Chapter 3

DISCUSSION

Spatio-temporal variations of qualitative and quantitative abundance of planktonic decapoda in the Bay of Bengal is very prominent. On quantitative assessment, the planktonic decapods showed maximum abundance during summer monsoon followed by the fall intermonsoon, winter monsoon and spring intermonsoon. During summer monsoon, they have a wider distribution and high density especially towards the southern coastal region. According to Paulinoso (1979b), spawning of some of the commercially important species of decapods takes place all along the Indian coast during summer. The increased spawning activity results in the release of a large quantity of larval population to the coastal waters. The larval forms together with the holoplanktonic group (Luciferidae) support the high density of planktonic decapods along the coastal waters during SM. Coastal station along 13°N transect was characterised with signatures of upwelling which enhances the biological production through nutrient input from the subsurface waters. The zooplankton population including the planktonic decapods get attracted towards the upwelling
region and form aggregations. Paulinose (1979b) reported the affinity of
decapod larvae to the upwelling region. But this was found to be
antagonistic to the findings of Panikkar and Rao (1973); in their opinion,
the decapod larvae come late in the sequence of production
commencing from phytoplankton, and they would therefore get located
at places away from the actual upwelling areas. The effectiveness of
upwelling in larval transport, however, depends on the position of
larvae in the water column, a position that is governed mainly by
turbulent mixing and larval behaviour, i.e. vertical migration (Blanton et
al., 1995). During FIM (October) and WM (November to February) the
abundance was comparatively lower than in SM. According to Menon
and Paulinose (1973), during the period from October to November the
BoB sustains less density of planktonic decapods. They postulate that
during June to October, BoB appears to be very calm and it supports
more larval forms in the zooplankton and subsequent reduction in the
winter due to high turbulence. During WM, the waters around the
southern peninsula had a good representation of decapod larvae,
whereas most of the east coast of India, mainly north of Madras, had
low concentration (Paulinose, 1979a). The total abundance of planktonic
decapoda during SIM was relatively low, and whatever available was
concentrated towards the southern region. Spring is a period of
increased solar radiation and surface heating. This season is generally
considered low-productive oligotrophic period, especially, towards the
southern transects. According to Jyothibabu et al., (2006), BoB
experiences strong oligotrophic condition during SIM. 'Microbial food
web loop' is more active during this period. The small phytoplankton cells available are grazed by the ciliates, and it becomes the prey for other zooplankton and thus enters into the classical food chain. The increased abundance of planktonic decapods could be related to this condition. Gowswami (1983) reported high incidence of decapods in the zooplankton samples during abnormally high SST. Qualitative analysis of the samples reveals that the dominant taxon was Luciferidae, which is a holoplanktonic form; it can sustain in the warm waters.

Fall intermonsoon was characterised by the prevalence of low saline surface water along the northern region due to the persistent river discharge right through the SM. The nutrient-rich water might support the phytoplankton production and thus in turn support the abundance of zooplankton population. Coastal stations especially to the north of 15°N transect, experienced low saline surface water due to the river discharge. This increased nutrient flux sometimes possibly enhance the phytoplankton standing stock, either in the surface waters or subsurface waters, rather than strong stratification. The high density to planktonic decapods may be associated either with the food availability or with the transportations through water currents. Certain larval forms were found to adhere to the continental shelf area associated with the river run off. In some cases, the low saline water makes an estuarine situation which is more preferable for certain decapods for their breeding and feeding.

The coastal waters of northern and middle transects during SM and WM were characterised by relatively higher density of decapods
than oceanic waters. The coastal waters of India are known to be comparatively rich in decapod larvae. From IIOE samples, Menon and Paulinose (1973) observed that midcentral region of southeast coast and coastal waters of Gangetic delta have fairly high abundance of planktonic decapods, especially larval forms.

Besides upwelling, various other physical processes were identified during the course of the present study period. The response of planktonic decapods to physical processes was quite interesting. During spring intermonsoon, summer monsoon and fall intermonsoon, cyclonic eddies were observed at the oceanic stations, along 19°N, 17.5°N and 19°N transects respectively. The detailed hydrographical features which prevailed in the corresponding transect is given in Part 1, Chapter 3. According to PrasannaKumar et al., (2004a), cold core eddies are seasonal phenomena in the BoB and are identified as a mechanism of nutrient injection in the oceanic waters and associated high biological production. During winter monsoon, along 13°N transects at 82°E, a cyclonic gyre was observed. As in an eddy, cold gyre also enhances the biological production through the circular movement of the current which brings the nutrient rich subsurface water to the photic zone. In the regions where these physical processes were active, the number of planktonic decapods remained relatively large. The aggregation of decapods in these regions may be because of two reasons: firstly, the increased phytoplankton due to the nutrient enrichment might enhance the zooplankton population, including planktonic decapoda for forage; secondly, it may be due to the retention of planktonic form, especially
the larval forms of decapoda by their increased buoyancy. According to Mc William and Philips (1983); Griffiths and Brandt (1983), eddies and gyres play an important role in the oceanic circulation, which can influence distribution as well as retention of larvae of mesopelagic crustaceans.

Marked diurnal variation was observed with increased abundance of decapods at night time during summer monsoon and spring intermonsoon, compared to other seasons, especially along the coastal stations. During summer, 17°N transect experienced freshwater discharge and the 13 and 15°N transects showed signatures of upwelling along the coastal waters. This particular environmental condition during the summer monsoon may attract the planktonic decapod population towards surface waters during night time for feeding. High zooplankton biomass and high decapod density at night were also observed by Nair et al., (1977). Generally, zooplankton collections in the BoB and adjacent areas are rich in decapod larvae during night (Paulinose 1979b). During winter, along the southern transects, less abundance of planktonic decapods was observed and hence no pronounced diurnal variation.

Regarding the relative abundance, the samples were dominated by members of Sergestoidea followed by Caridea and Brachyura. The seasonal variation in the abundance of Sergestoidea showed that, during summer monsoon, the number increased enormously followed by fall intermonsoon, winter monsoon and spring intermonsoon. Sergestidae and Luciferidae are the two families which contributed mainly to the
abundance of Sergestoidea along the basin. Luciferidae, the holoplanktonic epipelagic shrimp family, with its larvae and adults contributed appreciably to a large percentage of mesozooplankton along the coastal waters around India. Genus Lucifer is successful and widely distributed in the tropical and subtropical waters (Hashizume and Omori, 1998; Naomi et al., 2006). Their distribution is patchy in nature in the Indian waters, more towards the coastal belt, however, their percentage contribution and species composition may vary according to the seasonal pattern. According to Rajagopalan et al., (1992), Lucifer was abundant in the plankton throughout the year exhibiting peak dominance during the southwest monsoon and immediate post-monsoon months. This is supported with the present result of increased abundance during the summer monsoon (May to September) followed by fall intermonsoon (October). Towards the oceanic region, the abundance was decreasing irrespective of seasons, except in some stations along 19°N transect. Of the total population of Luciferid shrimp in the Indian waters around 12% are from the area between 100 to 200m and 8% from the oceanic waters beyond 200m (Naomi et al., 2006). Antony et al., (1989) depicted the distribution pattern of Lucifer spp. in the Arabian Sea and Bay of Bengal and found that the coastal regions of BoB were richer in abundance >10,000 no1000m\(^3\). Patterns of seasonal variation in spatial distribution of lucifers were prominent during the study period. The maximum abundance of lucifers was noticed along the coastal stations irrespective of seasons. During summer and winter monsoon, the coastal as well as oceanic stations of northern region were
found to experience low saline, cold waters due to the fresh water influx which resulted in enhanced phytoplankton production. This may be the reason for the increased abundance of lucifers in the region. As compared to the other groups of planktonic decapods, lucifer enjoy the whole of their life as plankton, and thus they may have a wide range of tolerance of various environmental conditions, compared to the other meroplanktonic forms. Recent research conducted in the East China Sea, suggests that species like *Lucifer hansenii* and *Lucifer intermedius* are useful indicators for the effect of long term climate change on aquatic ecosystems (Ma *et al.*, 2009).

Family Sergestidae are often represented with the larval stages of *Sergestes* sp and *Acestes* sp. Sergestids are major component in the micronekton community, which constitutes an important link between the zooplankton and higher trophic levels in the pelagic ecosystem. Their larval stages were very common in the zooplankton samples all the year round. George (1968) reported that year-round breeding of certain species of decapoda suggest the fair presence of meroplankton throughout the year. According to Achuthankutty and Selvakumar (1979) *Acestes* shrimps are very common in Indian waters along the coastal region and inshore areas (Achuthankutty *et al.*, 1973) within the continental shelf. Along the north western coast of India *Acestes indicus* appear in big shoals in the inshore and coastal waters almost throughout the year and contribute about 20% of the estimated annual crustacean landings. The seasonal distribution of the larvae showed that they occur abundantly during October to January Pillai (1973). The
percentage contribution of *Acetes* was quite lower than of the *Sergestes* species in the present study. This may be due to the present samplings which are mostly beyond 50m of the continental shelf area or, in other words, the larval stages of *Acetes* may not get transported to the oceanic regions because mostly they prefer the more productive coastal waters. The increased abundance of Sergestid larval forms, especially, *Acanthosoma* and *Mastigopus* (later stages) in the offshore area of the continental shelf may be because of their aggregation and transportation of the larval population to the area of parent population. *Elaphocaris* (early stages) were concentrated more towards the coastal region, which might be due to the proximity of the parental populations for breeding purpose. The occurrence of adult Sergestid shrimp in the zooplankton sample quite often might be related with its feeding habits. Sergestids are zooplankton feeders and their food includes copepods, chaetognaths, ostracods, molluscs, euphausiids, detritus and organic debris.

Caridea was the second dominant taxon after Sergestoidea during all seasons except spring intermonsoon. The increased abundance of decapods in the plankton samples was due to the highest abundance of Caridea along the southern region. The supporting species were *Thalassocaris* sp., *T. obscura* (larval stages; zoea and mysis). Gopalamenon and Williamson (1971) described the distribution of *Thalassocaris* in the Indian Ocean and found that the *T. Lucida* is more abundant in the vast stretches of the BoB. While the coastal species *T. crinata* is more restricted towards the eastern part of the BoB. Zoea and mysis stages of *T.obscura*
were found to contribute equally along with the larval stages of \( T. \) sp. at the 15, 13 and 11°N transects. Earlier studies (Gopalamenon and Williamson, 1971) reported smaller number of \( T. \) obscura and their larval stages from the BoB. Other species of Caridea were rarely distributed in the study region.

Among Penaeoidea, the dominant families present during the course of this study period were Solenoceridae, Benthesicymidae and Penaeidae. But in all the seasons studied, the concentrations of larvae of penaeoids were comparatively lower than the larvae of Sergestoidea and Caridea. Family Solenoceridae which was present during summer and winter monsoon months had very low density (<10 no 100m\(^{-3}\)) and during intermonsoon months their density was very thin or nil. Though, the members of the family Solenoceridae support the commercial fishery along the coast, the breeding and larval development of this species is still unknown. Similarly members of the family Solenoceridae, Benthesicymidae and Penaeidae also had only scattered distribution at a few stations, mostly of the mysis stage. The adults of \( Gennadas \) sp under the Benthesicymidae and mysis and postlarval stages of \( Metapenaeus \) affinis, \( Metapenaeus \) barbata, \( Atypopenaeus \), \( Trachypenaeopsis \), \( Penaeopsis \) rectacuta, \( Parapenaeopsis \) inveteiagoris etc under family Penaeidae were often noticed. Larvae were more concentrated in the upper water column (MLD) and the adult animals in the lower strata. Karuppasaamy et al., (2006) observed the presence of pelagic shrimps of the genus \( Gennadas \) from the deep scattering layer of Eastern Arabian Sea. The abundance of mysis stages of \( Gennadas \) sp. was more during summer
monsoon than in the other seasons. However, it is possible to make an inference regarding the presence of more of mysis stages during summer monsoon which might be due to the coincidence of breeding habits during this season and migration of post larval and juvenile stages to the oceanic waters carried by prevailing currents. Low number of larval forms in the samples especially of family Penaeidae, may be due to the sampling, mostly beyond 50m depth. Inshore species of family Penaeidae are known to spawn in the areas of lesser depths (<50m) and deep water species spawn mostly in deeper waters. In the case of commercially important penaeids, the larval forms perform shoreward movement and there are no reports of coast to coast movement or one region to another. Therefore, the occurrence of larvae would reasonably indicate the presence of a spawning population of adults in the neighbourhood areas (Paulinose and George, 1976).

Paulinose and George (1976) had made an attempt to correlate the occurrences and abundance of penaeid larvae with its fishery in the Arabian Sea and BoB, and found that a maximum number of larval forms were obtained from the BoB, with two outstanding areas: 1) along the coast off Madras, and 2) off the Nicobar islands. According to their observation, the Indian Ocean region was very poorly represented with the species of deep water and oceanic penaeids. Information on the oceanic species penaeids in the Indian waters is very meagre and hence wide scope for future research is open.

Presence of brachyuran larvae in the planktonic samples was quite frequent during the study period, with maximum abundance
during the spring intermonsoon and falls intermonsoon. Generally, during spring intermonsoon the concentration was more towards the coastal stations of southern transects.

From an observation made during these studies covering over a wide area, it is clear that the distribution patterns of planktonic decapods vary considerably with seasons. The hydrographic features play a vital role in the occurrence and abundance of decapod larvae in the plankton community. Incidence of several seasonal features, such as river water influx, localized coastal upwelling, eddies (either warm core or cold core) etc. would affect directly or indirectly in distribution and abundance of planktonic decapods. In general, the Bay of Bengal was found to be more productive in summer season and holds high decapod density, than in winter. More intensive studies may be planned so as to assess and validate the quantitative and qualitative diversity of planktonic community, especially the commercially important species of decapod larvae and allied groups, with a view to formulating an index of commercial fishery potential and its maximum sustainable exploitation.

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