Chapter 4

HYDROGRAPHY OF THE STUDY AREA
4.1 Introduction

Environmental parameters of the marine environment are gradually influenced by changes in rainfall, ocean currents, winds and other geographical conditions. Seasonal variations of different environmental features in the coastal marine ecosystems will depend on the fresh water inflow, tidal changes and introduction of potentially new physical, chemical and biological changes, thus altering the biological quality. The objectives of this study were to summarise the major physicochemical and biological parameters in the study area during the period from 2000 to 2002, to provide some background information on pollution problems, and to study changes in the selected water quality parameters.

4.2 Materials and Methods

The details of sample collection, sample preservation and analysis for the determination of salinity, dissolved oxygen (D.O), pH and major nutrients are given in chapter 2.

4.3 Results and Discussion

Physico chemical parameters recorded at the study area during the cruises of FORV Sagar Sampada are given in Table 4.1. At stations where the depth was below 200 m, the bottom salinities were only slightly higher than the surface values whereas the difference between surface and bottom salinities were considerably higher at stations of higher depths (>200 m). From the salinity distribution pattern, it is also found that there is an increase in salinity from south to north. The increased salinity in the north has possibly resulted out of the high
saline north Arabian Sea water reaching the area in the southerly flow during the premonsoon period. The decrease in salinity towards the south may be due to the slow spreading of the high saline water southwards losing their high salinity characteristics and also due to the emptying of many rivers into the Arabian Sea near this area. The important rivers draining into Arabian Sea in the south are, Kali river in Karnataka, river Mandovi and Zuari near Goa and around 41 rivers in Kerala. (Pillai, 1991). The salinity of surface water samples during the monsoon season (May- August) is found to be lower (33.38-34.5 ‰ in May and 33.03-34.25 ‰ in August) when compared to that of the other two seasons when the salinity was 35.7-35.98 ‰ in February and 34.8-35.5 ‰ in October. The surface dissolved oxygen ranged from 2.01 ml/l to 4.89 ml/l. At stations of depth below 100 m, the range was between 2.3-3.7 ml/l. At higher depths, D.O. as low as 0.1 ml/l was observed.

Macronutrients like nitrite-N, phosphorus and total nitrogen were relatively lower in surface waters than in the bottom waters. Phosphorus ranged from Non-Detectable level (ND) to 0.07 ppm in surface water and from 0.001-0.05 ppm in the bottom water. Nitrite-N had an average concentration of 0.034 ppm in the surface and 0.040 in the bottom. All these nutrients were relatively lower in the surface, which can be due to uptake of nutrients by phytoplankton at surface and regeneration by microbial oxidation in the bottom sediments and release into the overlying water (Vita Pariente, 1997). Since phytoplankton utilizes phosphate and nitrate simultaneously, the concentrations...
of these nutrients fluctuate in a similar manner (Harvey, 1926). Decomposition of organic matter resulting in the release of the thermodynamically stable nitrogen species, \textit{i.e. nitrate}, may be the major factor resulting in higher nitrate concentration at greater depths, where the water is also characterized by low values of dissolved oxygen and temperature.

\textbf{4.4 Physico chemical parameters of seawater in the off Cochin area}

The samples collected from off Cochin area can be grouped as samples collected during premonsoon (January-April), Monsoon (May- August) and Post Monsoon seasons (September – December). The results of physico chemical parameters in various seasons in the study period are given in tables 4.2 – 4.8.

\textbf{4.4.1 Water Temperature}

There were not much fluctuations in surface seawater temperature (S.W.T) between different stations. The variation in surface water temperature in the study period is represented in Fig. 4.1. At station 1, water temperature ranged from 25.5°C (monsoon season) to 28.75°C (pre-monsoon). In station 2, surface water temperatures ranged from 25.5°C in the monsoon to 28.8°C. The highest temperature was noted in pre-monsoon season. In station 3 it was 26.5°C - 29.13°C. In station 4, seawater temperature varied from 25.5°C - 29.38°C, highest being recorded in the pre monsoon period. In station 5, the range in temperature was from 26.5°C - 29.38°C. Station 6 recorded temperature ranging from 26°C - 29.5°C and in station 7 surface water temperatures ranged from 26°C - 29.5°C. In all the stations highest temperature was recorded in the pre-
monsoon season. In the present study, the fluctuations of water temperature were in the range of 25.29.5°C. A drop in temperature is noticed in monsoon period and the highest being in pre-monsoon period. Statistical analysis of variance has shown that there was significant variation in seawater temperature in different seasons studied (p<0.01) as is recorded by Qasim et al., (1969) and Meenakumari (1989), (Appendix 1, Table 1). When the temperature of the initial year of study was compared with that of the second year there was not much change in the surface water temperature.

**4.4.2 Salinity**

Of all the hydrographical factors studied, salinity was found to fluctuate largely at this area (Fig. 4.2). At station 1, the salinity of the surface water varied from 30.37‰ in post-monsoon to 33.52‰ in the pre-monsoon. In monsoon season also salinity was lowered to 30.9‰. At station 2, the lowest salinity was observed in monsoon season (26.61‰) and the highest was in pre-monsoon (33.7‰). In station 3, salinity ranged from 21.86‰ in monsoon to 33.6‰ in pre-monsoon. In station 4, salinity ranged from 32.16‰ in monsoon to 33.51‰ in pre-monsoon season. Salinity ranged from 30.35-34.05‰ in station 5 and from 30.08-34.04‰ in station 6. In station 7, the range in salinity was from 27.11 to 33.46. Comparing the average salinities in the initial year of study with that of the second year there was a slight increase in salinity for the second year of study in most of the stations. The annual rainfall data indicated that the rainfall in year 2002 in Ernakulam district was comparatively lower than that in the year 2001.
(Guhatha, 2006). This fact correlates well with the increase in salinity observed in surface water in the second year of study. Analysis of Variance showed that there is highly significant variation in salinity in different studied seasons (p<0.01), (Appendix 1, Table 2). Recording of high salinity in the pre-monsoon months was due to low amount of rainfall and high rate of evaporation in the shallow coastal areas owing to high atmospheric temperature. Erlansen (1936) reported that the salinity of the surface water in the estuary becomes almost fresh in the active monsoon period. A drop in salinity in the monsoon might be due to the increased fresh water inflow by the rivers and also by the heavy rainfall.

4.4.3 pH

There was no spatial variation in the case of the pH level of water at these seven stations (Fig. 4.3). The pH was comparatively lower during the monsoon season. It ranged from 8.00-8.31 in station 1, 8.11-8.3 in station 2, 7.99-8.29 in station 3, 8.11-8.3 in station 4, 8.19-8.31 in station 5, 8.12-8.31 in station 6 and from 8.07-8.32 in station 7. Statistical analysis showed a significant variation in pH in different seasons of the year (p< 0.01), (Appendix 1, Table 3). In the monsoon and post monsoon season pH was relatively low. pH fluctuations are mainly due to fresh water discharge. Low pH was usually observed during the period when salinity values were lower indicating the influence of fresh water drainage on pH.
4.4.4 Dissolved Oxygen

In the study area, horizontal distribution of dissolved oxygen (D.O) in surface waters did not show much variation (Fig. 4.4). The dissolved oxygen ranged from 3.5 ml/l-7.2 ml/l in station 1, 5.3-7.06 ml/l in station 2 and 4.9-7.53 ml/l in station 3. Lower values were observed during monsoon season. In station 4, dissolved oxygen ranged from 6.9 ml/l, 6.67-7.15 ml/l in station 5, 6.33-7.6 ml/l in station 6 and 5.7-7.6 ml/l in station 7. Lower values were observed in monsoon and higher values in post-monsoon season. Oxygen variations were dependent on the extent of mixing of the water and the photosynthetic activity of the phytoplankton. Fairly high values of oxygen were observed for most part of the year. Statistical analysis (Appendix 1, Table 4) showed that there is significant variation in dissolved oxygen in different season (p <0.01) the lower being in the monsoon. There was no significant spatial variation in dissolved oxygen between stations.

4.4.5 Nutrients

The concentration of phosphorus in the water sample fluctuated from month to month (Fig. 4.5). There was no uniform pattern for the distribution of the nutrient over the different stations. The highest phosphate concentration observed at station 1 was 0.27 ppm in the post-monsoon season. In station 2, the phosphorus values ranged from 0.06 ppm-0.31ppm. At station 3, the concentration of phosphorus ranged from 0.08-0.28 ppm. The concentration of phosphorus in station 4 was 0.10-0.2 ppm and in station 5 the range was 0.03-
Phosphorus concentration in station 6 ranged from 0.09 ppm in post monsoon period to 0.29 ppm in monsoon and the range was between 0.05 - 0.24 ppm in station 7. Statistical analysis showed a significant variation in phosphorus in different seasons studied (p < 0.01), (Appendix 1 Table 6). Higher values of phosphorus were observed in the monsoon season. The earlier reported values for phosphates in the Cochin area ranged from 0.01 - 3.22 μg/l by Meenkumari (1989), 0.85 - 1.6 μg/l by Manikoth and Salih (1974). Higher values obtained for total phosphorus in the present study may be attributed to the enrichment of phosphate by land run-off and land drainage (Qasim, 1969).

Nitrite was found in traces in all the seven stations and not pronounced as that of total phosphorus. An increase in concentration was observed for the post monsoon period. The decline in concentration in the other seasons can be attributed to the higher planktonic productivity in these months (Gupta and Pylee, 1964). Qasim and Sankaranarayanan (1969) reported that the Nitrite-N was more during monsoon period contrary to what has been observed in this study. Total nitrogen varied from 1.55 ppm to 3.1 ppm at station 1, the highest recorded concentration was in pre-monsoon season. At station 2 the total Nitrogen varied from 1.9 ppm to 3.32 ppm in surface water. In station 3 the range was from 1.6 - 3.31 ppm, in station 4, from 1.32 - 2.65 ppm. The concentration of total nitrogen varied from 1.9 - 3.59 ppm in station 5, 1.5 - 2.6 in station 6 and from 1.95 - 2.64 ppm in station 7. There was a significant variation in total nitrogen concentration in surface water in the different seasons studied (p< 0.05) (Appendix 1, Table, 7).
but such a significant variation was not observed for nitrite nitrogen (Appendix 1, Table 5). Relatively high value of nutrients in the study area indicated the prevailing unhealthy water quality of the area.

Environmental conditions in most tropical coastal areas are governed by marked seasonal changes induced by the monsoonal cycles, rainfall, wind, fresh water inflow and introduction of new physical, chemical and biological changes. The study of the hydrography of the coastal waters of Cochin shows that prevailing southwest and northeast monsoons considerably influences the chemical and physical factors. The increased dependency of agriculture on chemical fertilizers and pesticides in the catchment areas of rivers and estuaries and increased population pressure and fast urbanization give rise to the heavy sewage effluents are the possible anthropologic factors leading to high concentration of nutrients in the area studied.
Table 4.1 Physicochemical parameters recorded at the study area during the cruises of FORV Sagar Sampada.

<table>
<thead>
<tr>
<th>Cruise</th>
<th>Area</th>
<th>Temperature (°C)</th>
<th>Salinity (%)</th>
<th>D.O.(ml/l)</th>
<th>pH</th>
<th>NO₃-(ppm)</th>
<th>NO₂-(ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>181</td>
<td>Surface</td>
<td>24-26.73</td>
<td>35.57-35.98</td>
<td>3.28-4.89</td>
<td>8.07-8.18</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>23-24.8</td>
<td>35.52-36.01</td>
<td>3.76-2.3</td>
<td>8.09-8.11</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td>184</td>
<td>Surface</td>
<td>28.3-28.96</td>
<td>33.4-34.52</td>
<td>3.13-4.8</td>
<td>8.11-8.56</td>
<td>ND</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>28.5-28.77</td>
<td>33.03-34.25</td>
<td>2.011-4.16</td>
<td>8.05-8.76</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td>191</td>
<td>Surface</td>
<td>28.22-28.77</td>
<td>33.86-35.23</td>
<td>0.122-3.8</td>
<td>8.04-8.55</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>14.55-27.96</td>
<td>33.45-34.38</td>
<td>2.7-4.5</td>
<td>8.11-8.9</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td>197</td>
<td>Surface</td>
<td>27-28.5</td>
<td>34.5-34.96</td>
<td>0.21-2.4</td>
<td>8.31-8.87</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>15.25-22.33</td>
<td>34.8-35.6</td>
<td>2.5-4.5</td>
<td>8.9-8.97</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td>204</td>
<td>Surface</td>
<td>26-27.8</td>
<td>33.5-34.78</td>
<td>0.5-3.25</td>
<td>7.97-8.76</td>
<td>ND</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>23-24.5</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2 Physico chemical parameters of surface water from stations in off Cochin area during postmonsoon season (2000)

<table>
<thead>
<tr>
<th>Stn.</th>
<th>D.O(ml/l)</th>
<th>Salinity(%)</th>
<th>PH</th>
<th>NO₂-N(ppm)</th>
<th>P(ppm)</th>
<th>S.W.T(°C)</th>
<th>Total N ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.8</td>
<td>30.99</td>
<td>7.81</td>
<td>0.02</td>
<td>0.07</td>
<td>26.5</td>
<td>1.55</td>
</tr>
<tr>
<td>2</td>
<td>6.5</td>
<td>29.14</td>
<td>8.23</td>
<td>0.03</td>
<td>0.06</td>
<td>26.3</td>
<td>1.99</td>
</tr>
<tr>
<td>3</td>
<td>5.9</td>
<td>32.79</td>
<td>8.15</td>
<td>0.03</td>
<td>0.08</td>
<td>27</td>
<td>1.77</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>32.94</td>
<td>8.15</td>
<td>0.035</td>
<td>0.1</td>
<td>26</td>
<td>1.32</td>
</tr>
<tr>
<td>5</td>
<td>6.86</td>
<td>33.12</td>
<td>8.27</td>
<td>0.025</td>
<td>0.03</td>
<td>26</td>
<td>2.44</td>
</tr>
<tr>
<td>6</td>
<td>6.33</td>
<td>34.29</td>
<td>8.25</td>
<td>0.024</td>
<td>0.09</td>
<td>26.5</td>
<td>1.98</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>32.52</td>
<td>8.17</td>
<td>0.05</td>
<td>0.05</td>
<td>26.5</td>
<td>1.98</td>
</tr>
</tbody>
</table>

Table 4.3 Physico chemical parameters of surface water from stations in the off Cochin area during pre monsoon season 2001

<table>
<thead>
<tr>
<th>Stn.</th>
<th>D.O(ml/l)</th>
<th>Salinity(%)</th>
<th>PH</th>
<th>NO₂-N(ppm)</th>
<th>P(ppm)</th>
<th>S.W.T(°C)</th>
<th>Total N ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.8</td>
<td>33.52</td>
<td>8.28</td>
<td>0.036</td>
<td>0.16</td>
<td>28.75</td>
<td>1.99</td>
</tr>
<tr>
<td>2</td>
<td>7.1</td>
<td>33.75</td>
<td>8.3</td>
<td>0.03</td>
<td>0.17</td>
<td>28.88</td>
<td>3.32</td>
</tr>
<tr>
<td>3</td>
<td>6.95</td>
<td>33.60</td>
<td>8.29</td>
<td>0.02</td>
<td>0.15</td>
<td>29.13</td>
<td>1.98</td>
</tr>
<tr>
<td>4</td>
<td>7.55</td>
<td>33.51</td>
<td>8.29</td>
<td>0.02</td>
<td>0.14</td>
<td>29.38</td>
<td>2.65</td>
</tr>
<tr>
<td>5</td>
<td>7.15</td>
<td>34.04</td>
<td>8.31</td>
<td>ND</td>
<td>0.15</td>
<td>29.38</td>
<td>3.32</td>
</tr>
<tr>
<td>6</td>
<td>6.95</td>
<td>34.05</td>
<td>8.31</td>
<td>0.014</td>
<td>0.13</td>
<td>29.5</td>
<td>2.65</td>
</tr>
<tr>
<td>7</td>
<td>7.6</td>
<td>33.46</td>
<td>8.32</td>
<td>0.016</td>
<td>0.17</td>
<td>29.5</td>
<td>1.98</td>
</tr>
</tbody>
</table>
Table 4.4 Physicochemical parameters of surface water from stations in the off Cochin area during monsoon season in the year 2001

<table>
<thead>
<tr>
<th>Stn</th>
<th>D.O(mg/l)</th>
<th>Salinity(‰)</th>
<th>pH</th>
<th>NO₃-N(ppm)</th>
<th>PO₄-P(ppm)</th>
<th>S.W.T{C(°)}</th>
<th>Total N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5</td>
<td>30.99</td>
<td>8.01</td>
<td>0.01</td>
<td>0.22</td>
<td>25.5</td>
<td>2.27</td>
</tr>
<tr>
<td>2</td>
<td>5.3</td>
<td>26.61</td>
<td>8.11</td>
<td>0.05</td>
<td>0.175</td>
<td>26.5</td>
<td>2.44</td>
</tr>
<tr>
<td>3</td>
<td>4.9</td>
<td>21.86</td>
<td>7.91</td>
<td>ND</td>
<td>0.2</td>
<td>26.5</td>
<td>1.61</td>
</tr>
<tr>
<td>4</td>
<td>6.6</td>
<td>32.16</td>
<td>8.11</td>
<td>ND</td>
<td>0.215</td>
<td>25.5</td>
<td>3.59</td>
</tr>
<tr>
<td>5</td>
<td>7.0</td>
<td>30.35</td>
<td>8.19</td>
<td>ND</td>
<td>0.17</td>
<td>26.5</td>
<td>2.91</td>
</tr>
<tr>
<td>6</td>
<td>7.5</td>
<td>30.08</td>
<td>8.13</td>
<td>ND</td>
<td>0.14</td>
<td>26</td>
<td>2.61</td>
</tr>
<tr>
<td>7</td>
<td>5.7</td>
<td>27.11</td>
<td>8.07</td>
<td>ND</td>
<td>0.01</td>
<td>26</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Table 4.5 Physicochemical parameters of surface water from stations in the off Cochin area during postmonsoon season in the year 2001

<table>
<thead>
<tr>
<th>Stn</th>
<th>D.O(mg/l)</th>
<th>Salinity(‰)</th>
<th>pH</th>
<th>NO₃-N(ppm)</th>
<th>PO₄-P(ppm)</th>
<th>S.W.T{C(°)}</th>
<th>Total N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.2</td>
<td>30.37</td>
<td>8.31</td>
<td>ND</td>
<td>0.27</td>
<td>26.7</td>
<td>2.42</td>
</tr>
<tr>
<td>2</td>
<td>7.06</td>
<td>31.92</td>
<td>8.28</td>
<td>0.03</td>
<td>0.31</td>
<td>28.8</td>
<td>1.95</td>
</tr>
<tr>
<td>3</td>
<td>7.53</td>
<td>32.52</td>
<td>8.29</td>
<td>ND</td>
<td>0.28</td>
<td>27</td>
<td>2.65</td>
</tr>
<tr>
<td>4</td>
<td>7.93</td>
<td>32.28</td>
<td>8.3</td>
<td>0.11</td>
<td>0.2</td>
<td>26.5</td>
<td>1.99</td>
</tr>
<tr>
<td>5</td>
<td>6.93</td>
<td>31.61</td>
<td>8.3</td>
<td>0.02</td>
<td>0.3</td>
<td>26</td>
<td>2.20</td>
</tr>
<tr>
<td>6</td>
<td>7.6</td>
<td>31.37</td>
<td>8.32</td>
<td>0.01</td>
<td>0.29</td>
<td>27</td>
<td>2.41</td>
</tr>
<tr>
<td>7</td>
<td>7.8</td>
<td>32.1</td>
<td>8.33</td>
<td>0.03</td>
<td>0.24</td>
<td>27</td>
<td>2.41</td>
</tr>
</tbody>
</table>
### Table 4.6 Physico chemical parameters of surface water from stations in the off Cochin area during premonsoon season in the year 2002

<table>
<thead>
<tr>
<th>Stn.</th>
<th>DO (ml/l)</th>
<th>Salinity (%)</th>
<th>pH</th>
<th>NO\textsubscript{2}-N (ppm)</th>
<th>P (ppm)</th>
<th>S.W.T (°C)</th>
<th>Total N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.06</td>
<td>33.3</td>
<td>8.26</td>
<td>ND</td>
<td>0.18</td>
<td>26.5</td>
<td>3.17</td>
</tr>
<tr>
<td>2</td>
<td>6.33</td>
<td>29.9</td>
<td>8.28</td>
<td>0.006</td>
<td>0.04</td>
<td>26.83</td>
<td>2.30</td>
</tr>
<tr>
<td>3</td>
<td>5.8</td>
<td>33.06</td>
<td>8.22</td>
<td>0.023</td>
<td>0.01</td>
<td>26.83</td>
<td>1.96</td>
</tr>
<tr>
<td>4</td>
<td>6.2</td>
<td>33.24</td>
<td>8.25</td>
<td>ND</td>
<td>0.50</td>
<td>27.66</td>
<td>2.20</td>
</tr>
<tr>
<td>5</td>
<td>6.66</td>
<td>33.01</td>
<td>8.33</td>
<td>0.02</td>
<td>0.28</td>
<td>27</td>
<td>2.20</td>
</tr>
<tr>
<td>6</td>
<td>7.2</td>
<td>32.08</td>
<td>8.33</td>
<td>ND</td>
<td>0.13</td>
<td>27</td>
<td>2.04</td>
</tr>
<tr>
<td>7</td>
<td>6.06</td>
<td>31.82</td>
<td>8.19</td>
<td>ND</td>
<td>0.19</td>
<td>27</td>
<td>2.64</td>
</tr>
</tbody>
</table>

### Table 4.7 Physico chemical parameters of surface water from stations in the off Cochin area during monsoon season in the year 2002

<table>
<thead>
<tr>
<th>Stn.</th>
<th>DO (ml/l)</th>
<th>pH</th>
<th>Salinity (%)</th>
<th>P (ppm)</th>
<th>NO\textsubscript{2}-N (ppm)</th>
<th>Total N (ppm)</th>
<th>S.W.T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.8</td>
<td>8.2</td>
<td>33.42</td>
<td>0.25</td>
<td>ND</td>
<td>2.9</td>
<td>27.5</td>
</tr>
<tr>
<td>2</td>
<td>6.2</td>
<td>8.3</td>
<td>26.2</td>
<td>0.08</td>
<td>ND</td>
<td>2.01</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>7.2</td>
<td>8.23</td>
<td>34.33</td>
<td>0.02</td>
<td>0.05</td>
<td>2.01</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>7.4</td>
<td>8.1</td>
<td>33.96</td>
<td>0.8</td>
<td>ND</td>
<td>1.98</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>5.2</td>
<td>8.3</td>
<td>32</td>
<td>0.38</td>
<td>0.03</td>
<td>1.9</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>8.3</td>
<td>33</td>
<td>0.2</td>
<td>ND</td>
<td>1.5</td>
<td>28</td>
</tr>
<tr>
<td>7</td>
<td>7.6</td>
<td>8.2</td>
<td>32.4</td>
<td>0.3</td>
<td>ND</td>
<td>1.98</td>
<td>28</td>
</tr>
</tbody>
</table>
Table 4.8 Physico chemical parameters of surface water from stations in the off Cochin area during postmonsoon season in the year 2002

<table>
<thead>
<tr>
<th>Stn.</th>
<th>DO (mg/L)</th>
<th>pH</th>
<th>Salinity %</th>
<th>P (ppm)</th>
<th>NO$_2^-$-N (ppm)</th>
<th>Total N (ppm)</th>
<th>S.W.T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.2</td>
<td>8.22</td>
<td>30.71</td>
<td>0.19</td>
<td>ND</td>
<td>1.32</td>
<td>28</td>
</tr>
<tr>
<td>2</td>
<td>7.4</td>
<td>8.25</td>
<td>31.98</td>
<td>0.23</td>
<td>ND</td>
<td>1.9</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>8.23</td>
<td>33.96</td>
<td>0.28</td>
<td>ND</td>
<td>3.31</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>7.2</td>
<td>8.26</td>
<td>32.88</td>
<td>0.15</td>
<td>ND</td>
<td>1.32</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>7.2</td>
<td>8.23</td>
<td>33.42</td>
<td>0.34</td>
<td>0.03</td>
<td>2.65</td>
<td>29</td>
</tr>
<tr>
<td>6</td>
<td>7.2</td>
<td>8.25</td>
<td>32.7</td>
<td>0.26</td>
<td>0.05</td>
<td>1.32</td>
<td>29</td>
</tr>
<tr>
<td>7</td>
<td>6.4</td>
<td>8.29</td>
<td>33.6</td>
<td>0.23</td>
<td>ND</td>
<td>1.95</td>
<td>29.5</td>
</tr>
</tbody>
</table>
Fig. 4.1 Seasonal variations of Sea Water Temperature at the study area (7 stations) during 2000-02

Fig. 4.2 Seasonal variations of salinity at the study area (7 stations) during 2000-02
Fig. 4.3 Seasonal variations of pH in sea water at the study area (7 stations) during 2000-02

Fig. 4.4 Seasonal variations of D.O. in sea water at the study area (7 stations) during 2000-02
Fig. 4.5 Seasonal variations of nutrients in the sea water at the study area (7 stations) during 2000-02
Appendix I

Table 1 Results of two way ANOVA on seawater temperature (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>0.634281</td>
<td>5</td>
<td>0.126856</td>
<td>0.35277</td>
<td>0.875567</td>
<td>2.602988</td>
</tr>
<tr>
<td>Columns</td>
<td>43.58221</td>
<td>5</td>
<td>8.716443</td>
<td>24.23927</td>
<td>7.65E-09</td>
<td>2.602988</td>
</tr>
<tr>
<td>Error</td>
<td>8.990003</td>
<td>25</td>
<td>0.3596</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>53.2065</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Results of two way ANOVA on salinity (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>24.21832</td>
<td>6</td>
<td>4.036386</td>
<td>1.018504</td>
<td>0.444555</td>
<td>2.661302</td>
</tr>
<tr>
<td>Columns</td>
<td>103.4476</td>
<td>3</td>
<td>34.48254</td>
<td>8.700999</td>
<td>0.00088</td>
<td>3.159911</td>
</tr>
<tr>
<td>Error</td>
<td>71.33498</td>
<td>18</td>
<td>3.963055</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>199.0009</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Results of two way ANOVA on pH of water (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>0.032536</td>
<td>6</td>
<td>0.005423</td>
<td>2.527279</td>
<td>0.059367</td>
<td>2.661302</td>
</tr>
<tr>
<td>Columns</td>
<td>0.24741</td>
<td>3</td>
<td>0.08247</td>
<td>38.43615</td>
<td>4.93E-08</td>
<td>3.159911</td>
</tr>
<tr>
<td>Error</td>
<td>0.038621</td>
<td>18</td>
<td>0.002146</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.318567</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 1 con...

Table 4 Results of two way ANOVA on dissolved oxygen (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>4.00697</td>
<td>6</td>
<td>0.667829</td>
<td>1.934124</td>
<td>0.129933</td>
<td>2.661302</td>
</tr>
<tr>
<td>Columns</td>
<td>15.79803</td>
<td>3</td>
<td>5.26601</td>
<td>15.2511</td>
<td>3.47E-05</td>
<td>3.159911</td>
</tr>
<tr>
<td>Error</td>
<td>6.21517</td>
<td>18</td>
<td>0.345287</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 26.02017  27

Table 5 Results of two way ANOVA on nitrite nitrogen in water (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>0.003401</td>
<td>6</td>
<td>0.000567</td>
<td>1.192204</td>
<td>0.354302</td>
<td>2.661302</td>
</tr>
<tr>
<td>Columns</td>
<td>0.001638</td>
<td>3</td>
<td>0.000546</td>
<td>0.148317</td>
<td>0.356589</td>
<td>3.159911</td>
</tr>
<tr>
<td>Error</td>
<td>0.008559</td>
<td>18</td>
<td>0.000476</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 0.013599  27

Table 6 Results of two way ANOVA on phosphorus in water (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>0.00238</td>
<td>6</td>
<td>0.000397</td>
<td>0.431718</td>
<td>0.84816</td>
<td>2.661302</td>
</tr>
<tr>
<td>Columns</td>
<td>0.14517</td>
<td>3</td>
<td>0.04839</td>
<td>0.786583</td>
<td>4.12E-09</td>
<td>3.159911</td>
</tr>
<tr>
<td>Error</td>
<td>0.016541</td>
<td>18</td>
<td>0.000919</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 0.164093  27

Table 7 Results of two way ANOVA on total nitrogen in water (off Cochin) in different seasons

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rows</td>
<td>2.261862</td>
<td>6</td>
<td>0.376977</td>
<td>1.837372</td>
<td>0.148066</td>
<td>2.661302</td>
</tr>
<tr>
<td>Columns</td>
<td>2.345955</td>
<td>3</td>
<td>0.781985</td>
<td>3.811366</td>
<td>0.028215</td>
<td>3.159911</td>
</tr>
<tr>
<td>Error</td>
<td>3.693094</td>
<td>18</td>
<td>0.205172</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 8.300911  27