and mature ova in the same ovary manifests the possibility of a prolonged spawning season in the population of both the species. The average fecundity of *H. woodmasoni* and *H. gibbosus* were estimated as 6586 and 20672 respectively and this form only 2.29% of the regeneration capability of their counterparts of coastal waters. Fecundity showed a direct correlation with length and weight of the prawns and carapace length. The distribution and mobilization pattern of total carotenoid in the body tissues such as exoskeleton, muscle and hepatopancreas of *H. gibbosus* during different stages of gonad maturation in males and female showed that exoskeleton of female *H. gibbosus* exhibited a higher concentration of carotenoids (32.47 $\mu$ g/g) than males (30.87 $\mu$ g/g). The values ranged between 29.21 $\pm$  2.39  $\mu$ g/g in stage I females and 38.32  $\pm$ 1.70  $\mu$ g/g in spent females, thus indicating certain degree of mobilization during maturation. The variation between different stages was found statistically



significant ( $P < 0.05$ ). In males, exoskeleton carotenoids between different maturity stages was found significant at 5 %level.

The concentration of carotenoids in the muscle tissue though of lower level, was maximum in females ( $4.21\mu\text{g/g}$ ) than males ( $2.95\mu\text{g/g}$ ). In females, the muscle carotenoids increased from  $2.86 \pm 0.21\mu\text{g/g}$  in stage I to  $5.23 \pm 1.63$  in head roes, thereafter decreased during larval development to  $4.20 \pm 0.74$  in the spent, thus indicative of mobilization of pigment during maturation. In males, no significant changes could be discernible among the maturity stages.

The carotenoid concentration in the ovary of females ( $12.77\mu\text{g/g}$ ) was remarkably higher than testis in *H. gibbosus* ( $4.29\mu\text{g/g}$ ). The carotenoid concentration in the ovary showed a sharp increase from  $7.93 \pm 0.96$  in stage I to  $27.88 \pm 1.30$  in stage 3(head roe). Thereafter, it decreased from  $15.70 \pm 1.00$  in the orange berry to  $6.68 \pm 1.19$  in the spent stage. The variation found was highly significant ( $P < 0.05$ ) between maturity stages. No such variations could be seen between maturity stages of males. A comparison of total carotenoids among various species of deep sea prawns inhabiting in different depth zones showed that there exists glaring differences in the total carotenoid content both in exoskeleton as well as muscle tissue.

In females of *H. woodmasoni* and *H.gibbosus*, the moisture content and fat content showed no significant variation where as protein content and ash content of muscle tissue and NFE content showed significant variation between maturity stages while in males only NFE content showed significant variation at 5% level. Proximate composition of hepatopancrease in *H.woodmasoni* showed significant variations between maturity stages ( $P<0.05$ ) in the moisture ( $57.40\pm 0.43$ ) and fat content ( $31.30 \pm 0.56$ ). Protein ( $14.30 \pm 1.06$ ) and ash content ( $1.60 \pm 0.80$ ) of muscle tissue showed significant variation in *H.gibbosus* at 5 % level.

The growth parameters estimated for *H.woodmasoni* were as follows-males:  $L_{\alpha} = 160.59$ ,  $K = 0.82 \text{ yr}^{-1}$ ,  $t_0 = 0.97$ ; females  $L_{\alpha} = 188$ ,  $K = 0.60 \text{ yr}^{-1}$ ,  $t_0 = 0.96$ . These with regard to *H. gibbosus* were - males:  $L_{\alpha} = 200$ ,  $K = 0.73 \text{ yr}^{-1}$ ,  $t_0 = 0.98$  and for females  $L_{\alpha} = 203$ ,  $K = 0.53 \text{ yr}^{-1}$ ,  $t_0 = 0.86$ . Growth performance Index ( $\phi$ ) was also worked out using Munroe's Phi Index (Pauly, 1983): *H.woodmasoni* -males  $\phi = 4.33$ , females  $\phi = 4.33$ ; *H.gibbosus* males  $\phi = 4.37$ , female  $\phi = 4.34$ . In both the species, there is the possibility a single prolonged recruitment pulse every year starting from October to February for *H.woodmasoni* and November to March for *H.gibbosus*. The length at maximum of *H.woodmasoni* was observed as 157.99mm in males and 178.95 mm in females during when they attain an age of around 5 yrs. The  $L_{\text{max}}$  of *H.gibbosus* was

estimated as 195.44 mm at the age of 6 yrs for males and 198.60 mm at 7 yrs for females. Based on the above data, the longevity of above two deep sea prawn species was found to be two times more than to coastal shrimps. In view of their slow growth rate, it can reasonably be inferred that the time required for their recruitment to the exploitable stock will be at least two times higher when compared to their counterparts in the coastal waters.

The instantaneous rate of total mortality coefficient (Z) and natural mortality coefficient (M) were estimated by different methods and the average so computed of Z and M values were taken for further analysis both for *H.gibbosus* and *H.woodmasoni*. The relative yield per recruitment and Length converted Cohort Analysis were carried out to assess the level of exploitation of the existing stock.

The mean Z values of *H.woodmasoni* females and males were 4.58 and 3.12 respectively while M values were 1.16 and 1.38 respectively. In *H.gibbosus* the Z values of female and males were 3.56 and 5.18 and the M values were 1.06 and 1.56 respectively. The relative yield per recruit analysis of *H.woodmasoni* showed that the present level of exploitation (0.53) has exceeded the optimum exploitation rate (0.50) in males while the females are subjected to the over exploitation (0.74) when compared to males. In *H.gibbosus* also, the males were over exploited (0.75) than females (0.67) beyond the sustainable level.

## RECOMMENDATIONS

The recommendations evolved for the sustainable exploitation and management of deep sea prawns off Kerala coast based on the results of the present study are furnished below:

- ❖ The commercially important deep sea prawns off Kerala coast are subjected to over exploitation. This situation calls for imposition of strong regulatory measures for conservation of stock.
- ❖ The peculiarities associated with the various life history traits such as growth rate, reproductive behaviour etc. were not given adequate consideration while exerting the fishing effort and intensifying the fishing activity. The present pattern of exploitation of deep sea prawns similar to that of coastal shrimps will not be enduring. Strong regulations are required on the number of deep sea boats deployed for deep sea prawn fishery along Kerala coast.
- ❖ In order to regulate the quantity exploited by deep sea trawlers it is recommended that either catch quota system or limited access

system for deep sea trawlers may be introduced along Kerala coast for the sustainable exploitation of deep sea prawns.

- ❖ The results of the present study revealed that the peak spawning of deep sea prawns takes place during December – January and therefore a total ban on deep sea fishing may be imposed by the Government of India during the above two months.
- ❖ Strong surveillances should be made to ensure that the cod end mesh size of the trawl nets maintain the statutory mesh size of 35mm as stipulated by KMFRA and imposed by Govt. of Kerala.
- ❖ In order to discourage the introduction new trawlers targeted for the exploitation of deep sea prawns off Kerala coast it is recommended that no fresh license should be issued to trawlers from any of the agencies.

## **REFERENCES**

## References

- Abe, K. (1965) Studies on a prawn (*Pandalopsis coccinata* Urita) off the coast of Kushiro, Hokkaido .I. *Breeding*. Scientific Report of the Hokkaido Fisheries Experimental Station. , 4:13-21.
- Abelló, P., F. J. Valladares and N. Castello (1988) Analysis of the structure of decapod crustaceans assemblages of the Catalan coast (North-west Mediterranean). *Mar. Biol.*,98:39-49.
- Achuthankutty, C.T. and A.H. Parulekar (1984) Biochemical composition of muscle tissue of penaeid prawns. *Mahasagar.*, 17 (4) : 239-242.
- Adensamer (1898) *Denk. Kais. Akad. Wien.*, LXV ,1898: 624.
- Adiyodi, R.G.and T. Subramaniam (1982) In: *Reproductive biology of invertebrates*, Vol. I (eds.) K.G.Adiyodi and R.G. Adiyodi, John Wiley, New York, 1982,443 p.
- Aiken, D. E. (1980) Molting and growth of lobsters. In: Cobb J. S., Philips, B.F. (eds.) *Biology and management of lobsters*. Vol1. Academic Press, New York., 99: 91-163.
- Alagaraja ,K., M. J. George, K. N. Kurup and C. Suseelan (1986) Yield-per-recruit analysis on *Parapenaeopsis stylifera* and *Metapenaeus dobsoni* from the Kerala state , India. *J. Applied Ichthyology* ., 2:1-11.
- Alagaraja, K. (1984) Simple methods for estimation of parameters for assessing exploited fish stocks. *Indian J. Fish.*, 31(2): 177-195.
- Alcock , A. and A. F. Mc Ardle (1901) Illustrations of the zoology of the Royal Indian Marine Survey Ship 'Investigator' ,Crustacea , Pt.7.pl.36-45.
- Alcock, A and A. R. S. Anderson (1894) Natural history notes from H. M. Indian Marine Survey Steamer 'Investigator', Commander C. F. Oldham, R. N. Commanding series .II.,No.14.An account of a recent collection of

deep sea crustacea from the Bay of Bengal and Laccadive Sea. *J. Asiat. Soc. Bengal.* ,63(2) :141-185.

Alcock, A. (1906) *Catalogue of the Indian Decapod Crustacea in the collection of the Indian Museum* .Part-III. Macrura. Fasciculus I. The prawns of the *Penaeus* group. Calcutta ,1-55p.

Alcock, A. and A.R.S. Anderson (1899) Illustrations of the zoology of the Royal Indian Marine Survey Ship 'Investigator', *Crustacea.*, Pt.7 , pl.36-45.

Alcock,A .(1905) A revision of the genus *Penaeus* , with diagnoses of some new species and varieties. *Ann. Mag. Nat. Hist., Ser.*, 7(16): 508-532.

Alcock,A and A.R.S.Anderson (1899) Natural history notes from H. M. Royal Indian Marine Ship 'Investigator' ,Commander T. H. Heming ,R. N. Commanding Series III.,No.2. An account of the deep sea crustacea dredged during the surveying season of 1897-98. *Ann. Mag. nat. Hist., Ser.7(3)* :1-27,278-292.

Alcock, A. (1899) A summery of the deep-sea zoological work of the Royal Indian marine Survey Ship 'Investigator' from 1884 to 1897 .*Sci. Mem. Med.Off.Army India.*,11:1-93.

Alcock, A. (1901) *A descriptive catalogue of the Indian deep-sea crustacea, Decapoda, Macrura and Anomala in the Indian Museum ,being a revised account of the deep sea species collected by the Royal Marine Ship' investigator'*, Baptist Mission press Calcutta, India. ,p.286

Alcock,A. (1902) A naturalist in Indian Seas or four years with the Royal India marine Survey Ship 'Investigator', John Murray, London,pp.1-328.

Alden ,P. Stickney and Herbert C. Perkins (1981) Observations on the food of the larvae of the northern shrimp , *Pandalus borealis* Kroyer (Decapoda , Caridea) . *Crustaceana* ., 40(1) : 36-48.



- Allen, Y. O. and M. R. Landry (1984) Nucleic acids as growth rate indicators for early developmental stages of *Calanus pacificus*. *Fishery Investicion.*, 2(9): 19-25.
- Allen, C. E., P. A. Tyler and M. S. Varney (2000) Lipid profiles of *Nematocarcinus gracilis* a deep-sea shrimp from below the Arabian Sea oxygen minimum zone. *Hydrobiologia* ,440 :273-279.
- Allen, J.A. (1967) Crustacea: Euphausiacea and Decapoda with an illustrated key to the British species. *Fauna of the Clyde Sea area.* , 116p.
- Allen, J.A. (1963) Observations on the biology of *Pandalus montagui* (Crustacea: Decapoda) *J.Mar.Biol.Ass.U.K.*,43 (3):665-682.
- Allen, J.A. (1959) On the biology of *Pandalus borealis* Kroyer, with reference to a population off the Northumberland coast *J.Mar.Biol.Ass.U.K.*,38 (1):189-220.
- Alvarez, Z. (1946) Crustaceos Decapods Meiterraneos. *Inst. esp. Est. medit. Barcelona. Pub. Sobre Biol. medit.*, (2) : 1-181.
- Alvarez, Z.R. (1968) Crustaceos Decapodos Ibericos. *Invest. Pesq. medit.*, (2): 1-181.
- Anderson , P.J. (2000) Pandalid shrimp as indicators of marine ecological regime shift. *J. Shellf. Res.*,19 (1) : 549p.
- Anderson ,P. J (1991) Age , growth and mortality of the northern shrimp *Pandalus borealis* Krøyer in Pavlof Bay , Alaska . *Fish. Bull.*, Seattle WA ,89(4):541-553.
- Anderson, A.R.S. (1896) An account of the deep-sea Crustacea collected during the season 1894-95. Natural history notes from the R. I. M. Survey Steamer 'Investigator', Commander C. F. Oldham, R. N., Commanding. *J. Asiat. Soc. Bengal.*, 65(2) :88-106.

- Anderson, W. W. and M.J. Linder (1945) A provisional key to the shrimps of the family Penaeidae with special reference to American forms. *Trans. Amer. Fish. Soc.*, 73: 284-319.
- Anderson, W.W. and M.J.Lindner (1971) Contribution to the biology of the royal red shrimp, *Hymenopenaeus robustus* Smith. *U.S.Fish Wildl. Serv., Fish.Bull.*, 69(2):313-336.
- Anderson,S.O.(1991) Cuticular proteins form the shrimp *Pandalus borealis*. *Comp. Biochem. Physiol.*, B.Vol.99 B , no.2 , pp.453- 458.
- Ando ,S.and M. Hatano (1986) Deterioration chum salmon (*Oncorhynchus keta*) muscle during spawning migration- XIV , carotenoid in the serum lipoprotein of chum salmon associated with migration .*Bull. Fac. Fish .Hokkaido. Univ.*, 37 : 148- 156.
- Anekutty, J. (2003) Histological, histochemical and biochemical characterization of male morphotypes of *Macrobrachium rosenbergii* (De man) .PhD Thesis. *Cochin.Univ.Sci.and Tech.*, Cochin, India. 164p.
- Anibeze , C.I.P. (2000) Length-weight relationship and relative condition of *Heterobranchus longifilis* (Valenciennes ) from Idodo River , Nigeria. *Naga , The ICLARM Quarerly .*, 23(2): 34-35.
- Anon (1984) Synopsis of marine prawn fishery of India. *Mar. Fish. Infor. Serv. T& E .Ser.* 37:1-10.
- Aoto, T. (1952) Sexual phases in the prawn, *Pandalus Kessleri* Czerniavski, with special reference to the reversal of sex. *Journal of the Faculty of Science, Hokkaido University, Series 6, Zoology* 11:1-20.
- Aquilla, A. (1991) Deep sea prawn fishing: Oceanorama Inst. *Oceanogr.Pand Ricard.*, No. 17: 21-25.
- Arana, P. (1970) Crecimiento relativo del camaron nylon, *Heterocarpus reedi*, de la costa de Valparaiso. *Invs. Marinas.*, 1 (6) :111-138.

- Arrobas, I and A.R.Cascalho (1987) On the biology and fishery of *Aristeus antennatus* (Risso, 1816) in the south Portuguese coast. *Inv.pesq.*, Barcelona. 51 : 233-243.
- Audouin, J. (1965) Repartition bathymetrique des crevettes sur les cotes algeriennes entre les iles zaffarines et les iles Habibas. *Rapp.Comm.int Mer Medit.*, 18 (2): 171-174.
- Ayyappan, A. and R.S. Biradar (2000) Manpower requirements and human resource development in fisheries sector. Brainstorming session, CIFE , Mumbai.
- Balsiger , J.W.(1981) A review of pandalid shrimp fisheries in the northern hemisphere- In: T. Frady ,ed., Proceedings of the international pandalid shrimp symposium .Feb.13-15 1979.P 7-35.Kodiak ,Alaska ,University of Alaska . *Sea Grant Rep.*,81-83.
- Balss , H.( 1925 ) Macrura der Deutschen Tiefsee- Expedition.2. natantia. Teil A. *Wiss.Ergebn . Dtscch. Tiefsee-Exped. 'VALDIVIA'*, 20:217-315.
- Balss, H. (1914) Ostasiatische Decapoden. II. Die Natantia und Reptantia. *Abh.bayer.Akad. Wiss.*, 2(10): 1-101.
- Banerji, S.K. and M.J. George (1967) Size distribution and growth of *Metapenaeus dobsoni* (Miers) and their effects on the trawler catches off Kerala. *Proc.Symp.Crustacea. Mar.Biol.Ass.India.*, part II; 634-648.
- Barnard, K.H. (1947) Description of new species of South African Decapod Crustacea, with notes on synonymy and new records. *Ann. Mag. Nat. Hist.*, Ser.11 (13): 361-392.
- Barnard, K. H. (1950) Descriptive catalogue of south African Decapod Crustacea. *Ann. S. Afr. Mus.*, 38: 1-837.
- Bas, C. (1966) La gamba rosada (*Aristeus antennatus*). Publicaciones Tecnicas de la Junta de Estudios de Pesca, 5: 143-155.

- Bas, C. and F. Sardá (1998) Long term morphometric variations in a population of the deep sea shrimp *Aristeus antennatus* (Risso, 1816) (Decapoda, aristeidae). *Crustaceana.*, 71(4): 369-377.
- Basford, E.J., A. Eletherieu and D. Raffelli (1989) The epifauna of the northern sea. *J.mar.Biol.Ass.U.K.*, 28: 32-41.
- Bate, C.S. (1881) On the Penaeidea. *Ann. mag. nat. Hist.*, Ser. 5,8; 169-196.
- Bate, C.S. (1888) Report on the Crustacea Macrura collected H. M. S. "Challenger" during the years 1873-76. *Rep. Voy. Challenger*, Zool., 24 : 1-942.
- Beams, H.W.and R.G. Kessel (1963) *J.Cell.Biol.*, 18,621.
- Belogradov ,E.A. (1981) About feeding fishery shrimps in difference regions of Fare East's Sea-Proc.TNIRO.75: 117-120.
- Berenboim , B.I. (1989) On regulation of shrimp *Pandalus borealis* fishery in the Barents Sea. *ICES : COPENHAGEN* ., 12pp.
- Berenboim, B.I. (1981) Feeding of northern shrimp in Barents Sea .*Biol .Morya.* , 5:28-32.
- Berenboim, B.I. (1992) Northern shrimp (*Pandalus borealis*) from the Barents Sea (Biology and Fishery ) ,*Murmansk* , PINRO .,135p.
- Bergström , S. (1992) Demography and sex change in pandalid shrimps . Department Of Zoology, Göteborg University. Electronic copy.
- Bergström, B. (1992) Growth, growth modeling and age determination of *Pandalus borealis*. *Mar.Ecol.Prog.Ser.*, 83: 167-183.
- Berkeley ,A.A.(1929) Sex reversal in *Pandalus danae*. *Am.Nat.*,63:571-573.
- Berry, R.J. (1970) Shrimp mortality rates derived from fishery statistics. *Proc. Gulf .Carrib.Fish.Inst.*, 22:66-78.
- Bertalanffy, L.V. (1938) A quantitative theory of organic growth. *Human Biol.*, 10(2):181-213.

- Bertalanffy, L.V. (1934) Untersuchungen über die Gesetzmäßigkeiten des Wachstums. 1. Allgemeine Grundlagen der Theorie. *Roux'Arch. Entwicklungsmech.Org.*, 131:613-653.
- Beverton, R.J.H. and S.J. Holt (1957) On the dynamics of exploited fish populations. *Fish. Invest. Minist. Agri. Fish. Food G.B. (2 Sea Fish.)* 19: 533p.
- Beverton, R.J.H. and S.J. Holt (1959) A review of the life spans and natural mortality rates of fish in nature and their relation to growth and other physiological characteristics. *In. Cibe. Found. Colloq. Aeging.*, 5:142-180.
- Bhadra, S. and R.S. Biradar (2000) Population dynamics of penaeid prawn *Penaeus merguensis* off Mumbai coast. *J. of the Indian Fish. Ass.*, 27: 65-77.
- Bhimachar, B.S. (1965) Life history and behaviour of Indian prawns. *Fish. Tech.*, 2(1): 1-11.
- Bianchi, G. (1992) Demersal assemblages of the continental shelf and upper slope of Angola. *Mar. Ecol. Prog. Ser.*, 81:101-120.
- Bishop, J.D. and S.H. Shella (1994) Discrete seasonal reproduction in an abyssal peracarid crustacean. *Deep Sea Res.*, 42 (11-12) : 1789-1800.
- Bjerkeng, B., T. Storebakken and S. Liaaen-Jensen (1992) Pigmentation of rainbow trout from start of feeding to sexual maturation. *Aquaculture.*, 108: 333- 346.
- Blackstone, N.W. (1986) Relative and specific growth rates in Crustaceans. *Growth.*, 50(1): 118-127.
- Bliss, D.E. (1983) (ed) *The biology of Crustacea*. Academic Press. New York.

- Bozzano, A., L. Recasens and P.Sartor (1997) Diet of the European hake *Merluccius merluccius* (Pisces: Merlucciidae) in the western Mediterranean (Gulf of Lions). *Sci.Mar.*, 61 : 1-8.
- Brian, A. (1931) La biologia del fonda a Scampi nel mare Ligure. *Boll. Mus. Zool. Anat. Genova*, 11 (45): 1-6.
- Bullis, H.R.Jr. (1956) preliminary results of deep-water exploration for shrimp in the Gulf of Mexico by M/V *Oregon* (1950-1956). *Commer. Fish. Rev.*, 18(12): 1-12.
- Bullis, H.R.Jr. and J.R. Thompson (1959) Shrimp exploration by the M/V *Oregon* along the north east coast of South America. *Commer.Fish.Rev.*,21 (11):1-9.
- Bullis, H.R.Jr. and W.F.Rathjen (1959) Shrimp explorations off south-easter coast of the United States (1956-1958) *Commer.Fish.Rev.*,21 (6):1-20.
- Bullis, H.R. Jr. and J.R. Thompson (1965) Collection b the exploratory fishing vessels " Oregon", "Silver Bay", "Combat" and " Pelican" made during 1956 to 1960 in the south western North Atlantic. *U. S. FishWildl. Serv. Spec. Sci. Rep.-Fish.*, (510):1-130.
- Burukovsky, R.N. (1972) On the function of the rostrum in shrimps (InRuss). *Trudy Atlant. NIRO (Atlant nauchno-issled Inst morsk ryb Khoz Okeanogr).*, 42: 176-179.
- Burukovsky, R.N. (1992) Methods of biological analysis of some tropical and subtropical shrimps. – In collect. papers Fishery – *Biological Investigations of marine Invertebrates.M.VNIRO*,160p.
- Butler,T.H. (1964) Growth ,reproduction and distribution of pandalid shrimps in British Columbia *.J.Fish.Res.Bd. Canada.* ,21(6):1403-1452.
- Butler, T.H. (1968) The shrimp fishery of British Columbia *.FAO Fish. Rep.*,57(2):521-526.

- Butler , T.H. (1970) Synopsis of biological data on the prawn *Pandalus platyceros* Brandt,1851. *FAO Fish. Rep.*,57(4): 1289-1316.
- Caddy , J.( 1987) size-frequency analysis for Crustacea: moult increment and frequency models for stock assessment . *Kuwait Bull. mar. Sci.*, 9:43-61.
- Caihong , F., T. J. Quinn and G. H. Kruse (2000) Analyses of harvest strategies for pandalid shrimp populations . *J. Shelf. Res.*, Vol .19 (1) : 559p.
- Calman, W. T. (1925) On macrurous decapod crustacea collected in South African waters by the S.S. "Pickle" with a note on specimens of the genus *Sergestes* by H.J. Hansen. *Rep. Fish. Mar. Biol. Sur. S. Afr.*, 4 (3); 1- 26.
- Calman, W. T. (1939) Crustacea: Caridea. *John Murray Exped. Sci. Rep.*, 6 (4): 183-224.
- Calman, W.T. (1909) Crustacea. In. Ray Lankester (ed.), *A treatise on Zoology*, pt. 7, appendiculata, fasc.3, pp.1-346.Adam and Charles Black, London.
- Calman, W.T. (1923) The synonymy of a penaeid prawn , *Penaeopsis philippii* (Spence Bate ) . *Ann. Mag. nat. Hist.*, (9) 12 : 536-539.
- Campbell, A. (1988) Growth of tagged American lobster, *Homarus americanus*, in the Bay of Fundy. *Can.J.Fish.Aquatic.Sci.*, 40: 1667-1675.
- Carbonell ,A.and P. Abello (1998) Distribution characteristics of pandalid shrimps (Decapoda: Caridea: Pandalidae) along the western Mediterranean Sea .*J. of Nat .Hist.*, 32: 1463-1474.
- Carr, M. R.(1997) Primer user manual .Plymouth routines in multivariate ecological research Plymouth Marine Laboratory , Plymouth , U.K.
- Cartes , J.E. (1991) Análisis de las comunidades y estructura trófica de los crustáceos decápodos batiales del Mar Catalán . PhD. thesis, *Universitat Politècnica de Catalunya* , Barcelona .

- Cartes , J.E. and F. Sardá (1993) Zonation of deep-sea decapod fauna in the Catalan Sea (Western Mediterranean) .*J.Nat.Hist.*,26: 1035-1323.
- Cartes ,J.E.(1993)Diets of deep-water pandalid shrimps on the Western Mediterranean slope .*Mar.Ecol.Prog.Ser.*, 96(1):49-61.
- Cartes ,J.E., F.Sarda , J.B.Company and J.Lleonart (1993) Day-night migrations by deep-sea decapod crustaceans in experimental sampling in the Western Mediterranean Sea. *J.Exp.mar.Biol.*, 171: 63-73.
- Cartes ,J.E., J.C. Sorbe and F.Sarda (1994) Spatial distribution of deep-sea decapods and euphuasiids near the bottom in the northwestern Mediterranean. *J.Exp.mar.Biol.*, 179: 131-144.
- Cartes ,J.E.(1995) Diets of , and trophic resources exploited by , bathyal penaeoidean shrimps from the Western Mediterranean:
- Castell , J.D. and A. L. Lawrence (1989) Relationship between maturation and biochemical composition of the gonads and digestive glands of the shrimp *Penaeus azeticus* Ives and *Penaeus setiferus* (L.) *J.Crust. Biol.*, 9:202-211.
- Ceccaldi ,H.J. (1966) Evolution des ieufs et cycle de reproduction chez *Plesionika edwardsii* (Brandt) – Revue Travaux Station marine Endoume., 44: 403-412.
- Cessay, K. (2000) The local population of shrimp (*Pandalus borealis*) , stock size and age structure at Arnarfjordur, Northwest Iceland .Final project, , 21p.
- Chace, F.A. (1936) Revision of the bathypelagic prawns of the family Acanthephyridae, with notes on a new family, Gomphonotidae, *J. Wash. Acad. Sci.*, 26 (1): 24-31.
- Chace ,F.A. Jr.(1992) On the classification of the Caridea (Decapoda ) . *Crustaceana.* ,63(1): 70-80.



- Chace, F.A. (1940) The bathypelagic Caridean Crustacea, Plankton of the Bermuda Oceanographic Expedition- IX. *Zoologica.*, 25 (11): 117-209.
- Chakraborty, S. K., V. D. Deshmukh, M. Z. Khan, K. Vidyasagar and S. G. Raje (1997) Estimates of growth, mortality, recruitment pattern and maximum sustainable yield of important fishery resources of Maharashtra coast. *I.J.Mar.Sci.*, 26: 53-56.
- Champion, H. F. B. (1973) New records of penaeid prawns from the east coast of southern Africa with notes on *Penaeus marginatus* Randall and a new species of *Metapenaeopsis*. *Crustaceana.*, 25(2): 181-203.
- Childress, J.J., S.M. Taylor, G.M. Cailliet and M.H. Price (1980) Price patterns of growth, energy utilization and reproduction in some meso – and bathypelagic fishes off Southern California. *Marine Biol.*, 61: 27-40.
- Childress, J.J. and M. Nygaard (1974) Chemical composition and buoyancy of midwater crustaceans as function of depth of occurrence off Southern California. *Mar.Biol.*, 27: 225-238.
- Childress, J.J. and M.H. Price (1983) Growth rate of the bathypelagic crustacean *Gnathopausia ingens* (Mysidacea: Lophogastridae). I. Dimensional and population structure. *Mar.Biol.*, 27 : 225-238.
- Chilton, C. (1911) The Crustacea of the Kerdec Islands. *Trans.N.Z. Inst.*, 43: 544-573.
- Chou, W.R., S. H. Lai and L. S. Fang (1999) Benthic crustacean communities in waters of Taiwan and their relationship to environmental characteristics. *Acta Zoologica Taiwanica.*, 10(1) :25-33.
- Choubert ,G. and T. Storebakken (1989) Dose response to astaxanthin and canthaxanthin pigmentation of rainbow trout fed various dietary carotenoid sources. *Aquaculture.*, 81: 69-77.

- Clark ,A., C.C.E.Hopkins and E.M.Nelson (1991) Egg size and reproductive output in the deep-water prawn *Pandalus borealis* Kroyer ,1838. *Functional Biol.*, 5(6): 724-730.
- Clark ,M. (2001) Are deepwater fisheries sustainable – the example of orange roughy ( *Hoplostethus atlanticus*) in New Zealand . *Fish. Res.*, 51:123-135.
- Clarke, K.R., R. M. Warwick and B. E. Brown (1993) An index showing breakdown of seriation , related to disturbance , in a coral reef assemblage .*Mar. Ecol. prog. Ser.*, 92: 205-219.
- Clarke,A. (1977) Seasonal variation in the total lipid content of *Chorismus antarcticus* (Pfeffer) (Crustacea : Decapoda ) at South Georgia. *J. Exp. Mar .Biol. Ecol.*, 27:93-106.
- Clarke,A. (1979) Lipid content and composition of the pink shrimp, *Pandalus montagui* (Leach) (Crustacea : Decapoda ) . *J. Exp. Mar .Biol. Ecol.*, 38: 1-17.
- Clarke, T. (1972) Exploration for deep benthic fish and crustacean resources in Hawaii. *Univ.Hawaii. Hawaii Inst. Mar.Biol.Tech.Rep.*, 29:1-18.
- CMFRI (2003) Annual report 2001-02. *Central Mar. Fish. Res. Inst.*, Kochi.92p.
- Cobb, J.S.and B.E.Phillips (1980) (eds.) *Biology and management of lobster*. Academic Press, London.
- Colloca Francesco (2002) Life cycle of the deep-water pandalid shrimp *Plesionika edwardsii* (decapod, Caridea) in the central Mediterranean Sea . *J. Crustacean Biol.*, 22(4): 775-783.

- Company, J. B. and F. Sardá (1997) Reproductive patterns and population characteristics in five deep-water pandalid shrimps in the Western Mediterranean along a depth gradient (150-1100m) Vol.148: 49-56.
- Company, J. B. and F. Sardá (2000) Growth parameters of deep-water decapod crustaceans in the Northwestern Mediterranean Sea ; a comparative approach. *Marine Biol.*, 136: 79-90.
- Company, J. B., J. E. Cartes and F. Sardá (2001) Biological patterns and near bottom population characteristics of two pasiphaeid decapod crustacean species, *Pasiphea sivado* and *P.multidentata* in the north – western Mediterranean Sea . *Marine Biol.*, 139: 61-73.
- Conan, G. (1985) Periodicity and phasing of moulting .*Crustaceans Issues* .. 3:73-99.
- Coutiere, H. (1905) Sur une forme de phaneres propres aux Pandalidae. *C.R. Acad.Sci.Paris.*,140-674-676.
- Coutiere , H. (1906) Notes sur la synonymis et al developpement de quelques Hoplophoridae (Compagnes de la "Princesse Alice" 1904-1905) . *Bull. Mus. Oceanogr. Monaco.*, 70: 1-20.
- Coutiere , H. (1938) Sur quelques Crustace's provenant des campagnes de la "Princesse Alice" .*Result. Camp. Sci. Monaco.*, 97 : 188-190.
- Crosnier , A. and E. De Bondy (1968) Les creverttes commercialisables de la cote ouest de l' Afrique intertropicale . Etat de nos connaissances sur leur biologie et leru perch en juillet 1967. *Init. Doc. techn. ORSTOM.*, (7) : 1-60.
- Crosnier, A. and J. Forest (1973) Les crevettes profondes de l' Atlantique oriental tropical. *Faune Tropicale.*, 19: 1-409.
- Crosnier ,A. and C. Jouannic (1973) Note d' information sur les propection de la pente continental malgache effectuees par le N.O.Vauben –

bathymetric sedimentologie –Pech au chalut . *Doc. Sci. Centre ORSTOM Nosy –Be.*, (42) : 1-18.

- Crosnier, A. and J. Forest (1968) Note preliminaire sur les Carides recureillis par l' " Omnango" au large du plateau continental, du Gabon a l' Angola (Crustacea Decapod Natanita). *Bull. Mus. Hist. nat. Paris.*, 39 (96): 1123-1147.
- Crossier, G.F. (1969) Effects of controlled diet on the morphological color change of a marine teleost. *J.Exp.Mar.Biol.Ecol.*,4:1-8.
- Crozier,G.F. (1970) Tissue carotenoids in pre-spawning and spawning sockeye salmon (*Oncorhyncus nerka*) . *J. Fish. Res. Board. Can.*, 27: 973-975.
- Cushing, D. H. (1981) Fisheries Biology: A study in fish population dynamics . Second edition Press Wisconsin. 295p.
- Czerpak , R. and B. Czeczuga (1969) Studies of the pigments in the shrimp *Crangon crangon* (Crustacea : Malacostraca) . *Mar. Biol.*, 3: 122-5.
- D'Incàò, F. and D.K. De Calasans (1978) Relacoes biometricos do "camaraõ rosa" *Penaeus paulensis* Perez-Farfante, 1967 na lagoa dos patos. Atlantica , Base Oceanografica , Inversidad de Rio Grande , Brazil .. 3 : 75-78.
- D'onghia, G., A. Matarrese, A.Tursi and P.Miorano (1994) observations on the biology of *Aristeus antennatus* and *Aristaeomorpha foliacea* in the Ionian Sea In: M.L.Bianchini &S.Ragonese (eds.). Life cycles and fisheries of deep water red shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* N.T.R.-I.T.P.P.Special publication, 3: 55-56.
- D'Onghia, G., F. Mastrototaro, A. Matarrese, C.Y.Politou and Ch. Mytilineou (2002) Biodiversity of the upper slope demersal community in the eastern Mediterranean: Preliminary comparison between two areas with and without trawl fishing., *J. Northw. Atl. Fish. Sci.*, vol.31: 263-273.

- D'onghia ,G., P.Maiorano,P.Maiorano ,P.Panza ,P.Panetta and A.Tursi (1998) Distribution , biology and population dynamics of *Aristaeomorpha foliacea* (Risso, 1827) (Crustacea , Decapoda) from the north-western Ionian Sea (Mediterranean Sea) .*Crustaceana* ., 71 (5) : 518-544.
- Dahlstrom,W.A. (1970) Synopsis of biological data on the ocean shrimp *Pandalus jordani* Rathbun,1902. *FAO Fish.Rep.*, (57)Vol.IV:1377-1416.
- Dailey, M.D. and S. Ralston (1986) Aspects of the reproductive biology, spatial distribution, growth and mortality of the deepwater caridean shrimp , *Heterocarpus laevigatus* , in Hawaii. *Fishery Bull.U.S.* , 84: 915-925.
- Dall , W., B.J Hill, P.C. Rothlisberg and D . J. Staples (1990) The biology of the penaeidae. *Advances in Marine Biology* , 27:18-25.
- Dall , W., D. M. Smith and L. E. Moore (1995) Carotenoids in the tiger prawn *Penaeus esculentus* during ovarian maturation . *Mar.Biol.*, 123: 435-441.
- Dana, J.D. (1852) Crustacea. United States Exploring Expedition during the years 1838,1839,1840,1841,1842 under the command of Charls Wilkes.U.S.N., 13: 1-1393.
- Dana ,J.D. (1855) Crustacea . United States Exploring Expedition during the years 1838,1839,1840,1841,1842 under the command of Charls Wilkes.U.S.N., 13 (atlas): 1- 27, pl.1-96.
- De Man, J.G.(1911) The decapoda of the Siboga Expedition . Part 1.Family Penaeidae , *Siboga Exped. Monogr.*, 39A:1-131.
- De Man,J.G.(1920) The Decapoda of the Siboga Expedition.Part. IV.Families Pasiphaeidae , Stylodactylidae , Oplophoridae , Nematocarcinidae , Thalassocaridae , Pandalidae , Psalidopodida , Gnathphyllidae , Processidae , Glyphocrangonida and Crangonida . *Siboga Exped. Monogr.*, 39A:1-138.

- Demestre ,M. (1990) Biología pesquera de la gamba *Aristeus antennatus* (Risso, 1816) en el mar Catalan. PhD dissertation .*University of Barcelona* , Barcelona.
- Demestre ,M. (1994) Biology and demography of *Aristeus antennatus* in the Catalan Sea (NW Mediterranean) In: Bianchini ,M.L. Ragonese,S.(Eds.) Life cycles and fisheries of the deep-water shrimps *Aristeomorpha foliacea* and *Aristeus antennatus*. Proceedings of the International Workshop. , Istituto di Tecnolgia della Pesca e del Pescato. NTR-ITPP Special Publication.3,pp.17-18.
- Demestre, M and P. Abelló (1993) Growth and distribution of *Solenocera membranacea* (Risso, 1816) (Decapoda, Dendrobranchiata) in the Northwestern Mediterranean Sea. *Scientia mar.*, 57(2-3) : 161-166.
- Demestre,M. and P. Martin (1993) Optimum exploitation of a demersal resource in the western Mediterranean : the fishery of the deep-water shrimp *Aristeus antennatus* (Risso , 1816) .*Sci.mar.*, 57 (2-3) : 175-182.
- Descouturelle , G.(1976) Influence de la temperature et de la sexulaite sur la duree des stades d'intermue chez la crevette d' eau duce *Atyaephira desmaresti* Millet . Vi Milieu., 25: 149-162.
- Devaraj ,M. and E. Vivekanandan (1999) Marine capture fisheries of India : Challenges and opportunities., *Current Sci.*, 76:314-332p.
- Dhall, W. and D. J. W. Moriarty (1983) Functional aspects of nutrition and digestion : The Mid gut.pp 215-251.In: D.E.Bliss and L.H. Mantel (Eds.) *The biology of crustacea Vol.5. Internal anatomy and physiological regulation*. Academic Press Inc., Orlando , Florida.
- Dieuzeide,R.(1955) Introduction :dragages et chalutages. Notes faunistiques sur la zone mesoabyssale. *Bull.Stat .Castiglione.*, (7): 7-86.

- Dieuzeide,R.( 1960) Le fond chalutable a 600 meters , par le travers de Catiglione. Recherche sur le facies a *Isidiella elongata* Esper. *Bull. Stat. Castiglione.*, (10) : 63 –106.
- Doflein , F.(1902) Ostasiatische Decapoden. *Abh. Beyer. Akad. Wiss.*, 21 (3): 611-670.
- Dow, R.L. (1966) a method of forecasting the relative abundance of northern shrimp (*Pandalus borealis* Kr.) in Maine waters. *Comm. Fish.Rev.*,28(3) :14-16.
- Dow, R.L. (1967) Temperature limitations on the supply of northern shrimp (*Pandalus borealis*) in Maine (USA) waters. *Mar. Biol. Ass .India, Proc. Symposium on crustacea.* ,Pt. 4: 1301-1304.
- Drach,P. (1939) Mue det cycle d'intermue chez les crustaces decapods. *Annls Inst. Oceanogr.*, Paris (NS) 19 : 103- 392.
- Emmerson, W.D.(1980) Induced maturation of prawn *Penaeus indicus*. *Mar.Ecol.Prog.ser.*, 2:121-131.
- Erdman, D.S. (1968) Spawning cycle, sex ratio and weights of Blue Marlin off Puerto Rico and the Virgin Islands. *Trans.Amer.Fish.Soc.*, 97: 131-137.
- Establier ,R.(1966) Estudio sobre los caroteinides de plantas y animals marinos.1.Disstrubucion de carotinoides en el crustaceo *Plesionpenaeus edwardsianus* (Johnson). *Investigacion pesq.*, 30 :207-22.
- Estrada , M., F ,Vives and M. Alcaraz (1985) Life and productivity of the open sea .In: Margalef ,M (ed) *Key environments :Western Mediterranean* . Pergamon press, Oxford, P 148-197.

- Estrada ,M and J. Salat (1989) Phytoplankton assemblages of deep and surface water layers in a Mediterranean frontal zone. *Sci.Mar.*,53(2-3):203-214.
- Ettershank ,G. (1983) How old is that Krill ? *Aust.Fish.*, 42(7) :22-23.
- Evelyn ,T.P.T .(1967) Pigments from a sockeye salmon (*Oncorhynchus nerka* ) with unusual skin coloration. *J. Fish. Re. Bd. Canada.*, 24: 2195-2199.
- Farina ,A.C., J. Freire and E.G. Gurriaran (1997) Megabenthic decapod crustacean assemblages on the Galician continental shelf and upper slope ( north-west Spain) , *Mar. Biol.*, 127:419-434.
- Farmer ,A. S.(1973) Age and Growth in *Nephrops norvegicus* (Decapoda :Nephropidae) .*Mar.Biol.*, 23:315- 325.
- Faxon, W. (1896) Supplementary notes on the Crustacea. Reports on the results of dredging, under the supervision of Alexander Agassiz, in the Gulf of Mexico and the Caribbean Sea, and on the East Coast of the United States, 1877 to 1880, by the U.S. Coast Survey Steamer 'Blake'. *Bull. Mus. compo. zool. harv.*, 30 : 151-166.
- Faxon ,W. (1895) The stalk eyed Crustacea. Reports on an exploration off the West Coasts of Mexico , Central and South America , and off the Galapagos Islands , in charge of Alexander Agassiz , carried by the U.S. Fish Commission Steamer 'Albatross' , during 1891. *Mem. Mus. compo. zool. harv.*, 18: 1-192.
- Faxon, W. (1893) Reports on the dredging operations off the west coast of Central America to the Galapagos to the west coast of Mexico , and in the Gulf of California in charge of Alexander Agassiz , carried by the U.S. Fish Commission Steamer 'Albatross' , during 1891. Preliminary descriptions of new species of Crustacea , *Bull Mus.compo.zool.harv.*, 24: 149-220.



- Finney, W. C. and L.G. Abele (1981) Allometric variation and sexual maturity in the obligate coral commensal *Trapezia ferruginea* Latreille (Decapoda , Xanthidae) Crustacea., 41 (2) : 114-129.
- Fisher , L.R., S.K. Kon and S.Y.Thompson (1964) Vitamin A and carotenoids in certain invertebrates .7 . Crustacea: Copepoda. *J. Mar. Biol. Ass. U.K.*, 44: 685-92.
- Fisher , L.R., S.K.Kon and S.Y.Thompson (1952) Vitamin A and carotenoids in certain invertebrates .1 . Marine crustacea. *J.Mar.Biol.Ass.U.K.*, 31:299-58.
- Fisher , L.R., S.K.Kon and S.Y.Thompson (1953) Vitamin A and carotenoids in some Mediterranean crustacea with a note on the swarming of *Meganyctiphanes*. *Bulletin de l'Instiut Oceanographique* ., 50(1021) 19pp.
- Fisher , L.R., S.K.Kon and S.Y.Thompson (1954) Vitamin A and carotenoids in certain invertebrates .2 . Studies of seasonal variations in some marine crustacea. *J.Mar.Biol.Ass.U.K.*,33: 589-612.
- Fisher ,L.R. (1962) The total lipid material in some species of marine zooplankotn. *Conseil International pour l' Explanation de la Mer* , *Rapports et Proces-Verbaux des Reunions* .,153:129-36.
- Fisher, L. R., S. K. Kon and S. Y. Thompson (1957) Vitamin A and carotenoids in certain invertebrates .6 . Crustacea : Penaeidea. *J. Mar. Biol. Ass. U. K.*, 36: 501-7.
- Fitz ,H.C.and R.M.Weigert (1991) Tagging of juvenile blue crabs, *Callinectes sapidus* , with micro wire tags: retentions , survival and growth through multiple molts. *J.Crust.Biol.*, 11: 229-235.
- Folsch , J., M. Lees and G. H. Sloanne Stanley (1957) A simple method for the isolation and purification of total lipid from animal tissue. *J. Biol. Chem.*, 226:497-509.

- Ford ,E. (1933) An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. *J. mar. biol. Ass. U. K.* , 19:305-384.
- Forest, J. (1964) Sur une crevette recueillie au cours de la campagne de chalutage dans le golfe Guinee *Plesionika williamsi* sp.nov. *Bull.Mus.Hist.nat.Paris.*, Ser.2, 35(6): 620-629.
- Fournier, D.A., Sibert, J.R. and M.Terceiro (1991) Analysis of length frequency samples with relative abundance data for the Gulf of Maine northern shrimp (*Pandalus borealis*) by the MULTIFAN method. *Can. J.Fish.Aquat.Sci.*, 48: 591-598.
- Foxton, P. (1970a) The vertical distribution of pelagic decapods (Crustacea : Natantia ) collected on the SOND cruise 1965. I . The Caridea. *J.Mar.Biol.Ass.U.K.*, 50: 939-60.
- Foxton, P. (1970b) The vertical distribution of pelagic decapods (Crustacea : Natantia ) collected on the SOND cruise 1965. II . The Penaeidea and general discussion . *J.Mar.Biol.Ass.U.K.*, 50: 961-1000.
- Foxton, P. (1972) Observations on the vertical distribution of the genus *Acanthehphyra* (Crustacea : Decapoda) in the eastern North Atlantic with particular reference to species of the 'purpurea' group . *Proc. Royal Soc. of Edinburgh, B.*, 73: 301-13.
- France ,R., Holmes, J. and A. Lynch (1991) use of size-frequency data to estimate the age composition of crayfish populations. *Can. J.Fish.Aquat.Sci.*, 48: 2324-2332.
- Gage, J. D and P .A. Tyler (1991) Deep sea biology: a natural history of organisms at the deep sea floor. *Cambridge Univ. Press*, London.
- Garcia ,S. and L. Le Reste (1981) Life cycles , dynamics , exploitation and management of coastal penaeid shrimp stocks. *FAO Fish . Tech. Pap.*, (203) :215p.

- Garcia,S.(1977) Biologie et dynamique des populations de crevette rose *Penaeus duorarum notialis* Perz Farfante 1967, en cote d' Ivoire . Trav.Doc.ORSTOM , 79: 221p.
- Gayanilo ,Jr.F.C., P.Sparre and D.Pauly (1996) The FAO-ICLARM Stock Assessment Tools (FiSAT) User's guide. *FAO Computerise information Series (Fisheries)* No. 8 Rome , FAO, 126p.
- George ,M. J. (1959) Notes on the bionomics of the prawn *Metapenaeus monoceros* Fabricius , *Indian J. Fish.*, 6(2) : 268-279.
- George ,M. J. (1966) On a collection of penaeid prawns from the offshore waters of the south-west coast of India. *Proc.Symp. on Crustacea. Mar.Biol.Ass.India.*, pt.1:337-346.
- George , M. J., S. K. Dharmaraja and G. Subbaraju (1980) Trends in total marine fish production in India-1989.*Mar.Fish.Infor.Serv., T & E Ser.*, No.22 : 1-17.
- George ,J.C. and B.S. Patel (1956) The seasonal variation in fat content of the liver and gonad in marine and freshwater decapod. *J. Anim. Morpho. Physiol.*, 3: 49-55.
- George ,M.J. and P.V. Rao (1966) Distribution of sex ratios of penaeid prawns in the trawl fishery off Cochin. *Proc. Symposium on Crustacea , Mar. Biol. Ass. India.* , pt.2: 698-700.
- George, M. J. P.V. Rao (1966) *On some decapod crustaceans from the south west coast f India. Ibid.*, Part I,327.
- George ,M.J. and P.V. Rao (1967) Distribution of sex ratios of penaeid prawns in the trawl fishery off Cochin. *Proc. Symposium on Crustacea . Mar. Biol. Ass. India.*,pt.2: 698-700.

- George ,R. Y. and R. J. Menzies (1967) Indication of cyclic reproductive activity in abyssal organisms. *Nature* ., 215:878.
- George, M. J. (1969) Systematics-Taxonomic considerations and general distribution. *Bull. Cent. Mar. Fish. Res. Inst.*, No.14 : 5-28.
- George, M. J. (1979) Taxonomy of Indian prawn (Penaeidae , Crustacea , Decapoda ) *Contributions to Marine Sciences dedicated to Dr.C. V. Kurien* ., pp. 21-59.
- George, M. J., K. Alagaraja, K.K.Sukumaran, G.Nandakumar, S. Ramamurthy and K. Y. Telang (1988) The present status of shrimp trawling and its impact on shrimp stocks of Karnataka coast. *Seminar Proceedings Problems and Prospects of Marine Fishing and Fish processing in Karnataka.*, pp.1-14.
- George,M.J., K.Raman and P.K.Nair (1963) Observations on the offshore prawn fishery of Cochin. *Indian J. Fish.*, 10(2A): 460-499.
- Ghidalia, W.(1985) Structural and biological aspects of pigments . pp 301-375. In: D. E. Bliss and L H. Matel (Eds.) *The biology of crustacea Vol.9 Integument, pigments and hormonal process*. Academic Press Inc. Orlando , Florida.
- Giese , A. C.(1969) A new approach to the biochemical composition of the mollusc body . *Oceano. Mar. Biol . Ann. Rev.*, 7: 175 – 229.
- Giese ,A.C., L. Greenfield ,H. Huang ,A. Farmanfarmaian ,R. Boolootian and R. Lasker ( 1958) Organic productivity in the reproductive cycle of the purple sea urchin .*Biol. Bull.*, 116: 49-58.
- Gilchrist ,B. M. and W. L. Lee (1967) Carotenoids and carotenoid metabolism in *Carcinus maenas* (Crustacea : Decapoda ) *J. of Zool.* ,151;171-80.
- Gillam ,A.E., M.S. El Ridi and R.S. Wimpenney (1939) The seasonal variation biological composition of certain plankton samples from the North

- Sea in relation to their content of vitamin A, carotenoids, chlorophyll, and total fatty matter. *J.Exp.Biol.*, 16:71-88.
- Golani, D. and Galil (1991) Trophic relationships of colonizing and indigenous goatfishes (Mullidae) in the eastern Mediterranean with special emphasis on decapod crustaceans. *Hydrobiologia*, 218 : 27-33.
- González, E. and I. Olaso (1987) Cambios espaciales y temporales de los crustaceos decapodo de la plataforma continental de Galicia ,(NW de Espaniol) . *Investigacio n' pesq.*, 57 (1) : 323-341.
- Goodwin ,T.W. (1950) Carotenoids and reproduction .*Biol. Rev. Cambridge* ., 25:391-413.
- Goodwin ,T.W. and S. Srisukh (1949) Some observations on astaxanthin distribution in marine crustacea. *Biochemical Journal.*, 45:268-70.
- Gopakumar,G.( 1997) *Biochemical composition of Indian food fish*. CIFT, Cochin.,P:1-17.
- Gopalakrishnan, V. (1952) Food and feeding habits of the prawn *Penaeus indicus* . *J.Madras Univ.*, 22 B(1): 69-75.
- Grover, H.J. and R. O. Juliano ( 1976) Length-weight relationship of pond raised milk fish in the Philippines. *Aquaculture.* , 7, 339.
- Guézé, P. (1976) La pêche aux crevettes de profondeur à la Réunion (suite). *Trav.Doc.ORSTOM.*, 47:269-283.
- Gulland, J. A. (1971) *The fish resources of the ocean*. Fish news (Books) Ltd., West Byfleet, England, for FAO: 255p.
- Gulland, J.A. (1969) Manual of methods for fish stock assessment, 1. Fish population analysis. *FAO.Mar.Fish.Sci.*, No.4 ,FRS/M4,154p.
- Hall , S.J. (1999) The effects of fishing on marine ecosystems and communities . *Fish Biol. And Aquat. Res. Series I*, Blackwell Science .,273p.

- Hall, D.N.F. (1961) The Malayan Penaeidae (Crustacea, Decapoda) part II. Further taxonomic note on the Malayan species. *Bull.Raffles Mus.*, 26: 76-119.
- Hall, D.N.F. (1962) Observations on the biology of some Indo west Pacific Penaeidae (Crustacea, Decapoda) *Fish.Publ.Colonial off. London.*, 17 :1-229.
- Hancock, D.A. and G. Henriques (1968) Stock assessment in the shrimp (*Heterocarpus reedi*) fishery of Chile. *FAO Fish. Rep.*,57(2):443-465.
- Hardy , R.W., O.J.Torrissen and T.M. Scott (1990) Absorption and distribution of <sup>14</sup>C labelled canthaxanthin in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture.*, 87: 331-344.
- Harrison , K.E.(1990) The role of nutrition in maturation , reproduction and embryonic development of decapod crustaceans :A review *J.Shell Fish.Res.*,9:1-28.
- Harrison, K. (1988) Seasonal reproduction in deep-sea Crustacea (Isopoda : Asellota ). *J. Nat. Hist.*, 22:175-197.
- Hart, T.J. (1946) Report on trawling surveys on the Patagonian continental shelf. *Discovery Rep.*, 23: 223-403.
- Hartnoll, R. G. (1978) The determination of relative growth in Crustacea. *Crustaceana.*, 34 (3) : 282-293.
- Hartnoll, R. G. (1985) *Growth , sexual maturity and reproductive output* .In: A.M. Wenner (ed.) , *Factors in adult growth. Crustacean Issues* , 3:101-128.(A. A. Balkema ,Rotterdam &Boston).
- Hartnoll, R. G. (1983) *Growth*. In: Bliss, D. E. (ed) *The biology of Crustacea. Vol8. Academic Press, New York.*, pp.214-282.
- Hartnoll, R.G. (1974) Variation in growth pattern between some secondary sexual characters in crabs. *Crustaceana.*, 27: 131-136.

- Hastings, W.H. (1976) Fish nutrition and fish feed manufacture .FAO Tech. Conf. on Aquaculture, Japan .FIR: AQ/Conf/76/ R 23,13.
- Hawk, P. B., B. L. Oser and W. H. Summerson (1954) *Practical Physiological Chemistry*. McGraw-Hill Book Company Inc., New York.
- Haynes, E. E. (1976) Description of zoeae of coonstripe shrimp, *Pandalus hypsinotus*, reared in the laboratory. *Fish. Bull. United States.*,74:323-342.
- Haynes, E.E. (1978) Description of larvae of the humpy shrimp , *Pandalus goniurus* , reared in situ in Kachemak Bay , Alaska. *Fish. Bull. United States.* , 76:235-248.
- Haynes, E.E. (1979) Description of larvae of the northern shrimp *Pandalus borealis* Krøyer reared in situ in Kachemak Bay , Alaska. *Fish. Bull. United States.*,77: 157-173.
- Heegaard , P. (1967) On behaviour , sex-ratio and growth of *Solenocera membranacea* (Risso , 1816) (Decapoda , Penaeidae) . *Crustaceana* ., 13: 227-237.
- Herring ,P. J. (1973) Depth distribution of the carotenoid pigments and lipids of some oceanic animals .2. Decapod crustaceans. *J. Mar. Biol. Ass.U.K.*,53:539-562.
- Hida ,T.S. and W.T. Pereyra (1966) Results of bottom trawling in Indian seas by R/V/ Anton Bruun in 1963. *Proc.Indo-Pacific Fish.Couc.*, 11(2): 156-171.
- Hill, C. (1992) Interactions between year classes in the benthic amphipod *Monoporeia affinis* – effects of juvenile survival and growth. *Oecologia* ., 91 : 157-162.

- Hinsch ,G.W.and M.V.Cone (1969) *J.Cell Biol.*, 40,336.
- Hiroshi ,I .(1978) On the distribution and life history of a side striped shrimp, *Pandalopsis japonica* Balss , in the Japan Sea. *Bull . Japan Sea reg. Fish. Res. lab.*, 29: 147-157.
- Hjort , J. and J. T. Ruud (1938) Deep-sea prawn fisheries and their problems. *Hvalrad. Skr.*, No.17,144p.
- Hoglund ,H .(1962) Catch-composition in the Swedish deep-sea prawn fishery (*Pandalus borealis*) .I.C.E.S.,C.M.,No.39.
- Holden,M.J.& D.F.S.Raitt (1974) (Eds.) Manual of Fisheries Science, Part 2.Methods of Resources Investigation and their applications. *FAO. Fish.Tech.Pap.*.115,1-214.
- Holthuis, L.B. (1980) FAO species catalogue . Vol. 1. Shrimp and prawns of the world. An annotated catalogue of species of interest to fisheries . *FAO Fish. Synop.*, (125) Vol.1 : 1-271.
- Holthuis, L. B. (1951) The Caridean Crustacea of Tropical West Africa. *Atlantide Rep.*, (2): 7-187.
- Holthuis, L.B. (1952) Crustaces Decapodes Macrures. *Res. Scient. Exp. Ocanogr. Belge Eaux cotieres afric.Atlanctic.Sud* (1948- 1949), 3 (2): 1-88.
- Holthuis, L.B. (1955) The recent genera of caridean and stenopodidean shrimps (Class Crustacea, order Decapoda, super section Natantia), with keys of their determination. *Zool.Verhand., Leiden*, 26: 1-157.
- Holthuis,L.B. and C. Maurin (1952) Notes sur *Lysmata unicornis* nov.sp.et sur deux autres especes interessentes de Crustaces Decapodes Macroures de la cote atlantique du Maroc. *Proc.Kon. Nederl.Akad.Westensch.*, 55(2) :197-202.
- Holthuis,L.B. and Rosa,Jr. (1965) List of species of shrimps and prawns of economic value .*FAO Fish. Tech.Pap.*, 52: 21pp.



- Hopkins, C.C.E., J.R. Sargent and E.M. Nilssen (1993) Total lipid content and lipid and fatty acid composition of the deep-water prawn, *Pandalus borealis* from Balsfjord, northern Norway: growth and feeding relationships. *Mar. Ecol. Prog. Ser.*, 96:21-76.
- Hopper, A.G. (Ed.) (1995) Deepwater fisheries of the North Atlantic oceanic slope. In: Proceedings of the NATO Advanced Research Workshop on Deepwater Fisheries of the North Atlantic Oceanic Slope, Hull, UK, 1994. Kluwer Academic Publishers. Nordrecht. Netherlands, 421p.
- Horsted, S.A. and E. Smidt (1956) The deep-sea prawn (*Pandalus borealis* Kr.) in Greenland waters. *Meddr. Danm. Fisk.-og. Havunders.*, 1(11): 1-118.
- Hubbs, C. and L. Stavenhagen (1958) Effects of maternal carotenoid deficiency on the viability of darter (*Osteichthyes*) offspring. *Physio- Zool.*, 31: 280-283.
- Huber, M. E. (1985) Allometric growth of the carapace in *Trapezia* (Brachyura, Xanthidea) *J. Crustacean Biol.*, 5(1): 79-83.
- Hui-Chen Kao., Tin-Yam Chan and Hsiang-Ping Yu (1999) Ovary development of the deep-water shrimp *Aristaeomorpha foliacea* (Risso, 1826) (Crustacea : Decapoda: Aristeidae) from Taiwan., *Zoological Studies.*, 38(4): 373-376.
- Humphrey, G. (1941) C.S.I.R. (Australia), Pamphlet III.
- Hynes, H.B.N. (1950) The food of fresh water Stickle backs (*Gasterosteus aculeatus* and *Pygosteus punjiti*) with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.*, 19(1): 36-58.
- Ikeda, T. (1991) RNA content of Antarctic krill (*Euphausia superba*), an estimator of natural growth rate. Proc. NIPR Symp. *Polar Biol.*, 2: 26-33.

- Inogradov, E. (1970) *Proc.R.Soc.*, 17: 253- 260.
- Intes, A. (1978) Peche profonde aux casiers en NouvelleCaedonie et iles adjacentes: Essais preliminaries. *ORSTOM (Noumea) Rapports Scient., Et Techn.*, 2:1-10.
- Ishikawa, Y., Y. Miyake and S. Yasuie (1966) Chromatophores and carotenoids in cultured Kuruma prawn , *Penaeus japonicus* Bate , of different body colours. *Bull .Fish.Exp.Station Okayama Pref.*, 18-24.
- Ito , H .(1970) On the distribution and life history of a side striped shrimp, *Pandalopsis japonica* Balss , in the Japan Sea. *Bull .Japan Sea Reg,Fish.Res.Lab.*,27:147-157.
- Ivanov , B.G. and V.V. Krylov (1980) Length-weight relationship in some common prawns and lobsters (*Macrura* , *natantia* and *reptantia* ) from the western Indian Ocean . *Crustaceana* ., 38 (3) : 279-289.
- Ivanov , B.J. (2000) Pandalid shrimps of the boreal area : History of fisheries and research with special reference to Russia . *J. Shellf. Res.*, Vol .19 (1) : 554p.
- Ivanov, B.G. and A.M. Hassan (1976) On shrimp of the genera *Parapenaeopsis*, *Trachypenaeus*, *Metapenaeopsis* (Crustacea, Decapoda, Penaeidae) from the Western Indian Ocean. *Zool. Journ.*, 55(9) :1299-1307.
- Ivanova, I.V. (2000) About *Pandalus borealis* (Kroyer) nutrition on Flemish cap .*J.Northwest Atlantic Fishery Sci.* Serial No.N4307 ,NAFO SCR Doc.00/65.
- Ivlev,V.S. (1961) Experimental ecology of the feeding fishes. Yale University Press: New Haven , Conn.
- Jeckel ,W.H.,J.E.A.De Moreno and V.J.Moreno (1989) biochemical composition , lipid classes and fatty acids in the ovary of the shrimp , *Pleoticus muetteri* Bate. *Comp.Biochem.Physiol.*, B :92: 271-276.

- Jennings ,S. and M. Kaiser (1988) The effects of fishing on marine ecosystems and communities. *Advances in Marine Biology.*, 34:352pp.
- Jensen ,A.J.C.(1965) *Pandalus borealis* in the Skegerak (Length, growth and changes in the stock and fishery yield) .*Rapp. R .V .Reun. Cons. perm. int. Explor. Mar.* 156:109-111.
- Jensen ,A.J.C.(1967) *Pandalus borealis* in the North Sea and Skegerak. *Mar. Biol. Ass. India, Proc .Symposium on Crustacea* ,Pt.4:1317-1319.
- Job, T.J.(1940) Nutrition of Madras perches .*Rec.Indian Mus.*,42:286-364.
- John , C.C. and C.V. Kurian (1959) A preliminary note on the occurrence of deep water prawn and spiny lobster off the Kerala coast .*Bull.Cent. Res. Inst. Univ. Kerala, Ser. C.*, 7 (1) : 155-162.
- Johnson, D.S. (1973) Notes on some species of *Macrobrachium* (Crustacea; Decapoda; Caridea; Palaemonidae). *J.Singapore National Acad.Sci.*, 3 : 273-291.
- Jones, R. (1984) Assessing the effects of changes in exploitation pattern using length composition data with notes on VPA and cohort analysis. *FAO Fish.Tech.Pap.*, (2560:118p.
- Jones,R. and N.P. Van Zalinge (1981) Estimates of mortality rates and population size for shrimp in Kuwait waters. *Kuwait .Bull.Mar.Sci.*, 2:273-288.
- Joung Shoou-Jeng and Che-Tsung Chen (1992) *Nippon Suisan Gakkaishi.*, 58 (3) ,481.
- June, F. C. (1953) Spawning of yellow fin tuna in Hawaiian waters. *U. S. Fish .Wildl. Serv. Fish . Bull.*, 54:47-64.
- Kamiguchi ,Y. (1971) *J. Fac. Sci. Hokkaido Univ.*,18,15.
- Kashiwagi, M. (1974) Ecological studies on the "Hokkai-ebi" , *Pandalus kessleri* found in Yamada Bay –I. On growth and egg carrying period . *Bull. of the Japanese Soc. of Sci. Fish.* 40: 635-642.

- Katayama, T., T. Miyahara, Y. Kunisaki, Y. Tanaka and S. Imai (1972) Carotenoids in the sea bream *Chrysophrys major* Fac. Fish *Kayoshima Univ.*, 22:63-72.
- Kathiravel, M., C.Suseelan and P.Vedavyasa Rao (1989) Biology, population and exploitation of the Indian deep sea spiny lobster, *Puerulus sewelli* Ramadan , *Fishing Chimes.*, 8(11): 16-25.
- Kemp ,S.and R.B.S. Sewell (1912) Notes on decapoda in the Indian Museum .III. Species obtained by R.I.M.S. " Investigator" during the survey season 1910-11 . *Rec. Indian Mus.*, 7: 15-32.
- Kemp, S.W. (1910) The Decapoda collected by the " Huxley" from the north side of the Bay of Biscay in August 1906. *J. mar. biol. Ass. U. K.*, 8(5) : 407-420.
- Kemp,S.W. (1906) On the occurrence of genus *Acantheephyra* in deep water off the west coast of Ireland. *Fisheries Ireland Sci. Invest.*, 1905(1): 1-28.
- Kemp, S.W. (1909) The decapods of the genus *Gennadas* collected by H.M.S. " Challenger". *Proc.zool.Soc.London.* 1909:718-730.
- Kensley, B.F. (1969) Decapod crustacea from the South-west Indian Ocean. *Ann.S. Afr.Mus.*, 52(7): 149-181.
- Kesteven, G.L. (1971) Diagnosis of the condition of a fishery. *CSIRO Aust. Div.Fish. Oceanogra.Circular* NO.5: 7-24.
- King, M. (1995) *Fisheries biology, assessment and management.* Fishing News Books. Australia. 341p.
- King, M.G. and R.B. Moffitt (1984) The Sexuality of tropical deep water shrimps (Decapoda: Pandalidae) .*J. Crustacean Biol.*, 4(4): 567-571.
- King, M.G. (1984) The species and depth distribution of deep water Caridean Shrimps (Decapoda, Caridea) near some southwest Pacific Islands. *Crustaceana.*, 47(2) :174-191.

- King, M.G. and A.J. Butler (1985) Relationship of life-history patterns to depth in deep-water Caridean Shrimps (Crustacea: Natantia) *Mar. Biol.*, 86:129-138.
- Kithara, T. (1985) Behaviour of carotenoids in the masu salmon (*Oncorhynchus masou*) during anadromous migration. *Bull. Jap. Soc. Sci. Fish.*, 51(2): 253-255.
- Kithara, T. (1983) Behaviour of carotenoids in chum salmon (*O.keta*) during anadromous migration. *Comp. Biochem. Physiology.*, 76 B:97-101.
- Klima, E.F. (1965) Evaluation of biological stains, ink and fluorescent pigments as marks for shrimp. *Spec. Sci. Rep. U.S. Fish. Wildl. Serv.*, 511: 1-8.
- Klima, E.F. (1969) length-weight relation and conversion of "whole" and "headless" weights of royal-red shrimp, *Hymenopenaeus robustus* (Smith). *U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish.*, 585:1-5.
- Koch, H. (1989) Deep water shrimp surveys off Mozambique. *Fischerei-Forschung*., Vol.27, no.4, 25-31.
- Kotte, E. (1903) Beitrage zur kenntnis des Hautsinneorgane und des peripheren Nerven systems des Tiefsee-Decapoden. *Zool. Jahrb. Abt. f. Anat.*, 17: 619-658.
- Krishnakumar, P.K., R. Damodaran and P.N.K. Nambison (1987) Carotenoid content and tolerance of green mussel *Perna viridis* (Linnaeus) to acute Mercury and Zinc toxicity. *Indian J. of Mar. Sci.*, 16: 155-157.
- Kubo, I. (1949) Studies on the penaeids of Japanese and adjacent waters. *J. Tokyo Coll. Fish.*, 36 (1) :1-467.
- Kubo, I. (1951) Bionomics of the prawn *Pandalus kessleri* Czerniavsky. *J. Tokyo Univ. Fish.*, 38:1-26.
- Kulkarni, G.K. and R. Nagabhushanam (1979) Mobilization of organic reserves during ovarian development in a marine penaeid prawn *Parapenaeopsis hardwickii* (Miers). *Aquaculture*., 18 :373- 377.

- Kunju, M.M (1976) Some aspects of the biology of *Solenocera indica* Nataraja. *FAO Fish., Rep.*, 2(57): 467- 486.
- Kurata, H. (1957) The biology of the prawn, *P.hypsinotus* .*J. Hokkaido Fish. Exp. Station (Hokusuishi Geppo)* 14:8-21.
- Kurian, C.V. (1965) Deep water prawns and lobsters off the Kerala coast. *Fish. Tech.*, 2(1): 51-53.
- Kurian, C.V. (1964) On the occurrence of the deep-water prawn *Penaeopsis rectacutus* (Spence Bate) off the Kerala coast. *Curr.Sci.*, 33 (7) : 216-217.
- Kurian, C.V. and V.O. Sebastian (1976) *Prawns and prawn fisheries of India*. Hindustan Publishing Corporation (I), New Delhi.,286p.
- Kurup ,B.M. (2001) Impact of ban on monsoon trawling imposed along Kerala coast on the exploited marine fishery resources and its socio-economic implications. Report submitted Minister for Fisheries and Tourism, Govt. of Kerala . 151p.
- Kurup, B.M.and B. Kuriakose (1994) Fecundity indices in an indigenous endangered carp *Labeo dussumeiri*. *Fish. Tech.*, 31(1): 8-11.
- Kurup, N.S. and P.V. Rao (1974) Population characteristics and exploitation of the important marine prawns of Ambalapuzha. *Indian J. Fish.*, 21(1) : 183-210.
- Kutkunh ,J.H. (1966) Dynamics of penaeid shrimp populations and management implications. *U.S. Fish. Bull.*, 65(2): 313-338.
- Kuttyamma , V.J . ( 1974) Observations on the food and feeding of some penaeid prawns of Cochin area . *J.mar.Biol.Ass.India* ., 15 (1) : 189-194.
- Lagarde re, J.P. (1977) Recherches sur la distribution verticale et sur l'alimentation des crustaces decapodes bentiques de la pente continentale du Golfe de Gascogne. Analyse des groupements

- carcinologiques. *Bull .Cent. E'tud Rech. Scient. Biarritz .*,11: 367--440.
- Lagardere, J.P. (1970) Les crevettes du golfe de Gascogne. *Tethys*, 3(3): 655-675.
- Lagardère, J.P. (1972) Recherches sur l' alimentation des crevettes de la pente continentale marocaine, *Tethys.*, 3(3) :655-675.
- Lagardere,J.P. (1973) Distribution des de capodius dans le sud du Golfe de Gascogne .*Revue Trav Inst. Pe Ch marit .*, 37:77-95.
- Lalitha Devi ,D. (1986) Growth and population dynamics of the Indian white prawn *Penaeus indicus* H.M.Edwards from Kakinada , *Proc. Indian Acad. of Sci.*, 96(5): 529-539.
- Lalitha Devi, D.(1987) Growth and population dynamics of the three penaeid prawns in the trawling grounds off Kakinada. *Indian J. Fish.*, 34(3):245-263.
- Landenberger ,D.E.(1968) Studies on selective feeding in the Pacific starfish *Pisaster* in southern California .*Ecology .*, 49:1062-1075.
- Larry ,D. and H. Salwin (1966) A new carotenoid pigments in shrimp . *J. Ass. Off. Agri. Chem.*, 49 : (681-3).
- Lawrence , A.L., D.Ward, S.Missler ,A.Brown ,J.McVey and B.S. Middleditch (1979) Organ indices and biochemical levels of ova from Penaeid shrimp maintained in captivity versus those captured in the wild . *Proc.World Maricult. SOC.*, 10:453-463.
- Le Cren ,E.D. (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis* ) *J. Anim. Ecol.*, 20:21-219.
- Le Loeuff, P. and A.Intes (1968) La faune benthique duplateau continental de la Cote d'Ivoire Recoltes au Chalut-Abondacne-Repartition-Variations

- Saisonniers. *Doc. Scient. prov. Centre Rech. Oceanogr. Abidjan.*, 25, 110p.
- Le Reste, L., J. Marcille and F. Barbe (1974) Biometric de quelques crevettes peneides a Madagascar, *ORSTOM, Doc. Sci. Mission Nosy-Be.*, 46: 1-29.
- Lebour, M.V. (1922) The food of plankton organisms. *J. Mar. Biol. Ass. U. K.*, (n.ser.) 12: 647-677.
- Lebour, M.V. (1940) The larvae of Pandalidae. *J. Mar. Biol. Ass. U.K.*, 24: 239-252.
- Lee, R.F., J. Hirota and A.M. Barnett (1971) Distribution and importance of wax esters in marine copepods and other zooplankton, *Deep-sea Research.*, 18: 1147-65.
- Leger, C. (1985) Digestion, absorption, and transportation of lipid in C.B. Cowey, A.M. Machie and J.C. Bell (eds.) *Nutrition and feeding of fish.* Academic Press. New York.
- Lemmens, J.W.T.J. (1959) Nucleic acid levels, cellular activity and growth during Peurulus stages of the western rock lobster (*Panulirus cygnus*). *J. Exp. Mar. Biol. Ecol.* 194: 143-156.
- Lenel, R. (1965) Sur le metabolisme des pigments de *Carcinus maenas* Linne. *Bulletin. Societe lorraine des sciences.*, 1: 1-134.
- Leppakoski, E. (1975) Assessment of degree of pollution on the basis of macrobenthos in marine and brackish water environment. *Acta. Acad. Abo. Ser. B.*, 35: 258-269.
- Lethakutty (1993) Mobilization of total carotenoids in relation ovarian maturation in the prawn *Metapenaeus dobsoni*. M.F.Sc (Mariculture) dissertation, *Central Institute of Fisheries Education.*, 60p.



- Linder, H.J. (1959) Studies on the fresh water fairy shrimp *Chirocephalopsis fundyi* (Forbes). 1. Structure and histochemistry of the ovary and accessory reproduction tissue. *J. Morphol.*, 104: 1-60.
- Lindner, M.J. and W.W. Anderson (1956) Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus*. *U.S. Fish. Bull.*, 106:555-645.
- Lloyd, R.E. (1907) Contributions to the fauna of the Arabian Sea, with descriptions of new fishes and crustacea. *Rec. Indian Mus.*, 1: 1-12.
- Longhurst, A.R. (1970) Crustacean resources. In. 'The fish resources of the ocean'. FAO, p 206-255.
- Longhurst, A. R. (1970) Crustacean resources. *FAO Fish Tech. pap.*, 97 :252-305.
- Longhurst, A.R.(1971) Crustacean resources. In 'The fish resources of the Ocean'-FAO .,pp206-255.
- Love, R.M. (1970) *The chemical biology of fishes* Vol.II. Advances 1968-1977. Academic Press Inc., (London).
- Ludwig, A.J. and J.F. Reynolds (1988) Statistical ecology – A primer on methods and computing. John Wiley & Sons Eds., 337p.
- Macdonald, P.D.M. and T.J. Pitcher (1979) Age-groups from size frequency data: a versatile and efficient method of analyzing distribution mixtures. *J. Fish. Res. Bd. Canada* ., 36:987-1001.
- Macpherson, E.(1991) Bio geography and community structure of the decapod crustacean fauna of Namibia (Southeast Atlantic) *J. Crust. Biol.*, 11:401-415.
- Maoka, T., M. Katsuyama, N. Kaneko and T. Matsuno (1985) Stereochemical investigation of carotenoids in the Antarctic Krill *Euphausia superba* . *Bull. Jap. Soc. Sci. Fish.*, 51:1671-1673.

- Maria J. Figueiredo , I. Figueiredo and P.B. Machado (2001) Deep-water penaeid shrimps (Crustacea : Decapoda) from off the Portuguese continental slope: an alternative future resource? *Fish.Res.*, 321-326.
- Markle , D. F., M. U. Dadswell and R. G. Halliday (1988) Demersal fish and decapod crustacean fauna of upper continental slope of Nova Scotia from La Havre to St. Pierre Banks. *Can. J. Zool.*, 66:1952-1966.
- Martinez Bano, M.P. , F. Vizquete, J.Mas and F. Faraco (1991) Report .Technical consultation on stock assessment in the Balaoaric and Gulf of Lions Statistical divisions.6. Rome : FAO , no. 447 .
- Mary Labropoulou and K. Ioannis (1999) Patterns of resource use in deep-water decapods .*Mar.Ecol.Prog.Ser* .184: 171-182.
- Massuti, E., B.Morales-Nin and C.Stefaescu (1995) Distribution and biology of five grenadier fish (pisces: Macrouridae) from the upper and middle slope of the Northwestern Mediterranean. *Deep-sea Res.*, 42:307-330.
- Massuti, M. (1953) Bionomia de los fondos de 300 a 600 metros en el sur y suroeste de Mallorca, *Bol.Inst.espan.Oceanogr.*, (63) 3-20.
- Massuti ,M.(1959) La gamba (*Parapenaeus longirostris* Lucas) Primeras observaciones en los caladeros del Golfo de Cadiz y Africa Occidental . *Investnes pesq.*, 15 :51-80.
- Massuti, M. (1967) Resultados de las pruebas experimentales efectuadas en aguas de Mallorca para la pesca con nasas de las gambas de profundidad.*Pub.Tec.Jun.Est.pes.*, 6: 190-85.
- Mauchline, J (1972) The biology of bathypelagic organisms, especially Crustacea. *Deep Sea Res.*, 19: 753-780.

- Maurin, C.L. (1961) Repartition des crevettes profondes sur les cotes sud du bassin occidental de la Mediterranee et dans la region atlantique iberomarocaine. *Rapp.Comm.int.Mer Medit.* 16(2): 529-532.
- Maurin, C.L. (1963) Les crevettes captures par la "Thalassa" au large des cotes du trio de Oro et de mauritanie. Ecologie et peche. *Cons. Explor. Mer. Comite des Molluscques et Crustces*, 48,5p.
- Maurin, C.L. (1965) Les crevettes profondes de la region atlantique iberomarocaine: Repartition bathymetrique at geographique, importance economique, *Rapp.Cons.Explor.Mer.*, 156:116-119.
- Maurin, C.L. (1968) Les Crevettes captures par la "Thalassea" au large des cotes nord-ouest africaines. *Rev.roum.Biol. Zool.*, 13(6): 479-493.
- Mc Culloch, A.R. (1907) The results of deep-sea investigation in the Tasman Sea.II.The expedition of the "Woy Woy" .1. Fishes and Crustaceans from eight hundred fathoms. *Rec.Austr.Mus.*, 6;345-355.
- McBeth, J. W. (1970) Carotenoids of *Betaeus harfordi* (Crustacea: Decapoda). *Experientia.*, 26:144-5.
- Menon, M.K.(1955) Notes on the bionomics and fishery of the prawn *Metapenaeus dobsoni* (Miers) on the south-west coast of India. *Indian J.Fish.*, 2(1): 41-56.
- Menon, P.G. (1972) Decapod Crustacea from the International Indian Ocean Expedition: the larval development of *Heterocarpus* (Caridea). *J. Zool. Lond.*, 167: 371 -397.
- Mergrey , B.A. (1989) Review and comparison of age-structured stock assessment models from theoretical and applied points of view . *Am Fish Soc.Symp.*, 6:92-101.

- Merrett ,N.R. and R.L. Haedrich (1997) Deep sea Demersal Fish and Fisheries . Chapman & Hall , London .,282p.
- Mikulich,L.V. and B.G.Ivanov (1983) The far-eastern shrimp *Pandalus pensator* Stimpson (Decapoda, Pandalidae): description of laboratory–reared larvae. *Crustaceana.*, 44:61-75. ,
- Milne –Edwards, A. (1881) Descriptions de quelques Crustaces Macroures porvenanat des grandes profondeurs de la mar des Antilles. *Ann.Sc.nat. Zool.*, Ser6., 11(4): 1-16.
- Milne – Edwards,A. (1883) Recueil de figures de Crustaces nouveaux ou peu connus : 1-3,pl.1-44.
- Milne –Edwards ,H. (1837) Histoire naturelle des Crustaces , comprenant l'anatomie , la physiologie et la classification de ces animaux , 2:1-532.
- Milne-Edwards, A. and E.L. Bouvier (1900) *Heterocarpus grimaldii* espere nouvelle recueillie par le "Talisman" , l' "Hirondelle" et la "Prince Alice". *Bull. Soc. Zool. France*, 25:58.
- Milne-Edwards,A. and E.L. Bouvier (1909) Reports on the results of dredging , under the supervision of Alexander Agassiz, in the gulf of Mexico (1877-78) , in the Caribbean Sea(1878-79), and along the Atlantic Coast of the United States(1880) , by the US Coast Survey Steamer "Blake" .XLIV.Les Peneides et Stenopides. *Mem.Mu.Comp.Zool.Harv.Coll.*, 27: 177-274.
- Miquel, J.C. (1984) Shrimps and prawns .In: W. Fischer and G. Bianchi (Eds.) FAO Species Identification Sheets for Fisher Purposes, Western Indian Ocean (Fishing Area 51), Vol. 5. FAO Rome.
- Misra, R.K. (1959) A statistical study of growth in parts of the second pair of cheliped in some species of the Indian fresh water prawns of the genus *Palaemon*.*Proc. Nat. Inst. Sci.India.*, 25B(5): 237-253.

- Mistakidis, M.N. (1957) The biology of *Pandalus montagui* Leach. *Ministry of Agriculture, Fisheries and Food. London, Fishery Invest., ser.2,21(4):1-52.*
- Modin ,J.C.and K.W.Cox ( 1967) Post embryonic development of the laboratory reared larvae ,*Pandalus jordani* Rathbun .*Crustaceana.*, 13:197-219.
- Moffit ,R.M.(1983) *Heterocarpus longirostris* MacGilchrist from the Northern Marianas Islands. *Fish.Bull.United States.*, 81:434-436.
- Mohamed ,K .S. and A.D. Diwan (1992) Biochemical changes in different tissues during yolk synthesis in marine prawn *Penaeus indicus* H.Milne-Edwards. *Ind. J. Mar. Sci.* New Delhi; Vol. 21 , no.1 , pp.30-34.
- Mohamed ,K.H. and C. Suseelan(1973) Deep-sea prawn resources of the south-west coast of India. *Proc. Symp. Living Resources of the Seas round India*, Spl. pub. CMFRI., India ,pp.614-633.
- Mohamed ,K.H.and C. Sueelan (1968) Deep-sea prawn resources off the southwest coast of India. *Abstracts , Symp. Living Resources of the seas around India*. Spl. pub. CMFRI., India, pp. 614- 633.
- Mokhtar ,F. and R.Lenel (1971) Etudes des pigments carotenoids chez *Scyllarides latus* (Decapode Macroure) .Nature , localization et metabolisme *Comptes Rendu hebdomadaire desances de l'Academie des sciences .*, 273 D,2572-5.
- Monod ,T. (1966) Crevettes et crabes de la cote occidentale d'Afrique .*Mem. Inst. Fondam. Afr. Nore.*, (77):103-234.
- Monod.T. (1933) Sur quelques crustaces de l' Afrique occidentale (Liste des Decapodes mauritaniens et des xanthides ouest-africains). *Bull. Com.Etud.Sci.Afr. occ.franc.*, 15: 456-548.

- Moreira, C. (1901) Crustaceos de Brazil. Contribuicoes para of conhecimento da auna Brasileira, *Arch.Mus.nac.Rio.de Jan.*, 11: 1-151.
- Morgan, G.R. (1980) population dynamics of spiny lobsters. In. Cobb, J.S. and Philips, B.F. (eds) *The biology and management of lobsters*. Vol II.Academic Press, New York, pp: 189-217.
- Morris, R.J. (1972) Occurrence of wax esters in crustaceans from the North-east Atlantic. *Mar. Biol.*, 16: 102-7.
- Mourente, G.and A. Rodrigues (1991) Variation in lipid content of wild caught females of the marine shrimp *Penaeus kerathurus* during sexual maturation. *Mar.Biol.*, 110: 21-28.
- Murawski ,S.A.(2000) Definitions on over fishing from an ecosystem perspective. *ICES J.of Mar. Sci.* 57:649-658.
- Murie, J. (1903) Report on the sea fisheries and fishing industries of the Thames estuary, I.London.
- Muthiah ,M.S. (1994) Studies on the fishery and biology of the lizard fish , *Saurida* spp. from the Karnataka Coast .Ph.D. Thesis ,*Cochin Univ. of Science and Tech .*, 185p.
- Muthu, M.S. (1968) On some new records of penaeid prawns from the east coast of India. *Indian J.Fish.*, 15 : 145-154.
- Mytilineou, C.H., M.Castro, P.Gancho and A.Fourtouni (1998) Growth studies on Norway lobster, *Nephrops norvegicus* (L), in different areas of Mediterranean Sea and adjacent Atlantic. *Scientia mar.*, 62:43-60.
- Mytilineou, C.H., P.Maiorano, S.Kavadas, G.D.Donghia, K.Kapiris and F.Capezzuto (2001) Size structure comparison in some demersal species between two areas of different fishing impact in the deep waters of eastern-central Mediterranean (Ionian Sea). *Northwest Atl. Fish. Org.*, Ser.No.N4531: 1-6.

- Nalini, C. (1976) Observation on the maturity and spawning of *Metapenaeus monoceros* (Fabricius) at Cochin. *Indian J.Fish.*, 23(1&2) :23-30.
- Nandakumar , G., K.N.Rajan and K.Chellappan (2001) Is the deep sea prawn fishery of Kerala sustainable . *Mar. Fish. Inform. Ser., T & E Ser .*, No.170:5-9 p.
- Nandakumar ,G (1997) Biology , population characteristics and fishery of the speckled shrimp *Metapeanaeus monoceros* (Fabricious ,1798) along the Kerala coast ,Ph.D thesis, *Cochin Univ. of Science and Tech.* ,pp.48-64.
- Natarajan,A.V. and A.G. Jhingran (1961)Index of preponderance – A method of grading the food elements in the stomach analysis of fishes. *Indian J.Fish.*, 8(1): 54-59.
- Neal, R.A. (1968) An application of the virtual population technique to penaeid shrimp . *Proc. Annu. Conf. Southeast Assoc. Game Fish.Comm.*, 21:24.
- Needler ,A.B.(1938) The larval development of *Pandalus stenolepis* .*J. Fish. Res. Bd. Canada.*, 4(2) :88-95.
- Ohtomi ,J. and S. Irieda (1997) Growth of the deep water mud shrimp *Solenocera melantho* de Man , 1907 (Decapoda , Penaeoidea , Solenoceridae) in Kagoshima Bay , Southern Japan. *Crustaceana.*, 70 (1) : 45-57.
- Ohtomi ,J (1997) Reproductive biology and growth of the deep-water shrimp *Plesionika semilaevis* (Decapoda : Caridea ) . *J. Crust. Biol.*, 17: 81-89.
- Okazaki ,K and S. Kobayashi (1929) The seasonal variation of the glycogen content in the oyster , *Ostrea circumpicta* . *Sci. Repts , Tohoku. Univ. Ser. D.*, 4: 183-191.

- Olaso, I. (1990) Distribucio´n y abundancia del megabentos invertebrado en fondos de la plataforma canta´brica. *Publnes esplnst espan Oceanogr, Madrid* 5: 11-28.
- Olsen , R. L., K. Oeverboe and B. Myrnes (1991) Alkaline phosphates from the hepatopancreas of shrimp (*Pandalus borealis*) : A dimeric enzyme with catalytically active subunits.
- Olson, J.A. (1979) A simple dual assay for vit-A and carotenoids in human liver. *Nutrition Rep. International* .,19:807-813.
- Omori , M and S. Ohta (1981) The use of underwater camera in studies of vertical distribution and swimming behaviour of a segestid shrimp *Sergia lucens* . *J.Plankton Res.*, 3:107-120.
- Omori ,M (1971)Taxonomy and some notes on the biology of a new caridean shrimp , *Plesionika izumiae* (Decapoda ,Pandalidae),*Crustaceana* . , 20(3):241-256.
- Omori, M. (1974) The biology of pelagic shrimps in the ocean. *Adv.Mar.Biol.*,12:233-324.
- Oommen .P.V. (1980) Results of the exploratory fishery of Quilon Bank and Gulf of Mannar. *IFP Bulletin* No.4, 1.
- Oommen, P.V. (1974) A brief account of the topography and fishery potential on the south west coast of India. *Mahasagar -Bull.National Inst.Oceanogr.*, 7(1& 2) : 33- 39.
- Oren Sanz ,J.M., J.Armstrong , D.Armstrong and R.Hiborn (1998) Crustacean resources are vulnerable to serial depletion – the multifaceted decline of crab and shrimp fisheries in the Greater Gulf of Alaska .*Rev.Fish. Biol . Fish.*, 8(2): 117-196.
- Orsi Relini ,L and G. Relini (1988) An uncommon recruitment of *Aristeus antennatus* (Risso ) (Crustacea Decapoda Aristeidae ) in the Gulf of Genova , *Rapp. Comm. Int.Mer.Medit.*, 31(2):10.



- Orsi Relini, L. and G. Relini (1985) An attempt to assign von Bertalanffy growth parameters to *Aristeus antennatus* (Risso, 1816) (Crustacea, Decapoda) of the Ligurian Sea. *Rapp P-v Réun Commn Explor scient int mer mediterr.*, 29: 301-304.
- Ortmann, A.E. (1890) Results of the exploratory fishing in Quilon Bank and Gulf of Mannar. *IFP Bulletin No.4*: 1-49.
- Panikkar, N.K. (1952) Possibilities of further expansion of fish and prawn culture practices in India. *Curr. Sci.*, 21: 29-33.
- Passano, L.M. (1960) Molting and its control .In: Waterman, T.H.(ed) The physiology of Crustacea. Vol.I.Academic Press, New York., pp.473-536.
- Pathak ,S.C. and A.G. Jhingran (1977) *J.Inland Fish.Soc. India.*, 9,72.
- Patnaik ,L.(2001) Studies on total carotenoids in the non conventional fish *Priacanthus hamrur* (Forsskal) . M. F.Sc. (Mariculture) Dissertation , *Central Institute of Fisheries Education* .,60p.
- Paulinos ,V.T. and M.J. George (1976) Abundance and distribution of penaeid larvae as an index of penaeid prawn resources of the Indian Ocean *Indian J.Fish.*, 23 (1 &2) :127- 133.
- Paulo Sartor , Mario Sbrana , Bruno Reale and paola Belcari ( 2001) Impact of the deep sea trawl fishery on demersal communities of the Northern Tyrrhenian Sea (Western Mediterranean) .*Northwest Atl. Fish.Org. Deep-sea Fisheries Symposium.*, NAFO SCR Doc.01/106.
- Pauly , D. (1980) On the interrelationships between natural mortality , growth parameters and mean environmental temperature in 175 fish stocks. *J.Cons.CIEM.*, 39(3): 175-192.
- Pauly , D. (1982) Studying single species dynamics in tropical multi species context. In: D.Pauly and G.I.Murphy (eds.) Theory and management of Tropical Fisheries . Proceedings of the ICLARM/CSIRO Workshop

- on the theory and management of multi species stocks. 23-21  
January 1981, Coronulla , Australia.pp.33-70.
- Pauly ,D. (1983) Some simple methods for the assessment of tropical fish  
stocks. *FAO Fish Tech.Pap.*, 234:52p. Pauly ,D., J.Ingles and R.Neal  
(1984) Application to shrimp stocks of objective methods for  
estimation of growth , mortality and recruitment related parameters  
from length- frequency data. *Meeresforsch ,Rep. Mar.Res.*, 28(4) ;  
205- 211.
- Pauly ,D. and N. David (1981) ELEFAN I, a Basic program for the objective  
extraction of growth parameters from length-frequency data.  
*Meereforschung.*, 28(4):205-11.
- Pauly, D., J.Ingles and R.Neal (1984) Application to shrimp stocks of objection  
methods for the estimation of growth, mortality and recruitment related  
parameters from length-frequency data (ELEFAN 1and 11). In:  
J.A.Gulland and B.J.Rothschild (Ed.) *Penaeid shrimps-their biology and  
management*, Fishing News books Limited , Farnham, England: 220-  
234.
- Pauly,D and J.L. Munro (1984) Once more on the comparison of growth in fish  
and invertebrates – *ICLARM Fishbyte* 2:21.
- Pequegnat, L.H. (1970) *Deep-sea Caridean shrimps with description of six new  
species*. Texas A &H University Oceanographic studies. I.  
*Contributions on the biology of the Gulf of Mexico.* , 4: 59- 123.
- Perez Farfante, I. (1979) *Penaeopsis jerryi*, a new species from the Indian  
Ocean (Crustacea: Penaeoidea). *Proc.Biol.Soc.Wash.*, 92:208-215.
- Perez Farfante, I. (1980) Revision of the peaneid shrimp genus *Penaeopsis*  
(Crustacea: Decapoda). *Fish. Bull., U.S.*, 77(4): 721-763.
- Pesta ,O.(1913) Liste einiger decapoden gerera und species aus der Adria.  
*Zool.Anz.*, 42:403-408.

- Peterson, C.G.J. (1892) Fiskeribiologiske forhold Holbock Fjord. 1890-91. *Rep. Danske Biol. Sta.* 1890 (91), 1: 121-183.
- Philip, K.P. and K. Mathew (1996) Length-weight relationships and relative condition factor in *Priacanthus hamrur* (Forsskal) . *Fish. Tech.*, 33(2): 79-83.
- Pillai ,K.K. and N.B. Nair (1973) Observations on the biochemical changes in gonads and other organs of *Uca annulipes* , *Portunus pelagicus* and *Metapenaeus affinis* (Decapoda : Crustacea ) during reproductive cycle . *Mar. Biol.* , 18: 167- 168.
- Pillay ,T.V.R. (1952) A critique of the methods of study of food of fishes . *J. Zool. Soc. India.* , 4(2) : 195-200.
- Pipitone ,C., F. Badalamenti ,A.Cuttitta ,G. D'Anna and M.Gristina (1994) Preliminary results on the diet of *Aristaeomorpha foliacea* and *Aristeus antennatus*. *Proc. international workshop ,Istituto do Tecnologia della Pesca e del Pescato* , vol 3 .note Tecniche e Reprints .,Istituto di Tecnologia della pesca e del Pescatto ,Mazara del Vallo , Italy ,pp.47- 48.
- Plaut, I. and L. Fishelson (1991) Population structure and growth in captivity of the spiny lobster *Panulirus inflatus* from Dahab , Gulf of Aqaba , Red Sea. *Mar. Biol.*, 111: 467-472.
- Pontaine, B. (1979) Biology and fishery of shrimps: the deep-sea shrimp *Pandalus borealis* Kryøer, 1838 (in Fr.) *Peche Marit.*, No.1220 : 657-664.
- Poupine , J. (1993) Deep-sea fauna of the French West Indies : Fishing surveys on board R.V.POLKA carried out in 1993 . Orstorm. Etudes et Thses. *Institut Frantais de Recherche scientifique pour le D, veloppment en Coopratiion*. Paris , 90pp.
- Qasim, S.Z. (1972) The dynamics of food and feeding habits of some marine fishes. *Indian J. Fish.*, 19 (1&2) : 11- 28.

- Quinitio ,E.T. , K.Yamauchi , A. Hara and A. Fuji (1991) *Gen. Comp. Endocrinology* . New York NY Vol. 81 , no.3 , pp. 343 – 348.
- Ragonese ,S. and M.L. Bianchini (1995) Size at sexual maturity in red shrimp females , *Aristeomorpha foliacea*, from the Sicilian Channel (Mediterranean Sea) . *Crustaceana* . 68 (1) : 73- 82.
- Ragonese, S., M. L. Bianchini and V.F. Galulucci (1994) Growth and mortality of the red shrimp *Aristaeomorpha foliacea* in the Sicilian Channel (Mediterranean Sea) . *Crustaceana* ., 67: 348-361.
- Rajan,K.N. and G .Nandakumar (2001)Innovative exploitation of deep sea crustaceans along the Kerala Coast.*Mar.Fish.Inform.Ser., T & E Ser.*, No.168:1-5 p.
- Rajasree, R.and B.M. Kurup (2004) Fishery and biology of deep sea prawns landed at the fishing harbours of Kerala (South India), *Fishery Tech.*, *in press*.
- Ramadan, M.M. (1938) Crustacea: Penaeidae. *John Murray Exped.Sci.rep.*, 5(3): 35-76.
- Ramamurthy, S., G.G.Annigeri and N.S.Kurup (1978) Resource assessment of the penaeid prawn *Metapenaeus dobsoni* (Miers) along the Mangalore coast. *Indian J. Fish.*, 25 (1&2) : 52- 56.
- Ramamurthy,S.(1980) Resource characteristics of penaeid prawn *Parapenaeopsis stylifera* in Mangalore Coast . *Indian J. Fish.*, 27 (1&2) : 161-171.

- Rao ,P.V. and C. Suseelan (1967) On the egg and pre zoea stage of *Heterocarpus woodmasoni* Alcock (Crustacea , Decapoda ,Pandalidae). *J. Mar. Biol. Ass. India.*, 9(1):204-207.
- Rao, G.S. (1989) Studies on the reproductive biology of the brown prawn *Metapenaeus monoceros* (Fabricius, 1989) along Kakinada coast. *Indian.J.Fish.*, 36(2) : 107- 123.
- Rao, G.S.(1994) Mortality rates and stock assessment of *Metapenaeus monoceros* along the Kakinada coast. *J.mar.biol.Ass.India.*, 36(1&2) :1-18.
- Rao, G.S., V.T. Subramanian, M.Rajamani, P.E. S. Manickam and G. Maheswarudu (1993) Stock assessment of *Penaeus* spp. off the east coast of India. *Indian J.Fish.*, 40 (172) : 1-19.
- Rao, P.V. (1968) Maturation and spawning of the penaeid prawns of the south west coast of India .*FAO Fish. Rep.*,(57) Vol.2:285-302.
- Rao,G.S.(1988) Exploitation of Prawn fishery resources by trawlers off Kakinada with a note on the stock assessment of commercially important species.*Indian J.Fish .*, 35: 140-155.
- Rasmussen, B. (1953) On the geographical variation in growth and sexual development of the deep sea prawn (*Pandalus borealis* Kr.) *Rept. Norwegian Fish .Mar. Invest.*,10(3) :1-160.
- Rasmussen, B. (1967) The fishery for deep sea prawns in Norway. *Proc. Symposium on Crustacea , Mar. Biol. Ass. India.*, Pt.4:1437-1441.
- Rathbun, M.J. (1906) The Brachyura and macrura of the Hawaiian Islands. *Bull.U.S.Fish Commn.*, 23 (3) : 827- 930.
- Read , G.H.L. and M.S. Caulton (1981) Changes in mass and chemical composition during the moult cycle and ovarian development in immature and mature *Penaeus indicus* Milne-edwards. *Comp. Biochem. Physiol.*, 66A: 431-437.

- Relini Orsi , L. and M . Semeria (1982) Maturatione ovarica nel peneide batiale *Aristeus antennatus* (Decapoda, Penaeidae) *Naturalista sicil.*S.IV.VI (Suppl.) .1: 121- 122.
- Relini ,G.and L.R. Orsi (1987) The decline of red shrimps stocks in the Gulf of Genova. *Inv. Pesq.*, Barcelona ., 51(1): 254-260.
- Relini Orsi ,L and G. Relini (1979) Pesca e riproduzione del gamebro rosso *Aristeus antennatus* (Decapoda, Penaeidae) ne Mar Lgirue , Quad .*Civ Satz. Idrobiol .Milano.*, 7:39-62.
- Relini Orsi ,L. and G. Relini (1990) The glass shrimp *Pasiphaea sivado* in the food chains of the Ligurian Sea .In: Barnes M. Gibson N(eds) Trophic relationships in the marine environment . Proc.24 the *Eur mar.Biol. Symp.* Aberdeen University Press. Aberdeen , pp:334-346.
- Ribeiro, A. (1970) Contribuicao para o estudo dos "Camaroes" de interesse economico da palataforma continental de Angola. *Notas Centro Biol. Aquat.trop.Lisboar.*, 21:93p.
- Rice,A.L. (1967) Crustacea (Pelagic Adults ).Order Decapoda.V.Caridea.Families: Pasipaheidae, Oplophoridae , Hippolytidae and Pandalidae, *Cons.Explor.mer.Zooplanton Sheet*, 12: 7p.
- Richard, P. (1978) Influence de la temperature sur la croissance et la mue de *Palaemon serratus* en fonction de leur taille, *Aquaculture, Amsterdam.* 14: 13-32.
- Ricker, W.E. (1975) Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Canada.*, (191):381p.
- Riggio, G. (1900) Contributo alla carcinologia del mediterraneo (Sunto). *Montore Zool.Ital.*, 11: 19- 20.
- Riggio,G. (1905) Contributo alla carcinologia del mediterraneo.I. Note sopra alquanti Corstacei del mare di Messina. *Natural Sicil.*, 17: 93- 287.

- Rikhtor, V.A. and V.N. Effanov (1976) On one of the approaches to estimation of natural mortality of fish populations. *ICNAF Res.Doc.*, 76/VI/8:12.
- Roa Rubén and Billy Ernst (1996) Age structure, annual growth and variance of size-at-age of the shrimp *Heterocarpus reedi*. *Mar. Ecol. Prog. Ser.* (137) :59-70.
- Rossignol, M. (1962) Catalogue des Crustacés Décapodes Brachyours, Anomours et Macrours Littoraux en collection au Centre d' Oceanographic de Pointe-Noire. *Cah. ORSTOM., Ser. Oceanogr.*, 1(2): 111-138.
- Rothlisberg, P.C. (1980) A complete larval description of *Pandalus jordani*, Rathbun (Decapoda :Pandalidae) and its relation to other members of the genus *Pandalus*. *Crustaceana*., 38:19-48.
- Russel, E. (1923) *Fish. Invest. London Ser. II. No.6.*
- Sardá, F. and M. Demestre (1987) Estudio biológico de la gamba *Aristeus antennatus* (Risso, 1816) en el Mar Catalán (NE de España). *Investigación pesq.*, 51: 213 - 232.
- Sardá, F. and M. Demestre (1989) Shortening of the rostrum and rostral variability in *Aristeus antennatus* (Risso, 1816) (Decapoda Aristeidae). *J. Crust. Biol.*, 9: 570- 577.
- Sardá, F. (1985) Estudio de la edad, crecimiento y frecuencia de muda, en cautividad de *Nephrops norvegicus* (L.) del mar Catalán. *Investigación pesq.*, 49: 139-154.
- Sardá, F., C. Basand J. Llenoart (1995) Functional morphometry of *Aristeus antennatus* (Risso, 1816) (Decapoda, Aristeidae). *Crustaceana.*, 68(4): 461-471.
- Sarda, F., J.E. Cartes and W. Norbis (1994) Spatio-temporal structure of the deep-water *Aristeus antennatus* (Decapoda; Aristeidae) population in the eastern Mediterranean. *Fish. Bull. U.S.*, 92: 599-607.

- Sardá, F., J.E.Cartes and J.B.Company (1994) Spatio-temporal variations in megabenthos abundance in three different habitats of the Catalan deep-sea (Western Mediterranean). *Mar. Biol.*, 120:211-219.
- Scariah, K.S., M. Devaraj, Joseph Andrews, M.B. Seynudeen, M.R. Beena, and Sindhu K. Augustine. (1999) Production pattern in the marine fisheries of Kerala. *Bull. Cent. Mar. Fish. Res. Inst.*, 2: 127p.
- Schmitt, W. L. (1926) Report on the crustacea macrura (Penaeidae Campylonotidae and Pandalidae) obtained by the F.I.S. "Endeavour" in Australian Seas. *Biol.Res.Fishing Exp."Endeavour"*, 5:309-381.
- Schultze, K. and K. Anger (1997) Larval growth patterns in the Aesop shrimp *Pandalus montagui*. *J. Crustacean Biol.*, 17(3):472-479.
- Sekharan ,K.V. (1975) Estimates of the stocks of oil sardine and mackerel in the present fishing grounds off the east coast of India. *Indian J.Fish.*, 21:177-182.
- Sekine ,S., S.Tatsumo and E. F. Imamura (1930) *Proc. 4<sup>th</sup> pacific Sci. Congress Batavia . Bandoengt.*, 3:349-351.
- Selvaraj ,C., S.Radhakrishnan and S.Parameswaran (1972) *J.Inland Fish.Soc.India .*, 4-87p.
- Senna, A. (1902) Nota sui Crostacei Decapodi Le esplorazioni abissali net Mediterraneo del R.Piroscafo "Washington" nel 1881. *Bull. Soc. ent. ital.*, 34 :235-367.
- Setubal, A.M. (1992) Structure and dynamics of benthic megafauna on the continental shelf offshore of Ubatuba, southeastern Brazil. *Mar. Ecol . Prog. Ser.*, 86: 63-76.
- Sewell,R.B.S.(1955) A study of the sea coast of Southern Arabia *.Proc.Linn.Soc.Lond.*, 165: 188-210.
- Shanmugham ,A., P.Soundarapandian , G.Pramod and T.Kannupandi (2000) Length-weight relationship and biometry of the groupers *Epinephelus*



*tauvina* (Forsk. , 1775) and *E.malabaricus* (Schneider , 1801) .  
*Indian J. Fish.*, 47(1): 7-11.

- Sharma, G.S. and A.V.S. Murty (1973 ) Prawn fishery off the west coast of India in relation to hydrographical conditions of the shelf waters. *Proc. Symp. Living Resources of the Seas round India*, Spl. pub. CMFRI., India ,pp.414-423.
- Sheehy ,M.R.J. (1990) Potential of morphological lipofuscin afe-pigment as an index of crustacean age . *Marine Biol.*, 107:439-442.
- Sherief , K., P.M. Mathew, S.Joseph and A. Korath (1992) In: *Freshwater Prawns* (Silas,E.G.) Kerala Agricultural University. 243 p.
- Sherief ,P.M. and T. Xavier (1994) Nutrient composition of the hepatopancrease of *Macrobrachium rosenbergii* and *Penaeus indicus* .*Seafood Export J.*, Sept.17-22.
- Shumway ,S. E., H.C.perkins, D.F.Schick and A.P.Stickney (1985) Synopsis of biological data on the pink shrimp *Pandalus borealis* Kroyer ,1838-*FAO Fisheries Synopsis* .,144:1-57.
- Siddiqui ,A.Q., A.Chattergee and A.A.Khan. ( 1975) *Aquaculture* .,7,181.
- Silas,E. G.(1969) Exploratory fishing by R. V. Varuna . *Bull. Cent. mar. Fish. Res. Inst.*, No.12:1-86.
- Sivertsen, E.and L.B. Holthuis (1956) Crustacea Decapoda (The Penaeidae and Stenopodida excepted) Rep. *Sci.Res."Michael Sars" North Atlant.deep-sea Exped.*1910, 5(12): 1-54.
- Skinner, D.M.(1985) In: *The Biology of Crustacea* ,Vol.9, *Integument, Pigments and hormonal process* (Bliss , D.E. & Mantel ,L.H. eds) p.444, Academic Press Inc.Harcourt Brace Jovanovich , Orlando , Florida.
- Smidt ,E. (1967 ) Deep-sea prawn (*Pandalus borealis* Kr.) in Greenland waters : biology and fishery. *Proc. Symposium on crustacea. Mar. Biol. Ass. India.*, Pt.4:1448-1453.

- Smith, S.I. (1882) Reports on the results of dredging on the east coast of the United States during the summer of 1880, by the U.S. Coast Survey Steamer 'Blake'. Report on the Crustacea. *Bull. Mus. Comp.Zool.Harv.*, 10 : 1-108.
- Smith ,S.I.(1884) Report on the Decapoda Crustacea of the Albatross dredgings off the east coast of the United States in 1884. *Rep.U.S.Fish.Comm.*, 10: 345- 426.
- Snedecor, G.W. and W.G. Cochran (1967) *Statistical Methods*. Oxford IBH Publishing Co., New Delhi pp.593.
- Somers, I.F.and G.P. Kirkwood (1991) Population ecology of the grooved tiger prawn, *Penaeus semisulcatus*, in the north-western Gulf of Carpentaria , Australia : growth , movement , age structure and infestation by the bopyrid parasite *Epipenaeon ingens* *Aust.J.Mar.Freshwat.Res.*, 42: 349- 367.
- Sparre , P. and S.C. Venema (1992) Introduction to tropical fish stock assessment . Part 1 . *FAO Fish. Tech. Pap.* ,306 (1),Rev.1 Rome FAO. 1992, 376p.
- Sparre ,P., E.Ursin and S.C.Venema (1989) Introduction to tropical fish stock assessment .part 1 .Manual . *FAO Fish. Tech. Pap.* No.3061. Rome, FAO., 337p.
- Spedicato ,M.T. , G. Lembo, P.Cabonara and T. Silecchia (1994) Biological parameters and dynamics of *Aristaeomorpha foliacea* and *Aristeus antennatus* .N.T.R.-I.T.P.P. Special Publication .3:35-36.
- Spence Bate, C. (1888) Report on the Crustacea Macrura collected by H.M.S." Challenger" during the years 1873-76. *Rep.Voy, Challenger, Zool.*, 24:1-942.
- Springer, S.and H.R. Bullis (1956) Collections by the Oregon in the Gulf of Mexico. *U. S. Fish Wildl. Serv. Spec. Sci. Rep. Fish.*, (196):134p.

- Squires, H.J. (1968) Relation of temperature to growth and self-propagation of *Pandalus borealis* in Newfoundland. *FAO Fish.Rep.*,57(2) :243-250.
- Ssentongo , G.W. and P. Larkin (1973) Some simple methods of estimating mortality rates of exploited fish populations. *J. Fish. Res. Board Canada.*, 30(95): 695-698.
- Starobogatov, Y.I. (1972) Penaeidae (Crustacea Decapoda) of the Tonking Gulf. *Akad. Nauk. USSR. Zool. Inst. Issled. Fauny Morei.*, 10(18) ;359-415.
- Stebbing, T.R.R.(1910) General catalogue of South African Crustacea. *Ann. S. Afr. Mus.*, 6: 281-593.
- Stefansson, G., U.Skuladottir and G.Petursson (1994) The use of a stock production type model in evaluating the offshore *Pandalus borealis* stock of north Icelandic waters, including the predation of northern shrimp by cod. *ICES, COPENHAGEN (DENMARK)*, 13pp.
- Steven, D.M. (1949) Carotenoid in the reproductive cycle of the brown trout. *J.Exp.Biol.*, 26:295-303.
- Stevenson ,D.K.and F. Pierce (1985) Life history characteristics of *Pandalus montagui* and *Dichelopandalus leptocerus* in Penobscot Bay ,Maine.*Fish Bull.*,U.S. 83:219-233.
- Storebakken,T., P. Foss, K.Schiedt , ,E.Ausreng, S. Liaaen-Jensen, and U. Manz (1987) Carotenoid diets for *Salmon*-IV.Pigmentation of Atlantic salmon with astaxanthin ,astaxanthin dipalmitic, and canthacanthin , *Aquaculture.*, 65: 279-292.
- Struhsaker, P. and D.C. Aasted (1974) Deepwater shrimp trapping in the Hawaiian Islands. *Mar.Fish. Rev.*, 36 (10): 24-30.
- Sudarsan , D. (1992) Deep sea fisheries – Development of marine fisheries for higher productivity and export . *In proc. of national workshop on development of marine fisheries for higher production and export*, 9-

- 10 June 1992, Cochin. *Ministry of Agriculture, Govt. of India*, 83-101p.
- Sugunan ,V.V. and M. Sinha (2001) Sustainable capture and culture based fishery in freshwaters of India. In Pandian ,T.J.(ed.) *Sustainable Indian Fisheries* . National Academy of Agricultural Sciences., 43-70p.
- Sund, O. (1920) Penaeides and Stenopides. Rep.Sci.Res."Michael Sars" *North Atlantic deep-sea Exped.1910.*, 3 (7) : 1-36.
- Suseelan, C. (1988) Bathymetric distribution and relative abundance of potentially commercial deep-sea prawns along the southwest coast of India. *Symposium on Tropical Mar. Living Res., Cochin, India*, 12-16 January, 1988. *Abstracts* , p.37.
- Suseelan, C and K.N. Rajan (1989) Stock assessment of the Kiddi shrimp (*Parapenaeopsis styliifera*) off Cochin pp15-30 *In Venema, S.C. and Zalinge , N.P(eds) Contributions to tropical fish stock assessment in India. FAO , Rome.*
- Suseelan, C. (1974) Observations on the deep-sea prawn fishery off the south-west coast of India with special reference to pandalids. *J. Mar. Biol. Ass. India*, 16(2): 491-511.
- Suseelan, C. (1985) Studies on the deep-sea prawns off south-west coast of India . Ph.D.Thesis , *Cochin Univ. Sci. and Tech.*, Kerala ., pp1-334.
- Suseelan, C., G. Nandakumar and K.N.Rajan (1989a) Results of bottom trawling by FORV Sagar Sampada with special reference to catch and abundance of edible crustaceans .*Proc.First Workshop Scient .Resul. FORV Sagar Sampada.*, 1989;337-346.
- Suseelan, C., M.S. Muthu, K. N. Rajan, G. Nandakumar , M. Kathiravel , N. Neelakanta Pillai, N. Surendranatha Kurup and K.Chellappan (1989b) Results of an exclusive survey for the deep-sea crustaceans

- off southwest coast of India .*Proc. First Workshop Scient .Resul . FORV Sagar Sampada.*, 1989;347-359.
- Takashima ,F., T.Hibiya ,PV.Nagan and K.Aida (1972) Endocrinological studies on lipid metabolism in rainbow trout-II. Effects of sex steroids , thyroid power and adrenocorticotropin on plasma lipid content. *Bull.Japan Soc.Sci. Fish.*, 40: 1155-1161.
- Tamura,T.M. (1950) On the life history of *Pandalus nipponensis* Yokoya . *Bull. of the Japanese Soc. of Sci. Fish.* 15:721-724.
- Taylor ,D.M.and J.M.Hoenig (1990) Growth per molt of male snow crab *Chionocetes opillio* from Conception and Bonavista Bays, Newfoundland. *Fish.Bull.(U.S).*, 88:753-760.
- Tegelberg , H.C. and J.M.Smith (1957)Observations on the distribution and biology of the pink shrimp (*Pandalus jordani*) off the Washington coast. *Washington Dept. Fish Res.Papers.*, 2(1) :1-10.
- Teshima,S., A.Kanazawa, S. Koshio and K ,Horinouchi (1989) Lipid metabolism of the prawn *Penaeus japonicus* during maturation variation in lipid profiles of the ovary and hepato pancreas. *Comp . Biochem. Physiol.*, 92 B ,1:45-49.
- Thessalou –Legaki, M.(1992) Reproductive variability of *Parapandalus narval* (Crustacea : Decapoda ) along a depth gradient. *Estuar. Coast. Shelf Sci.*, 35:593-603.
- Thomas, M.M. (1975) Age and growth, length-weight relationship and relative condition factor of *Penaeus semisulcatus* de Hann. *Indian J. Fish.*, 22: 133-142.
- Thomas, M.M. (1979) On a collection of deep sea decapod crustaceans from the Gulf of Mannar. *J.mar.biol.Ass.India.*, 21 (1&2) : 41-44.
- Thompson, J.R. (1967) Development of a commercial fishery for the penaeid shrimp *Hymenopenaeus robustus* Smith on the continental slope of

the southeastern United States. . *Proc. Symposium on crustacea. Mar. Biol. Ass. India.*, Pt.4:1454 - 1459.

- Tinbergen, N. (1953) *Social behaviour in animals*. John Wiley and Sons, Inc., New York, N.Y. 150p.
- Tirmizi, N. M. (1960) Crustacea: Penaeidae. Part II. Series Bethesicymae. *John Murray Exped. Sci. Rep.*, 10 (7): 319-383.
- Tirmizi, N.M. and O. Bashir (1973) Shore and offshore penaeid prawns of northern Arabian Sea: I-vii. 1-46.
- Torrissen, O.J. (1989) Pigmentation of salmonoids. Interactions of astaxanthin and canthaxanthin on pigment deposition rainbow trout. *Aquaculture.*, 79:363-374.
- Trong, P.D. (1996) Zoobenthos on mangrove ecosystem on the north-west coastal zone of Tonkin Gulf. Ph.D. Thesis, Pedagogic University of Ha Noi, Ha Noi., 156p.
- Trong, P.D., D.C. Thung, L.T. Thanh, L.V. Ken, N.D. Ngai and L.T. Thuy (2000) Species composition, abundance and biomass distribution of zoobenthos in Vietnamese waters. *Proc. SEAFDEC seminar on Fish. Res. in the South China Sea, Area IV, Vietnamese waters.*, 55-77.
- Tsukuda, H. (1963) Studies on the pigment of a deep sea prawn *Pandalus borealis* Krøyer. 1. identification and concentration of pigments. *Bull. Jap. Sea Reg. Fish. Res. Lab.*, 11: 109-15.
- Tully (1936) *J. Biol. Bd. Canada*, 2: 477- 484.

- Turpaeva, E.P. (1948) A feeding some invertebrates of Barents Sea .*The Zool.Mag.*, Vol 27(6): 503-512.
- Turpaeva, E.P. (1953) Food grouping marine base invertebrate. Works *IO AN USSR* ., Vol.7 : 259-299.
- Turuk ,T.N. (1972) Variation in the relative weight of liver of Atlantic cod. *Trudy polyar .nauchno-issled.Inst.Mosrk.Rub.Khoz.Okeanogr.*, 28: 88-95.
- Tyler, P.A.(1986) Studies of a benthic time-series: reproductive biology of benthic invertebrates in the Rockall Trough. *Proc.R.Soc.Edinb.*, 88B:175-190.
- Tyler, P.A.(1988) Seasonality in the deep sea . *Oceanogr. Mar. Biol. Annu. Rev.*, 26:227-258.
- Venner, A.M.(1985) (eds).*Factors in adult growth*. Vol.I.AA Balkema, Rotterdam
- Victor ,B and R. Sarojini (1985) Oocyte differentiation and vitellogenesis in the caridean prawn *Cardina rajadhari* (Bouvier) .*Curr.Sci.*, Vol.54, No.13.
- Vijayan, V., L.Edwin and K. Ravindran (2000) Conservation and management of marine fishery resources of Kerala state, India. *Naga, The ICLARM Quarterly.*, 23(3): 6-9.
- Vilela, H. (1936) Catalogo dos Crustaceos Decapodes e Estomatopodes. Colecccao Oceanografica de D.Carls I. *Bull. Soc. portug.Sc.nat.*, 12(27): 215- 242.
- Vivekanandan, E. (2001) Sustainable coastal fisheries for nutritional security. In Pandian, T.J. (ed.) *Sustainable Indian Fisheries*. National Academy of Agricultural Sciences., 6-18p.
- Walford , L.A. (1946) A new graphic method of describing the growth of animals. *Biol.Bull.*, 90 (2) : 141-147.

- Wang ,R., S.Chen and Z.Zhong (1989) Proceedings of China first symposium on southern Ocean Expedition ,Hangzhou , China,May, 1988, pp:143-150.
- Weinberg ,R. (1980) On the food and feeding habits of *Pandalus borealis* Krøyer 1838.*Arch.Fischereiwiss.*31p.
- Weinberg, R. (1982) Studies on the influence of temperature, salinity, light and feeding rate on laboratory reared larvae of deep sea shrimp, *Pandalus borealis* Kroyer, 1838. *Meeresforschung.*,29: 136-153.
- Wenner , E.L. and D.F. Boesch (1979) Distribution patterns of epibenthic decapod Crustacea along the shelf-slope coenocline, Middle Atlantic Bight, USA. *Bull .biol. Soc. Wash.*, 3: 106-133.
- Wickins ,J.F.(1972) Experiments on the culture of the spot prawn *Pandalus platyceros* Brandt and the giant freshwater prawn *Macrobrachium rosenbergii* (de Man) .*Fishery Investigations*, Series 2,27:1-23.
- Wilder, M.J. (1974) Biological aspects and fisheries potential of two deepwater shrimps. *Heterocarpus ensifer* and *H.laevigatus* in waters surrounding Guam. Master of science Thesis. Univ of Guam., 1-79.
- Williams, F. (1968) Report on the Guinean Trawling survey. OAU-STRC Pub., No.99, (1): 1-828.
- Wolfe ,E.A. and D.G. Cornwell (1964)Carotenoids of cavernicolus crayfish .*Science* ., 144:1467-9.
- Wolfe ,E.A. and D.G. Cornwell (1965) Composition and tissue distribution of carotenoids in crayfish. *Comparative biochemistry and Physiology.*, 16: 205-13.
- Wood –Mason, J. (1891) Phylum Appendiculata. Branch Arthropoda . Class Crustacea . In J. Wood –Mason and A.Alcock (editors ) , Natural history notes from H.M. Indian Marine Survey steamer 'Investigatro' , Commander R.F. Hoskyn ,R.N., Commanding Series II , No. 1. On



the results of deep-sea dredging during the season 1890-91. *Ann. Mag. nat. Hist.*, Ser. 6, 8 : 268-286.

- Wood –Mason, J. (1892) Natural History notes from H.M. Indian Marine Survey steamer 'Investigatro' , Commander R.F. Hoskyn ,R.N., Commanding Series II , No. 1. On the results of deep-sea dredging during the season 1890-91. *Ann. Mag. nat. Hist.*, Ser. 6, 9 :358-370.
- Wootton, R.J.(1984) Introduction :Strategies and tactics in fish reproduction , In:G.W. Potts and R.J.Wootton (eds.). *Fish reproduction: Strategies and Tactics*. Academic Press Inc. Lond. Ltd., 1-12p.
- Wouters , R. ,J. Nieto and P.Sorgeloos (2003) A review of recent research on shrimp brood stock nutrition and artificial diets .*Lab.Aqua. & Artemia Reference Cent.* University of Ghent , Belgium.
- Wu,R. S.S.(1982) Periodic defaunation and recovery in a subtropical epibenthic community , in relation to organic pollution .*J. Exp. Mar. Biol. Ecol.*, 64: 253-269.
- Yahiaou , M., A.Nouar and A.Messili (1986) Stock evaluation of two species of deep-sea shrimp of the penaeid family : *Aristeus antennatus* and *Parapenaeus longirostris* .*FAO Fish .Rep.*, 34: 221-231.
- Yahiaoui, M.(1994) Growth, mortality and exploitation of *Aristeus antennatus* near Alger and of *Aristeomorpha foliacea* near Annaba .In.Bianchini M.L., Ragonese,S(Eds.) *Life Cycles and Fisheries of the Deep-water Shrimps *Aristeomorpha foliacea* and *Aristeus antennatus**. Proceedings of the International Workshop. *Istituto di Tecnologia della Pesca e del Pescato*. NTR-ITPP Special Publication 3,pp.53-54.
- Yaldwyn, J.C. (1957) Deep-water Crustacea of the genus *Sergestes* (Decapoda, natantia) from Cook Strait. *Victoria Univ. Wellington Zool. Pub.*, 22: 1-27.

- Yano, J. and S. Kobayashi (1969) Calcification and age determination in crustacea. Part 1. Possibility of age determination in crabs on the basis of number of lamellae in cuticles. *Bull. Jap. Soc. Sci. Fish.*, 35 (1); 34-40.
- Yasuda, J. (1957) Species, distribution, movement and composition of shrimps. Study of rationalization of the shrimp fishery in Seto-Inland Sea.2. *Bull. Naikai Reg.Fish.Res.Lab.*, (10)28-36.
- Yonge, C.M. (1924) Studies on the comparative physiology of digestion .II .The mechanism of feeding, digestion and assimilation in *Nephrops norvegicus*. *Brit.J.Exp.Biol.*,1:349-389.
- Young, C.G. (1900) The stalk-eyed Crustacea from British Guiana, West Indies and Bermuda, 1-514.
- Zacharia , P.U. (2003) Studies on the fishery biology and population dynamics of the white fish *Lactarius lactarius* (Bloch and Schneider,1801) along the Karnataka coast .Ph.D.Thesis , Dept. of Biol. Sciences ,Mangalore University .180p.
- Zarenkov, N.A. (1971) Contribution a l' etude des especeds et de la distribution géographique des crevettes marines appartenant aux familles des Hippolytidae et des Pandalidae (Crustcea Decapoda). *O. Univ.Moscva.Complexnie Issledovaniia prirodi okeana*, 2: 175- 195.

## **PUBLICATIONS**

#### PAPERS PUBLISHED:

- Kurup,B.M. and R. Rajasree (2003) Ring seine operations in Kerala waters by IBE and OBM-fitted boats : Relative Merits. *Fishing Chimes* ., 23(2) :19-24.
- Kurup,B.M. and R. Rajasree (2003)Performance Of Inboard Fitted Canoes Operating Ring Seine Along Kerala coast . *Fish.Tech.*, 40(2 ):95-100.
- Rajasree,R. and B.M.Kurup (2002) Status of exploited marine fishery in Kerala (South India) with special reference to the effects of conservation and management measures imposed in providing respite to fish stocks. VI<sup>th</sup> Asian Fisheries Forum Mumbai, India .18-22 Dec. 2002. Abstracts 45p.

#### PAPERS ACCEPTED :

- Rajasree, R. and B.M.Kurup (2004) Fishery and biology of deep sea prawns landed at various harbours of Kerala. *Fish.Tech.*, (in press).
- Kurup,B.M. and R. Rajasree (2004) Status of bottom trawl fishery of Kerala. *Fish.Tech.*, (in press).
- Kurup,B.M. and R. Rajasree (2004) Regulatory and management mechanisms introduced in the marine fisheries sector of Kerala with reference to their status of imposition and effectiveness in providing respite to fish wealth. *J. mar. Biol. Ass. India.*, (in press).
- Rajasree, R. and B.M.Kurup (2004) Fecundity indices of hump back nylon shrimp *Heterocarpus gibbosus* (Bate). *J.mar.Biol.Ass.India.*, (in press).



68652