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$^2$ 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$^2$ 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 0.8 million 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 shelf 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.


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), González 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 Suseelan (1968), Silas (1969), Mohamed and Suseelan (1973) and Suseelan (1974, 1985).

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

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).


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

1.3 DESCRIPTION OF THE STUDY AREA

Kerala with a total terrestrial area of 38863 km$^2$ 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 with in the territorial limit of the state is about 13,000 km$^2$. 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, gonado-somatic 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

- Mopla Bay
- Puthiyappa
- Beypore
- Ponnani
- Munambum
- Murikkumpadam
- Cochin
- Thottappally
- Sakthikulangara
- Neendakara

Arabian Sea