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Research Article

SEASONAL CHANGES OF HYDROGRAPHIC PROPERTIES IN SEA WATER OF CORAL REEF ISLANDS, GULF OF MANNAR, INDIA

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ABSTRACT : The present investigation was carried out the hydrographic parameters of Thoothukudi and Vembar group, Gulf of Mannar. During the study period maximum rainfall was recorded during the monsoon season at Nallathanni Island and minimum was during the summer season at Kaswari Island. The maximum atmospheric temperature was observed in summer season at Nallathanni Island and the minimum atmospheric temperature was recorded during the monsoon season at Upputhanni and Nallathanni Islands. The surface water temperature (°C) ranges between 32.08 to 26.31°C and bottom water temperature (°C) ranges between 30.68 to 25.46°C. Sea water transparency (m) ranges were 3.27m to 0.59m at all the study station. The surface water salinity (‰) ranges from 35.09 ppt- 30.83 ppt and bottom water salinity ranges from 35.86 ppt – 32.51 ppt. The surface water pH values range from were 7.68 to 7.48 and bottom water pH values range from 7.88 to 7.49. The Dissolved oxygen (SW) concentration ranges from 5.12 ml/l to 4.36 ml/l and dissolved oxygen (BW) ranges from 4.57 ml/l to 4.08 ml/l at all the study stations respectively. The surface water inorganic nitrate concentration (mg/l) ranges from 0.63 to 0.06 and Bottom water nitrate (mg/l) range from 0.81 to 0.06. The surface water nitrite ranged from 0.059 to 0.002 at all the study locations. The Magnesium (mg/l) content on surface water varied between 1580 - 1052 and bottom water were 1537 to 1064 at all the stations. Organic phosphate (mg/l) ranges at surface water range from 1.88 to 0.18 and bottom water were 1.74 to 0.18. Dissolved calcium (mg/l) on surface water ranges from 518 to 293 at Thoothukudi and Vembar group of islands correspondingly.
Key wards: Physico-Chemical parameters, coral islands, Thoothukudi, Vembar, Gulf of Mannar Islandsr

INTRODUCTION

Water, the most vital resource for all kinds of life, is very much adversely affected by human activities. Man has rapidly advanced his efforts to counteract this to cope up with this scenario. Ever since the industrial revolution, natural and polluted waters have been studied in great detail all over the world [1 - 6]. Considerable data is now available on most kind of pollutants and their effect on the ecosystem as well as on the organism.

The marine hydrography is much complicated due to the dynamic nature of this ecosystem. Changes in the hydrographical parameters such as salinity, dissolved oxygen, dissolved carbon dioxide; nutrients and so on affect the activities and growth of the organisms in the ecosystem [7]. Studies on the impact of abiotic variables of the aquatic ecosystem are very vital for any pollution monitoring evaluation. It is an accepted fact that in an aquatic environment, among the various abiotic factors, changes in salinity, temperature and pH can be considered as the three main variables which definitely pose a threat on the biota [8 – 11].

Corals are one of the most significant symbiotic associations in animal kingdom in which partnership between tiny unicellular algae and various marine animals together enable the formation of corals reefs [12]. Corals are made up of calcareous skeletons of millions of tiny marine organisms. The lower organisms lay down calcium. So that the reef growth beneath the cell layers builds the corals continuously over hundreds of thousands of years [13]. The annual growth of corals is very slow. Based on environmental conditions, they may increase in size from a few mm to 5cm every year. Fresh corals have grown over 30cm within Tuticorin harbour where the break waters had only recently been constructed [13]. Corals mainly grow in warm tropical areas (70℉-85℉) with shallow and clean waters.

Corals do not grow beyond 150 feet [14] even minor pollutants present in the sea that prevent sun light reaching the sea bed alter the growth of corals. Coral reefs are extremely sensitive to changes in the environment. Even slight changes in the reef environment may have detrimental effect on the health of entire coral colonies. These changes may be due to a variety of factors. But they generally fall within two categories viz., natural disturbance and anthropogenic disturbances have been linked to vast majority of decreases in coral cover and general health, when coral reefs and humans occur together [15]. The seasonal changes of sea water temperature was affected the coral reproduction and metabolic activities [16].

The present study was designed to know the complete ecology and pollution monitoring aspects of a water body in the Thoothukudi and Vembar group of coral Islands in the Gulf of Mannar. An attempt has been made to collect data on the water quality parameters including the nutrients of the entire system. The samples were collected for a period of one year (2007 – 2008) at different points in the selected sites of the island.

MATERIALS AND METHODS

Surface water samples were collected at monthly intervals from Thoothukudi and Vembar group of Islands for a period of one year from July 2007 to June 2008. Rain fall data were obtained from the meteorological department located at Kadaladi of Ramanathapuram district, from this the rain fall data of Kadaladi and Vallinokkam were obtained. Since these two stations are very close to the Vembar group of islands, the rainfall data of this area was considered as the data of the Vembar group of islands. From Vilathikulam block of Thoothukudi district, the data for Surankudi and Vippar were obtained. Since these two stations are very close to Thoothukudi group of islands, the data was taken into consideration as the rainfall data of Thoothukudi group of islands. Temperature was measured using a standard centigrade thermometer. Salinity was estimated standard titration method of the Mohr- Knudsen [17] and pH was measured using an ELICO Grip pH meter. Dissoved Oxygen was estimated by the modified Wrinkler's method [18] and expressed as ml/l. For the analysis of nutrients, surface water samples were collected in clean polyethylene bottles and kept immediately in an ice box and transported to the laboratory. The water samples were then filtered using Millipore filtering system and analysed for phosphate, Calcium, Magnesium, dissolved organic nitrate and nitrite adopting the standard procedures described by [17] and expressed in iμ. Simple correlation co-efficient (r) analysis between different parameters and the Analysis of Variance (ANOVA) have been employed for the statistical interpretation of data obtained from the study is discussed.

RESULTS

Monthly variations in metrological and Physico-chemical (Hydrographic) parameters viz., rainfall, atmospheric temperature, surface water temperature, bottom water temperature, salinity, transparency, pH, dissolved oxygen, nitrite, nitrate, Calcium, Magnesium, Inorganic phosphate. Rainfall recorded in the study area was given in the Figure 1. The annual rainfall in Van, Koswari and Kariyachalli of Thoothukudi group of islands were 35.8mm, 33.2 mm and 56.8 mm/yr respectively. Among the three islands maximum rainfall was recorded in Kariyachalli Island only during the study period. Monthwise record showed that in Thoothukudi group of islands the maximum rainfall was recorded during rainy season only, whereas during other months very scanty rain or totally nil rain was recorded. As for as Vembar group of islands were concerned the annual rainfall recorded was more or less equal in all islands and the rainfall recorded was 68mm, 94mm, 76mm/yr in Upputhanni, Pulivinichalli and Nallathanni island respectively.

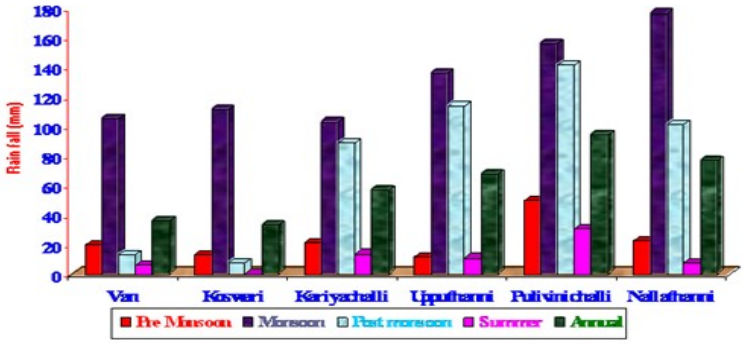


Figure 1 Seasonal variations of rain fall observed in the study areas during the study period (July 2007 – June 2008).

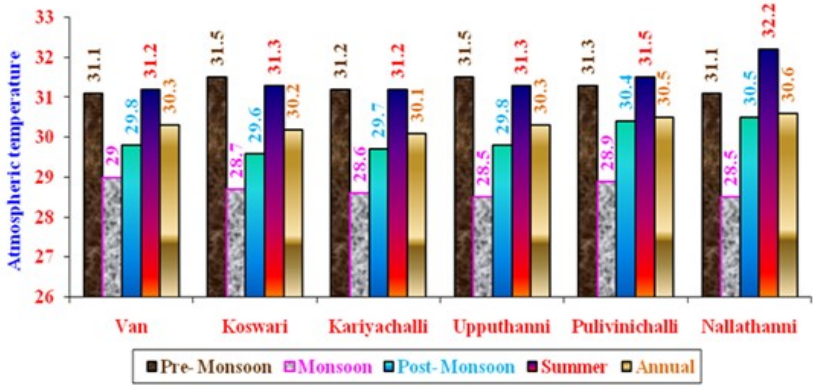


Figure 2 Seasonal variation of atmospheric temperature (^{0}c) of six selected islands during the study period (July 2007 to June 2008).

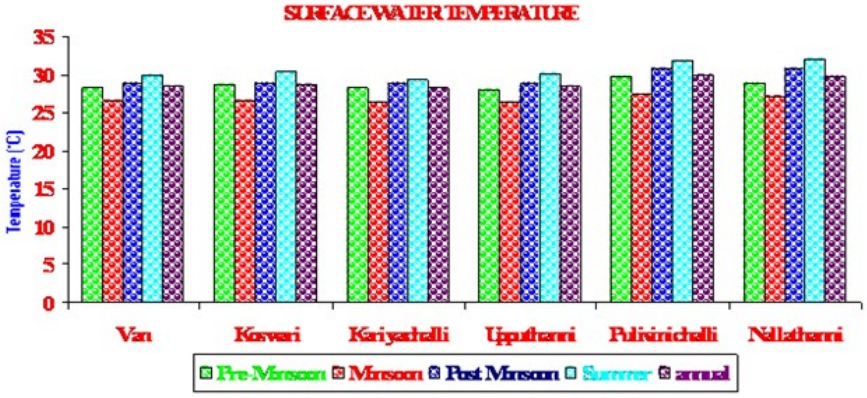
The monthwise data showed that the Vembar group of islands received rainfall throughout the year except certain months. When compare to the Vembar group of islands the Thoothukudi group of islands received a less quantum of rainfall during the study period.

Atmospheric temperature

Figure 2, shows the atmospheric temperature recorded at each station in Thoothukudi and Vembar group of islands. Average air temperature varied from 26.9^{0}C to 31.9^{0}C in Van Island, 26.5^{0}C to 32.3^{0}C in Kaswary Island, 26.4^{0}C to 32.2^{0}C at Kariyachalli Island, 26.7^{0}C to 32.9^{0}C in Upputhanni Island, 26.9^{0}C to 32.1^{0}C in Pulivinichally Island and 26.4^{0}C to 32.3^{0}C at Nallathanni Island. In almost all stations the least atmospheric temperature (28.3^{0}C to 28.9^{0}C) was observed during the monsoon season while the highest temperature (31^{0}C to 32.9^{0}C) was observed during summer season.

Water temperature

Monthly variations in the surface and bottom water temperature in the six islands at Thoothukudi and Vembar group in Gulf of Mannar region are depicted in Figure 3. Surface water Temperature of Van Island ranged from 24.5^{0}C to 30.5^{0}C, Koswari Island from 24.3^{0}C to 31.4^{0}C and Kariyachalli Island ranged from 24.4^{0}C to 29.8^{0}C of Thoothukudi group of islands and 24.3^{0}C to 30.5^{0}C at Upputhanni Island, 25.7^{0}C to 32.13^{0}C at Pulivinichalli Island and 24.5^{0}C to 33.9^{0}C at Nallathanni Island of Vembar group, Gulf of Mannar. Bottom temperature of Van Island ranged from 23.9^{0}C to 29.2^{0}C, Koswari from 23.5^{0}C to 30.1^{0}C and in Kariyachalli Island from 24.1^{0}C to 28.4^{0}C at Thoothukudi group of Islands. In Vembar group of Islands the minimum observed bottom temperature was 23.8^{0}C and maximum temperature was 30.9^{0}C. Bottom water temperature observed in Upputhanni Island ranged from 23.8 ^{0}C to 29.1^{0}C, at Pulivinichalli Island 25.1^{0}C to 30.2^{0}C and at Nallathanni Island as 24.5^{0}C to 30.9^{0}C.



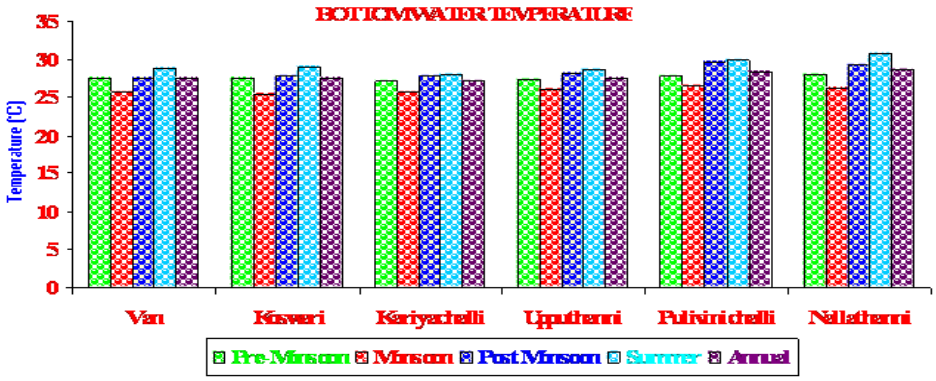


Figure 3 Seasonal mean variation of water temperature obtained at different stations studied during the study period (July 2007 to June 2008).

The month wise observation showed that the maximum temperature (27.91^{0}C to 32.08^{0}C) was noted during April to June (summer season) while the minimum value (25.47^{0}C to 27.44^{0}C) were observed during October to December (monsoon season) in most of the study area. The highest surface and bottom water temperature was recorded during the month of June to August (pre-monsoon) in all islands. During all seasons both the surface and bottom water temperatures showed very slight variations (0.5^{0}C to 1.3^{0}C) in almost all stations. In almost all stations the surface water temperature correlates with the atmospheric temperature to a greater extent. In almost all study area the minimum water temperature (25^{0}C-27^{0}C) was noted during the monsoon season and maximum (27^{0}C and 32^{0}C) during the summer season. While during the pre-monsoon and post-monsoon season in almost all stations the temperature level falls between 27^{0}C-30^{0}C.

Transparency

Transparency and the level of light penetration of the study area are reported in the Figure 4.

Maximum light penetration was noticed in Van, Kaswari, Kariyachalli and Upputhanni island during the month of September (3.4, 5.2, 3.3 and 3.1 meter) and in Pulivinichalli and Nallathanni islands during January and February (3.5 and 3.4 meter).

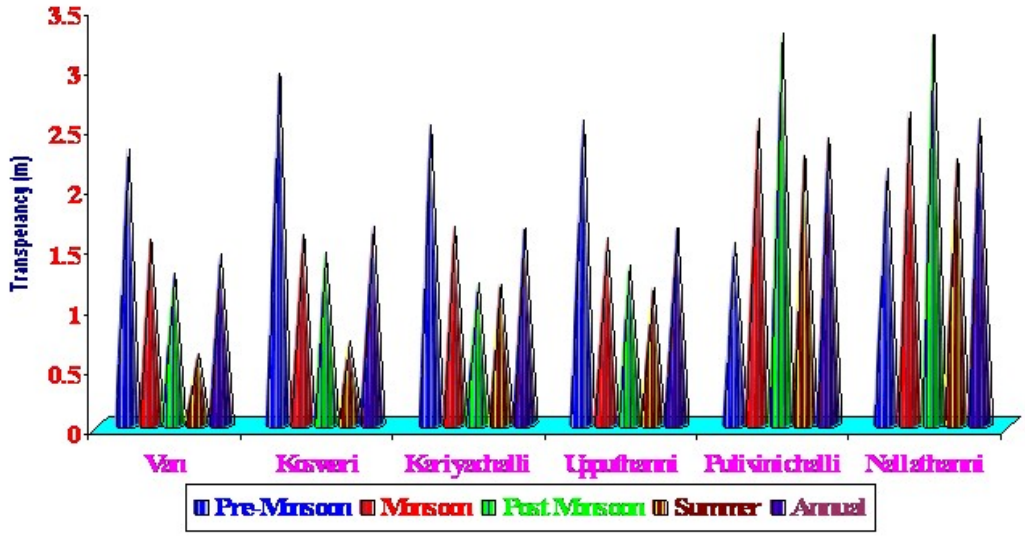


Figure 4 Seasonal mean variation of water transparency observed at different stations during the study period (July 2007 to June 2008).

Minimum transparency of sea water noticed during the month of March to June in Van, Kaswari and Kariyachalli, March in Upputhanni island (0.5m-0.7m), In Pulivinichalli island (1.1m) the minimum transparency was observed during the month of August and in Nallathanni island, the minimum transparency (1.2) was noted during the month of may.

During the month of August, September, December and January high values of water transparency observed in Van, Kaswari, Kariyachalli and Upputhanni. From October onwards up to April a drastic decline in the light penetration level was noticed which revealed the turbid nature of the water in these two islands (Pulivinichalli and Nallathanni Island). In the months of July and August the water showed slight decline in transparency in Pulivinichalli and Nallathanni Islands.

Maximum transparency was noted during in almost all stations during the pre- monsoon period except in Pulivinichalli and Nallathanni Island. Here the maximum transparency was noted during the post-monsoon season. The minimum transparency was recorded in all stations during the summer season.

Salinity

The surface and bottom water salinity in Thoothukudi and Vembar group of Islands are shown in Figure 5. Surface water salinity of Van Island ranged from 31.7 to 34.9ppt, Koswari 31.17 to 34.7ppt, Kariyachalli 31.1 to 36.4ppt, Upputhanni 32.1 to 35ppt, Pulivinichalli 30.1 to 34.6ppt and Nallathanni Island 31.1 to 35ppt.

Bottom water salinity of Van Island ranged from 32.2 to 35.3 ppt, Koswari 32.1 to 35.1ppt, Kariyachalli ranged from 32.2 to 37.2ppt, Upputhanni 33.1 to 35.6ppt, Pulivinichalli 32.2 to 35.3ppt and Nallathanni Island ranged from 32.3 to 35.6ppt.

The monthwise report on salinity showed that the highest surface and bottom water salinity was observed during the month of April to June (summer season) whereas the lowest surface water salinity was observed during the month of October to December (monsoon season) in all the six islands studied.

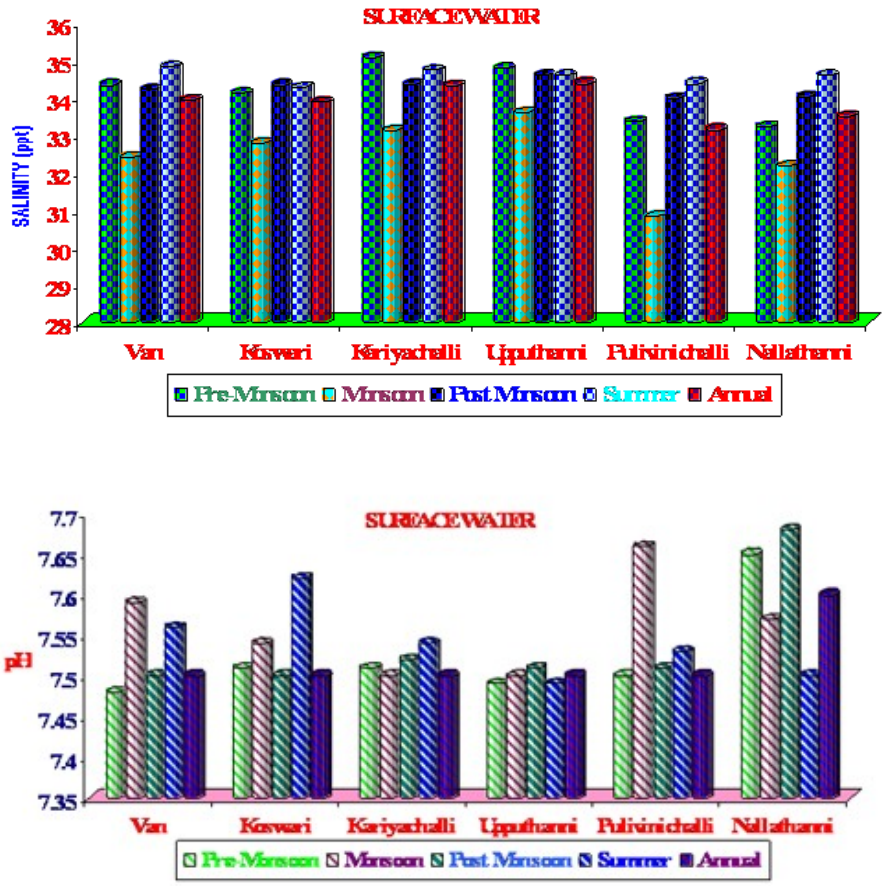


Figure 5 Seasonwise variations of water salinity observed at different stations during the study period (July 2007 to June 2008) in Thoothukudi and Vembar group of islands.

Hydrogen ion concentration (pH)

The monthly variations of pH in the surface and bottom waters of the six islands are presented in Figure 6. There was no much variation observed in the pH value in almost all seasons in all studied stations. There was no much deviation in the surface and bottom water pH. The range of pH falls between 7.1 to 8 in almost all stations. Surface water pH in Van Island ranged from 7.4 to 7.8, in Kaswari Island from 7.5 to 7.9, Kariyachalli Island ranged from 7.5 to 7.6, Upputhanni Island average 7.5, Pulivinichalli Island 7.1 to 8 and Nallathanni Island 7.5 to 7.9 respectively.

Seasonwise analysis showed that, the minimum pH (7.49) was observed during the monsoon season in almost all stations and slight increase in pH (8) was noted during the pre- monsoon and monsoon period in both surface and bottom waters. There was no marked difference noticed in the pH values between surface and bottom waters.

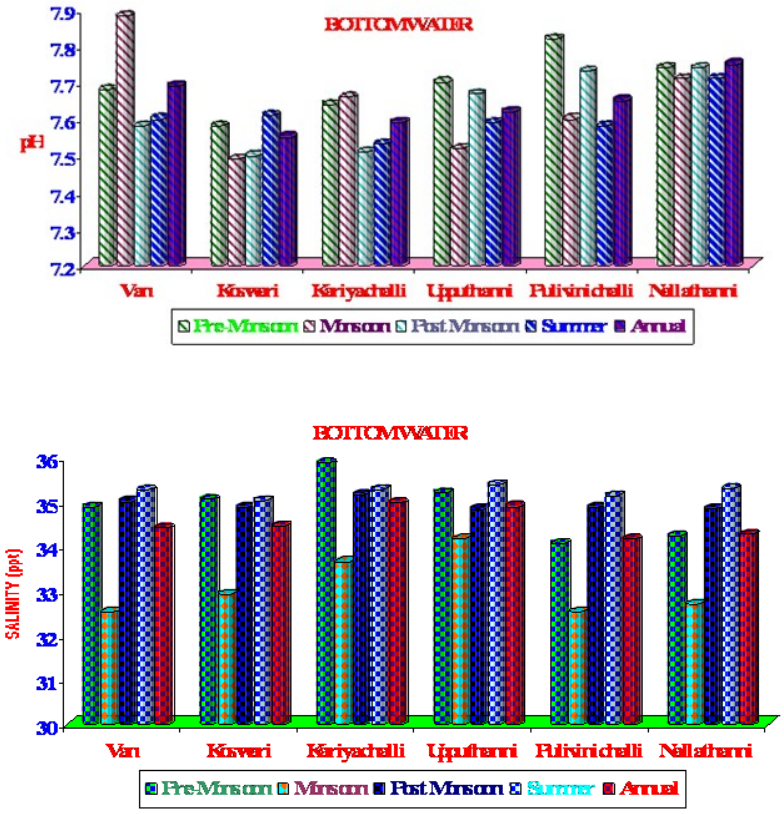


Figure 6 Seasonal mean variation of water pH observed at different stations during the study period (July 2007 to June 2008).

Dissolved oxygen (DO)

Monthly observations regarding the dissolved oxygen content in surface and bottom waters of six islands studied were shown in Figure 7. The level of dissolved oxygen in all study sites did not show much variation throughout the study period both in the surface and bottom waters. The dissolved oxygen level fell between 3.8 to 6.7mg.l^{-1}.

Dissolved oxygen in surface water of Van island ranged between 4.2 to 5.1mg.l^{-1}, from 4.2 to 5.4mg.l^{-1} in Koswari island, 4.2 to 5.6mg.l^{-1} Kariyachalli island, 4.5 to 5.4 mg.l^{-1} Upputhanni island, 4.5 to 6.7mg.l^{-1} Pulivinichalli island and 4.2 to 5.5mg.l^{-1} Nallathanni island, whereas the dissolved oxygen in bottom water varied from 4.03 to 5.07mg.l^{-1} in Van Island, 3.8 to 4.8mg.l^{-1} in Koswari island, 4.2 to 5.2mg.l^{-1} in Kariyachalli island, 4.1 to 5.1mg.l^{-1} in Upputhanni island, 4.1 to 5.07mg.l^{-1} in Pulivinichalli island and 4.1 to 5.5mg.l^{-1} in Nallathanni island.

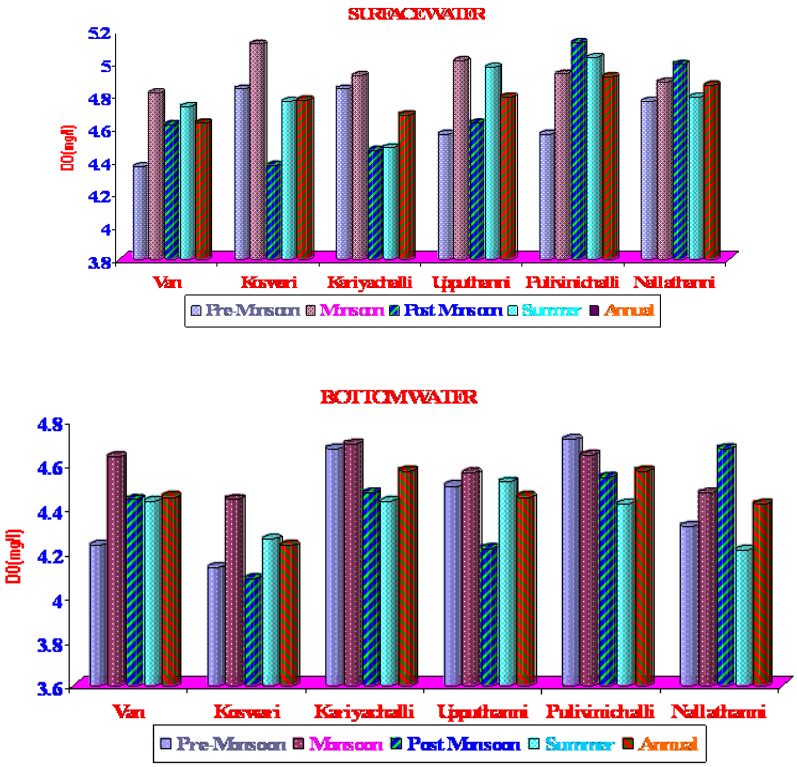


Figure 7 Seasonal variation of dissolved oxygen observed in the water obtained from different stations during the study period (July 2007 to June 2008).

In van island lowest value of dissolved oxygen in surface and bottom water were noticed during July to September (pre-monsoon). But in Koswari Island the lowest value of dissolved oxygen in surface and bottom water was noticed during January to April (post monsoon). In Kariyachalli Island the lowest value was noted during the month of March (summer). In Pulivinichalli and Nallathanni Island the lowest value of dissolved oxygen was noted at surface and bottom water during month of January to May (post monsoon and summer). In all stations the dissolved oxygen content was comparatively lower in bottom waters. A high value of dissolved oxygen content was obtained during the monsoon and post monsoon seasons. Most of the island the low values of dissolved oxygen was noted during the pre-monsoon and summer seasons.

Phosphate concentration

The dissolved inorganic phosphate found in the surface and bottom waters of the study area were presented in Figure 8.

Figure 8 Seasonal variation of phosphate observed in water obtained from different stations during the study period (July 2007 to June 2008).

The annual dissolved inorganic phosphate observed in surface water ranged from 0.4μg.l^{-1} to 1.07μg.l^{-1} and bottom water ranged from 0.1μg.l^{-1} to 2.03μg.l^{-1} in almost all study stations. The dissolved inorganic phosphate in surface water of Van Island ranged between 0.4μg.l^{-1} to 1.07μg.l^{-1}, Koswari Island 0.1μg.l^{-1} to 0.95μg.l^{-1}, Kariyachalli 0.2μg.l^{-1} to 0.38μg.l^{-1}, Upputhanni 0.1μg.l^{-1} to 0.33μg.l^{-1}, Pulivinichalli 0.11μg.l^{-1} to 1.6μg.l^{-1}, and Nallathanni island as 0.16μg.l^{-1} to 2.3μg.l^{-1}.In bottom water the range of dissolved Inorganic phosphate observed in Van island as 0.4μg.l^{-1} to 1.04μg.l^{-1}, Koswari Island 0.1μg.l^{-1} to 0.95μg.l^{-1}, Kariyachalli 0.4μg.l^{-1} to 0.37μg.l^{-1}, Upputhanni 0.3μg.l^{-1} to 0.5μg.l^{-1}, Pulivinichalli 0.17μg.l^{-1} to 2.03μg.l^{-1}, and Nallathanni island 0.1μg.l^{-1} to 1.8μg.l^{-1} respectively.

The Maximum inorganic phosphate in both surface and bottom waters were observed during the pre-monsoon and monsoon season in Pulivinichalli and Nallathanni islands. In all other stations the phosphate level does not show much variation in almost all seasons.

Calcium concentration

Total dissolved calcium in surface waters in all study area ranged from 270mg/l to 605mg/l in Van island, the monthly observation of calcium level observed ranged between 270mg/l to 453mg/l and 245 mg/l to 605 mg/l In Koswari island, 316.7 mg/l to 440mg/l in Kariyachalli, 325mg/l to 440 mg/l in Upputhanni Island 325mg/l to 600 mg/l in Pulivinichalli Island and 325mg/l to 520mg/l in Nallathanni Island (Figure 9).

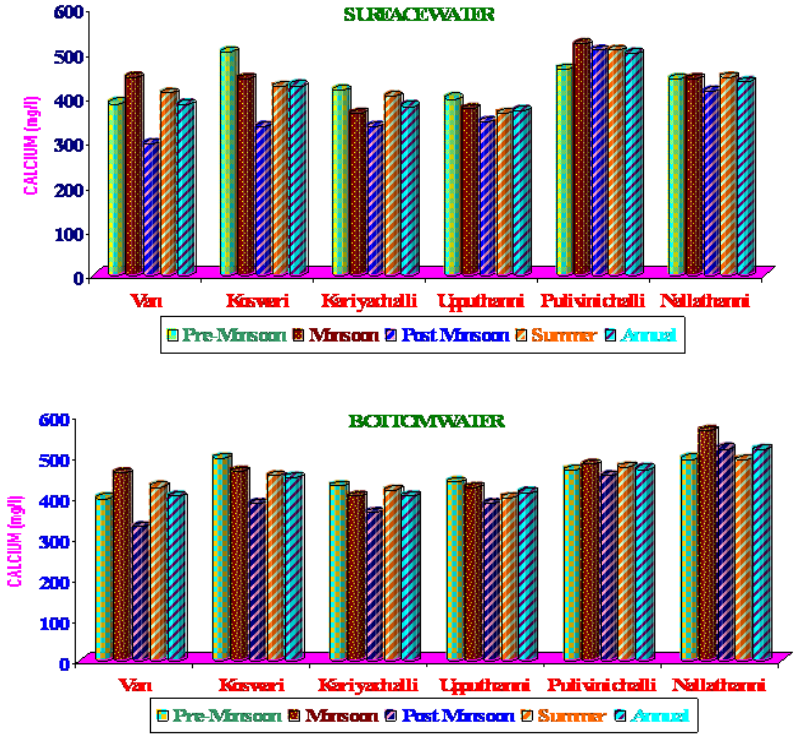


Figure 9 Seasonal variation of calcium in water obtained of different stations during the study period (July 2007 to June 2008).

Total dissolved calcium in bottom waters varied from 320 mg/l to 470 mg/l in Van island, 325mg/l to 605mg/l In Koswari island, 316mg/l to 465mg/ l in Kariyachalli, 325 mg/l to 480mg/l in Upputhanni Island 325mg/l to 536.7mg/l in Pulivinichalli Island and 325mg/l to 640mg/l in Nallathanni Island.
The highest surface water calcium was noticed during the monsoon and pre- monsoon season in almost all study area while a slight decline was noticed during the post monsoon season and once again during the summer the level of calcium reached to the maximum level in almost all stations studied.

Magnesium concentration

A monthly variation in the dissolved Magnesium in the surface and bottom waters of the study area of Gulf of Mannar islands was presented in Figure 10.
The dissolved Magnesium in surface water ranged from 940.7mg/l to 1755mg/l and bottom water ranged from 952.3mg/l to1831mg/l. The dissolved Magnesium in surface water of Van island ranged between 1120mg/l to 1755mg/l, Koswari Island 940.7mg/l to 1475mg/l, Kariyachalli Island 1044mg/l to 1500.3mg/l, Upputhanni Island 1067.5mg/l to 1545.4mg/l, Pulivinichalli Island 1087.2mg/l to 1455mg/l and Nallathanni Island 1030.3mg/l to 1366.3mg/l. The magnesium level in bottom water of Van Island ranged between 1096mg/l to 1832mg/l, Koswari Island 952.4mg/l to 1475mg/l, Kariyachalli 1057mg/l to 1501mg/l, Upputhanni 1048mg/l to 1553mg/l, Pulivinichalli 1044.5mg/l to 1384.2mg/l and Nallathanni Island 1172mg/l to 1546mg/l respectively.

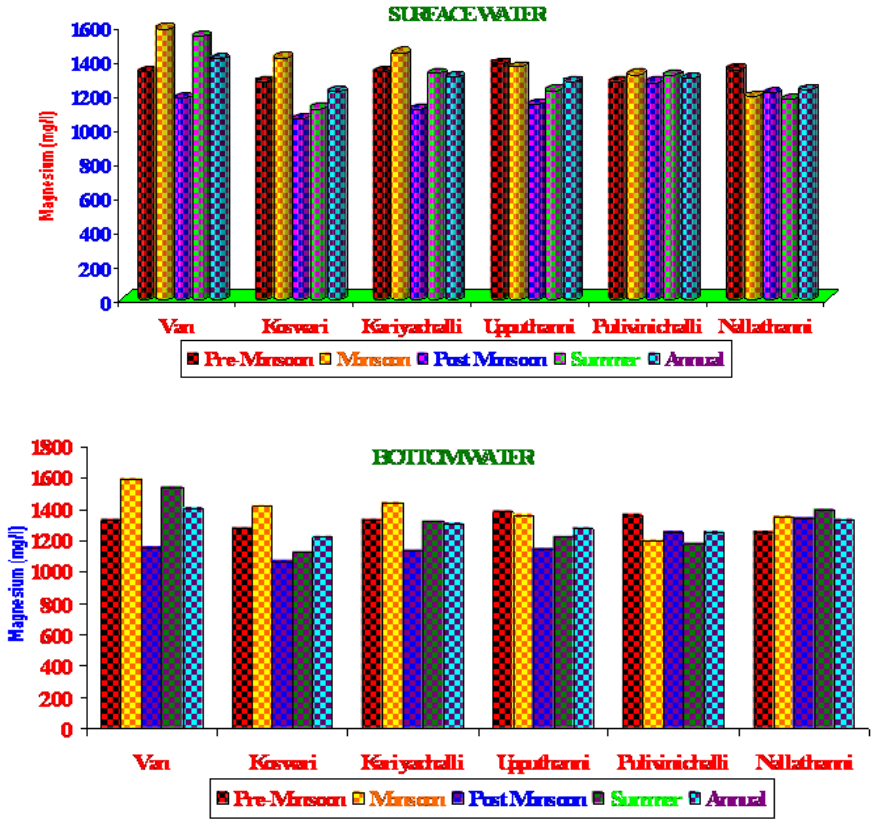


Figure 10 Seasonal variation of magnesium in water obtained of different stations during the study period (July 2007 to June 2008).

The maximum value of Magnesium in surface and bottom waters occurred during the monsoon season and the lowest value of magnesium was recorded during the post- monsoon and summer season in almost all stations studied.

Nitrite concentration

The monthly variation of the total Nitrite concentration in the surface and bottom waters of the six stations studied in Gulf of Mannar coast were displayed in Figure 11.

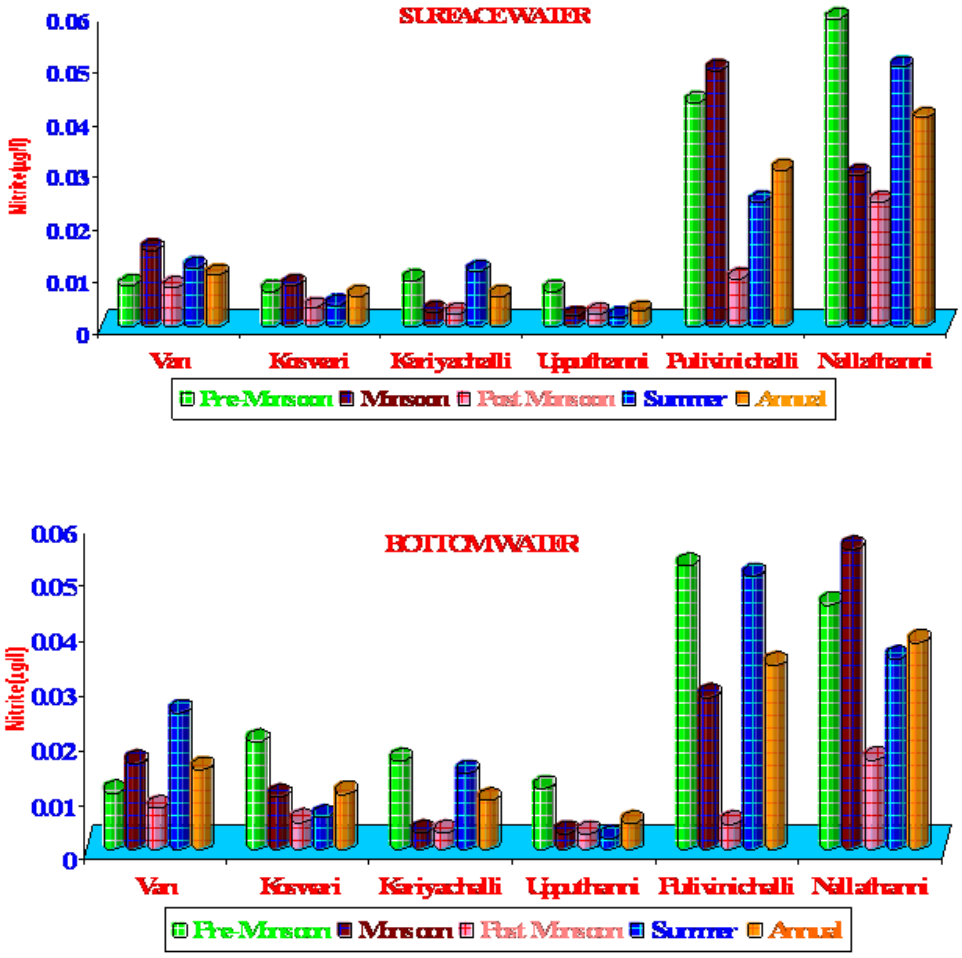


Figure 11 Seasonal variations of nitrites in water obtained of different stations during the study period (July 2007 to June 2008).

Total Nitrite concentration in surface waters of the study ranged from 0.01μg.l^{-1} to 0.05μg.l^{-1} both in the surface and bottom waters. The nitrite content of Van Island, ranged from 0.01μg.l^{-1} to 0.04μg.l^{-1} and in Koswari Island, 0.01μg.l^{-1} to 0.06μg.l^{-1} in Kariyachalli, 0.01μg.l^{-1} to 0.06μg.l^{-1} in Upputhanni Island, 0.01μg.l^{-1} to 0.06μg.l^{-1} in Pulivinichalli Island 0.01μg.l^{-1} to 0.06μg.l^{-1} and in Nallathanni Island 0.02μg.l^{-1} to 0.06μg.l^{-1} .

Total Nitrite in bottom waters varied from 0.01μg.l^{-1} to 0.05μg.l^{-1} in Van island, 0.02μg.l^{-1} to 0.08μg.l^{-1} in Koswari island, 0.01μg.l^{-1} to 0.06μg.l^{-1} in Kariyachalli, 0.01 μg.l^{-1} to 0.04μg.l^{-1} in Upputhanni Island,0.02μg.l^{-1} to 0.07μg.l^{-1} in Pulivinichalli Island and 0.01μg.l^{-1} to 0.06μg.l^{-1} in Nallathanni Island.

Maximum values were recorded during the pre-monsoon season, while minimum values were recorded during the summer season in almost all the study stations both in the surface and bottom waters.

Nitrate concentration

The nitrate content in the waters of study area ranged between 0.12μg.l^{-1} to 1.35μg.l^{-1} with the maximum during summer and minimum during monsoon and post-monsoon season both in surface and bottom waters (Figure 12).

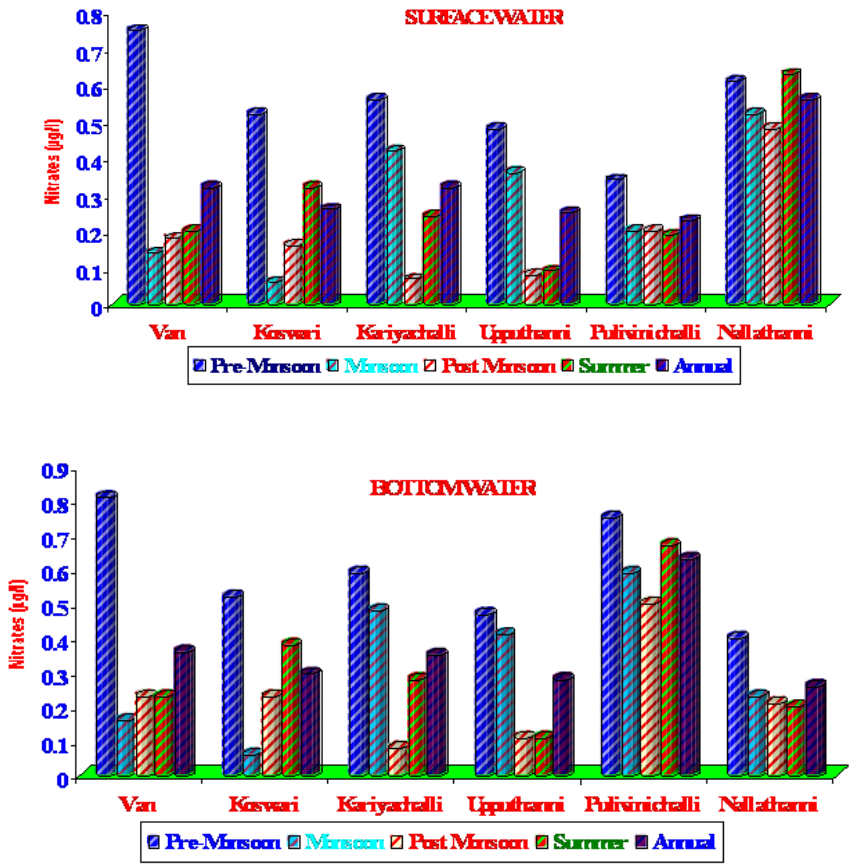


Figure 12 Seasonal variations of nitrates in water obtained of different stations during the study period (July 2007 to June 2008).

The dissolved Nitrates recorded in surface water of Van Island ranged from 0.2μg.l^{-1} to 1.23μg.l^{-1}, Koswari Island from 0.4μg.l^{-1} to 0.84μg.l^{-1}, Kariyachalli island from 0.2μg.l^{-1} to 0.83μg.l^{-1}, Upputhanni island from 0.2μg.l^{-1} to 0.73μg.l^{-1}, Pulivinichalli island from 0.16μg.l^{-1} to 0.6μg.l^{-1} and Nallathanni island from 0.22μg.l^{-1} to 0.84μg.l^{-1} and in bottom water the range of concentration of Nitrates of Van island ranged from 0.2μg.l^{-1} to 1.35μg.l^{-1} Koswari Island 0.4μg.l^{-1} to 0.74μg.l^{-1}, Kariyachalli 0.2μg.l^{-1} to 0.83μg.l^{-1}, Upputhanni 0.2μg.l^{-1} to 0.75μg.l^{-1}, Pulivinichalli 0.3μg.l^{-1} to 0.88μg.l^{-1} and Nallathanni island 0.16μg.l^{-1} to 0.7μg.l^{-1} respectively. The bottom water Nitrate contents were slightly higher than the surface water values in all the study locations.
The highest value of Nitrates in surface and bottom waters occurred during the premonsoon season and lowest value of Nitrates in surface and bottom waters occurred during the post-monsoon season at all the study stations.

Statistical analysis

Correlation co-efficient analysis of both surface and bottom water at Van Island showed a significant positive correlation between salinity, water temperature, phosphate with temperature, and nitrate with temperature. But the level of dissolved oxygen, pH, carbon and transparency negatively correlated with the temperature during the entire study period (Table 1 & 2).

Correlation coefficient analysis of both surface and bottom waters of Koswari Island showed significant positive correlation between salinity, water temperature, pH, phosphate and nitrate. But the level of dissolved oxygen, transparency, carbon, magnesium and nitrite were negatively correlated with the temperature during the entire study period (Table 3 & 4).

Table 1 Correlation coefficient (r) values obtained between various physio-chemical, parameters of surface water during the study period (July 2007 – June 2008) at Van Island

	AD.T	SW.T	SW.S	SW.pH	SW.DO	TRANS	SW.C	SW.M	SW.P	SW.NITRA	SW.NIT
AD.T	1										
SW.T	.189	1									
SW.S	.507	.813(**)	1								
SW.pH	-.057	-.044	-.111	1							
SW.DO	-.650(*)	.322	-.146	.495	1						
TRANS	-.292	-.363	-.178	-.170	-.155	1					
SW.C	-.132	-.297	-.349	.208	.163	-.072	1				
SW.M	.018	-.228	-.302	.709(**)	.320	-.231	.683(*)	1			
SW.P	-.313	-.142	-.329	-.193	.195	.471	.230	.098	1		
SW.NITRA	.235	-.098	.174	-.036	-.319	.748(**)	-.152	-.092	.217	1	
SW.NIT	.397	.043	.421	-.127	-.519	.078	-.525	-.278	-.630(*)	.311	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, **SW.T** – Surface water Temperature, **SW.S**- Surface water Salinity, **SW.pH** - Surface water pH, **SW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **SW.C** – Surface water Calcium, **SW.M** – Surface water Magnesium, **SW.P** – Surface water Phosphate, **SW.NITRA** – Surface water Nitrate, **SW.NIT** – Surface Water Nitrite.

Table 2 Correlation coefficient (r) values obtained between various physio-chemical, parameters of bottom water during the study period (July 2007 – June 2008) at Van Island

	AD.T	BW.T	BW.S	BW.pH	BW.DO	TRANS	BW.C	BW.M	BW.P	BW.NITRA	BW.NIT
AD.T	1										
BW.T	.807(**)	1									
BW.S	.876(**)	.971(**)	1								
BW.pH	-.739(**)	-.711(**)	-.698(*)	1							
BW.DO	.125	-.313	-.186	.218	1						
TRANS	-.255	-.211	-.178	.110	-.112	1					
BW.C	-.285	-.500	-.361	.606(*)	.226	-.171	1				
BW.M	-.199	-.387	-.276	.609(*)	.280	-.215	.695(*)	1			
BW.P	-.137	-.506	-.403	.047	.322	.429	.316	.129	1		
BW.NITRA	.071	.185	.180	-.013	-.272	.750(**)	-.299	-.108	.159	1	
BW.NIT	.139	.510	.417	-.262	-.717(**)	.157	-.462	-.293	-.629(*)	.430	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, B**W.T** – Surface water Temperature, B**W.S**- Surface water Salinity, **BW.pH** - Surface water pH, **BW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **BW.C** – Surface water Calcium, **BW.M** – Surface water Magnesium, **BW.P** – Surface water Phosphate, **BW.NITRA** – Surface water Nitrate, **BW.NIT** – Surface Water Nitrite.

Correlation coefficient analysis of both surface and bottom waters of Kariyachalli island showed significant positive correlation with salinity, pH, nitrate and nitrite while the dissolved oxygen content, transparency, magnesium and phosphate were negatively correlated with the temperature during the entire study period (Table 5 & 6).

Correlation coefficient analysis of both surface and bottom waters of Upputhanni island showed significant positive correlation with salinity, phosphate and nitrite while the dissolved oxygen, transparency, calcium, magnesium and nitrate were negatively correlated with the water temperature (Table 7 & 8).

Correlation coefficient analysis of both surface and bottom waters of Pulivinichalli island showed significant positive correlation with salinity, magnesium and nitrate while the remaining parameters such as dissolved oxygen, transparency, calcium and nitrite were negatively correlated with the water temperature (Table 9 & 10).

Table 3 Correlation coefficient (r) values obtained between various physio-chemical, parameters of surface water during the study period (July 2007 – June 2008) at Kaswori Island.

	AD.T	SW.T	SW.S	SW.pH	SW.DO	TRANS	SW.C	SW.M	SW.P	SW.NITRA	SW.NIT
AD.T	1										
SW.T	.310	1									
SW.S	.205	.829(**)	1								
SW.pH	.331	.061	-.027	1							
SW.DO	-.020	-.124	-.184	.474	1						
TRANS	-.256	-.316	-.057	-.188	-.108	1					
SW.C	-.300	.132	.095	-.043	.316	.629(*)	1				
SW.M	-.432	-.417	-.268	-.121	.176	.443	.478	1			
SW.P	.079	.143	.128	-.016	.439	.209	.435	.185	1		
SW.NITRA	.024	-.051	-.046	.219	.445	.450	.615(*)	-.095	.398	1	
SW.NIT	-.647(*)	.128	.103	-.023	.124	.038	.430	.034	-.107	.404	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, **SW.T** – Surface water Temperature, **SW.S**- Surface water Salinity, **SW.pH** - Surface water pH, **SW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **SW.C** – Surface water Calcium, **SW.M** – Surface water Magnesium, **SW.P** – Surface water Phosphate, **SW.NITRA** – Surface water Nitrate, **SW.NIT** – Surface Water Nitrite.

Table 4 Correlation coefficient (r) values obtained between various physio-chemical, parameters of bottom water during the study period (July 2007 – June 2008) at Kaswori Island.

	AD.T	BW.T	BW.S	BW.pH	BW.DO	TRANS	BW.C	BW.M	BW.P	BW. NITRA	BW.NIT
AD.T	1										
BW.T	.297	1	.								
BW.S	.489	.854(**)	1								
BW.pH	.318	.295	.209	1							
BW.DO	.026	-.289	-.327	-.337	1						
TRANS	-.256	-.164	.039	.285	-.313	1					
BW.C	-.359	.275	.069	.146	-.080	.558	1				
BW.M	-.440	-.340	-.472	.211	-.131	.435	.462	1			
BW.P	.087	.107	.169	-.332	.072	.197	.395	.162	1		
BW.NITRA	-.384	-.004	-.045	-.090	.164	.416	.423	.183	.112	1	
BW.NIT	-.466	.336	.199	-.126	.354	.178	.457	-.027	.084	.657(*)	1

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

AD. T – Atmospheric temperature, B**W.T** – Surface water Temperature, B**W.S**- Surface water Salinity, **BW.pH** - Surface water pH, **BW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **BW.C** – Surface water Calcium, **BW.M** – Surface water Magnesium, **BW.P** – Surface water Phosphate, **BW.NITRA** – Surface water Nitrate, **BW.NIT** – Surface Water Nitrite.

Correlation coefficient analysis of both surface and bottom water of Nallathanni island showed significant positive correlation with salinity, dissolved oxygen, phosphate and nitrate while the other parameters such as pH, transparency, magnesium were negatively correlated with the water temperature throughout the study period (Table 11 & 12).

Table 5 Correlation coefficient (r) values obtained between various physio-chemical, parameters of surface water during the study period (July 2007 – June 2008) at Kariyachalli Island.

	AD.T	SW.T	SW.S	SW.pH	SW.DO	TRANS	SW.C	SW.M	SW.P	SW.NITRA	SW.NIT
AD.T	1										
SW.T	.457	1									
SW.S	.316	.784(**)	1								
SW.pH	.216	.032	-.023	1							
SW.DO	-.142	-.134	.214	-.668(*)	1						
TRANS	-.295	-.300	.015	-.091	.075	1					
SW.C	.011	.381	.661(*)	-.226	.362	.465	1				
SW.M	-.424	-.578(*)	-.391	-.119	.229	.544	.098	1			
SW.P	.177	.441	.166	-.495	.033	-.377	-.046	-.144	1		
SW.NITRA	-.045	-.166	-.209	.474	-.422	.177	-.425	.257	.044	1	
SW.NIT	-.082	.178	.026	.118	-.270	.010	.379	-.214	-.230	-.614(*)	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, **SW.T** – Surface water Temperature, **SW.S**- Surface water Salinity, **SW.pH** - Surface water pH, **SW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **SW.C** – Surface water Calcium, **SW.M** – Surface water Magnesium, **SW.P** – Surface water Phosphate, **SW.NITRA** – Surface water Nitrate, **SW.NIT** – Surface Water Nitrite.

Table 6 Correlation coefficient (r) values obtained between various physio-chemical, parameters of bottom water during the study period (July 2007 – June 2008) at Kariyachalli Island.

	AD.T	BW.T	BW.S	BW.pH	BW.DO	TRANS	BW.C	BW.M	BW.P	BW.NITRA	BW.NIT
AD.T	1										
BW.T	.322	1									
BW.S	.410	.792(**)	1								
B.W.pH	.160	-.480	-.183	1							
BW.DO	.127	-.078	.178	.522	1						
TRANS	-.295	-.126	-.002	-.018	-.243	1					
BW.C	-.159	.215	.384	-.174	.135	.462	1				
BW.M	-.438	-.480	-.480	.093	-.077	.557	.166	1			
BW.P	.107	-.017	-.104	.225	.594(*)	-.246	.106	.284	1		
BW.NITRA	.047	-.189	-.115	-.183	-.425	.295	-.177	.459	-.069	1	
BW.NIT	.318	.201	-.047	-.103	.088	-.045	.175	-.121	-.013	-.428	1

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

AD. T – Atmospheric temperature, B**W.T** – Surface water Temperature, B**W.S**- Surface water Salinity, **BW.pH** - Surface water pH, **BW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **BW.C** – Surface water Calcium, **BW.M** – Surface water Magnesium, **BW.P** – Surface water Phosphate, **BW.NITRA** – Surface water Nitrate, **BW.NIT** – Surface Water Nitrite.

Table 7 Correlation coefficient (r) values obtained between various physio-chemical, parameters of surface water during the study period (July 2007 – June 2008) at Upputhanni Island.

	AD.T	SW.T	SW.S	SW.pH	SW.DO	TRANS	SW.C	SW.M	SW.P	SW.NITRA	SW.NIT
AD.T	1										
SW.T	.376	1									
SW.S	.319	.667(*)	1								
SW.pH	-.276	.102	-.006	1							
SW.DO	-.330	.237	.013	.400	1						
TRANS	-.195	-.250	.201	.039	-.232	1					
SW.C	-.073	-.158	.144	-.239	-.206	.741(**)	1				
SW.M	-.191	-.420	-.014	-.213	-.085	.649(*)	.738(**)	1			
SW.P	-.153	.389	.417	-.381	-.012	-.120	-.236	-.414	1		
SW.NITRA	-.106	.182	-.230	.142	.160	.185	.199	-.020	-.056	1	
SW.NIT	-.247	-.019	-.269	.521	-.023	-.091	.115	-.147	-.372	.481	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, **SW.T** – Surface water Temperature, **SW.S**- Surface water Salinity, **SW.pH** - Surface water pH, **SW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **SW.C** – Surface water Calcium, **SW.M** – Surface water Magnesium, **SW.P** – Surface water Phosphate, **SW.NITRA** – Surface water Nitrate, **SW.NIT** – Surface Water Nitrite.

Table 8 correlation coefficient (r) values obtained between various physio-chemical, parameters of bottom water during the study period (July 2007 – June 2008) at Upputhanni Island

	AD.T	BW.T	BW.S	BW.pH	BW.DO	TRANS	BW.C	BW.M	BW.P	BW.NITRA	BW.NIT
AD.T	1										
BW.T	.401	1									
BW.S	.255	.643(*)	1								
BW.pH	.004	.014	.332	1							
BW.DO	-.118	-.130	-.136	.019	1						
TRANS	-.195	-.185	.283	.310	.240	1					
BW.C	.013	-.113	.064	-.297	.003	.614(*)	1				
BW.M	-.192	-.317	-.038	-.291	.242	.639(*)	.688(*)	1			
BW.P	-.082	-.068	.285	.230	-.104	-.012	-.072	-.419	1		
BW.NITRA	-.123	-.154	.087	.118	.727(**)	.331	-.009	.166	.359	1	
BW.NIT	-.067	.258	-.416	-.565	-.048	-.348	.180	-.129	-.274	-.286	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, B**W.T** – Surface water Temperature, B**W.S**- Surface water Salinity, **BW.pH** - Surface water pH, **BW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **BW.C** – Surface water Calcium, **BW.M** – Surface water Magnesium, **BW.P** – Surface water Phosphate, **BW.NITRA** – Surface water Nitrate, **BW.NIT** – Surface Water Nitrite.

Table 9 Correlation coefficient (r) values obtained between various physio-chemical, parameters of surface water during the study period (July 2007 – June 2008) at Pulivinichalli Island.

	AD.T	SW.T	SW.S	SW.pH	SW.DO	TRANS	SW.C	SW.M	SW.P	SW.NITRA	SW.NIT
AD.T	1										
SW.T	.317	1									
SW.S	.534	.828(**)	1								
SW.pH	-.335	-.098	-.146	1							
SW.DO	-.069	.260	.133	.046	1						
TRANS	-.401	.006	.003	.292	.500	1					
SW.C	-.110	-.302	-.158	-.089	-.078	.436	1				
SW.M	.134	-.227	-.233	.075	-.194	.172	.614(*)	1			
SW.P	-.522	-.266	-.304	.583(*)	-.096	-.118	-.030	.055	1		
SW.NITRA	.335	-.109	.227	-.072	-.133	-.506	-.328	-.433	.136	1	
SW.NIT	-.373	-.397	-.679(*)	.051	-.189	-.068	-.146	.402	.272	-.442	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, **SW.T** – Surface water Temperature, **SW.S**- Surface water Salinity, **SW.pH** - Surface water pH, **SW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **SW.C** – Surface water Calcium, **SW.M** – Surface water Magnesium, **SW.P** – Surface water Phosphate, **SW.NITRA** – Surface water Nitrate, **SW.NIT** – Surface Water Nitrite.

Table 10 Correlation coefficient (r) values obtained between various physio-chemical, parameters of bottom water during the study period (July 2007-June 2008) at Pulivinichalli Island.

	AD.T	BW.T	BW.S	BW.pH	BW.DO	TRANS	BW.C	BW.M	BW.P	BW.NITRA	BW.NIT
AD.T	1										
BW.T	.315	1									
BW.S	.599(*)	.843(**)	1								
BW.pH	.183	-.023	.268	1							
BW.DO	.294	-.326	-.082	.536	1						
TRANS	-.401	.196	.114	-.097	-.065	1					
BW.C	.261	-.228	.112	-.009	.340	.041	1				
BW.M	-.041	.074	-.031	.516	-.036	-.439	-.481	1			
BW.P	.258	-.620(*)	-.249	.335	.195	-.422	.361	.116	1		
BW.NITRA	.507	-.105	-.033	.085	.169	-.546	.225	.387	.545	1	
BW.NIT	.478	.176	.136	-.194	.135	-.240	.056	.048	-.125	.346	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, B**W.T** – Surface water Temperature, B**W.S**- Surface water Salinity, **BW.pH** - Surface water pH, **BW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **BW.C** – Surface water Calcium, **BW.M** – Surface water Magnesium, **BW.P** – Surface water Phosphate, **BW.NITRA** – Surface water Nitrate, **BW.NIT** – Surface Water Nitrite.

Table 11 Correlation coefficient (r) values obtained between various physio-chemical, parameters of surface water during the study period (July 2007 – June 2008) at Nallathanni island.

	AD.T	SW.T	SW.S	SW.pH	SW.DO	TRANS	SW.C	SW.M	SW.P	SW.NITRA	SW.NIT
AD.T	1										
SW.T	.269	1									
SW.S	.604(*)	.571	1								
SW.pH	-.178	-.069	.030	1							
SW.DO	.157	-.180	.199	.114	1						
TRANS	-.266	-.103	.209	.218	.370	1					
SW.C	.203	-.134	.313	-.127	.068	-.170	1				
SW.M	-.170	.018	-.334	-.116	-.500	-.317	-.305	1			
SW.P	.070	-.656(*)	-.215	-.082	-.167	-.440	.408	.193	1		
SW.NITRA	.154	.184	-.102	-.544	-.310	-.598(*)	.184	.455	.310	1	
SW.NIT	.777(**)	.010	.356	-.039	.286	-.130	.174	.081	.034	-.001	1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

AD. T – Atmospheric temperature, **SW.T** – Surface water Temperature, **SW.S**- Surface water Salinity, **SW.pH** - Surface water pH, **SW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **SW.C** – Surface water Calcium, **SW.M** – Surface water Magnesium, **SW.P** – Surface water Phosphate, **SW.NITRA** – Surface water Nitrate, **SW.NIT** – Surface Water Nitrite.

Table 12 Correlation coefficient (r) values obtained between various physio-chemical, parameters of bottom water during the study period (July 2007 – June 2008) at Nallathanni island.

	AD.T	BW.T	BW.S	BW.pH	BW.DO	TRANS	BW.C	BW.M	BW.P	BW.NITRA	BW.NIT
AD.T	1										
BW.T	.387	1									
BW.S	.531	.854(**)	1								
BW.pH	.030	.085	.118	1							
BW.DO	-.109	.027	-.012	.162	1						
TRANS	-.266	-.145	.012	.013	.331	1					
BW.C	-.426	-.494	-.366	.342	.065	.104	1				
BW.M	-.012	-.005	.125	-.024	-.199	-.004	.595(*)	1			
BW.P	-.525	-.292	-.365	.319	.271	-.410	.473	.101	1		
BW.NITRA	.111	-.177	.129	-.010	.083	-.054	-.190	-.265	.147	1	
BW.NIT	-.303	-.350	-.608(*)	-.185	-.078	-.082	.060	.098	.217	-.532	1

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed).

AD. T – Atmospheric temperature, B**W.T** – Surface water Temperature, B**W.S**- Surface water Salinity, **BW.pH** - Surface water pH, **BW.DO** – Surface water dissolved oxygen, **TRANS** – Transparency, **BW.C** – Surface water Calcium, **BW.M** – Surface water Magnesium, **BW.P** – Surface water Phosphate, **BW.NITRA** – Surface water Nitrate, **BW.NIT** – Surface Water Nitrite.

DISCUSSION

Hydrographic parameters are vital for the normal growth of biota in a water ecosystem [7]. Hydrographic parameters of different sites of Gulf of Mannar have been reported by several authors [19 - 25]. The detailed investigation on the hydrography of Thoothukudi and Vembar group of islands had been conducted in the study area discussed in this chapter.

Among all the physical and chemical properties of the water, temperature gets special attention since it play crucial role in the abundance, health, reproduction, recruitment, diversity and growth of corals.

Water temperature on most coral reef remains fairly constant throughout the year, with optimal growth at temperature of 22-30^{0}C [26]. Gopinathan *et al.*, [27] reported that tropical aquatic organisms including shell and fin fishes grow very well at water temperature ranging between 25 and 30. Heat stress can lead to colony death. Temperature increases of 1-2 above the long-term average for one to two weeks is known to trigger bleaching, causing corals to turn white due to the loss of the symbiotic zooxanthellae [28 – 30].

Coral reefs are generally restricted to water with temperature ranged between 18^0 and 36^{0}C, with an optimal range of 26-28^{0}C. Within this range, certain corals will grow faster or slower, depending on temperature [31, 32]. According to Warner *et al.*,[33] a slight increase in tropical temperatures in the marine ecosystem could have significant impact on the distribution of corals in the tropics and Drastic thermal shifts can result in reduced coral vitality (bleaching, reproductive inhibition) or, in extreme instance, total destruction of entire reef systems.

Rainfall has a direct influence on the atmospheric temperature, water temperature and salinity of water. It also has a dynamic influence on coastal aquatic ecosystems. Rainfall has a direct influence in determining the rate of river discharge into the estuarine and marine ecosystem causing a wide variation in salinity and water temperature. More over rainfall influences the water level of the estuarine system. It also has an influence on the inorganic and organic contents of the marine ecosystem [34, 35]. In Thoothukudi, the North East monsoon brings heavy rainfall from October to December with highest rainfall in the month of October. However during the South west monsoon (June to September) very less rainfall has been recorded in the Thoothukudi Region. Of these two monsoons the north East monsoon is the important one as far as agriculture and fisheries of the Thoothukudi Region are concerned. Based on the seasonal pattern of rainfall, the year can be divided into four seasons, pre-monsoon (July, August and September), Monsoon (October, November and December), Post- Monsoon (January, February and March) and summer (April, May and June) [36, 37]. Water currents were reported from east to west and currents was strongest off the east coast.

In the present study, also the highest value of rainfall (102mm-176.3mm) was recorded during the North east Monsoon season (October to December) in most of the islands while the summer received the least rain fall in almost all islands. A similar pattern of rainfall has been reported by earlier works in the Gulf of Mannar in which the North East monsoon contributes the major portion of the annual rainfall [19, 34, 38].

Air temperature is an important physical factor that has a universal influence and frequently a limiting factor for the growth and distribution of organisms. The temperature of an area is determined by its latitude, altitude, proximity to the sea and also due to the influence of ocean currents and winds. In Thoothukudi a warm tropical climate is experienced throughout the year, with very little seasonal changes in temperature. The temperature remains almost constant throughout the year. In the present study, the temperature recorded in the six islands showed that June and July are the hottest months of the year. The month of December showed a decline in monthly mean temperature in all the study islands. This may be due to the influence of North East monsoon during October to December. It is quite obvious that the day time temperature is controlled by the effect of rainfall and humidity. Since in the study area normal rainfall is prevailed throughout the year, the temperature level was also maintained more or less in the same level in all the study stations [27, 38]. From this study it is concluded that the rainfall level and the temperature prevailed in the study area provide a suitable environment for the growth of the corals and other related organisms [39, 40, 41]. When compared to Vembar group of islands, the Thoothukudi group received less rainfall during the study period. The fall in rainfall may be due to the influence of industrial air pollution that is a common feature in Thoothukudi.

In the present study water temperature fluctuated within a narrow limit in all seasons in all the studied islands. The temperature ranged between 26.5^{0}C to 29.6^{0}C during pre-monsoon, post monsoon and monsoon periods where as it was slightly shoot up to 29.9^{0}C to 30.1^{0}C during summer in all stations. In comparison it was observed that in almost all study area the atmospheric temperature observed was between 26^{0}C to 32^{0}C in all stations, which was somewhat higher than the water temperature. Similar results have been reported in earlier hydrographic studies of Gulf of Mannar [19, 42, 25, 43]. Since in the study area the water temperature falls within the optimum range (26^{0}C-28^{0}C) during several months, which were required for the blooming growth of corals, the coral fauna observed in the study area was also high. In all the six stations studied a significant drop in temperature was observed during October to December which is the monsoon season for Gulf of Mannar region and this may be the reason for drop in water temperature in the study area during this season [7].

In the present study there was not much variations noticed between the surface and bottom waters, probably due to the shallow nature of the study area [7, 27, 41]. But Asha *et al*., [44] reported that the sea surface temperature is higher than the atmospheric temperature in Thoothukudi Bay. The spatial variation observed in temperature could be due to the variable intensity of prevailing currents and the consequent mixing of water [45]. In the study area the change in surface and bottom water temperature observed may be due to the discharge of hot water from the Thoothukudi Thermal Power Station (TTPS) and also drastic climatic changes and global warming prevailed in the study area.

The salinity of coastal and offshore environment is influenced by a number of environmental factors such as runoff, precipitation evaporation, surface current patterns, and upwelling [26]. Coral reefs are normally found in areas with salinities of 32 to $40^{0}/_{00}$. Salinity fluctuations are key factor determining local zonation patterns of corals. Rapid decreases in salinity after monsoon rains or flood rains or rates of evaporation that are outside the normal range experienced in a particular environment, can create conditions that fail to sustain corals [26]. In addition to the effects of heavy rainfall, upwelling, natural fluctuations in salinity, and discharges from freshwater point sources and wastewater and power plants have caused coral mortality events [46]. Experimental studies have found that most corals will not tolerate salinities at 110% of normal levels for more than two weeks, while salinities of 150% of normal levels will kill a coral within 24 hours [47]. In addition to the potential for increased coral mortality associated with higher than normal salinities, a 20% reduction in salinity resulted in up to an 84% decrease in reproduction success [48].

In the present study comparatively high values of salinity were observed in Thoothukudi and Vembar group of islands, especially during the monsoon and post monsoon seasons. Maximum salinity values were obtained in all the six stations during the month of October to March and minimum in the month of October to December. A very marked decline in salinity values were observed during the monsoon (October to December) season. The low value of salinity during the monsoon season noted in the present study may be due to the entry of fresh water into the sea due to monsoon [25, 44]. The high salinity observed during the pre-monsoon, post-monsoon and summar season in the present study might be due to the evoparation of surface water and upwelling of water [26]. Wide salinity fluctuations and factors that increase or decrease salinity levels can have detrimental impacts on benthic reef building corals.

Atkins, [49] established pH of the water as indispensable factors for all hydrographical studies. The pH of sea water generally ranges from 7.5 to 8.4, and is slightly alkaline [50]. The high buffering activity of sea water often checks wide variations of pH in coastal waters [51]. Fluctuations of dissolved oxygen content, and CO_2 influence the pH in inland water bodies [52]. In the present study the pH of the six stations of Gulf of Mannar were very close to the neutral pH with slight variation. The water was slightly alkaline throughout the year. Monthly and seasonal pH values recorded in the coral reef environment of the studied Thoothukudi and Vembar group of islands varied between 7.5 to 7.8. The minimum pH value recorded during the pre-monsoon and monsoon season could be due to entry of fresh water [53].

The dissolved oxygen in water and available to aquatic organisms, one of the most important indicators of the condition of a water body; concentrations below 5 mg/l are stressful and may be lethal to many fish and other species [26]. Dissolved oxygen levels in seawater column are related to several other factors such as temperature, salinity, wave action, amount of plankton present, pollution and the influence of including external water masses [54]. The dissolved oxygen is known to decide the suitability of aquatic ecosystems to support the survival and growth of aquatic organisms. Chandraprakash and Reddy, [55] reported that dissolved oxygen concentrations greater than 3.5 ml/l were always associated with rich fish populations and species diversity. In the present study, all the study sites were rich in dissolved oxygen concentration and it ranged between 4.1 to 6.7 mg/l. There was no much difference observed between the surface and bottom levels of dissolved oxygen in all stations at all seasons. Krishnapillai *et al.*, [56] had reported maximum DO of 6.04 mg/l in surface water during November 1979 in the Palk Bay region. Asha *et al*., [44] also reported DO content ranged between 1.38 $ml.l^{-1}$ to 2.76 $ml.l^{-1}$ in the Bay water. Radhakrishna and Krishnapillai, [57] observed maximum DO of 5.17 mg/l in the shelf water Bombay. Kumaraguru and Jayakumar, [25] reported 4.5 to 4.6 ml/l in Hare island of Mandapam group of islands in Gulf of Mannar.

Light is an important factor affecting the distribution of corals on the reef [58]. Banner, [59] reported that light affects the growth forms of corals. Corals that are restricted to shallower depths in coastal areas, particularly near urban areas may be exposed to increased levels of sediments transported in form upland sources, resulting in higher sedimentation rates as well as reduced light transmission [60].

Penetration of light into water is determined by various physical factors such as current, wind, turbidity, certain substances from bottom sediments and also by biological phenomenon such as algal bloom. Transparency of water is subjected to great variations from season to seasons, owing to the difference in the amount of stirring, discharge of silt laden water of rivers and production of planktons [50]. According to Kaliyamoorthy, [61] in shallow waters with muddy bottom, high turbidity may be caused by wind stirring up the bottom sediments. In the present study light penetrations was found to be vary during different months of the year. The value observed in the present study ranged from 0.5 to 5.23 which are higher than the value (2.1 ± 1.95 m) of Thoothukudi region reported by Mathews and Patterson Edward, [62]. In all stations a decrease in light penetration was noticed during the period from October, November and April to July. Generally low transparency values are expected in the monsoon months especially during flood condition, due to the increase in turbidity of water and intensity of solar radiation [63]. Effluents and solid wastes dumped into the coast by the factories of Thoothukudi, dumping of municipal wastes, dynamite fishing and coral mining may be the reasons for the low transparency of water column in Thoothukudi and Vembar coast during the study period.

Nutrients are naturally found in coastal waters and required by organisms on the reef. Coral reefs thrive in waters that contain low levels of inorganic nutrients [64]. Terrestrial discharges of nutrients and other pollutants to coastal waters have increased considerably from pre-industrial levels, reflecting increases in human activities in the surrounding watershed [26]. Persistently high concentration and fluxes of nutrients are major factors contributing to the decline of reefs. Coral reef ecosystem can persist in areas affected by elevated nutrients and plankton productivity as long as water circulation removes excess productivity increases to such an extent that water clarity and light penetration is reduced, normal functioning of the reef may be affected [65]. The nutrient content of the marine ecosystem is determined by their concentrations in the riverine and coastal water source and the properties of each in the mixture [66]. The dissolved nutrients are indispensable constituents for primary production. Of these, nitrate and phosphate enhance primary productivity. Both are necessary for the survival of autotrophy, yet they exist in very small concentrations in water [67]. Steeman and Neilson, [68] considered nutrient replenishment as the single most important factors in controlling phytoplankton growth in the tropics. The normal range of nutrients are 10.7 $\mu g.l^{-1}$, Nitrite 6.8$\mu g.l^{-1}$, Phosphate 0.69 $\mu g.l^{-1}$ has been reported by Asha *et al*., [44]. Irrespective of man's influence, the concentration of the nutrients like phosphate and nitrate are characteristically higher in river water and lead to a general enhancement of nutrients in coastal and estuaries water influence by land drainage [69]. In the present study, normal range of phosphate (0.14$\mu g.l^{-1}$ to 1.5$\mu g.l^{-1}$) were recorded in all stations during all season which is very close to the previous reports evolved from this area [25].

Calcium and magnesium are the most abundant major cations in natural surface and bottom water. Calcium may dissolve readily from rocks or be leached from soils. In the presence of CO_2 calcium carbonate in water is dissolved, in which case the resulting buffered system is likely to maintain the pH of most natural water between 6 to 8. Typically, Ca concentration in natural fresh water falls below 10mg/l, although waters in the proximity of carbonate rocks and limestone's (Coral reef) may contain calcium ranging from 30 to 100 mg/l [70]. Calcium usually occurs at high concentration in the coral reef environment. In the present study also calcium was found to be in high concentration during monsoon and minimum during post-monsoon and summer in Thoothukudi and Vembar group of Islands [71].

Magnesium level was noted high in Thoothukudi and Vembar region during the entire study period in all the stations. Magnesium content exhibited a major peak during the pre-monsoon and monsoon season while it exhibited minor peak during the post- monsoon season [71].

Inorganic phosphate concentration is a useful index of the state of eutrophication of water bodies [72]. Water receiving raw or untreated sewage, agriculture drainage and certain industrial waste usually contain significant concentration of phosphate. Phosphorus is as soluble reactive and dissolved organic phosphorus and polyphosphate [35]. In the present study dissolved inorganic phosphate was found to be in high concentration during pre-monsoon and monsoon in Thoothukudi and Vembar group of islands [27, 25, 73]. Among the six stations studied the phosphate concentration was high in Pulivinichalli Island especially during the monsoon season [38]. Sources of nitrate in the study area are mainly due to the domestic sewage, natural run off, agricultural waste and some industrial wastes [66].

In the present study the nitrate content exhibited a high concentration during the pre- monsoon season and low concentration during the post- monsoon season [74, 75, 76]. Wide range in nitrate content has also been reported by Mohamed *et al.*, [38] in Gulf of Mannar coast. The high concentration of nitrate in the present study may be due to heavy monsoon rains which brought in large amount of nutrients into the marine ecosystem through the river such as Mookiyour, Vembar and Vippar River and the major Thoothukudi sewage waste dumping channel the Bukkle Odai.

Nitrite usually occurs at much lower concentration than the nitrate. Nitrite has been reported to be accumulated to appreciable levels only in regions of low oxygen tension [77]. Nitrite can be formed as a result of bacterial activity through either the oxidation of ammonia or the reduction of nitrate [78 - 81]. The nitrite in the present study showed a similar trend of variation to that of nitrate. High values were recorded during pre-monsoon season. post-monsoon showed the least value of nitrite contents [82].

Water quality is a function of meteorological, hydrological, anthropogenic influences, and can be a limiting factor for the growth of the corals. The findings of the present study show that the hydrographic parameters of the study sites in the Thoothukudi and Vembar group of islands are reasonably favorable for the growth and persistence of corals. Although some parameters like temperature, turbidity, sedimentation and few nutrients exceeded the optimum level during some seasons, the corals were not affected severely. The changes were noted during particular months and seasons for shorter duration only and they were once again reached their normal level within a short time. Hence the environment in the study area is most favorable for the healthy development of corals and other benthos.

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