Physico-chemical Parameters
PHYSICO-CHEMICAL PARAMETERS

Introduction

The physical structure of the artificial reefs may also divert prevailing currents; create nutrient upwelling and ambient turbulence where fish tend to aggregate upstream, rather than to the range of lee waves (Vik, 1982; Grove and Sonu, 1985). Although hydrographic parameters are important to water column productivity and hence, the biotic success of artificial reefs, reviews of artificial reef research (Bohnsack and Sutherland, 1985; Bortone and Kimmel, 1991), however, have shown that water qualities at the artificial reef sites have always been overlooked. As with seasonal colonization studies in the marine environment, the commonest water quality measurements in artificial reef studies are water temperature irradiance ratio, visibility and current speed (Seaman and Sprague, 1991; Carter et al., 1985; Sanders et al., 1985). There are however, few published works on artificial reef hydrographic in Asia, only one of three artificial reef sites in Ranong province, Thailand for habitat rehabilitation purposes has had its spatial hydrography recorded. Other examples are the investigation of chlorophyll $a$ and Phaeophytin at a Malaysian artificial reef (Shamsuddin, 1990) and hydrography nutrients and phytoplankton at an experimental artificial reef in Hong Kong (Lam, 1999).

Water quality parameters included suspended solids, salinity, temperature, current strength, current direction, dissolved oxygen, inorganic nutrients (Phosphate, Nitrate and Nitrite) and chlorophyll $a$ content, with no
attempt to relate the data to biotic factors on the artificial reefs (Limspaichol et al., 1997). Wave direction, force, tidal and oceanic currents have been shown to play an important role in the success of artificial reefs (Kojima, 1960; Hamashima et al., 1969; Vik, 1982; Grove and Sonu, 1985). By extracting particles from the water, communities of filter-feeding benthic invertebrates may have a beneficial effect on coastal water quality (Newell, 1988). Artificial reefs supporting filter feeder communities may be able to mitigate water quality degradation from organic enrichment. This approach appears to have been adopted for instance in the Caspian Sea (Bugrov, 1994) and the Mediterranean Sea (Pronzato et al., 1999). The release of dissolved inorganic nutrients from filter feeding communities may obviate improvement to water quality accomplished through filtering of organic particles by stimulating phytoplankton blooms (Miller, 2002).

Although ecological studies do suggest that artificial reefs may be able to contribute to water quality enhancement, rigorous quantitative experimental studies at multiple sites with similar environments are necessary (Miller, 2002). Reefs with encrusting animals and plants are able to filter water for organic and mineral particles. The sessile filtering organisms accumulate toxic metals and utilize dissolved phosphates and nitrates. Artificial reef complexes of sessile filtering organisms would enhance aquatic habitats in the bay through their natural cleaning capacity. This would lead to improve water quality (Myatt and Myatt, 1990).

The objective of this study was to investigate the physical and chemical qualities of the water in artificial reef and control sites.
Material and Methods

Collection of water samples

Eleven physical and chemical parameters of surface and bottom waters were monitored monthly at six sites (FC Site-1, FC Site-2, FC Site-3, FA Site-4, Control 1, and Control 2). The schedule of sampling was monthly intervals in all study sites. The samples were collected from the 3 Ferro Cement (FC) artificial reef sites and control-1 for a period of 17 months from June 2002 to October 2003. The sampling was carried out in Fly ash (FA) artificial reef site and control-2 for a period of 12 months from February 2004 to January 2005.

Methods of Analyses

The physico chemical parameters such as air and water temperature, salinity, dissolved oxygen, pH, water transparency, calcium, magnesium, inorganic phosphates, nitrates and nitrites were measured. Air and water temperature was measured using thermometer. Salinity was measured using Refractometer. Dissolved oxygen was analysed according to Strickland and Parsons (1972), pH using pH meter, and transparency by using Secchi disc. Analyses of calcium (Ca), magnesium (Mg) were done titrimetrically. The inorganic phosphates (PO₄) were determined based on Murphy and Riley (1962). Nitrates (NO₃) and nitrites (NO₂) were measured spectrophotometrically by following the method of Strickland and Parson (1972).
Statistical analyses

Because of the similarity in topography and proximity of the six study sites, the physico-chemical data recorded for these stations were used in the subsequent statistical analyses. Separate two-way ANOVA was performed to find out the significance in these parameters between seasons and between surface and bottom water. The differences between surface and bottom water were detected by the student ‘t’ test (Zar, 1984).

Correlation coefficient between eleven hydrographic parameters studied in the present study viz., air temperature, water temperature, salinity, dissolved oxygen, pH, and water transparency, concentrations of nitrite, nitrate, and phosphates within each site including surface and bottom samples was analysed separately by the Pearson product-movement correlation coefficient (Sokal and Rohlf, 1995).

Results

Fig 1A - 11B shows the monthly variations of various physico-chemical parameters at all study sites.

Physical parameters

Air Temperature

Air temperature at all study sites shows a well defined seasonal pattern (Fig 1A and 1B) fluctuating within the range of 26.5 – 32.6°C at FC site 1 with a mean air temperature value of 30.73±1.63°C. FC site 2 and 3 recoded a range...
of 26.4°-33.5°C with a mean value of 30.58±1.60°C and 30.64±1.64°C respectively. For FA site 4, the range is 27.9-33.6°C, with a mean value of 30.68±1.97°C was recorded. The range for control sites 1 and 2 varies from 26.3-33.4°C and 29.7-32.4°C respectively and their mean values are 30.84±1.58°C and 30.88±1.02°C respectively.

Fig. 1A. Air temperature (FC Sites)

Fig. 1B. Air temperature (FA Site)

The seasonal difference was confirmed by the results of the ANOVA for FC and control sites (Table 1), which shows significant difference in air temperature (P<0.05) between months, but between stations the difference was
insignificant (P>0.05). For FA site (Table 3), the difference of air temperature between both months and stations was not significant (P>0.05).

**Water Temperature**

Water temperature at all study sites showed a well defined seasonal pattern (Fig 2A and 2B) fluctuating within the range 24.2-32.6 °C during the entire study periods at all study sites, with a mean surface water value of 28.8±1.68°C and bottom water value of 27.85± 1.63°C at FC site1.

![Fig. 2A. Water temperature (FC Site)](image1)

![Fig. 2B. Water temperature (FA Site)](image2)
In FC sites 2 and 3, the mean surface water values were 28.69±1.83°C and 28.72±1.79°C and bottom water values 27.78±1.61°C and 28.21±1.76°C. The FA site 4 shows a mean surface water value of 30.68±1.97°C and bottom water 28.50±1.38°C. The mean surface water temperature values of 28.89±1.67°C and 27.84±1.36°C were recorded at control sites 1 and 2 respectively, while in bottom water the values were 30.88±1.02°C and 29.09±1.30°C respectively. Results of ANOVA showed that there was significant difference in between months (P<0.05) for surface and bottom waters at FC site (Table 1 and 2), but no significant difference between the stations. There was no significant differences (P>0.05) recorded between stations and months for surface water at FA sites (Table 3), but for the bottom waters (Table 4), significant difference (P<0.05) was observed between months. But between stations, the water temperature values were found to be insignificant (P>0.05). The student 't' test results showed that there was no significant difference between the surface and bottom waters (Table 5A) at all artificial reef sites, but control sites 1 and 2 showed significant difference at P<0.05 level. The correlation coefficient between the surface and bottom water temperatures (Table 5B) showed highly significant difference (P<0.01) at all study sites.

Salinity

Salinity generally fluctuated between 30‰ and 36‰ during the entire study period at all study sites (Fig 3A and 3 B). The mean surface and bottom water values of 33.15±1.84‰ and 32.46±1.31‰ were recorded at FC site 1. In FC sites 2 and 3, the mean surface water salinity was recorded as 33.51±
1.84 % and 33.91± 1.35% and the bottom values as 34.05±1.60% and 34.38±1.26% respectively. As for FA site 4, the mean surface water salinity was 32.83±1.34% and for bottom water 33.09±0.83% was recorded. In control sites 1 and 2, the mean surface water salinity was recorded as 33.41±1.50% and 32.75±1.60% and bottom water values as 32.94±1.27% and 33.60±0.94% respectively.

Fig. 3A. Salinity (FC Site)

Fig. 3B. Salinity (FA Site)

The results of ANOVA for FC sites showed that there was significant difference in salinity between stations and months (P<0.05) for surface waters...
(Table 1), and for bottom waters (Table 2), between months there was significant difference (P<0.05), but between stations the difference was not significant. For FA site (Table 3 and 4), there was no significant (P>0.05) differences between stations and months for surface and bottom waters. The student 't' test results (Table 6A) showed that there was no significant difference between surface and bottom water salinity at all study sites. The Pearson correlation test coefficient between the surface and bottom water salinity (Table 6B) showed highly significant (P<0.01) at FC site 2, 3 and FA site 4, control 1 and 2. But not significant differences occurred at FC site 1.

**pH**

The monthly variations of hydrogen ion concentration in surface and bottom water are given in Fig 4A and B. Small difference in pH was recorded for surface and bottom water at FC site 1 and they fluctuated within the range 7-8.2, with a mean surface water value of 7.53±0.12 and bottom water 7.57±0.16. For FC sites 2 and 3, the mean surface water pH was 7.54±0.08 and 7.54±0.12 and the bottom water value was 7.61±0.16 and 7.67±0.15 respectively. In FA site 4, the mean surface water pH was 7.54±0.15 and the mean bottom water value was 7.72±0.25. In control 1 and 2, the mean surface water value was recorded as 7.53±0.08 and 7.54±0.40, while the bottom water value as 7.75±0.15 and 7.82±0.22.
The ANOVA results (Table 1, 2, 3 and 4) showed that there was no significant (P>0.05) difference between months and stations in the surface and bottom water pH at all study sites. The student's t test between surface and bottom waters pH (Table 7A) showed significant difference (P<0.05) for FC site 3, FA site 4 and control site 2, but not significant for FC site1, 2 and control site 1. Pearson correlation test coefficient between the surface and bottom water (Table 7B) showed no significance for all artificial reef sites but control sites 1 and 2 shows high significance (P<0.01).
**Dissolved Oxygen**

A pattern of seasonal variation is observed for dissolved oxygen at surface and bottom water (Fig 5A and 5B). Fluctuation in dissolved oxygen at surface water value was more than bottom water. For FC site 1, the mean dissolved oxygen value for surface and bottom waters were 4.80±0.58 and 4.34±0.54 ml/l respectively. As for FC sites 2 and 3, the mean surface water value was recorded as 4.81±0.52 and 4.88±0.40 ml/l, while for bottom water the values were 4.65±0.40 and 4.61±0.46 ml/l respectively. The mean surface water value at FA site 4 was 4.63±0.30 ml/l.

![Fig. 5A. Dissolved oxygen (FC Site)](image)

![Fig. 5B. Dissolved oxygen (FA Site)](image)
The ANOVA for FC sites (Table 1 and 2) shows that the dissolved oxygen level was found to be significant between months (P<0.05) and was insignificant (P>0.05) between stations in surface water. Likewise for bottom water, it was significant between station as well as months (P<0.05). Insignificant difference (P>0.05) was observed between stations and months of surface and bottom water at FA site (table 3 and 4). Statistical analysis (student ‘t’ test) shows that the variation of dissolved oxygen between surface and bottom water differ significantly (P<0.05) in FC site 1, control sites 1 and 2 (Table 8A). But it was not significant (P>0.05) at FC sites 2, 3 and FA site 4. Pearson correlation coefficient between surface and bottom waters values of dissolved oxygen showed significant positive correlation (P<0.01) (Table 8B) in all sites.

Transparency

Water transparency at the study sites showed a well defined seasonal pattern (Fig 6A and 6B), fluctuating with in the range of 0.6-3.5m, with a mean transparency value of 1.52±1.13 (FC Site 1), 1.58±0.77m (FC Site 2), 1.60±0.74 (FC Site 3) and 2.63±0.53m (FA Site 4). For control sites 1 and 2, the mean value of transparency recorded was 1.35±0.81 and 2.42±0.76 respectively. The ANOVA results showed significance in between months (P<0.05) (Table 1 and 3) but not significant in between stations for FC and FA artificial reef sites.
Chemical parameters

Calcium

The monthly variations of calcium (mg/l) in surface and bottom waters are given in Fig 7A and 7B. Calcium at the study sites showed a well defined seasonal pattern, fluctuating within the range of 240-640 mg/l. The mean surface and bottom water values of 428.24±90.29 and 450.59±72.84 were recorded at FC site 1. The mean surface values for FC sites 2, 3 and FA site 4 was recorded as 387.65±60.16, 373.53±31.01 and 433.33±56.14 while for bottom water, the values were 414.71±52.93, 407.06±32.36 and 466.67±56.14.
For control site 1, mean calcium value for surface water was 394.71±57.13 and for the bottom water, the value was 411.18±52.66. The mean calcium values for surface and bottom water at control site 2 was recorded as 500±46.71 and 521.67±48.59 respectively.

Results of ANOVA showed significant level (P<0.05) at surface and bottom waters of FC sites (Table 1 and 2). In FA site, significance was seen between stations while no significance between months for surface water, but
for bottom waters (Table 3 and 4) showed significance (P<0.05) between months and stations. The student ‘t’ test results showed significance (Table 9A) in between surface and bottom waters at FC site 3 (P<0.05), but not significant in other study sites.

Pearson product correlation results for calcium in surface and bottom water are shown in Table 9B, where highly significant (P<0.01) is seen at all study sites.

**Magnesium**

The monthly variation of magnesium concentration in surface and bottom water is given in Figs 8A and 8B. The mean surface water value was 1285.80±235.66 mg/l while the bottom water value was 1293.15±235.66 mg/l at FC site 1. In FC sites 2 and 3, mean surface water value was recorded as 1347.42±180.62 mg/l and 1323.66±165.38 mg/l while the bottom water as 1356.71±176.33 mg/l and 1334.41±170.96 mg/l. In FA site 4, the mean value for surface water was recorded as 1224.52±122.43 mg/l and for bottom water it was 1249.73±118.40 mg/l. As for control site 1 and 2, the mean surface values were 1411.69±201.97 mg/l and 1289±115.62 mg/l while the bottom values were 1418.29±210.43 mg/l and 1333.98±122.52 mg/l respectively.
The ANOVA results for FC site (Table 1) showed significance (P>0.05) in between stations and months at surface water while for bottom water (Table 2), significance between months (P<0.05) and no significance between stations. FA site (Table 3 and 4) showed no significance (P>0.05) in between stations and months at surface and bottom waters. The student ‘t’ test showed that there was no significance (Table 10A) in magnesium value between surface and bottom waters of all study sites. Pearson product moment
correlation coefficient results for the values between surface and bottom waters (Table 10B) showed highly significant results at all study sites (P<0.01).

**Phosphates**

The monthly variations of phosphate values in surface and bottom waters are given in Fig 9A and 9B. Phosphates at the study site showed a well defined seasonal pattern. The mean value of Phosphate for FC site 1 was 0.18±0.22μg/l in both surface and bottom water. For FC site 2, 3 and FA site 4, the mean surface water values were recorded as 0.16±0.12, μg/l, 0.14±0.12μg/l and 1.26±0.77μg/l while bottom values were 0.18±0.13 μg/l, 0.16±0.12 μg/l and 1.28±0.70 μg/l. As for control site 1, the mean surface water value 0.18±0.27μg/l and bottom water value 0.25 μg/l were recorded. The mean surface and bottom water values 0.50±0.49μg/l and 0.60±0.63 μg/l were recorded respectively at control site 2.

The seasonal variation was confirmed by the results of the ANOVA (Table 1 and 2) for FC sites, which shows no significance (P>0.05) between stations, but significant (P<0.05) between months for both surface and bottom

![Fig. 9A. Phosphate (FC Site)]
water. The ANOVA results (Table 3 and 4) for FA site shows significance between stations (P<0.05) and not significant (P>0.05) level between months for both surface and bottom water. The student 't' results (Table 11A) showed that there was no significant (P>0.05) differences between surface and bottom waters Phosphate levels at all study sites. A Pearson correlation test coefficient between surface and bottom water values (Table 11B) showed highly significant (P>0.01) at all the study sites.

**Nitrates**

Nitrates at all the study sites showed seasonal pattern (Fig 10A and 10B), and fluctuations were within the mean range 0.23±0.12-0.63±0.16μg/l for all study sites. A mean surface water value of 0.36±0.31μg/l and bottom water value 0.39±0.28μg/l were recorded at FC site 1. In FC sites 2 and 3, the mean surface water value 0.40±0.26μg/l and 0.31±0.25 μg/l, and bottom water value 0.44±0.25 μg/l and 0.33±0.26μg/l were recorded respectively.
As for FA site 4, the mean surface water value 0.56±0.18μg/l and bottom water value 0.63±0.16μg/l were recorded. In control site 1 and 2, the mean surface water values 0.34±0.32μg/l and 0.23±0.12 μg/l and bottom water values 0.39±0.35μg/l and 0.26±0.14 μg/l were recorded respectively. The results of ANOVA (Table 1 and 2) showed that the values between months are significant (P<0.05), but insignificant (P>0.05) between stations at surface and bottom water of FC sites. Table 3 and 4 showed that the values between stations are significant (P<0.05), but not significant in between months at P>0.05 level for surface and bottom water at FA site. The student‘t’ test (Table 12A) revealed that the values between surface and bottom waters showed no
significant differences at P>0.05 level at all study sites. A correlation test coefficient (Table 12B) between surface and bottom water showed highly significant results at P<0.01 level at all study sites.

Nitrites

The nitrite level in the water samples are given in Fig. 11A and 11B. Nitrite levels have a lower concentration in seawater than nitrate because the nitrate is readily oxidized to nitrite. The mean surface and bottom water values of 0.008±0.007 µg/l and 0.014±0.013 µg/l were recorded at FC site 1. For FC site 2 and 3, the mean surface water values were 0.008±0.009 µg/l and 0.007±0.009 µg/l while the bottom water values were recorded as 0.013±0.015 µg/l and 0.010±0.013 µg/l respectively. For FA site 4, the mean surface water value 0.040±0.023 and bottom water value of 0.034±0.025 µg/l were recorded. In control sites 1 and 2, mean surface water values 0.02±0.015 µg/l and 0.031±0.020 µg/l while bottom water values 0.019±0.017 µg/l and 0.04±0.02 µg/l were recorded respectively.

Fig. 11A. Nitrite (FC Site)
The results of ANOVA for FC sites (Table 1 and 2) showed significance (P<0.05) between stations and months for surface and bottom water. But, in FA site there was no significant difference (P>0.05) (Table 3 and 4) in nitrite values between surface and bottom water. The student ‘t’ test (Table 13A) shows no significant differences (P>0.05) between surface and bottom water at all study sites. A Pearson correlation test coefficient between surface and bottom water (Table 13B) showed highly significant results (P<0.01) at all study sites.

Correlation analysis

The Pearson correlation coefficient was calculated to find out the relationship between the hydrographic parameters of surface and bottom water in each site (Table 14A to 19B).

Correlation coefficient (Table14A) of surface water at FC site 1 showed a significant positive correlation observed between water temperature and air temperature, calcium with transparency and Magnesium, nitrate and nitrite
concentration with magnesium. For bottom water at FC site 1, significant positive correlation (Table 14B) was observed between water temperature and nitrate, calcium with magnesium, magnesium with nitrate and nitrite, and nitrate with nitrite. But salinity had a significant negative correlation with phosphate.

In the surface water at FC site 2 (Table 15A), salinity showed a significant negative correlation with air and water temperature. Calcium positively correlated with air and water temperature and salinity. Significant positive correlation was observed between nitrate with air and water temperature, calcium, magnesium and nitrate. The correlation coefficient for the bottom water at FC site 2 (Table 15B) showed significant positive correlation between salinity and phosphate, magnesium with nitrate and nitrite. But water temperature with salinity and pH, salinity with calcium, dissolved oxygen with phosphate had significant negative correlation.

The correlation result of surface water at FC site 3 (Table 16A) showed positive correlation between water temperature and air temperature. Salinity had negatively correlated with water temperature. Significant positive correlation was observed between pH with dissolved oxygen and nitrate. Calcium was also positively correlated with magnesium and nitrite. At FC site 3, bottom water (Table 16B) showed significant positive correlation between air temperature and nitrate, dissolved oxygen with nitrate and nitrite, magnesium with calcium and nitrate and between nitrate and nitrite.
The significant positive correlation was observed in the surface water at FA site 4 (Table 17A) for water temperature with air temperature and salinity. Phosphate had a significant negative correlation with air and water temperature. The bottom water at FA site 4 (Table 17B) showed a significant positive correlation in water temperature with salinity and nitrate with nitrite. Water temperature had a significant negative correlation with phosphate.

Significant positive correlation was observed in surface water at control site 1 for air temperature with water temperature, dissolved oxygen with nitrite, transparency with phosphate and nitrate (Table 18A). Table 18B showed the correlation results for bottom water at control site 1. Salinity had significant negative correlation with water temperature. Likewise pH was negatively correlated with nitrite.

Significant positive correlation was observed in salinity and dissolved oxygen with air and water temperature, air temperature with water temperature, and calcium with magnesium in surface water at control site - 2 (Table19A). At control site - 2 bottom water (Table 19B), water temperature had significant positive correlation with pH, salinity with dissolved oxygen and calcium with magnesium

Discussion

By extracting particles from the water, filter-feeding benthic invertebrate communities may have a beneficial effect on coastal water quality (Newell, 1988). Some of these animals (e.g. Sponges) may even be able to filter and sequester other pollutants, such as heavy metals, as well as organic matter.
Thus, artificial reefs supporting filter-feeder communities may be able to mitigate water quality degradation from organic enrichment. Laihonen et al. (1996) described a similar approach utilizing marine plants for absorbing excess dissolved nutrients. Reefs with encrusting animals and plants are able to filter water for organic and mineral particles. The sessile filtering organisms accumulate toxic metals and utilize dissolved phosphates and nitrates. Artificial reef complexes of sessile filtering organisms would enhance aquatic habitats in the bay through their natural cleaning capacity. This would lead to improved water quality (Myatt and Myatt, 1990).

The seasonal variation in water temperature at the study sites followed closely that of air temperature and hence reflected the climate of study sites. The surface sea water temperatures were generally 2°C higher than the bottom water temperatures. The temperature ranges of 26.5 – 32.6°C and 23.4 – 30°C for the surface and bottom water respectively are comparable to the mean surface and bottom water values 23.56°C and 22.81°C recorded respectively by Lam (1999) at Hoi Ha Wan, Hong Kong. In the present study, water temperature at all study sites was observed to vary between 23.4°C and 32.6°C. Boyd and Pillai (1984) reported that tropical aquatic organisms including shell and fin fishes grow very well at water temperature ranging between 25°C and 30°C and in exceptional cases temperature up to 35°C could also be tolerated. The average temperature of the surface water in Gulf of Mannar varies from 25°C to 30°C. The surface water temperature of the Gulf of Mannar is slightly higher than that of the Palk Bay (Prasad, 1957).
The salinity values at the study sites were observed to vary between 30‰ and 36‰. Friedrich (1969) reported that salinity in all seasons was slightly lower than the 35‰ for the open sea water of Hoi Ha Wan, Hong Kong. The result obtained in this study correlates with all study sites showing fluctuation in all seasons. The maximum salinity values recorded in Hong Kong coastal waters are <35‰ and have also been reported upon in earlier hydrographic studies i.e., 33.0‰ (Morton and Wu, 1975) and 32.6‰ (Yip, 1978). Lam (1999) reported that the salinity generally fluctuates between 24‰ and 37‰ throughout the year, at an experimental artificial reef at Hoi Ha Wan, Hong Kong, and Salinity exhibited bimodal type of oscillation in the temporal distribution in all study sites and this phenomenon has been reported to be the common feature of many Indian coastal water ecosystem. Sewell (1925-32) reported that during the South-West monsoon time, the direction of the current is from South to North side of the Gulf of Mannar region. This current brings in large amount of “Oceanic” water from the Southern part of the Arabian Sea. As these waters have a high salinity of 34.5 -35‰, there is a general rise in the salinity of the water of the Gulf of Mannar and Palk Bay. This may be due to the prevalence of high winds and to the rather high atmospheric temperature there is a certain amount of evaporation which cause a further rise in the salinity.

Marine water is slightly alkaline and pH usually ranges from 7.5 to 8.4 whereas surface waters have a generally narrow range of 8.1 to 8.3 (Sverdrup et al., 1942). Reid (1961) reported that oceanic water is typically buffered between 8 and 8.3. In comparison, the pH at the study site showed a wide range.

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between 7 and 8.2. The pH values indicate the amount of dissolved carbon dioxide in the water column and in turn, reflect phytoplankton photosynthetic activities and dissolved oxygen levels in the sea (Atkins, 1923). The pH exhibited insignificant (P>0.05) variation in between months and sites. Similarly, the pH values in surface water did not show any significant relationship with bottom water at artificial reef sites, but significant results occurred in control sites.

Dissolved oxygen levels in a 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 (Morton and Wu, 1975; Wear et al., 1984). In the present study, the dissolved oxygen ranged between 3.6 ml/l and 6.2 ml/l. The dissolved oxygen is known to decide the suitability of aquatic ecosystems to support the survival and growth of aquatic organisms. Ellis (1937) reported that dissolved oxygen concentrations greater than 3.5 ml/l were always associated with rich fish population and species diversity. According to Boyd and Pillai (1984) dissolved oxygen level above 3.5 ml/l is required for the better survival, reproduction and better growth of fishes. Though the impact of dissolved oxygen on fin and shellfishes is well known, the optimum level required for the better survival and growth of various other fauna has not been stipulated properly. In the present study, the fluctuation in dissolved oxygen at surface water was more than the bottom water. For FC sites, the mean dissolved oxygen values for surface and bottom waters were 4.80±0.58 and 4.34±0.54 ml/l respectively. The mean surface water value at FA site was 4.63±0.30 ml/l, These findings reveal better growth
and reproduction of artificial reef assemblage communities. Kumaraguru and Jayakumar (1998) reported that the range of dissolved oxygen in surface and bottom water were 4.5 to 4.6 ppm. An oxygen level of 5.5 mg/l is generally considered to be an indication of unpolluted water (Menzies et al., 1963). The study site is therefore, fairly well oxygenated. Lam (1999) reported that surface water has higher dissolved oxygen levels than bottom waters because oxygen diffuses through the air-water interface. The present study revealed that the surface water have minimum 1 ml/l level of dissolved oxygen more than the bottom water. The surface and bottom water dissolved oxygen level observed to show significant correlation at all study sites.

Water transparency and suspended solids are used as an indication of turbidity and hence affect the penetration of sunlight onto the artificial reef (Lam, 1999). Reid and Wood (1976) reported that the transparency depth higher than 2.5m indicates clear coastal water. In this present study, the average mean transparency is 2.63, at fly ash artificial reef sites. The major ions, calcium and magnesium at the study area showed a significant correlation between surface and bottom water values. The bottom water value was slightly higher than that of surface water. The phosphate concentration shows a well defined seasonal pattern. Jayaraman (1954) reported that the mean monthly values for phosphates in the Gulf of Mannar vary between 0.15 and 0.30 µg/l and in the Palk Bay, between 0.12 and 0.25 µg/l. The average mean phosphate level could, therefore, give information on water quality. Sverdrup et al. (1942) and Murphy and Riley (1962) suggested the range of phosphate levels for unpolluted seawater as 0 to 6.13 µg/l and 0.09 to 14.72 µg/l respectively.
Values greater than 19.93 $\mu$g/l$^{-1}$ should be regarded as *Prima facie* evidence of pollution which potentially causes eutrophication (Murphy and Riley, 1962). In the present study, the normal range of phosphate values occurred in all study sites. Kumaraguru and Jayakumar (1998) have reported the range of phosphate values in Gulf of Mannar as 1.55 – 4.02 ppm and similar result was obtained in the present study. The phosphate values for the study area mostly fluctuated between 3 $\mu$g/l$^{-1}$ to 13 $\mu$g/l$^{-1}$. The bottom water had slightly higher phosphate values than the surface (Lam, 1999) and such condition was seen in the study area.

Lam (1999) reported that, among the three forms of inorganic nitrogen, nitrate showed a year round higher value than ammonia and nitrite. Such nutrients either originated from the freshwater run-off from surrounding hills or from the bottom sediments (Wear *et al.*, 1984). Sundararaj and Krishnamurthy (1975) reported that nitrate showed a wide range of fluctuation from 0 to 20.3 $\mu$g/l and the nitrite values were between 0.09 and 1.04 $\mu$g/l. Nitrite values were generally higher in bottom water. In this present study, the bottom water contains higher level of nitrite content and it ranges between 0.23 $\mu$g/l to 0.63 $\mu$g/l. Kumaraguru and Jayakumar (1998) recorded that nitrate ranges from 14 – 21.01 ppm for Gulf of Mannar. The seasonal variations in the nitrate content may also be partly due to the fluctuations in the number and activity of the denitrifies. It has, however, to be borne in mind that the denitrifies occur in more or less restricted areas subject to the influence of land drainage (Jayaraman, 1954). In this present study nitrate range showed a minimum level because there were no influence of land drainage at all study sites.
Artificial reef habitats can provide sources of food, shelter, and sites for orientation and reproduction. Presence of any species depends on suitable living conditions which include access to food resources, shelter from predators, and normal physical conditions within biological tolerances of an organism. Water quality is a function of meteorological, hydrological, anthropogenic influences, and can be a limiting factor for the management of the artificial reef. The finding of the present study shows that the hydrographic parameters of the selected study sites are favourable to the development of various biological resources. Although ecological studies do suggest that artificial reefs may be able to contribute to water quality enhancement, quantitative experimental studies at multiple sites with similar environments are necessary.
Table 1. Two way ANOVA analysis (5% level) of hydrographic parameters between stations and months in Surface water of FC and control site 1.

<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>Remarks</th>
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"**"- significant at 5% level, "NS"- Not significant
Table 2. Two way ANOVA analyses (5% level) of hydrographic parameters between stations and months in bottom water of FC sites and control site 1.

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"**"- significant at 5% level, "NS"- Not significant
Table 3. Two way ANOVA analysis (5% level) of hydrographic parameters between stations and months in surface waters of FA site and control site 2.

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"**"- significant at 5% level, "NS"- Not significant
Table 4. Two way ANOVA analysis (5 % level) of hydrographic parameters between stations and Months in Bottom waters of FA site and control site 2.

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<th>Source of Variation</th>
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<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>Remarks</th>
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<td>4307.576</td>
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"*"- significant at 5% level, "NS"- Not significant
Table 5A. Student 't' test analysis of water temperature between surface and bottom water

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<th>Study sites</th>
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<th>Remarks</th>
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<td>0.064</td>
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<td>2.921</td>
<td>0.008</td>
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"**"- significant at 5% level, "NS"- Not significant

Table 5B. Pearson product – moment correlation Coefficient 'r' of the water temperature between surface and bottom water

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<td>0.973</td>
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</tr>
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<td>FC site 3</td>
<td>32</td>
<td>0.83</td>
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"**"- significant at 5% level, "NS"- Not significant

Table 6A. Student 't' test analysis of salinity between surface and bottom water

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"**"- significant at 5% level, "NS"- Not significant
Table 6B. Pearson product – moment correlation coefficient ‘r’ of the salinity between surface and bottom water

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<tbody>
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<td>FC site 3</td>
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<td>Control site 1</td>
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<td>0.961</td>
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"**"- significant at 5% level, "NS"- Not significant

Table 7A. Student ‘t’ test analysis of pH between surface and bottom water

<table>
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</table>

"**"- significant at 5% level, "NS"- Not significant

Table 7B. Pearson product – moment correlation coefficient r of the pH between surface and bottom water

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"**"- significant at 5% level, "NS"- Not significant
Table 8A. Student ‘t’ test analysis of dissolved oxygen between surface and bottom water.

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<th>P Value</th>
<th>Remarks</th>
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"**"- significant at 5% level, "NS"- Not significant

Table 8B. Pearson product–moment correlation coefficient r of the dissolved oxygen between surface and bottom water

<table>
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<tr>
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<td>32</td>
<td>0.897</td>
<td>**</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>0.934</td>
<td>**</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>0.754</td>
<td>**</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>0.832</td>
<td>**</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.907</td>
<td>**</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>0.953</td>
<td>**</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant

Table 9A. Student ‘t’ test analysis of calcium between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>t Stat</th>
<th>P Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
<td>32</td>
<td>-0.794</td>
<td>0.433</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>-1.392</td>
<td>0.173</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>-3.084</td>
<td>0.004</td>
<td>*</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>-1.454</td>
<td>0.16</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>-0.874</td>
<td>0.389</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>-1.114</td>
<td>0.277</td>
<td>Ns</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant
Table 9B. Pearson product – moment correlation coefficient \( r \) of the calcium between surface and bottom water

<table>
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<tr>
<th>Study sites</th>
<th>df</th>
<th>( r )</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
<td>32</td>
<td>0.989</td>
<td>**</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>0.877</td>
<td>**</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>0.895</td>
<td>**</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>0.962</td>
<td>**</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.981</td>
<td>**</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>0.785</td>
<td>**</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant

Table 10A. Student ‘t’ test analysis of magnesium between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>t Stat</th>
<th>P Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
<td>32</td>
<td>-0.091</td>
<td>0.928</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>-0.152</td>
<td>0.88</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>-0.186</td>
<td>0.853</td>
<td>Ns</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>-0.513</td>
<td>0.613</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>-0.093</td>
<td>0.926</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>-0.925</td>
<td>0.365</td>
<td>Ns</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant

Table 10B. Pearson product – moment correlation coefficient \( r \) of the magnesium between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>( r )</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC Site 1</td>
<td>32</td>
<td>1</td>
<td>**</td>
</tr>
<tr>
<td>FC Site 2</td>
<td>32</td>
<td>0.998</td>
<td>**</td>
</tr>
<tr>
<td>FC Site 3</td>
<td>32</td>
<td>0.997</td>
<td>**</td>
</tr>
<tr>
<td>FA Site 4</td>
<td>22</td>
<td>0.977</td>
<td>**</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.987</td>
<td>**</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>0.796</td>
<td>**</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant
Table 11A. Student ‘t’ test analysis of phosphates between surface and bottom water.

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>t Stat</th>
<th>P Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
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<td>-0.031</td>
<td>0.975</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
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<td>0.717</td>
<td>Ns</td>
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<tr>
<td>FC site 3</td>
<td>32</td>
<td>-0.353</td>
<td>0.726</td>
<td>Ns</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>-0.08</td>
<td>0.937</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.179</td>
<td>0.859</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>-0.471</td>
<td>0.642</td>
<td>Ns</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant

Table 11B. Pearson product – moment correlation coefficient r of the Phosphates between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>r</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
<td>32</td>
<td>1</td>
<td>**</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>0.544</td>
<td>**</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>0.99</td>
<td>**</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>0.964</td>
<td>**</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.969</td>
<td>**</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>0.968</td>
<td>**</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant

Table 12A. Student ‘t’ test analysis of Nitrates between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>t Stat</th>
<th>P Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
<td>32</td>
<td>-0.226</td>
<td>0.823</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>-0.354</td>
<td>0.726</td>
<td>Ns</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>-0.277</td>
<td>0.783</td>
<td>Ns</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>-0.957</td>
<td>0.349</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>-0.446</td>
<td>0.659</td>
<td>Ns</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>-0.566</td>
<td>0.577</td>
<td>Ns</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant
Table 12B. Pearson product – moment correlation coefficient $r$ of the Nitrates between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>$r$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
<td>32</td>
<td>0.974</td>
<td>**</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>0.598</td>
<td>**</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>0.993</td>
<td>**</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>0.854</td>
<td>**</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.995</td>
<td>**</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>0.985</td>
<td>**</td>
</tr>
</tbody>
</table>

"**" - significant at 5% level, "NS" - Not significant

Table 13A. Student 't' test analysis of Nitrites between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>t Stat</th>
<th>P Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
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<td>-1.584</td>
<td>0.123</td>
<td>NS</td>
</tr>
<tr>
<td>FC site 2</td>
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<td>-1.178</td>
<td>0.248</td>
<td>NS</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>0</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>0.689</td>
<td>0.498</td>
<td>NS</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>-0.742</td>
<td>0.464</td>
<td>NS</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>-0.771</td>
<td>0.449</td>
<td>NS</td>
</tr>
</tbody>
</table>

"**" - Significant at 5% level, "NS" - Not significant

Table 13B. Pearson product – moment correlation coefficient $r$ of the Nitrites between surface and bottom water

<table>
<thead>
<tr>
<th>Study sites</th>
<th>df</th>
<th>$r$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC site 1</td>
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<td>0.944</td>
<td>**</td>
</tr>
<tr>
<td>FC site 2</td>
<td>32</td>
<td>0.95</td>
<td>**</td>
</tr>
<tr>
<td>FC site 3</td>
<td>32</td>
<td>0.967</td>
<td>**</td>
</tr>
<tr>
<td>FA site 4</td>
<td>22</td>
<td>0.825</td>
<td>**</td>
</tr>
<tr>
<td>Control site 1</td>
<td>32</td>
<td>0.835</td>
<td>**</td>
</tr>
<tr>
<td>Control site 2</td>
<td>22</td>
<td>0.923</td>
<td>**</td>
</tr>
</tbody>
</table>

"**" - significant at 5% level, "NS" - Not significant
Table 14 A. Pearson product – moment correlation of the hydrographic parameters at the surface water of FC site 1.

<table>
<thead>
<tr>
<th></th>
<th>Air temp.</th>
<th>Water temp</th>
<th>Salinity</th>
<th>pH</th>
<th>DO</th>
<th>Transparenc y</th>
<th>Ca</th>
<th>Mg</th>
<th>PO₄</th>
<th>NO₃</th>
<th>NO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temp</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water temp</td>
<td>0.971**</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>-0.439 NS</td>
<td>-0.398 NS</td>
<td>1.000</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>pH</td>
<td>0.170 NS</td>
<td>0.079 NS</td>
<td>-0.301 NS</td>
<td>1.000</td>
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</tr>
<tr>
<td>DO</td>
<td>-0.036 NS</td>
<td>0.024 NS</td>
<td>-0.070 NS</td>
<td>0.266 NS</td>
<td>1.000</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Transparency</td>
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<td>-0.369 NS</td>
<td>0.191 NS</td>
<td>-0.142 NS</td>
<td>-0.032 NS</td>
<td>1.000</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ca</td>
<td>0.114 NS</td>
<td>0.189 NS</td>
<td>-0.206 NS</td>
<td>-0.081 NS</td>
<td>0.168 NS</td>
<td>0.535*</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>0.032 NS</td>
<td>0.053 NS</td>
<td>0.127 NS</td>
<td>-0.355 NS</td>
<td>0.139 NS</td>
<td>0.108 NS</td>
<td>0.472*</td>
<td>1.000</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PO₄</td>
<td>0.050 NS</td>
<td>0.040 NS</td>
<td>-0.012 NS</td>
<td>0.218 NS</td>
<td>-0.098 NS</td>
<td>0.292 NS</td>
<td>-0.003 NS</td>
<td>-0.169 NS</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₃</td>
<td>0.438 NS</td>
<td>0.383 NS</td>
<td>-0.284 NS</td>
<td>-0.234 NS</td>
<td>-0.191 NS</td>
<td>0.200 NS</td>
<td>0.405 NS</td>
<td>0.657**</td>
<td>0.139 NS</td>
<td>1.000</td>
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<tr>
<td>NO₂</td>
<td>0.201 NS</td>
<td>0.166 NS</td>
<td>-0.029 NS</td>
<td>-0.169 NS</td>
<td>0.255 NS</td>
<td>-0.154 NS</td>
<td>0.103 NS</td>
<td>0.683**</td>
<td>0.035 NS</td>
<td>0.591 NS</td>
<td>1.000</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant
Table 14B. Pearson product–moment correlation of the hydrographic parameters at the bottom water of FC site 1.

<table>
<thead>
<tr>
<th></th>
<th>Water temp</th>
<th>Salinity</th>
<th>pH</th>
<th>DO</th>
<th>Ca</th>
<th>Mg</th>
<th>PO₄</th>
<th>NO₃</th>
<th>NO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temp</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>0.0076&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>0.3419&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.0849&lt;sup&gt;NS&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>0.1192&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.0543&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.1257&lt;sup&gt;NS&lt;/sup&gt;</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>0.3203&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.0577&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.0330&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.0480&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>0.1642&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.0521&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.1688&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.0639&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.4701*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO₄</td>
<td>0.0320&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.9107**</td>
<td>-0.1346&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.1770&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.0729&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.1743&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>NO₃</td>
<td>0.6087**</td>
<td>-0.3053&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.2159&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.1633&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.3160&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.5603*</td>
<td>0.2285&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>1</td>
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<td>NO₂</td>
<td>0.3331&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>-0.4646&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.2891&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.3717&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.0700&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.6450**</td>
<td>0.2167&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.5996**</td>
<td>1</td>
</tr>
</tbody>
</table>

"**"- significant at 5% level, "NS"- Not significant
Table 15A. Pearson product – moment correlation of the hydrographic parameters at the surface water of FC site 2

<table>
<thead>
<tr>
<th></th>
<th>Air temp.</th>
<th>Water temp</th>
<th>Salinity</th>
<th>pH</th>
<th>DO</th>
<th>Transparency</th>
<th>Ca</th>
<th>Mg</th>
<th>PO₄</th>
<th>NO₃</th>
<th>NO₂</th>
</tr>
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"**"- significant at 5% level, "NS"- Not significant
Table 15B. Pearson product – moment correlation of the hydrographic parameters at the bottom water of FC site 2.

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<td>-0.5226*</td>
<td>-0.4433&lt;sup&gt;NS&lt;/sup&gt;</td>
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<td>-0.0123&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.1958&lt;sup&gt;NS&lt;/sup&gt;</td>
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"**" - significant at 5% level, "NS" - Not significant
Table 16A. Pearson product – moment correlation of the hydrographic parameters at the surface water of FC site3.

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<th>Mg</th>
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<th>NO₃</th>
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"**" - significant at 5% level, "NS" - Not significant
Table 16B. Pearson product – moment correlation of the hydrographic parameters at the bottom water of FC site 3.

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<th>Mg</th>
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"**" - significant at 5% level, "NS" - Not significant
Table 17A. Pearson product–moment correlation of the hydrographic parameters at the surface water of FA site4.

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<th>Mg</th>
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"**"- significant at 5% level, "NS"- Not significant
Table 17B. Pearson product – moment correlation of the hydrographic parameters at the bottom water of FA site4.

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"**" - significant at 5% level, "NS" - Not significant
Table 18A. Pearson product–moment correlation of the hydrographic parameters at the surface water of control site 1

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<th>pH</th>
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<th>Mg</th>
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"**"- significant at 5% level, "NS"- Not significant
Table 18B. Pearson product – moment correlation of the hydrographic parameters at the bottom water of control site 1

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"*" - significant at 5% level, "NS" - Not significant
Table 19A.  Pearson product – moment correlation of the hydrographic parameters at the surface water of control site 2

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"**"- significant at 5% level, "NS"- Not significant
Table 19B. Pearson product – moment correlation of the hydrographic parameters at the bottom water of control site 2
(* = P<0.05, ** = P<0.01 Significance level.)

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"^*" - significant at 5% level, "^NS" - Not significant