Environmental Characteristics of the coastal waters and seasonal abundance of ornamental fishes

K.K Philipose “Distribution of marine ornamental fishes along the malabar coast with studies on the biology of important species” Thesis. Department of Zoology, St.Joseph's College Devagiri, University of Calicut, 2006
Chapter 4

Environmental Characteristics of the Coastal waters and Seasonal Abundance of Ornamental Fishes.

4.1. Introduction

Environment plays an important role in fish behaviour and abundance, which in turn profoundly influence the fishery. Information available on the environment and behaviour of marine ornamental fishes in the area and concerned data collected during the study period are summarized in this chapter.

Hornell and Nayudu (1923) gave detailed description of the physical and climatic characteristic of Malabar and the details of planktons in the coastal waters. Observations on the surface sea temperature from Calicut were later made by Chidambaram (1950), Pradhan and Reddy (1962), George (1953) and Kasturirangan (1957), which showed that the annual maximum of inshore sea temperature reaches by April/May. The lowest temperature of about 25°C was found in July/August and only in October/November there was a remarkable increase. Seshappa and Jayaraman (1956) observed the temperature at 19-meter depth where the temperature in pre-monsoon months was as high as that of surface and minimum temperature during August/September. Banse (1959) opined that the sudden decrease in temperature after the fury of monsoon subsides was caused by upwelling of cold bottom water with low oxygen content regularly found during the whole period of South-west monsoon. The proof of the deduction that the upwelling was the reason for peculiar
temperature condition in the Malabar Coast was the rise of temperature towards the open sea. This upwelling water coming from near the oxygen minimum layer was found to drive away the demersal fishes from the broad belt parallel to the coast.

Sharma (1968) studied the upwelling along the Calicut coast. The thermocline with temperature below 25°C start moving up from a depth of about 115 meters in February and by June reaches a depth of about 15 meters. By the middle of June a slight sinking to a depth of about 20 meters take place to rise again to a depth less than 10 meters by September. Then the sinking starts and reaches a depth of about 110 meters by November. The oxygen content of this upwelling water was found to be about 2.5 ml/L. Maximum intensity of upwelling is in Calicut-Karwar region (Ramasastry and Myrland, 1959; Rao and Ramamritham, 1976; Ramamritham and Rao, 1974). During July and August, the surface mixed layer become more or less obliterated with temperature declining to 26° and oxygen deficit layer migrating even up to the surface.

Anon (1976a) explained the upwelling phenomenon in this area in detail. The process starts in March/April and ends in October/November. In 1974 August, Cochin and Kasargod sections exhibited 1 ml O²/L at a depth of 20m. At outer stations it sloped down to 40m. With the slowing down of the southward coastal flow and setting or northward flow 1 ml O²/L start retreating. Upwelling either started first in north and slowly spread to south or it happened in the entire area within a short period. Similarly, sinking either starts in the south and spread to north slowly or it happens approximately the same time. The strength of upwelling varies from year to year. Though, upwelling start well in advance of monsoon, it is caused directly or indirectly by wind system. The low oxygen concentration below the
thermocline, which during upwelling is very shallow, forces the pelagic fishes towards the surface.

Seshappa and Jayaraman (1956) studied the phosphate cycle in the inshore waters of Malabar Coast and found that the bottom mud contains large quantities of interstitial and absorbed phosphates in the non-monsoon period. During monsoon there is a rapid release of phosphates into the overlying column of water and the quantity of phosphate in water increase to a maximum by August/September.

Subramanian and Sarma (1965) gave the volume of plankton in the coastal waters of Calicut during the years 1955-’62. They found a peak production of phytoplankton during the southwest monsoon, but fluctuated widely from year to year. Peak nanoplankton was in July and September, which is crucial for survival of fish larvae. 30-50% of the total phytoplankton was constituted by nanoplankton. The magnitude of phytoplankton in the Malabar area is of a very high order. From observations made by Mukundan (1967) it can be deducted that zooplankton abundance in Calicut waters increase by August and it is generally good till October.

Upwelling along the coast appeared to trigger the primary production, which was followed closely by secondary production of zooplankton. Zooplankton biomass tended to increase after April towards a peak sometime before December and fell into low values subsequently, January to April being a lean period. In general, January to March is a period of low plankton density over the shelf, April to June a period of moderate densities. July to September/October is the time of high plankton densities along the southwest coast of India then there is a fairly uniform concentration of plankton slightly beyond the near shore waters all along the coast. (Anon, 1976 b).
Johannessen et. al., (1987) made a study of the oceanographic conditions of the southwest coast of India, especially the water masses, coastal currents and upwelling. He observed that the fishes concentrate in the surface layer due to oxygen deficiency below the oxycline. Ornamental fishes were present in the area also during monsoon month, but even though they are not visible during rougher weather conditions of monsoon, they occurred in the deeper areas of the reef. Johannessen et. al., (1987).

According to Madhupratap et. al., (1994) upwelling and river runoff make the coastal surface waters nutrient rich and the primary production shoots up. Concomitant changes are discernible in zooplankton population. Higher density is sustained even after southwest monsoon period up to December. The increase of zooplankton need not necessarily depend on phytoplankton abundance alone, but can happen through the microbial loop (bacteria – heterotrophic flagellates – micro zooplankton – mesoplankton) or a short circuit of the loop (bacteria – ciliates – mesozooplankton). Presence of micro zooplankton during introduction of freshwater plumes can enhance zooplankton production by several hundred percent which happens along the coastal waters of west coast in rainy season.

Madhupratap et. al., (1994) had given changes of circulation of surface waters of the north Indian Ocean month by month. From February/March the coastal drift is southwards. An anticyclonic vortex is seen near Kerala coast, between Calicut and Cochin, which shifts westwards by April and disappear in May. By June the equator ward circulation move around the peninsula and a branch move north along the coast by October the reversal of southward flow set in and by November the drift is clearly northwards along the Malabar Coast. These changes in the coastal currents are basically due to monsoon currents.
During northeast monsoon the current is towards west causing a northward drift along the Malabar Coast. During the southwest monsoon the current is from east resulting in a southwards drift from February/March to October.

Ramamritham and Rao (1974) have observed strong southern drift especially in the region Calicut-Karwar, prominent in the upper layers during southwest monsoon. It starts in February, gets stronger and by June is well developed. It is most energetic during July-August, the peak southwest monsoon season. Data collected in 1987-88 showed a depth of 75-100 meters for this movement in June with a width of 150 Km (Madhupratap, et.al., 1994).

In general seasonal variations is oceanographic conditions are very repetitive from year to year. During southwest monsoon period, May to October the currents flow southwards, causing uplifting of isoclines for different oceanographic parameters near the coast and generates upwelling most strongly in August/September when water with oxygen content of less than 0.5 ml/L is observed to cover the whole shelf area over the bottom. In the northeast period, November to March, the current system reverses; thereby transporting the low salinity water from equatorial region called equatorial surface water with salinity less than 32.6% is seen up to a depth of 50-60m. In March the flow is reversed to southward and the low salinity equatorial surface water retreats and salinity increases to 33.4% (Anon, 1976 a).

Pradhan and Reddy (1962) have given the temperature and salinity values of the Calicut coastal waters. Salinity values show a minimum in July corresponding to peak monsoon and river runoff but the lowest temperature is recorded in August.
Marine ornamental fishes are found in the shallow water reefs along the Malabar coast. Their abundance in the coastal waters is greatly influenced by the environmental changes like salinity, Temperature, dissolved oxygen levels etc. Unlike in coral reef ecosystems, the rocky reef ecosystem undergoes seasonal changes and these changes greatly affects the fishes living within. Marine ornamental fishes are mostly resident fishes living in the crevices and rock pools. The onset of monsoon during the first week of June intensifies by July and brings in large amount of river run off into the coastal region and results in a decline in the salinity of the reef waters. The availability of marine ornamental fishes in the Thikkody reef ecosystem is discussed in this chapter and the results are given.

The present study was aimed to understand the influence of environmental characters in the abundance and seasonal variations of marine ornamental fishes along the Malabar coast.

4.2. Results

4.2.1. The Environment

4.2.1.1. Temperature

The average Temperature values for the year 2001 and 2002 showed that the lowest temperature 26.7°C was observed during July and the highest temperature 31.8°C during April. However there was a secondary peak 30.75°C was observed during December (Figure.4.1).

During 2001 the lowest temperature 27.2°C was observed during August 2001 and the highest temperature 32.6°C was observed during April 2001. The secondary peak 31.5°C was observed during December 2001 (Table.4.1). During 2002 the lowest
temperature recorded was 25.9°C observed during July 2002 and the highest 31.3°C during March 2002. The secondary peak 30.0°C was observed during December 2002(Table.4.2).

It can be seen that the temperature values of the surf water varied from 26.7°C to 32.6°C with averages between 26.7°C to 31.8°C during the study period.

4.2.1.2. Rainfall

The rainfall recorded at Thikkody during 2001 and 2002 is given in Table.4.1 & 4.2. In general the Calicut area receives an average annual rainfall of 350 cm to 375 cm. In 2001 the annual rainfall was 339 cm with highest rainfall 105 cm recorded during July 2001 and the lowest 2 cm recorded during March. During 2002 the highest rainfall 147 cm was recorded during July and the lowest 1 cm recorded during December 2002. When compared with 2001, rainfall during 2002 was fairly good with a total volume of 403 cm.

The Figure. 4.1 shows peak rainfall in June-July with a secondary peak in October. Good pre-monsoon showers normally occur in April/May. In 2001 pre-monsoon showers were fairly good recording 39 cm rain where as in 2002 the pre-monsoon showers recorded was only 25 cm. In 2002 southwest monsoon became active, rainfall started by 29th May, and it was heavy in June and July. The northwest monsoon was good in October recording 45 cm rainfall.

In 2001 after a very active monsoon in July there was a respite by 7th of August, which continued till 16th. By 10th September the rainfall subsided with only occasional showers afterwards. In 2002 there was intense rainfall in July but the respite came only by September 10th the cumulative rainfall in these years is shown in Figure. 4.1. The differences in July rainfall between the years are very clear. Normally a respite after intense
rainfall with good sunshine causes good fishing all along the coast. With a vigorous rainfall followed by a good lull always results in good fishing for ornamental fishes.

4.2.1.3. Salinity

The salinity increases from January and reaches a peak of around 35.0 ‰ by April. Like in the case of temperature, which comes down to the lowest value in July-August, the minimum salinity is observed in July when peak rainfall occurs. Salinity increases to a high value by December. The average salinity values for Thikkody surf waters for the year 2001 and 2002 are given in Figure.4.2. In 2001 the salinity values reached peak, 35.0 ‰ during April. Subsequent decline was very sharp to 29.9 ‰ during July. There was a secondary minimum with the northeast monsoon in November (Table.4.1). But in 2002 though the peak salinity was in April the decline was sharper than in 2001. The minimum salinity value 28.3 ‰ was observed in July 2002. The secondary minimum 33.4 ‰ was observed in November (Table.4.2).

4.2.1.4. Dissolved Oxygen

The two-year average oxygen values of the Thikkody surf waters increased from 4.25ml/l during January to a peak of 5.25ml/l during August and subsequently decreased to a minimum of 3.85ml/l during November (Figure.4.2). During 2001 the maximum oxygen value 5.7ml/l was observed during August and the minimum 4.1ml/l during December (Table.4.1). During 2002 the dissolved oxygen levels increased from 4.4ml/l during January to a peak in August and then declined in the following months. A secondary peak of 3.9ml/l was observed during December 2002 (Table.4.2).
4.2.1.5. Nitrite

The average values of nitrate in the surf waters of Thikkodi are given in Figure.4.3. The nitrate levels in the surf waters showed highest values in March and the lowest values in April. The nitrate levels showed a declining trend in the early months of the monsoon, then gradually increased to 0.38 Mu.g a/L during October, and again showed decline after the northeast monsoon. The nitrite value for the year 2001 and 2002 is given in Table.4.3 and Table.4.4 respectively.

4.2.1.6. Nitrate

The two yearly average nitrate values in the surf waters of Thikkody are given in Figure.4.3. The nitrate levels showed a peak in January and decreased in the pre-monsoon months. From July with the monsoon becoming very vigorous the nitrate values increased to a secondary peak during August. The lowest nitrate values were observed in November. The nitrate values for the year 2001 and 2002 are given in Table 4.3 and Table.4.4 respectively.

4.2.1.7. Silicate

The two yearly average silicate values in the surf waters of Thikkody are given in Figure.4.3. Similar to nitrate the silicate levels also showed a primary peak in January and minimum during October. The secondary peak after the monsoon was observed in August. The silicate values for the year 2001 and 2002 are given in Table.4.3 and Table.4.4 respectively.

4.2.1.8. Phosphate

The two yearly average phosphate values are given in Figure.4.3. The peak value for phosphate was observed in August after the peak monsoon and the minimum values
during December. The phosphate values for 2001 and 2002 are given in Table.4.3 and Table.4.4 respectively.

4.3.2. Seasonal abundance

50 species of marine ornamental fishes belonging to 18 families were monitored for their abundance in the fishery.

4.3.2.1. Acanthuridae

Members of the family Acanthuridae community known as surgeon fishes were represented in the fishery by 6 species. *Acanthurium nigricans, A.lineatus, A.matoides, A.leucosternon, A.Xanthopterus* and *Ctenochaetus strigosus*. Their abundance is given in figure.4.4.

4.3.2.2. Apogonidae

*Paramia quinquelineata* and *Apagon aureus* represented Apogonidae in the fishery and their abundance is given in Figure. 4.5.

4.3.2.3. Balistidae

Balistidae are very important marine ornamental fishes. *Odonus niger, Suflulanen Capistratus, Pseudobalistes flavimarginatus* and *Balistapus undulatus* represented balistidae in the fishery and their abundance is given in Figure.4.6.

4.3.2.4. Carangidae

Although carangids are very commonly available in the coastal waters only two species were taken in the present study for their ornamental value. *Trachinotus blochi* and *Trachinotus baillonii* was selected because of their rare beauty and adaptability to aquarium condition. Figure.4.7 shows the abundance of carangids in the Thikkody area.
4.3.2.5. Chaetodontidae

Butterfly fishes are probably the most important marine ornamental fishes available along the Thikkody coast. *Chaetodon collare, C.vagabundus, C.auriga* and *Heniochus acuminatus* were observed in the fishery. Figure 4.8 shows the abundance of butterfly fishes along the Thikkody coast.

4.3.2.6. Diodontidae

Porcupine fishes are very common in coastal waters. *Diodon hystrix* was observed in the fishery at Thikkody and Figure 4.9 shows its seasonal abundance.

4.3.2.7. Holocentridae

Commonly known as Soldier fishes and Squirrel fishes, holocentridae are very important aquarium fishes. Four species of holocentridae namely *Holocentrus diadema, H.ruher, Myripristus adustus* and *M.murdian* were represented in the fishery. Their seasonal abundance is given in Figure 4.10.

4.3.2.8. Labridae

Wrasses are some of the most beautiful marine ornamental fishes. Two species, viz *Thalassoma lunure, and labroides dimidatus* were observed in the fishery. Figure 4.11 the abundance of wrasses along the Thikkody coast.

4.3.2.9. Muraenidae

Morey eels are typical reef dwellers found throughout the coast. In Thikkody two species are represented in the fishery viz. *Gymnothorax favigineus* and *G.flavimarginatus*. Figure 4.12 shows its seasonal abundance.
4.3.2.10. Ostraciodontidae

Boxfishes and trunkfishes have rigid body made up of bony plates covered with a sensitive skin. In Thikkody two species were observed in the reef fishery viz. Lactaria cornuta and Ostracion tuberculatum. Their seasonal abundance is given in Figure.4.13.

4.3.2.11. Platacidae

Members of the platacidae are known as batfishes in the aquarium trade and are represented in the fishery by Platax orbicularis and Platax teira. Figure.4.14 shows the abundance of batfishes along the Thikkody coast.

4.3.2.12. Pomacanthidae

This family contains the highly sought after angelfishes. Angelfishes enjoy a unique place in marine aquaria for its beauty and elegance. Pomacanthus annularis is the only species recorded from Thikkody. Figure.4.15 shows its seasonal abundance.

4.3.2.13. Pomacentridae

Pomacentridae are the largest group observed in the fishery at Thikkody and Dharmadam. Neopomacentrus Cyanomos, N.filamentosus, N.nemurus, N.taeniurus. Abudufduf bengalensis, A.sexfasciatus, A.sexatilis, A.sordidus and A.septemfasciatus was the commonly available pomacentrids observed in the fishery. Figure.4.16 shows the abundance of pomacentrids along the Thikkody coast.

4.3.2.14. Scorpaenidae

Scorpion fishes or Lionfishes are highly sought after ornamental fishes for their easy adaptability to aquarium condition. Among the scorpion fishes Pterois volitans, P.antennata and P. radiata were observed in the fishery at Thikkody. Figure.4.17.
4.3.2.15. Serranidae

*Gramistes Sexlineatus, Cephalopholis boenack C.argus Epinepheles tauvina* represented Serranidae in the ornamental fishery in Thikkody. Their seasonal abundance is given in Figure.4.18.

4.3.2.16. Siganidae

Siganids are known as rabbit fishes in the ornamental fish trade and are very sturdy and sought after fishes. *Siganus Javus* is abundantly available in the Thikkody waters. Figure.4.19 shows the abundance of rabbitfishes along the Thikkody coast.

4.3.2.17. Tetradontidae

*Tetradon immaculatus* and *T.hispidus* represent puffer fishes in the fishery at Thikkody. Figure.4.20 shows their seasonal abundance.

4.3.2.18. Zanclidae

Zanclidae are known as Tobies or Moorish idols in aquarium trade. *Zanclus Cornutus* was the only species observed in the fishery. Figure.4.21 shows its seasonal abundance.

4.2.3. Discussion

It is observed that newly recruited juveniles of ornamental fishes start appearing in the coastal waters of Thikkody by October. Their abundance increases in January when surface temperature is the lowest. They maintain high abundance from November to March. The situation continues till the middle of May until the coastal waters become very rough prior to the monsoon. Surface temperature given by Hornell and Nayudu (1923) and Sheshappa and Jayaraman (1956) from July to September varied from 24.72°C to 26.6°C, with the mean value at 25.49°C. The present data gave an average value of 25.93°C. Since
November-march is the peak period of availability of ornamental fishes in the coastal waters, the optimum temperature for majority of the ornamental fishes in the coastal waters can be considered as around 25-26°C. When temperature of the coastal waters increase ornamental fishes goes to deeper region of the reef, probably for an environment of their temperature.

By May the coastal waters become very rough due to pre-monsoon turbulence and in June with the onset of Monsoon the temperature in the coastal waters decrease. The salinity also declines due to heavy river runoff this situation continues till the end of August along the Calicut coast (Yohannan and Balasubramanyan 1991). During this time the ornamental fishes are rarely collected in the cages in shallow waters and it is assumed that they moved to deeper waters to avoid the low saline waters along the coast (Philipose 1998).

During September intermittent algal blooms occur in the coastal waters almost on year after year basis with varying intensity. The resultant low oxygen water causes fish mortality along the Calicut coast. Sheshappa and Jayaraman (1956) reported this phenomenon and attributed this to the high production of phytoplankton in the inshore waters due to the abundance of nutrients resulting from upwelling. During 2001 and 2002 this was observed in the coastal waters. This also resulted in the movement of many ornamental fishes towards shallower regions of the reef.

Sharma (1968) studied the upwelling along the Calicut coast. The thermocline with temperature below 25°C start moving from a depth of about 115metres in February and by June reaches a depth of about 15metres. By the middle of June a slight sinking to a depth of about 20 Metres takes place and to rise again to a depth of 10 meter by September. Then the sinking starts and reaches a depth of about 110metres by November. The oxygen content of this upwelling water was found to be about 2.5ml/l. The maximum intensity of upwelling
is in Calicut – Karwar region (Ramasasy and Myrland 1959; Rao and Ramamrutham, 1976, Ramamrutham and Rao, 1974). During July and August, the surface mixed layer become more or less obliterated with temperature declining to 26°C and oxygen deficit layer migrating even to surface. This results in the movement of ornamental fishes in the reef to shallower regions and in extreme case results in mass mortality. Anon (1976a) explained the upwelling phenomenon in this area in detail. The process starts in March/April and ends in October/November. In 1974 August Cochin and Kasargod stations showed 1ml O₂/L at a depth of 20M. At outer stations it slopped down to 40 meter with the slowing down of the southward coastal flow and setting of northward flow, 1ml O₂/L start retreating. Upwelling either started first in north and slowly spread to south or it happened in the entire area within a short period. Similarly sinking either starts in the south and spread to north slowly or it happens approximately the same time. The strength of upwelling varies from year to year. Though upwelling start well in advance of monsoon, it is caused directly or indirectly by wind system. The low oxygen concentration below the Thermocline, which during upwelling in very shallow, forces the reef fishes towards the surface.

Sheshappa and Jayaraman 1956 studied the phosphate cycle in the inshore waters of Malabar Coast and found that the bottom mud contain large quantities of interstitial and absorbed phosphates in the non monsoon period. During monsoon there is a rapid release of phosphates into the overlying column of water and the quantity of phosphate in water increases to a maximum by July/August.

Nutrient supply and loss from reef are difficult to estimate. This has resulted in very limited knowledge about the nutrient budget for reef ecosystems. The importance of nutrients as a primary growth limiting element in the sea, the aspects of marine nitrogen
cycling and its availability has been well documented (Thomas 1970; Ryther and Dunstan, 1971; Corner and Davies, 1971; Dugdale 1976; Carpenter and Capone 1983). Similarly, nitrogen and its role in estuarine mangrove swamps and other aquatic ecosystem have also received attention (Boto and Wellington 1963, Ovalle et al., 1990; Gilbert and Garside, 1992). But the abundance and function of nitrogen in rocky reefs have been addressed only in limited studies.

Like dissolved nitrogen and phosphorus, Silicic acid concentration in reef waters are also low. Smith and Jokiel (1978) observed higher concentrations in areas of upwelling and Webb (1981) concluded that chemical and biological processes affect Silicate cycle in reefs. Seasonal differences in the uptake and release of silicic acid have been observed (Johannes et.al 1983 a). Studies on silicates in reefs have shown that there is low utilization of silicates in most reef environments (Smith and Jokiel, 1978; Smith et.al, 1984). The silicate values observed in the present study varying from 0.05 to 0.93 Mug a/L is perfectly normal and comparable with the results observed by Seshappa and Jayaraman (1956); Subramanian and Sharma (1965) and Mukundan (1967).

Generally speaking the nutrient levels in the coastal waters and reef ecosystem are largely influenced by the upwelling and monsoon activity. Nutrient availability influences the primary and secondary productivity of the coastal waters creating a conducive environment for the fishes to breed. Availability of food is an important factor for the juveniles to grow and recruit into the population and in the monsoon and post monsoon months the high levels of primary and secondary productivity ensures the food availability to the larvae and juveniles.
Earlier studies on reef zooplankton by Bakus (1964) indicate that plankton in reef areas are much more abundant than in the surrounding waters making the reefs ideal nursery grounds for the juveniles of marine ornamental fishes to grow and enter into the fishery. Spatial variations are insignificant while seasonal fluctuations are profound with the maximum biomass in the post monsoon period. This generally agrees with the observations at all the study centers where it was observed that most of the marine ornamental fishes breed in the monsoon months. Environment plays an important role in the breeding and recruitment of marine ornamental fishes along the Malabar Coast and thereby influences their abundance in the coastal waters.
Table 4.1. Temperature, Rainfall, Salinity and dissolved oxygen of the surface waters of Thikkodi during 2001

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°C)</th>
<th>Rainfall (cm)</th>
<th>Salinity (ppt)</th>
<th>Dissolved Oxygen (ml/l)</th>
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Table 4.2. Temperature, Rainfall, Salinity and dissolved oxygen of the surface waters of Thikkodi during 2002

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<td>3.5</td>
</tr>
<tr>
<td>Nov-2002</td>
<td>30</td>
<td>8</td>
<td>33.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Dec-2002</td>
<td>30</td>
<td>1</td>
<td>33.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Annual</td>
<td>28.9</td>
<td>403</td>
<td>32.9</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Table 4.3. Nitrites, Nitrates, Silicates and Phosphates in the coastal waters of Thikkody during 2001 (μ g/lit)

<table>
<thead>
<tr>
<th>Month</th>
<th>Nitrites</th>
<th>Nitrates</th>
<th>Silicates</th>
<th>Phosphates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-2001</td>
<td>0.05</td>
<td>0.94</td>
<td>0.91</td>
<td>0.69</td>
</tr>
<tr>
<td>Feb-2001</td>
<td>0.21</td>
<td>0.2</td>
<td>0.19</td>
<td>0.66</td>
</tr>
<tr>
<td>Mar-2001</td>
<td>0.73</td>
<td>0.33</td>
<td>0.33</td>
<td>0.42</td>
</tr>
<tr>
<td>Apr-2001</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.63</td>
</tr>
<tr>
<td>May-2001</td>
<td>0.6</td>
<td>0.19</td>
<td>0.19</td>
<td>0.87</td>
</tr>
<tr>
<td>Jun-2001</td>
<td>0.43</td>
<td>0.33</td>
<td>0.36</td>
<td>1.18</td>
</tr>
<tr>
<td>Jul-2001</td>
<td>0.3</td>
<td>0.48</td>
<td>0.45</td>
<td>1.32</td>
</tr>
<tr>
<td>Aug-2001</td>
<td>0.34</td>
<td>0.67</td>
<td>0.53</td>
<td>1.39</td>
</tr>
<tr>
<td>Sep-2001</td>
<td>0.38</td>
<td>0.58</td>
<td>0.53</td>
<td>0.94</td>
</tr>
<tr>
<td>Oct-2001</td>
<td>0.36</td>
<td>0.16</td>
<td>0.19</td>
<td>1.48</td>
</tr>
<tr>
<td>Nov-2001</td>
<td>0.08</td>
<td>0.021</td>
<td>0.02</td>
<td>0.87</td>
</tr>
<tr>
<td>Dec-2001</td>
<td>0.38</td>
<td>0.36</td>
<td>0.36</td>
<td>0.48</td>
</tr>
<tr>
<td>Annual</td>
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<td>0.347</td>
<td>0.339</td>
<td>0.91</td>
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</tbody>
</table>

Table 4.4. Nitrites, Nitrates, Silicates and Phosphates in the coastal waters of Thikkody during 2002 (μ g/lit)

<table>
<thead>
<tr>
<th>Month</th>
<th>Nitrites</th>
<th>Nitrates</th>
<th>Silicates</th>
<th>Phosphates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-2002</td>
<td>0.07</td>
<td>0.92</td>
<td>0.96</td>
<td>0.73</td>
</tr>
<tr>
<td>Feb-2002</td>
<td>0.05</td>
<td>0.31</td>
<td>0.25</td>
<td>0.59</td>
</tr>
<tr>
<td>Mar-2002</td>
<td>0.08</td>
<td>0.41</td>
<td>0.38</td>
<td>0.49</td>
</tr>
<tr>
<td>Apr-2002</td>
<td>0.03</td>
<td>0.09</td>
<td>0.09</td>
<td>0.67</td>
</tr>
<tr>
<td>May-2002</td>
<td>0.8</td>
<td>0.34</td>
<td>0.23</td>
<td>0.99</td>
</tr>
<tr>
<td>Jun-2002</td>
<td>0.51</td>
<td>0.44</td>
<td>0.32</td>
<td>1.33</td>
</tr>
<tr>
<td>Jul-2002</td>
<td>0.41</td>
<td>0.49</td>
<td>0.59</td>
<td>1.41</td>
</tr>
<tr>
<td>Aug-2002</td>
<td>0.48</td>
<td>0.61</td>
<td>0.65</td>
<td>1.49</td>
</tr>
<tr>
<td>Sep-2002</td>
<td>0.41</td>
<td>0.55</td>
<td>0.63</td>
<td>0.99</td>
</tr>
<tr>
<td>Oct-2002</td>
<td>0.39</td>
<td>0.22</td>
<td>0.34</td>
<td>1.49</td>
</tr>
<tr>
<td>Nov-2002</td>
<td>0.21</td>
<td>0.19</td>
<td>0.08</td>
<td>0.99</td>
</tr>
<tr>
<td>Dec-2002</td>
<td>0.29</td>
<td>0.41</td>
<td>0.39</td>
<td>0.53</td>
</tr>
<tr>
<td>Annual</td>
<td>0.31</td>
<td>0.415</td>
<td>0.409</td>
<td>0.975</td>
</tr>
</tbody>
</table>
Fig. 4.1. Average values of Temperature and rainfall in the coastal waters of Thikkody during 2001 & 2002

Fig. 4.2. Average values of salinity and dissolved oxygen in the coastal waters of thikkody during 2001 & 2002
Fig. 4.3. Average values of Nitrites, Nitrites, Silicates and Phosphates in the coastal waters of Thikkody during 2001 & 2002.
Fig. 4.4. Seasonal abundance of Acanthuridae at Thikkody

Fig. 4.5. Seasonal Abundance of Apagonidae at Thikkodi
Fig. 4.6. Seasonal Abundance of Balistidae at Thikkodi

Fig. 4.7. Seasonal abundance of Carangidae at Thikkody
Fig. 4.8. Seasonal Abundance of Chaetodontidae

- Chaetodon collaris
- Chaetodon vagabundus
- Chaetodon auriga
- Heniochus accuminatus

Fig. 4.9. Seasonal abundance of Diodontidae at Thikkody

- Diodon hystrix
Fig. 4.10. Seasonal Abundance of Holocentridae at Thikkodi

![Graph showing seasonal abundance of Holocentridae at Thikkodi.](image)

**Legend:**
- Holocentrus diadema
- Holocentrus ruber
- Myripristis adustus
- Myripristis mardjan

Fig. 4.11. Seasonal Abundance of Labridae at Thikkody

![Graph showing seasonal abundance of Labridae at Thikkody.](image)

**Legend:**
- Thalassoma lunare
- Labroides dimidatus
Fig. 4.12. Seasonal Abundance of Muraenidae at Thikkody

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Fig. 4.13. Seasonal Abundance of Ostraciodontidae at Thikkody

Lactaria cornuta Ostracion tuberculatum
Fig. 4.14. Seasonal Abundance of Platacidae at Thikkody

Fig. 4.15. Seasonal abundance of Pomacanthidae at Thikkody
Fig. 4.18. Seasonal Abundance of Serranidae at Thikkody

Fig. 4.19. Seasonal Abundance of Siganidae at Thikkody
Fig. 4.20. Seasonal Abundance of Tetradontidae at Thikkody

- Canthigaster margaritatus
- Tetradon immaculates
- Tetradon hispidus

Fig. 4.21. Seasonal abundance of Zanclidae at Thikkody

- Zanclus cornutus