Chapter 5

Influence of Hydrobiology on Fisheries

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5.1 Introduction

The total marine fish production in India in 2000 was about 2.7 million metric tones, out of which, the pelagic fish production was 1.36 million metric tones. However, their relative contribution to the total landings declined to 50% from about 71% in 1965. In contrast, the landings of demersal resource have consistently increased over the years and registered a production of 1.33 million metric tones in 2000 (Srinath, 2003).

The west coast of India accounts for over 70% of the national fish production and has been related to upwelling and the concomitant increased primary production in the area. Situated along the southwest coast of India, Kerala ranks next to Gujarat in fish landings, accounting for 30 percent of the production along the west coast (Morgan, 2006). The marine fish landings in Kerala are higher during the southwest monsoon (July – September: 33.7%) and postmonsoon (October-December: 29.6%) (Vivekanandan et al., 2003).

Out of the 44 rivers in the state, 41 flow from east to west. The bountiful marine fishery resources of Kerala are dependent on the rivers which facilitate water transport from the tropical forests and contributing significantly to coastal primary productivity (Kurian, 2005). River runoff, which enrich the coastal waters and the microbial loop, contributes to high zooplankton production (Madhupratap et al., 1994).

Over the years, landings have depicted wide fluctuations especially during the post-mechanization period, with significant changes in the species composition of the catch and the disappearance of previously important species (Vijayan et al., 2000).

Environmental variables play an important role in controlling the abundance and distribution of marine fish populations. The seasonal fluctuations in fisheries along the west coast are partly governed by the
intensity of upwelling and is one of the main factors controlling the seasonal abundance of fish in a particular region (Sankaranarayanan and Qasim, 1969). Fluctuations in the physical, chemical and biological oceanographic conditions have a profound influence on the periodic and seasonal migration of fishes in the sea (Rajagopalan and Krishnakumar, 2003).

When coastal fisheries is taken into consideration, upwelling in the southwest monsoon gyre along the southern part of the southwest coast assumes great importance. The upwelling which occurs along the west coast during the southwest monsoon enriches the water to a great extent leading to high organic production and a good pelagic fishery after the monsoon (James et al., 1983). The Kerala coast experiences significant upwelling during the southwest monsoon period (June - September), resulting in abundant phytoplankton and zooplankton production. Further, with regard to oceanography and biomass correlation, the phytoplankton / zooplankton biomass is fundamental, as many of the commercially important pelagic fishes are plankton feeders (Pillai et al., 1980).

The marine atmosphere, physico-chemical characteristics of sea water, phytoplanktons, zooplanktons and bacterial load of the pelagic realm eventually interact with fishes and the fishery (Murty, 1985). According to him, in order to relate oceanographic conditions with fisheries, one method is to correlate fish landings with various factors of the sea at the time of fishing and another is to seek the cause and effect on a scientific basis, thereby arriving at conclusions about those factors which affect fisheries. Such investigations help in developing forecast techniques but are essentially linked with local conditions.

The changing pattern of fisheries of the exploited zone along the Indian coasts and its impact on the stocks are regularly monitored by the Central Marine Fisheries Research Institute. Studies have revealed that the resource
availability is directly proportional to the landings at fish landing centers and are
ta true representation of the landings from the respective area.

This chapter outlines the effect of selected hydrobiological
parameters on the availability and abundance of some important fish
groups landed at Cochin.

5.2 Review of literature

Among the multispecies oriented fishery along the west coast of India,
the oil sardine, *Sardinella longiceps* and the Indian mackerel, *Rastrelliger
kanaguata* form the main stay of pelagic fisheries. The oil sardine is
distributed along the coastal waters of Arabian sea north of 8° N while
mackerel appears to enjoy a much wider distribution from about 30°S to
30°N, comprising the Indian ocean and the west Pacific Ocean (Madhupratap
et al., 1994). Both the species are coastal in occurrence and generally
caught by the same fishing techniques/efforts, which are carried out intensely
during the fishing season. It is generally believed that the landings in an area
are a representation of the stock abundance and that the catches of the two
species are comparable. Commercial fishery is restricted to 8°-18°N and both
fisheries are shallow water based; the usual depth of fishing being confined to
an area within 20 - 25 m depth (Anon., 1987).

The fishery becomes increasingly abundant from Quilon northwards
from September and both the fishes are abundant during winter in the
northern regions when the northward movement of water along the coast
is prevalent. It is possible that the fishes move along with the northward
current and as it produces convergence zones where zooplankton
accumulates, the migration of these pelagic fishes seem to be related to
feeding conditions (Rao et al.,1973).

Oil sardine form a major commercial fishery yielding about 15 to
20% of the total marine fish landings in India. Besides being a favoured,
nutritionally rich and affordable table fish occurring abundantly throughout
the year, it also serves as an important source of valuable by-products like
sardine oil and fish meal. It is a typical shoaling species and occur as a band along the southwest coast of India mainly within 40 km offshore. Large scale shoaling of fishes has been observed off the Kerala and Karnataka coasts (Anon., 1986). Out of the total annual landings of pelagic fish from Indian coasts, the oil sardine contributes more than 50% and their catches are appreciable during winter. The traditional fishing grounds are 15 - 25 m for non- mechanised boats while mechanised vessels operate in the depth range 26 - 60 m but not beyond 80 m bathymetric contour of the shelf bottom. Murty (1974) remarked that the surface circulation possibly controls the distribution of this species, although, the fishes migrate for selective feeding even under conditions of abundant food supply at any given place. The oil sardine shoals do not perform long distance migration (Blindheim and Monstard, 1976). Pillai et al. (1980) indicated that oil sardines prefer areas with less vertical gradient for breeding purposes and they normally move away from the coast in search of suitable environment.

The fishery of oil sardine commence in June - July with the entry of spawners which were spawned in the previous year. Spawning usually occur during June - September and the fecundity has been estimated to be 37,000-38,000 ova per female. By September – December, adults and large shoals of juveniles spawned earlier in the same year are also available. In the next year, the 0 - 1 year class attains about 140 - 160 mm size and enter the fishery. Oil sardines grow rapidly, mature early and a few survive through their second year of life. Age of first maturity is less than one year and would be about 150 mm in size (Raja, 1969). Nair (1960) observed an initial abundance of the species at the start of the monsoon season which coincided with the arrival of the adults and a second in September - October coinciding with the main fishery of juveniles.

The oil sardine is planktonivorous and diatoms form a significant part of the adult diet. Dinoflagellates and copepods are also important in the diet from October-January (Raja, 1969; Longhurst and Wooster, 1990).
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The fishery of oil sardines have shown wide fluctuations on a seasonal, annual and decadal scale (Pillai et al., 2003).

The availability of oil sardine fishery off the upwelling coast of southwestern India was noted as long ago, when Day (1865) suggested that the stocks were so uncertain in their availability that a planned industrial expansion of the fishery would probably fail. Banerjee (1967) reported that the oil sardine landings represent the standing stock rather than the availability or fishing effort. Longhurst and Wooster (1990) observed that the relationship between stock size and landings of oil sardine is most likely to be influenced by variations in fishing effort. They reported that the number of juveniles spawned during June - September in the early fishing season dominate the seasonal landings of oil sardine, so that each season’s catch is largely a reflection of the success of the single year class. Nair (1959) and Raja (1969) observed a collapse in oil sardine landings in the 1940’s and a return to very high catches in 1950’s. Decadal variations in the stock size have been observed in oil sardine (Longhurst and Wooster, 1990). They stated that in the modern period, the sardine fishery does not show strong decadal trends unlike in the early part of the century. Srinath (1998) and Jayaprakash (2002) also reported decadal scale trends in the abundance of oil sardine. According to them, the cyclic pattern of Indian oil sardine registered a shift from the low stock/low recruitment to higher levels despite the fishing pressure dominated by density dependants. The events which happen during the early part of the year especially during March - April had the greatest influence on the size of sardine stock in the subsequent fishing season.

Murty and Edelman (1971) observed significant correlation between sardine landings and pressure difference, with a reduction in catches upto the intermediate values and an increase at higher values. Raja (1969, 1972) reported that monsoon (June - August period) is the period of intense activity of spawning for oil sardines and that spawning activity is related to rainfall. Jayaprakash (2002) found that the fluctuations in
abundance of oil sardines are undoubtedly influenced by the trends in rainfall and that periods of intense rainfall do have a positive effect on its abundance and vice versa. He observed a time lag of 6 to 7 years between intense rainfall and oil sardine peak. Studies by Longhurst and Wooster (1990) revealed that periods of unusually high or low sardine abundance were related to periods of unusually high or low rainfall. They further observed that periods of sardine abundance occurred only during periods when monsoon onset was earlier rather than late. Madhupratap et al. (1994) also reported that late arrival of the southwest monsoon coincided with low catches of sardine.

The probability of oil sardine disappearing from the Malabar coast during summer months may perhaps be due to the unfavourable hydrographic and nutritional conditions existing in the upper layers coupled with an increase in surface temperature and paucity of food (Tholasilingam et al., 1968). Dulkhed (1972) postulated that sardines can become demersal during March - April, as evidenced by the gut content analysis of specimens collected from the bottom nets.

Longhurst and Wooster (1990) reported that the sea level in April signals the setting up of oceanographic conditions which will manifest several months later in the coastal regime leading to either the entry of spawning shoals to the coastal waters or the survival of larvae at the time of critical first feeding. The earliest spawned individuals begin recruitment to the fishery towards the end of July - October period. They hypothesized that an early upwelling indicated by low sea level in April would lead to inhibition of recruitment through exclusion of spawning fish in the neritic zone by oxygen deficient upwelled waters. They further observed that the sea level during April at Cochin is the best index for forecasting oil sardine landings at least six months in advance and deduced a critical value of 6.35 mm for Cochin MSL. Bumper catches of oil sardine are associated with high values of sea level (due to relatively weak upwelling of March - April period) and poor catches to low sea level (intensive upwelling). However, Madhupratap et al. (1994) did not...
observe any such correlation between sea level and sardine or mackerel landings for the period 1960 - 1990.

The Indian mackerel, *Rastrelliger kanagurta*, is another important pelagic fish resource of India in the context of national food security. Mackerel is heavily exploited from Kerala – Goa region and contributes about 73% to the total production (Yohannan and Sivadas, 2003). Mackerel fishery starts with the onset of the southwest monsoon and is mainly supported by size range from 160 - 229 mm and includes one year old and mature individuals (Noble, 1992). Mackerel spawns from April - December along the west coast with a peak in July – August (Anon, 1976). Bal and Virabhadra Rao (1984) reported that the spawning of mackerel is from June - September or April – September, while Raja (1969) observed an intense spawning activity between June - August. The Indian mackerel seems to have an extended spawning season and a single female produces upto 94,000 ova. High densities of larvae are found in April – July/August. The main spawning ground is believed to be between 8 to 15°N latitude in a 10 nautical mile belt (between 15 and 100 m). Longhurst and Wooster (1990) reported that along the Malabar coast, mackerel is wide spread and less neritic, which reproduces offshore. Mackerel is migratory in habit and its fishery is seasonal. The period of peak fishery is from September to December and in some years it may extend even up to March - April. High concentrations of mackerel occur along the southwest coast of India and is known to breed in the continental shelf region outside the conventional area and peak spawning occurs during April - May. The congregation of fish in the surface layers is more pronounced during upwelling season (Pillai, 1991). Madhupratap *et al.* (1994) opined that the stability of mackerel catches in modern times indicate that they are being fished optimally and is sustainable at the present level.

Chidambaram and Menon (1945) found significant correlation between the landings of mackerel and environmental factors such as rainfall, surface temperature, salinity, specific gravity of water and planktonic abundance. Pradhan and Reddy (1962) observed an inverse
The relationship between annual rainfall and mackerel catches in Calicut on the southwest coast of India. Ramamurthy (1965) found that high temperature and salinity affect mackerel fishery adversely and in North Kanara, the mackerel season coincides with a transition from the low saline and cooler conditions of the southwest monsoon to a high saline and warmer conditions of the summer. Peak mackerel landings coincide with or follow the abundance of plankton (Bhimachar and George, 1952). Noble (1962) observed that mackerel consumes a lot of phytoplankton and hence it is possible that an area where phytoplankton productivity is high, is favourable for mackerel abundance.

Remotely forced upwelling during February - May causes early appearance of the stock in the surface layers and any interannual variability in upwelling will influence the recruitment and abundance of the stock (Madhupratap et al., 1994).

Studies indicate that (Anon., 1976) sardines spawn close to the shore while mackerel does farther away from it. Madhupratap et al. (1994), however, found that both the species spawn in the inshore waters close to the coast especially in bays. The interannual variability of the two species does not follow a common pattern and variations in apparent abundance of the two species is not driven by the changing effect of the fishery fleet which has exploited the two species together (Longhurst and Wooster, 1990).

Hornell (1910), Nair and Chidambaram (1951) and Raja (1969), observed an inverse relationship between annual landings of the two species while, Longhurst and Wooster (1990) found no such correlation. They feel that the changes in abundance of oil sardine do not drive mackerel and that the population trends of oil sardine depend on environmental variables rather than density dependent factors. Madhupratap et al. (1994) opined that though, the two species take advantage of development in the same environmental conditions along the
west coast, they are not competitors in the true sense, although both are omnivorous. Adult sardines feed mainly on diatoms, while mackerel is predominantly a zooplankton feeder (Raja 1969, Anon, 1970). It was observed that periods of better rainfall with less interannual variability and years with very less rainfall, both do not have any bearing on the sardine and mackerel fishery (Madupratap et al., 1994).

It is generally believed that the observed differences in the relationship between upwelling, oil sardines and other pelagic species could be due to the differences in their reproductive ecology. The influence of upwelling and monsoon conditions need not affect the spawning of mackerel and other pelagic species. Unlike oil sardines, mackerel has an extended spawning during a year and can ensure successful recruitment elsewhere during the early monsoon. Murty and Vishnudatha (1976) reported that the fisheries of oil sardine and mackerel are associated with high salinity, moderate temperature and deeper thermocline. Pillai (1991) found that the comparatively high saline, low temperature upwelled waters favour both oil sardine and mackerel. He further inferred that both the species have little tolerance for temperature above 27.0°C. Rao et al. (1973) observed that low salinity values appear more favourable to sardines than mackerel. They also reported that the higher salinity values in the northern region appear to be more favourable to mackerel than oil sardines. It has been noted that delays in the onset of monsoon are often followed by delays in the fishing season for mackerel and oil sardine (Panikkar, 1949). Laevastu and Hela (1970) and Noble (1972) are of the view that the period of peak sinking activity (October - March) facilitates the concentration of zooplankton, which in turn, results in the formation of dense school of small pelagics like sardines and mackerel which feed mainly on zooplankton.

The penaeid prawns constitute the backbone of seafood export industry in India and is the major foreign exchange earner as well as a source of livelihood for millions of fishermen. Among the penaeid landings along North Kanara, Calicut and Cochin coasts, about 90% is contributed by
Metapenaeus dobsoni (Poovalan) and Parapenaeopsis stylifera (Karikkadi). Kerala is the highest contributor (28%) to the penaeid landings in India. Penaeid prawns breed throughout the year. Estuaries and backwaters are the nursery grounds for many commercially important penaeid species and provide a major source of recruitment for the inshore stock. Success of recruitment to the fishery depends mainly on the prevailing environmental conditions (Nandakumar and Maheswarudu, 2003)

George (1988) reported that about 75% of the prawn landings during monsoon is contributed by *P. stylifera* along the southern part of the southwest coast. *P. stylifera* is the most important species in the commercial fishery of Kerala, accounting for 38 - 50% of the total prawn landings of the state. It is basically a coastal species, inhabiting areas within the 30 m depth contour in the non monsoon months. This species leave the inshore grounds in large numbers with the commencement of southwest monsoon and remain in 20 - 40 m depth zone in June and in 40 – 60 m depth zone in the remaining monsoon months (Suseelan *et al.*, 1989, 1990 and 1993). They presumed that the effect of upwelling during monsoon months drive the prawn into deeper waters. Menon (1953) stated that by the end of May, *P. stylifera* begins to leave the inshore waters and after cessation of the southwest monsoon, they return in October. However, he observed good catches of prawns along Malabar coast with cast nets in quite shallow waters during the southwest monsoon. Later studies by Suseelan *et al.* (1998) ruled out the possibility of a return migration of the Karikkadi stock to the inshore fishing grounds after the cessation of monsoon.

Cephalopods such as squids, cuttle fishes and octopuses are commercially exploited all along the Indian coast and accounts for about 10% by value of the total marine products exported from the country. The cephalopod meat is high in protein and low in fat content which make them ideal for human consumption. Kerala accounts for 34% of the cephalopod production in the country and major landings occur during July – September period. Trawling within 30 m depth contour yields more of squids and near
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Shore species of cuttle fishes. Beyond this zone, cuttle fishes are caught more often. Trawl nets operating upto 100 m depth accounts for 85% of the cephalopod landings (Meiyyappan and Mohamed, 2003).

The threadfin breams, also called pink perch, constitute an important demersal finfish resource in the Indian EEZ. The increased availability of these fishes have led to the establishment of surumi plants along the coasts exclusively based on this species. The landings of threadfin breams have shown considerable increase since 1980, except for minor decline during certain years; Kerala, Karnataka and Gujarat being the major contributors. Abundance of threadfin breams are known to be influenced by upwelling and they move to inshore waters during the monsoon period along the west coast of India. In the coastal waters off Kerala, they spawn during the monsoon and postmonsoon periods (Murthy et al., 2003)

Sudarsan et al. (1988) found that threadfin breams form the most dominant component of the demersal finfish resource in the 50 - 100 m and 100 - 200 m depth strata between 8º and 11º N latitudes along the southwest coast. Studies on the depthwise intensity of threadfin breams indicate that its intensity is comparatively high between the depth range of 16 - 25 fathoms and that the peak period of landing is during August – October, with a maximum in the month of September (Perumal et al., 1974) Nair and Jayaprakash (1990) reported that the threadfin breams which are more abundant in relatively deeper waters, move into shallower areas during the monsoon period resulting in high catches and catch rates along Kerala coast. Nair and Reghu (1990) have shown that all along the southwest coast, the threadfin breams migrate and concentrate in the 41 – 80 m depth strata during June - September.

The ribbonfishes form a major and abundant fishery resource among the marine pelagic fishes of the Indian seas. The importance of this resource has increased considerably due to the export potential and hence has become a target group recently. Currently, large quantities of
ribbonfish are exported in the frozen form to Japan, China and other south east Asian countries. Along the west coast, during the monsoon period (June – July), the resource enters the fishing ground and the production increases and reaches a peak in the fourth quarter. In Kerala, peak landings are observed during October – December period with considerable interannual fluctuations. Ribbonfishes are abundant in the coastal waters of depth range 25 – 75 m (Nair and Prakasan, 2003). Rao et al. (1977) observed good concentrations of ribbon fishes upto 80 m depth along the Kerala coast from April to September.

In India, the whitebaits resource contribute on an average 1.7 to 5.8 % to the total marine fish landings and is mostly exploited from the southern maritime states. The landings from Kerala, Tamilnada and Karnataka accounts for 75 – 97 % of the total production of whitebaits (Jayaprakash, 2003). Whitebaits are confined to the Gulf of Mannar and Cape Comorin during the southwest monsoon season and later spreads along the west coast of India up to about 17ºN latitude (Blindheim and Monstad, 1976; Pillai, 1982). Jhingran (1975) noted that the spawning of whitebaits take place from November to March. They are normally found at bottom depths between 10 - 50m and exhibit typical diurnal migration. In November -December, the whole stock spreads along the southwest coast and by July-August, the stock is accumulated in the Gulf of Mannar. The distribution of whitebaits are also related to favorable environmental conditions (Anon., 1976).

Lizard fishes comprise an important component of the demersel fish resource of India. This group assumes significance by virtue of their high nutritive value and their acceptance as food both in the fresh and dry condition. Lizard fishes, in general, are graded “very good” for the preparation of surumi. Kerala contributes approximately 43.3% to the lizard fish landings in India and high catch rates are recorded in the third quarter (July – September) of the year. The abundance of lizard fishes increases from 20 – 40 m depths upto 150 – 200 m depths (Sivakami et al., 2003).
5.3 Materials and methods

The fishery data used for analysis has been adopted from the estimates of marine fish landings along the Indian coasts carried out by CMFRI, Cochin, employing the Stratified Multistage Random Sampling Design (Srinath, 2003).

The selection of species for the present study were based on important criteria and included the order of abundance, availability according to the landings data and their commercial importance. Thus, the monthly estimates of the landings (t) of oil sardine, mackerel, penaeid prawns, cephalopods, threadfin breams, ribbonfishes, whitebaits and lizard fishes for the Cochin zone during 2000 - 2002 were utilized.

The monthly landings data for the period 2000 – 2002 of the different species were plotted against sea level and rainfall anomaly for the corresponding months to study the influence of these factors on the observed variations in the availability and abundance of these resources.

The trends in fish production and seasonal distribution of various hydrobiological parameters were statistically analyzed to understand the relationship between these parameters and the availability of the different species.

5.4 Results

Data on the monthly and total annual landings of eight marine fish species for the period 2000 - 2002 were collected. The details are illustrated in Table 5.1 and Figs. 5.1 to 5.8.

The annual oil sardine landings at Cochin during 2000 and 2001 were 6963 t and 6200 t respectively but, increased to 7215 t in 2002 (Table 5.1). The fishery commenced by March - April and good landings were recorded till November; peak landings being recorded in April – May. The pattern of sardine landings showed wide interannual variations. The
enhanced landings in 2002 was mainly due to the higher landings in June, in addition to the normal quantum in other months. During June – August the landings were poor and a more or less similar observation was made during December – February also (Fig.5.1).

Mackerel landing were of the order of 887 t in 2000 while it decreased to 618 t in 2001. However, the landings increased considerably to 1218 t in 2002. The fishery started from May- June and high landings occurred in September – October. The landings were, however, very poor during November – January but gradually improved thereafter. The comparatively poor landings during the peak period (September – October) accounted for the low annual values in 2001 (Fig.5.2).

The penaeid prawns showed considerable fluctuation in total annual landings during 2000 – 2002. The maximum landings of 11203 t was recorded in 2000 while in 2001 it was as low as 5920 t (Table 5.1). The landings registered an increase in 2002 (9255 t). Generally, the landings of prawns were high during March - May and also in August. However, it was comparatively low through out the year in 2001, especially during the peak fishing season and accounted for the low annual landings (Fig.5.3).
The cephalopod landings in 2000 was 6413 t but it declined to 4003 t in 2001 and to 4240 t in 2002. Peak landings were observed during August – September and the highest landings registered in 2000 coincided with the high values in September - October (Fig.5.4).
The fishery of threadfin breams commenced from April / May and peak landings occurred in August. In 2000, the quantum of threadfin breams landed at Cochin was 4442 t, while in 2001 it was 4102 t (Table 5.1). However, the landings increased substantially to 7118 t in 2002. The comparatively poor landings obtained during August – September resulted in a rather low annual value in 2001 whereas the higher landings in August contributed to the higher value in 2002 (Fig.5.5).
Ribbonfishes landed at Cochin was maximum in 2001 and amounted to 3963 t. In 2000, the recorded landing was 3640 t while a low landing of 3235 t was obtained in 2002. The fishery for ribbonfishes commenced from May and peak landings were recorded in October. The comparatively good landings obtained in October 2000 and in November 2001 led to the higher annual values of the corresponding years. Major landings occurred only in October and resulted in a low annual catch of ribbonfishes in 2002 (Fig. 5.6).

![Fig 5.6 Monthly landings (t) of ribbonfish at Cochin during 2000-2002](image)

Whitebaits landings was only 1466 t in 2000 but increased to 1757 t in 2001 and a substantial increase in annual landings of 2888 t was recorded in 2002 (Table 5.1). The peak period of whitebaits availability was November and the landings during this month contributed significantly to the enhancement or reduction in annual landing of the respective year. The landings during March to May period was also found to be high. However, June to September and January to February were lean periods for whitebaits (Fig. 5.7).
Lizard fishes registered the highest landings (1852 t) in 2000 and the lowest (1218 t) in 2002. The fishery for lizard fishes commenced from May and the peak period of availability was August - September. The fishery was poor during November – March period. The reason for the poor landings of lizard fishes in 2002 was due to the low output during September – October period when compared to the previous years (Fig.5.8).
The major landings of oil sardine was during April- May. On the contrary, the mean sea level values were found to be low during this period. The landings of mackerel however, was found to be lower when compared to oil sardine. Oil sardine and mackerel showed considerable variations in their landings during June – August in all the three years of study. Curiously enough, the sea level values were at its lowest during this period. The oil sardine landings were again higher in October – November period while the corresponding peak for mackerel were during September – October. The sea level gradually increased during this period from the lowest levels in July (Figs. 5.9 and 5.10).

Penaeid prawns, Cephalopods and lizard fishes recorded peak landings during August - September and their comparatively high landings in 2000 coincided with the corresponding low values of sea level recorded during the year. Threadfin breams landings were also at its peak in August and the higher values recorded in 2002 were also during the years of relatively low sea level (Figs. 5.11, 5.12, 5.13 and 5.16)

Oil sardine, mackerel, threadfin breams, penaeid prawns and cephalopods landings were comparatively low in 2001. It should be noted here that during this year, relatively high rainfall occurred during the monsoon and postmonsoon periods. In contrast, ribbon fish landings were higher in 2001 (Fig. 5.14). However, high landings of oil sardine, mackerel, threadfin breams and whitebaits were reported in 2002. Higher rainfall also occurred in the premonsoon period of the year (Table 5.2 and Fig.5.15). The penaeid prawns, cephalopods and lizard fish landings were higher in 2000. The rainfall received during the year was much lower when compared to 2001 and 2002.
Table 5.1 Total annual landings (t) of the different fish groups at Cochin during 2000 – 2002.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil sardine</td>
<td>6963</td>
<td>6200</td>
<td>7215</td>
</tr>
<tr>
<td>Mackerel</td>
<td>887</td>
<td>618</td>
<td>1218</td>
</tr>
<tr>
<td>Penaeid prawns</td>
<td>11203</td>
<td>5920</td>
<td>9255</td>
</tr>
<tr>
<td>Cephalopods</td>
<td>6413</td>
<td>4003</td>
<td>4240</td>
</tr>
<tr>
<td>Threadfin breams</td>
<td>4442</td>
<td>4102</td>
<td>7118</td>
</tr>
<tr>
<td>Ribbon fishes</td>
<td>3640</td>
<td>3963</td>
<td>3235</td>
</tr>
<tr>
<td>Whitebaits</td>
<td>1466</td>
<td>1757</td>
<td>2888</td>
</tr>
<tr>
<td>Lizard fishes</td>
<td>1852</td>
<td>1464</td>
<td>1218</td>
</tr>
</tbody>
</table>
Table 5.2  Total seasonal rainfall recorded at Cochin during 2000-2002 and trend in landings of the fish groups studied

<table>
<thead>
<tr>
<th>Year</th>
<th>Date of onset of monsoon</th>
<th>Pre monsoon</th>
<th>Monsoon</th>
<th>postmonsoon</th>
<th>oil sardine</th>
<th>mackerel</th>
<th>Penaeid prawns</th>
<th>Cephalopods</th>
<th>Threadfin breams</th>
<th>Ribbon fishes</th>
<th>White - baits</th>
<th>Lizard fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1st June</td>
<td>479.4</td>
<td>1621.4</td>
<td>375</td>
<td>High</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>23rd May</td>
<td>597.4</td>
<td>1927</td>
<td>669.6</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>2002</td>
<td>10th June</td>
<td>616.4</td>
<td>1614.6</td>
<td>573.6</td>
<td>High</td>
<td>High</td>
<td></td>
<td>Hgh</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
Fig. 5.9 Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly oil sardine landings during 2000-2002.

Fig 5.10 Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly mackerel landings during 2000-2002.
Fig. 5.11 Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly penaeid prawn landings during 2000-2002

Fig. 5.12 Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly cephalopod landings during 2000-2002
Fig. 5.13 Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly threadfin breams landings during 2000-2002

Fig. 5.14 Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly ribbonfish landings during 2000-2002
Chapter 5  

Influence of Hydrobiology on Fisheries

**Fig. 5.15** Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly whitebait landings during 2000-2002

**Fig. 5.16** Graph showing the monthly anomalies in sea level and rainfall at Cochin and monthly lizardfish landings during 2000-2002
Information gathered on the landings of selected species were subjected to statistical analysis to delineate their relationship with various hydrobiological features. The results of correlation analysis are presented in Tables 5.3 and 5.4.

In general, the fishery resources did not show significant correlation with any of the hydrobiological parameters considered in the present study. However, whitebait landings showed negative correlation with DO at surface and positive correlation with sea bottom temperature \((p < 0.05)\) (Tables 5.3 and 5.4). Cephalopod and lizard fish landings also were negatively correlated with the vertical stability at bottom \((p < 0.05)\) (Table 5.4).
Table 5.3 Correlation coefficient (Pearsons) between the hydrobiological parameters at surface (stations 1, 2, 3 and 4 combined) and landings of different fish groups at Cochin during 2000 - 2002

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Oil sardine</th>
<th>Mackerel</th>
<th>Penaeid prawns</th>
<th>Cephalopods</th>
<th>Threadfin breams</th>
<th>Ribbon fishes</th>
<th>White baits</th>
<th>Lizard fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawater temperature</td>
<td>0.258</td>
<td>-0.234</td>
<td>0.11</td>
<td>-0.307</td>
<td>-0.249</td>
<td>0.074</td>
<td>0.223</td>
<td>-0.329</td>
</tr>
<tr>
<td>Density</td>
<td>0.122</td>
<td>-0.125</td>
<td>0.043</td>
<td>-0.115</td>
<td>-0.097</td>
<td>-0.028</td>
<td>0.023</td>
<td>-0.277</td>
</tr>
<tr>
<td>Vertical Stability</td>
<td>-0.152</td>
<td>0.189</td>
<td>-0.182</td>
<td>0.197</td>
<td>0.039</td>
<td>0.119</td>
<td>-0.125</td>
<td>0.271</td>
</tr>
<tr>
<td>Salinity</td>
<td>0.153</td>
<td>-0.131</td>
<td>0.054</td>
<td>-0.131</td>
<td>-0.119</td>
<td>-0.01</td>
<td>0.06</td>
<td>-0.29</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>-0.216</td>
<td>0.37</td>
<td>-0.293</td>
<td>0.352</td>
<td>0.081</td>
<td>0.358</td>
<td>-0.463(*)</td>
<td>0.142</td>
</tr>
<tr>
<td>Phosphate</td>
<td>-0.23</td>
<td>0.109</td>
<td>0.196</td>
<td>0.025</td>
<td>0.14</td>
<td>-0.172</td>
<td>0.149</td>
<td>0.175</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.116</td>
<td>0.086</td>
<td>-0.178</td>
<td>-0.003</td>
<td>0.029</td>
<td>-0.116</td>
<td>-0.153</td>
<td>0.079</td>
</tr>
<tr>
<td>Silicate</td>
<td>0.197</td>
<td>0.028</td>
<td>-0.029</td>
<td>0.169</td>
<td>0.027</td>
<td>0.263</td>
<td>0.261</td>
<td>0.19</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>-0.021</td>
<td>0.08</td>
<td>-0.034</td>
<td>0.0</td>
<td>-0.152</td>
<td>-0.22</td>
<td>-0.111</td>
<td>0.005</td>
</tr>
<tr>
<td>Zooplankton biomass</td>
<td>-0.231</td>
<td>0.401</td>
<td>-0.101</td>
<td>0.226</td>
<td>0.092</td>
<td>0.331</td>
<td>-0.28</td>
<td>0.138</td>
</tr>
<tr>
<td>Sealevel</td>
<td>0.329</td>
<td>0.064</td>
<td>-0.056</td>
<td>0.069</td>
<td>-0.309</td>
<td>0.155</td>
<td>0.328</td>
<td>0.059</td>
</tr>
<tr>
<td>Rainfall</td>
<td>-0.011</td>
<td>0.212</td>
<td>0.113</td>
<td>0.162</td>
<td>0.13</td>
<td>0.119</td>
<td>-0.086</td>
<td>0.377</td>
</tr>
</tbody>
</table>
Table 5.4 Correlation coefficient (Pearson's) between the hydrobiological parameters at bottom (stations 1, 2, 3 and 4 combined) and landings of different fish groups at Cochin during 2000 – 2002.

<table>
<thead>
<tr>
<th></th>
<th>Oil sardine</th>
<th>Mackerel</th>
<th>Penaeid prawns</th>
<th>Cephalopods</th>
<th>Threadfin breams</th>
<th>Ribbon fishes</th>
<th>Whitebaits</th>
<th>Lizard fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seawater temperature</strong></td>
<td>0.344</td>
<td>-0.181</td>
<td>0.229</td>
<td>-0.351</td>
<td>-0.253</td>
<td>0.004</td>
<td>.491(*)</td>
<td>-0.314</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>0.011</td>
<td>0.18</td>
<td>-0.308</td>
<td>0.173</td>
<td>-0.109</td>
<td>0.293</td>
<td>-0.2</td>
<td>-0.08</td>
</tr>
<tr>
<td><strong>Vertical Stability</strong></td>
<td>-0.171</td>
<td>-0.33</td>
<td>0.132</td>
<td>-.505(*)</td>
<td>-0.226</td>
<td>-0.289</td>
<td>0.232</td>
<td>-.426(*)</td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>0.032</td>
<td>0.126</td>
<td>-0.239</td>
<td>0.077</td>
<td>-0.163</td>
<td>0.272</td>
<td>-0.079</td>
<td>-0.155</td>
</tr>
<tr>
<td><strong>Dissolved Oxygen</strong></td>
<td>-0.295</td>
<td>0.119</td>
<td>0.088</td>
<td>0.02</td>
<td>0.126</td>
<td>-0.266</td>
<td>-0.054</td>
<td>0.155</td>
</tr>
<tr>
<td><strong>Phosphate</strong></td>
<td>0.182</td>
<td>-0.04</td>
<td>0.077</td>
<td>0.272</td>
<td>0.25</td>
<td>-0.06</td>
<td>-0.155</td>
<td>0.294</td>
</tr>
<tr>
<td><strong>Nitrate</strong></td>
<td>0.102</td>
<td>0.043</td>
<td>-0.023</td>
<td>0.216</td>
<td>0.177</td>
<td>0.091</td>
<td>0.001</td>
<td>0.227</td>
</tr>
<tr>
<td><strong>Silicate</strong></td>
<td>0.059</td>
<td>-0.094</td>
<td>-0.172</td>
<td>-0.203</td>
<td>-0.183</td>
<td>-0.34</td>
<td>-0.192</td>
<td>-0.191</td>
</tr>
<tr>
<td><strong>Chlorophyll a</strong></td>
<td>0.329</td>
<td>0.064</td>
<td>-0.056</td>
<td>0.069</td>
<td>-0.309</td>
<td>0.155</td>
<td>0.328</td>
<td>0.059</td>
</tr>
</tbody>
</table>

* Correlation is significant at 0.05 level (2-tailed)
5.5 Discussion

The southwest coast of Indian subcontinent is characterized by three major seasons – the premonsoon season (February - May), the monsoon period or the southwest monsoon season (June – September) and the postmonsoon season (October – January). Each of these seasons have characteristic oceanographic circulation patterns that determine the pattern of distribution of species assemblages on the southwest coast of India (Srinath et al., 2003). A perusal of the fishery data from the Cochin region revealed considerable interannual variations in landings of the selected species (Table 5.1) and were primarily related to the southwest monsoon and the associated upwelling.

Data on the hydrobiology of the study area revealed that during southwest monsoon, the characteristics of surface and bottom waters were indicative of the process of upwelling along the coast. The properties of the coastal water during this period were typical of the bottom waters which upwelled from deeper depths within the shelf region. The low temperature, poorly oxygenated, high saline waters with high nutrient content occupied the subsurface depths of the coastal region (Figs. 4.1 and 4.2). The intensity and duration of the process were well reflected in the water characteristics of the nearshore region. Vijayakumaran (2004) and Krishnakumar and Bhat (2008) observed that certain water properties of the inshore and nearshore regions serve as useful indicators of upwelling.

An assessment of the physicochemical properties of coastal water indicated that the upwelled water remained at subsurface levels in the coastal region till September/October. The temperature and dissolved oxygen values at bottom depths during the early postmonsoon period confirmed the prevalence of upwelling beyond the monsoon season. However, the substantially low nutrient values observed during the
postmonsoon season could be attributed to their increased utilization for primary production.

Generally high chlorophyll a and zooplankton biomass was observed at the surface during postmonsoon season (Tables 3.6 and 3.7). The sinking process which follows upwelling, coincides with the reversal of currents giving rise to convergence along the coast resulting in large scale aggregation of phyto and zooplankton population in the convergence zones (Anon., 1976; Pillai et al., 1998). The occurrence of pelagic fish shoals in large quantities for feeding in these regions during this period have been reported (Rao et al., 1973). Devaraj and Vivekanandan (1999) reported record catches during upwelling and the subsequent periods from the west coast of India.

It can be inferred from the sea level data that the process of upwelling commenced much earlier than the actual onset of the southwest monsoon and that the declension in mean sea level continued till July. The observed variations in intensity of the process could be understood from the relative variations in sea level value. It was further noted that upwelling was comparatively stronger in 2000, as evidenced by the steady fall in sea level from April to July where as the relative drop in sea level was less during 2001 and a concomitant weak upwelling (Fig.2.17).

With regard to the fishery of the different species under consideration, it was noted that the process of upwelling resulted in characteristics changes in water properties within the shelf and nearshore regions, greatly influencing the abundance and availability of these species.

The oil sardine stock was abundant during the premonsoon season along the coast and resulted in good landings in April and May. The major landing period of the season coincided with the period of low sea level. It was observed that during the early part of upwelling period, the stock appeared in large quantity along the coast. Oil sardine and mackerel
landings were considerably low during 2001. Curiously enough, the poor landings of oil sardine coincided with the late arrival of bulk stock in May as observed from the landings data in 2001. The drop in sea level also occurred relatively late in 2001 when compared to 2000 and 2002.

Timely occurrence of upwelling triggers favourable environmental conditions for the breeding and spawning of many commercially important pelagic fishes. Fluctuations in the process have an adverse effect on spawners, their spawning activity and the required food availability for the adults, especially the larvae at their critical period of first feeding (Longhurst and Wooster, 1990). They have reported that the success of recruitment in the early part of the season influences the landing of the species of the single year class during the year. The abundant food availability during upwelling period, causes the stock to remain within the coastal waters affording good landings. The juveniles spawned earlier in the season also contribute substantially to the fishery during the monsoon and postmonsoon period.

During the present study it was observed that the premonsoon availability of mackerel was low unlike oil sardines during all the three years of study. This could possibly be due to the fact that the stock is more widespread during this period and that the congregation of stock do not occur resulting in a substantial fishery. The very low and substantially high landings observed in 2001 and 2002 respectively, therefore, may not be a true reflection of the different conditions which prevailed during the corresponding years. At the same time, fishery dependant factors may also have influenced the landings. A striking feature of the observations made was that it does not support the inverse relationship between the annual landings of oil sardine and mackerel as reported earlier (Raja, 1969) instead, the two species were found to exhibit a more or less similar trend in abundance.

Mechanized fishing activities have been prohibited or partial during June – August following a ban imposed on monsoon trawling by the Kerala
State Government authorities since 1988 (Mohamed et al., 1998). Though, there was no uniformity in the duration and period of ban between 1989 and 1995, from 1996 onwards a 45 days trawl ban from 15th June to 29th July has regularly been in operation (Nandakumar et al., 2001). Landings during summer monsoon are therefore, not a true representation, since, fishing is restricted during peak monsoon (Madhupratap et al., 2001). Fishing by the smaller crafts which are permitted to carry out fishing during the ban period are also limited due to the unfavourable weather conditions during the season. Hence, the landings data may not truly represent the fish stock as the actual fishing effort by the traditional units vary during the ban period. However, Yohannan et al. (1999) reported that with the introduction of powerful outboard engines, the fishing activity during the monsoon has become easier resulting in increased exploitation. It was observed during the present study that the proportion of landings during the ban period varied widely in the case of oil sardine and mackerel in all the three years. These variations in landings, considerably influenced the annual landing figures. However, it is also important to note that, unlike in the premonsoon period, the landings of both the species were consistently high during the latter part of monsoon and early post monsoon periods following the peak period of upwelling.

Earlier workers have attempted to correlate landing data with rainfall. Longhurst and Wooster (1990) reported that unusually high or low sardine catch is related to periods of unusually high or low rainfall. Analysis of the data revealed that the low catches of oil sardine, mackerel, threadfin breams, penaeid prawns and cephalopods in 2001 were influenced by the intense rainfall during the monsoon season, which was 20% higher than that in 2000 and 2002 (Table 2.2). Interestingly, the higher landings of oil sardine, mackerel and threadfin breams occurred in 2002 and coincided with the comparatively high rainfall in the premonsoon period of the year. The mean sea level during May 2002 was also relatively low indicating the commencement of a strong upwelling.
Jayaprakash (2002) observed that the events in the early part of the year, have the greatest influence on the size of the sardine stock in the subsequent fishing season. According to him, periods of intense rainfall have a positive effect on sardine abundance and visa versa. Contrary to the observations made by Longhurst and Wooster (1990) and Madhupratap et al. (1994), the oil sardine landings depicted sizable reduction with an early onset of monsoon (Table 5.2). In the case of whitebaits, the rainfall data did not evince any relationship. On the other hand, intense rainfall (in 2001) resulted in good landings of ribbonfishes. During periods when rainfall was low in the premonsoon and postmonsoon season as in 2000 when compared to 2001 and 2002, lizard fishes cephalopods and penaeid prawns landings were found to be comparatively high.

Nandakumar and Maheswarudu (2003) reported that *M. dobsonni* and *P. stylifera* are the major constituents of the penaeid prawn fishery, contributing 90% to the catch at Cochin. It was observed during the present study that penaeid prawns were abundant in the premonsoon period from March to May, accounting for 40% of the annual landings. According to Nandakumar et al. (2001), fishing operations are mainly targeted at commercial species such as *P. stylifera* and *M. dobsonni* upto 30 m in non monsoon months. Experimental shrimp trawling off Cochin have established that during June – July, *P. stylifera* migrates in large numbers to the off shore area up to about 60 m depth as a result of upwelling (Suseelan et al., 1989). High landings of penaeid prawns were observed in August during the present study also. It is therefore reasonable to assume that heavy recruitment of juveniles to the *P. stylifera* fishery takes place in the month of June and July and the trawl ban in operation during the first half of monsoon could help this juveniles to grow into larger size and contribute to the fishery in August (Nandakumar et al., 2001). Reports based on average annual landings (1988 – 1997) in the state (Kerala) have indicated a conspicuous increase (82%) in the
landings of penaeid prawns during the ban period (Ammini, 1999). From the present data, it is clearly evident that the higher landings of penaeid prawns in 2000 and 2002 did occur when the intensity of upwelling was comparatively high.

In the case of cephalopods and lizard fishes, abundant landings were obtained during August - September following peak upwelling and the highest landings recorded in 2000 coincided with the comparatively high upwelling intensity.

The landings of threadfin breams was at its peak in August, immediately after the peak period of upwelling in July. The highest seasonal and annual landings occurred in 2002, while the lowest values were obtained in 2001. Pillai et al. (1998) reported that threadfin breams exhibit a shoreward as well as along shore migration following the movement of cold, high saline and oxygen deficient upwelling waters during the southwest monsoon. Murthy et al. (2003) also reported that threadfin breams move to inshore waters due to the influence of upwelling during monsoon period along the west coast of India and contributing substantially to trawl fishery during this period. However, a ban on fishing during monsoon period along the west coast states have resulted in reduced exploitation of these resources during the peak period of their abundance. The comparatively less intense upwelling observed in 2001 coincided with a heavy rainfall during the monsoon period would have adversely affected the movement of the species into the inshore regions resulting in comparatively poor landings during the year (Table 5.1).

Banse (1959,1968) observed that some demersal fishes suddenly disappear from the shallow areas with the onset of the southwest monsoon. James et al. (1983) and Pillai et al. (1999) noticed that certain deep water fishes are available in the shallower areas of the sea particularly during the post southwest monsoon. Following upwelling, there is an abundance of phytoplankton and zooplankton along the coast and
these fishes move towards the coast to take advantage of the available food. The striking difference observed in the landings of lizard fishes to that of cephalopods and threadfin breams was that, though, all of them are demersal in nature, their peak annual landings did not occur in the same year. The lizard fish landings were low in 2002 while that of cephalopods and threadfin breams were in 2001. In contrast, the peak landings of lizard fishes and cephalopods were in 2000 while that of threadfin breams occurred in 2002. Variations in the availability of these resources in their traditional fishing grounds are mainly related to the factors arising from the variations in intensity and duration of upwelling. This, coupled with a reduction in fishing effort during the monsoon season would have resulted in the observed variations in landings among the different species. From the present data it appears that the availability of cephalopods and lizard fishes are more related to feeding as their abundance occurred from August to early postmonsoon season, till the end of the upwelling period in October. Further, a negative correlation was observed among these fish groups and vertical stability at bottom depths (Table 5.4). Reduction in vertical stability at bottom depths during the southwest monsoon season have been reported earlier, as an indication of upwelling (Ramamirtham and Nair, 1964; Pillai, 1989). On the other hand, the major landings of threadfin breams decreased considerably after the peak/intense period of upwelling in August suggesting that their availability is more related to the intensity of upwelling which results in large scale changes in the oceanographic properties both at the surface as well as subsurface layers of the sea as observed by Pillai et al. (1999).

Sinking is the process which follows upwelling and is characterized by the downward movement of the comparatively dense surface layers. Sinking begins during September along the Cochin – Kasaragod sector and ends by January. The period of sinking along the southwest coast (October – March) coincides with peak fishing season. Convergence which prevail during this period facilitate concentration of zooplankton, which in turn, results
in the formation of dense schools of small pelagics which feed predominantly on zooplankton, facilitating their good catches (Ramamirtham and Jayaraman, 1961; Pillai, 1982). Nair and Prakasan (2003) reported that ribbonfishes move to the inshore waters during monsoon and contribute abundantly to the fishery in the postmonsoon period. It was observed during the present study that 60 to 80% of the total annual landings of ribbonfishes were during September-October period. It is possible that these species move in large quantities into the coastal waters for feeding following cessation of upwelling resulting in bumper landings.

The peak period of occurrence of whitebaits is found to be November consequent to the reversal of surface currents in October along the southwest coast of India. The species is confined to Gulf of Mannar region during the peak southwest monsoon period and later spreads along the south west coast during November-December (Blindhem and Monstad, 1976). The cessation of upwelling and the availability of plankton blooms provide whitebaits a favourable environment for the commencement of northward migration along the southwest coast (Pillai et al., 1980). The higher landings of whitebaits observed during March – May in the present study can be related to the return migration of the stock along with the southerly current which prevailed during this period.

The physical, chemical and biological oceanographic conditions prevailing in a particular region and their characteristic variations have a profound influence on the periodic and seasonal availability of fishes in that area. However, significant correlation could not be observed during the present study with regard to most of the selected fish groups and hydrobiological parameters (Tables 5.3 and 5.4). According to Madhupratap et al. (1994) any lack of correlation is not surprising considering the complexity of the physical and biological processes which occur in the sea. The stock abundance of every species is dependent on the favourable environmental conditions which support their successful spawning and subsequent larval growth. Time lag in the availability of
appropriate food due to breaks in monsoon/upwelling would be detrimental to the recruitment of juveniles (Pillai et al., 1998). Mann (1993) observed that merely obtaining a correlation does not imply the cause and effect as correlations hold good only for a few years and then break down.

Results based on field oriented time series data on the above parameters are essential to develop predictive models for the efficient exploitation of the marine fishery resources. Further, data from the satellite imageries also serve a very useful tool in locating and identifying fish concentrations at specific regions in the sea.

The ban on trawling is in effect during the monsoon period which coincides with the peak spawning season of most of our commercially important pelagic fishes. Demersal fishes also move to the surface layers as a result of upwelling during this period. According to Kurup (2001), the partial monsoon trawl ban introduced from 1988 along the coast of Kerala has a beneficial effect on the fishery, both on trawl landings and catch rates. Yohannan et al. (1999) is of the view that the intensified ring seine operations following introduction of powerful outboard engines along the coast of Kerala during the ban period has resulted in increased exploitation of the early juveniles and as a result, the fish stock can decline very fast. The fishing pressure and indiscriminate fishing practices can also eventually lead to depletion of the fishery stock. However, it is significant to note here that the trawl ban may result in the reduced exploitation of some of the demersal fishery resources which are abundantly available during this period. It is therefore, necessary to formulate and implement effective fishery management policies so that the resources can be better protected and sustainability maintained for future benefit of the nation.