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†Hydrological conditions in seagrass beds in Palk Bay and Gulf of Mannar, southeast coast of India

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Abstract

Comparative analysis has been made on the water quality parameters in three seagrass sites, Sangumal and Farm pond in Palk Bay; Thonithurai and one non seagrass site - Kundhukaal point in the Gulf of Mannar from January 2006 to December 2007. The atmospheric temperature ranged from 24.8° to 35.3 °C, sea surface temperature from 25° to 35°C, pH from 7.44 to 8.44, dissolved oxygen from 1.0 ml to 5.9 ml l^{-1} and total suspended solids from 10.7 mg to 122 mg l^{-1} in the four sites. The maximum concentration of phosphate, silicate, nitrite and nitrate in the water were 1.22 µmol, 5.83 µmol, 0.63 µmol and 2.03 µmol l^{-1} respectively. Sangumal had the maximum input of nutrients especially during the northeast monsoon. Pearsons correlation coefficient showed significant positive correlation ($\rho<0.01$) of sea surface temperature with pH, salinity, dissolved oxygen and negative correlation with total suspended solids, nitrite and ammonia. Though ANOVA did not show significant difference in water quality parameter between sites with and without seagrass, highly significant difference ($\rho<0.001$) was observed seasonally in sea surface temperature, salinity, nitrite, ammonia, wind velocity, rainfall and number of rainy days, thereby influencing the growth of seagrass beds.

Keywords: Seagrass, nutrients, sea surface temperature, chlorophyll, rainfall, Palk Bay, Gulf of Mannar

Introduction

The distribution and growth of seagrasses are regulated by a variety of water quality parameters such as temperature, salinity, nutrient availability, substratum characteristics, turbidity and submarine irradiance (Abal and Dennison, 1996; Dennison and Kirkman, 1996). The availability of nutrients affects the growth, distribution, morphology and seasonal cycling of seagrass communities (Short *et al*., 1995). Several studies (Neverauskas, 1987; Phillips and Menez, 1988; Johansson and Lewis, 1992; Short *et al*., 1996) have related the decline of seagrass distribution to the degree of nutrient loading within various catchments. Causes of seagrass degradation are sewage enrichment (Johansson and Lewis, 1992), enrichment of groundwater supplies (Short *et al*., 1996) and runoff from agricultural lands (Philips and Menez, 1988).

Palk Bay is shallow with maximum depth of 13 m in Indian territorial waters. The Gulf of Mannar has 21 islands with seagrass beds and coral reefs occuring in most of the islands. Palk Bay and Gulf of Mannar join at Pamban and near Adams Bridge. During southwest monsoon (June to August), the direction of current is clockwise in Palk Bay and the reverse in northeast monsoon (October to December). The moving sandbar in Adams Bridge buffer the impact of monsoon induced littoral currents in Palk Bay and Gulf of Mannar. In the present study three seagrass and a non seagrass site were selected to analyse the seasonal changes in water quality parameters and the impact of anthropogenic activities on the sites.

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Material and Methods

The sites (Fig. 1) were selected based on geographical differences and impact of changing current pattern nearshore. Sangumal seagrass site in Rameswaram Island is located in Palk Bay (09° 17′ 22.7″ N lat., 79° 19′ 49.5″E long.). There is a sewage outlet adjacent to this site. The seagrass beds are exposed in the lowest low tide during southwest monsoon up to a distance of 1-2 km from the shore. During northeast monsoon, as the current is in the reverse direction towards the coast from the Bay of Bengal seagrass beds are not exposed even during low tide. The seagrass beds are found at a distance of 50-75 m from the highest high tide, starting at 0.5-1 m depth extending up to 4-5 m depth.

In Thonithurai (Gulf of Mannar; 09°16′37.7″N lat. 79°10′36.2″E long.) seaweeds are cultivated in an area of about 1000 m^2. The seagrass bed is located 5-10 m from the high tide line up to a depth of 3-5 m. As the coast will be more exposed during the northeast monsoon, the seagrass beds will be exposed at 600-800 m from the shore during the lowest low tide.

Farm pond seagrass site in the mainland is located in Palk Bay (9° 17′28.4″N lat., 79°7′45.6″ E long.) adjacent to Pillaimadam lagoon which receives freshwater runoff during northeast monsoon. The seagrass beds are located at a distance of 400 to 500 m away from the mouth of the lagoon. Kundhukaal point, a non seagrass site located in the Gulf of Mannar (09°15′ 28.3″ N lat., 79° 13′ 15.4″ E long.) Rameswaram Island was monitored for the water quality parameter. The area has eroding shore and is exposed during northeast monsoon.

Water samples were collected using a fishing boat at monthly intervals from the above sites from January 2006 to December 2007 using standard sampling procedure (APHA, 1995) and seagrass species in these sites were identified using the key provided by Ramamurthy *et al*. (1992). The *in situ* atmospheric and sea surface temperatures were measured using mercury bulb thermometer. The pH and salinity were analysed using WTW Germany-series Multi 720 water analyser. The dissolved oxygen was measured by Winkler's titration method (Parsons *et al*., 1984). The total suspended solid was determined using a millipore filtration unit by estimating the residue retained on pre-weighed glass fiber filter after drying. Water samples collected for chlorophyll-*a*, was extracted by adding 90%v/v acetone as per standard procedure.

Nutrients, namely phosphate, silicate, nitrite and nitrate in the seawater were estimated following the standard procedure suggested by Strickland and Parsons (1968). The nitrate was reduced to nitrite by passing through a cadmium column. The method of indo-phenol blue reaction of Solarzano (1969) was followed for determination of ammonia. The colour extinction for chlorophyll-*a* and nutrients were

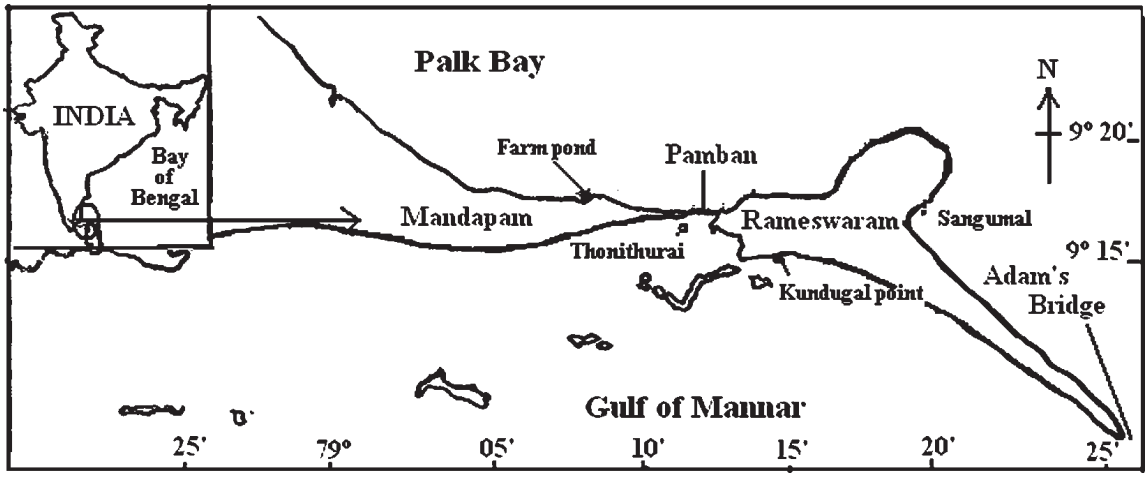

Fig. 1. Location map of the sampling sites in Palk Bay and Gulf of Mannar

measured in a spectrophotometer (Genesys 10UV).

The daily meteorological data such as wind velocity, direction, rainfall and number of rainy days were obtained from the field centre of Central Electrochemicals Research Institute, Mandapam Camp. The seasons were grouped as January to March (post monsoon), April to June (summer), July to September (premonsoon) and October to December (monsoon). The data were analysed using SPSS statistical package.

Results and Discussion

The distribution of seagrass species in the three sites is given in Table 1.

Atmospheric and sea surface temperature: Temperature affects processes important to the dissolved oxygen level in water such as the solubility of oxygen and rate of oxidation of organic matter (Ronald *et al*., 1999). In the present study, sea surface temperature had a significant (p<0.01) positive correlation with pH, salinity and dissolved oxygen and a significant negative correlation (p<0.05) with nitrite, total suspended solids and ammonia at all the sites. The atmospheric temperature ranged between 25.5° and 33° C in 2006 and 24.8° and 35.3° C in 2007. The maximum sea surface temperature of 35° C was observed in Sangumal during August 2006 and in Thonithurai, Farm pond and Kundhukaal point, the maximum sea surface temperature were 32.5°, 32.2° and 32.9° C in March 2006, August 2007 and April 2006, respectively.

Table 1. The seagrass species distributed in the three sites in Palk Bay and Gulf of Mannar

Species	Sangumal	Thonithurai	Farm pond
Cymodocea serrulata	+	+	+
C. rotundata	+	+	+
Syringodium isoetifolium	+	+	+
Halodule pinifolia	+	+	+
H. uninervis(broad leaf)	-	+	-
H. uninervis (narrow leaf)	+	+	+
Halophila ovalis	+	+	+
H. beccari	+	+	-
H. stipulacea	-	+	-
Enhalus acoroides	-	+	-
Thalassia hemprichii	+	-	-

+ denotes presence; - absence

pH: The maximum pH in Sangumal, Thonithurai, Farm pond and Kundhukaal point were 8.15, 8.44, 8.19 and 8.23 in April 2006, February 2007, August 2007 and November 2007 respectively. The minimum pH observed in Sangumal and Thonithurai were 7.44 and 7.71 in February 2007 and May 2006 respectively. In Farm pond and Kundhukaal point a minimum pH of 7.68 and 7.83 was observed in January 2007. ANOVA showed significant monthly difference (p<0.001) of pH in the various months. The seasonal variation in pH is given in Fig. 2. The low pH in Sangumal during premonsoon compared to other sites is due to a combination of factors like increase in input of sewage effluent caused by tourists during festivals and also due to changing wind direction and consequent current change when there is less flow of water resulting in higher total suspended solids and low dissolved oxygen. Pearsons correlation showed significant positive correlation (p<0.01) between pH and atmospheric temperature, sea surface temperature as well as dissolved oxygen.

Salinity: The maximum salinity of 37.1 ppt was observed in October 2007 in Sangumal. In Thonithurai, Farm pond and Kundhukaal point, the maximum salinity of 37.4, 36.4 and 37.2 ppt respectively were in September 2006. There was significant positive correlation (p<0.01) of salinity with atmospheric temperature, sea surface temperature and wind velocity. ANOVA showed highly significant difference (p<0.001) in salinity for different seasons in all the sites.

Dissolved oxygen: Maximum dissolved oxygen concentration in Sangumal, Thonithurai, Farm pond and Kundhukaal point were 5.06 ml, 5.23 ml, 5.9 ml and 4.82 ml 1^{-1} in June 2006, September 2007, October 2007 and December 2007 respectively, while the minimum dissolved oxygen were 1.05 ml, 2.33 ml, 2.47 ml and 2.89 ml l^{-1} in September 2006, August 2006, June 2007 and February 2007 respectively. Fig. 3 shows seasonal variation of dissolved oxygen in sampling sites. Thonithurai seagrass site does not show much variation in dissolved oxygen throughout the year which may be due to the mixing of water by the opposing currents at Pamban. The cultivation of seaweeds may also help maintain the water quality of the site.

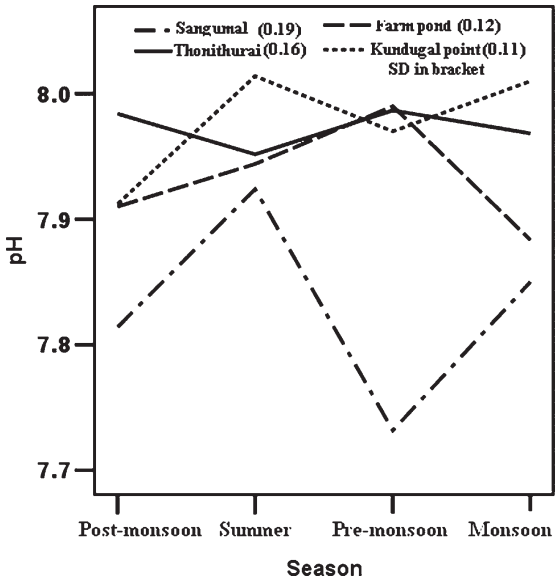

Fig. 2. Seasonal mean pH in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

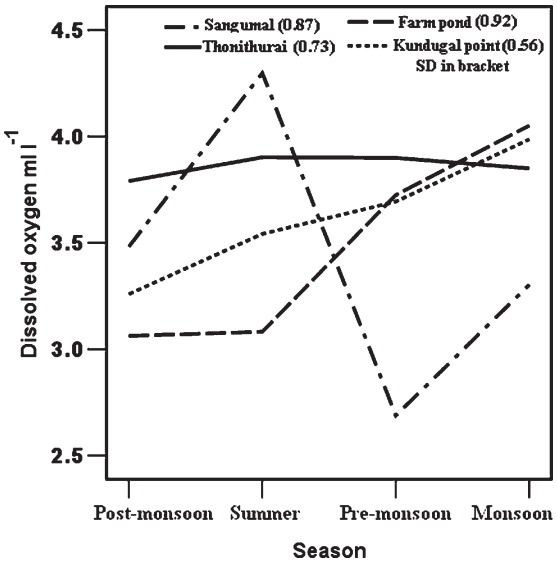

Fig. 3. Seasonal mean dissolved oxygen in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

Total suspended solids: Kundhukaal point and Thonithurai both in the Gulf of Mannar showed less chlorophyll-*a* and corresponding less total suspended solids during monsoon as the wind direction was northeast/northwest, causing less erosion and upwelling of nutrients. In summer it is reverse due to the impact of southwest monsoon.

The total suspended solids in Sangumal, Thonithurai, Farm pond and Kundhukaal point were 122 mg, 69.4 mg, 75.3 mg and 74 mg l^{-1} in October 2006, January 2007, April 2006 and May 2007, respectively while the minimum values were 13.5 mg, 10.7 mg, 16.4 mg and 19.4 mg l^{-1} in November 2006, May 2007, July 2007 and November 2007, respectively. The seasonal variation of total suspended solids is given in Fig. 4.

Chlorophyll-a: Elevated Chlorophyll-*a* concentration indicates more of phytoplankton and free floating microalgae which can shade seagrass meadows leading to decline in seagrass distribution (Duarte, 1995). The maximum chlorophyll-*a* concentration in Sangumal, Thonithurai, Farm pond and Kundhukaal point were 6.836 mg, 6.573 mg, 6.69 mg , and 8.003 mg m^{-3} in June 2006, September 2007, December 2007 and May 2007, respectively. Pearsons correlation showed significant positive correlation ($p<0.05$) of chlorophyll-*a* with phosphate and wind velocity. The seasonal variation of chlorophyll-*a* in the various sites is shown in Fig. 5. Higher chlorophyll-*a* concentration was observed in Sangumal and Farm pond during monsoon. Correspondingly the ammonia concentration was also higher during this period. In Sangumal, the increase in nutrient concentration in monsoon also led to an increase in total suspended solids. It is established by earlier workers in the Indian waters that when there is a fall in temperature and salinity followed by sudden increase in nutrients, a high rate of primary production can be expected (Marichamy *et al.*, 1985). Gopinathan and Rodrigo (1991) observed that the chlorophyll-*a* showed distinct seasonal variations and has direct relationship with primary production in Gulf of Mannar coastal waters. Further they observed that the southwest monsoon is not active in this coastal area and hence its influence on productivity and hydrological condition is marginal. In the present study, it is seen that both the seasons had effect on the productivity of the region. Higher chlorophyll-*a* concentration was

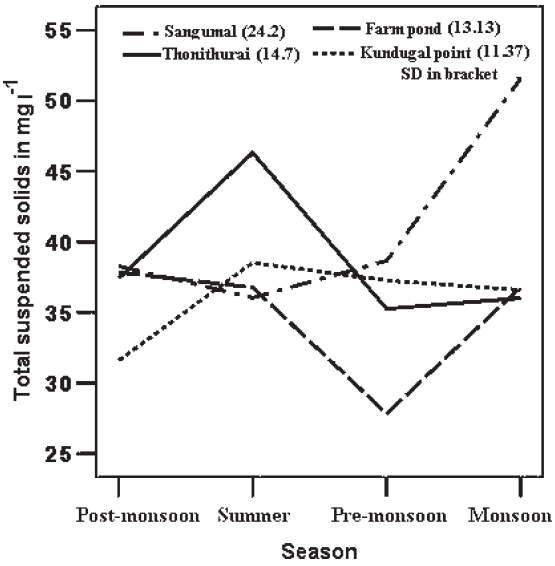

Fig. 4. Seasonal mean total suspended solids in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

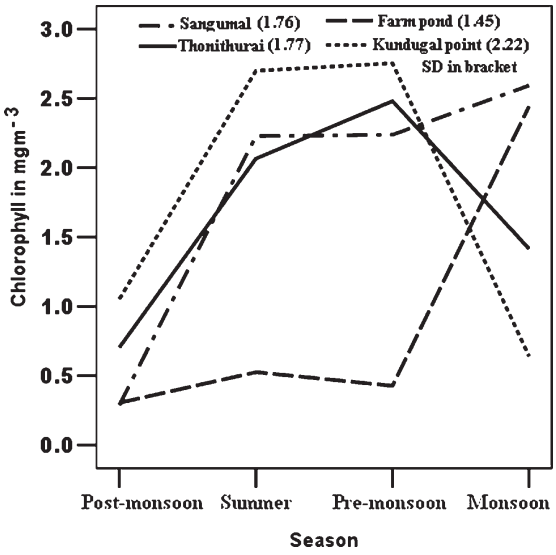

Fig. 5. Seasonal mean chlorophyll-a in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

observed in summer and premonsoon in Thonithurai and Kundhukaal point.

Meteorological data: The annual average rainfall, which occurred in 53 days in 2006 was 1251.6 mm while in 2007 it was 835.5 mm in 49 days. In October 2006 and 2007, the maximum rainfall was 518.3 mm (18 days) and 356 mm (10 days) respectively. October to December contribute more than 90% to the total rainfall. Salinity showed significant negative correlation (p<0.01) with number of rainy days. The monthly variation in rainfall is shown in Fig. 6.

Wind induced littoral current is a dominant force in the region. During rough season, patches of seagrasses are uprooted and transported by waves. According to Steeman and Jensen (1957) extensive investigation during different seasons is necessary to understand the productivity of Bay of Bengal as the monsoon shift has considerable influence on the productivity. Maximum average wind velocity of 24.2 km hr^{-1} was in summer, which impacts the Gulf of Mannar coast, followed by 22.5 km hr^{-1} in premonsoon which affects the Palk Bay coast, while the minimum wind velocity of 3 km hr^{-1} was observed in monsoon. The wind direction in November, December of 2006 and 2007 was northeast-northwest. In March and April mixed trend of northeast-northwest and southeast-southwest winds was observed, though the wind direction was predominantly northeast-northwest in March and southeast-southwest in April. The wind direction is southeast-southwest during May - July in both the

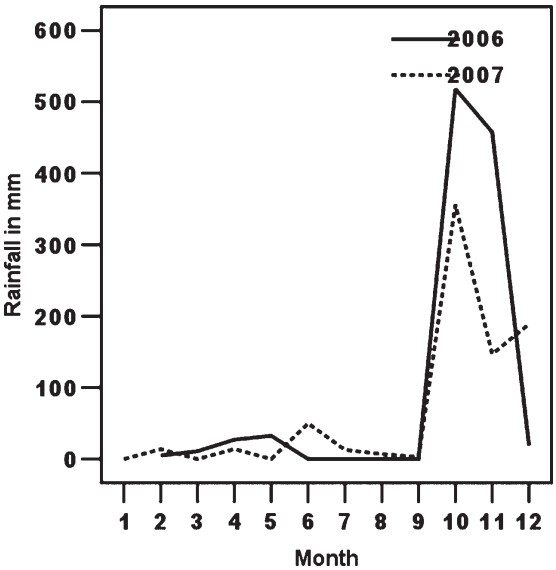

Fig. 6. Monthly variation in rainfall

years. It was observed that in August and September 2006 the wind direction was southeast-southwest. Mixed trend was observed in 2007, though the predominant wind direction was southeast-southwest. In October 2007 both wind directions were equally distributed while in October 2006 it was predominantly northeast-northwest. Mixed trend winds are indicators of current direction change in Palk Bay and Gulf of Mannar.

Nutrients: In comparison to all the sites, Sangumal has higher phosphate, nitrite and silicate levels which could cause adverse effect on seagrass diversity. According to Short *et al*. (1995) long-term nitrate additions cause severe decline of seagrass and enriched levels of ammonia and phosphate lead to reduction in shoot density and biomass of seagrass population. Maximum phosphate concentration in Sangumal, Thonithurai and Kundhukaal point were 1.23 µmol, 0.64 µmol and 0.03 µmol l^{-1} respectively, while in Farm pond it was below detectable level. ANOVA shows significant difference in phosphate levels between the sites. Fig. 7 shows seasonal variation of phosphate in the sampling sites. Pearsons correlation showed significant negative correlation (p<0.01) of phosphate with pH.

Maximum silicate concentration in Sangumal, Thonithurai, Farm pond and Kundhukaal point was 5.258 µmol, 5.744 µmol, 5.839 µmol and 1.998 µmol l^{-1} in June 2007, July 2007, October 2007 and March 2006 respectively. Fig. 8 shows seasonal variation of silicate in the sites. There is significant positive correlation (p<0.01) of silicate with that of phosphate as well as nitrate and ammonia (p<0.05). Negative relationship of silicate with salinity was observed, a trend similar to that observed by Subramanian and Kannan (1998) in Gulf of Mannar coastal waters. The high level of silicate during northeast monsoon in Farm pond may be due to freshwater flow to the lagoon. The major source of silicate for the other sites is the groundwater flow as rainfall is in short duration with high intensity which permeates quickly into the sand dunes.

Maximum nitrite concentration in Sangumal, Thonithurai, Farm pond and Kundhukaal point were 0.548 µmol, 0.632 µmol, 0.296 µmol and 0.548 µmol l^{-1} respectively. The seasonal variations of nitrite in

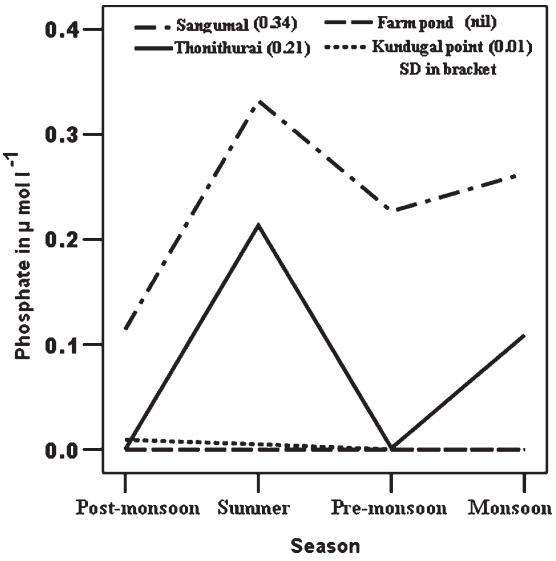

Fig. 7. Seasonal mean phosphate in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

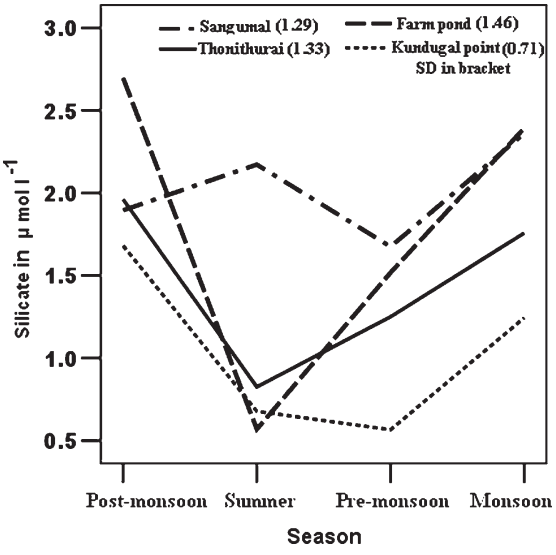

Fig. 8. Seasonal mean silicate in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

the different seasons are given in Fig. 9. Maximum nitrate values in Sangumal, Thonithurai, Farm pond and Kundhukaal point were 2.03 µmol, 1.1 µmol, 1.705 µmol and 0.623 µmol l^{-1} respectively. The seasonal variation of nitrate in the different sites is

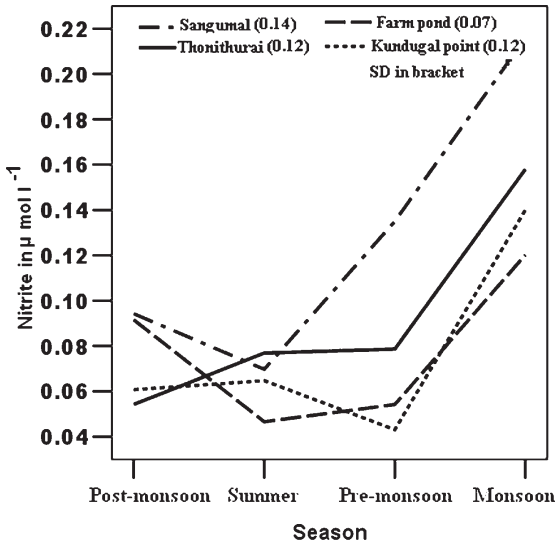

Fig. 9. Seasonal mean nitrite in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

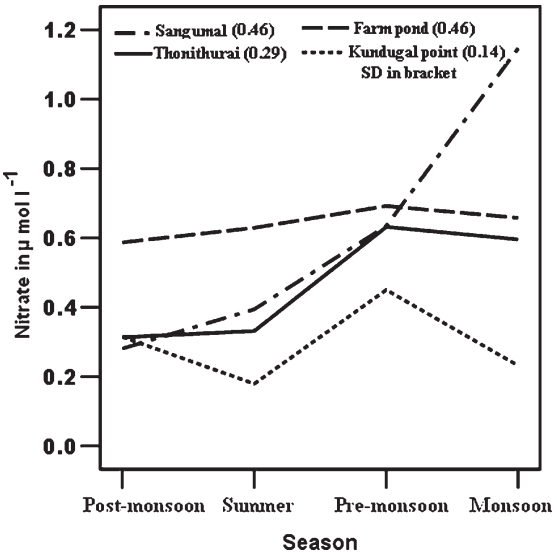

Fig. 10. Seasonal mean nitrate in the sampling sites in Palk Bay and Gulf of Mannar during 2006-2007

shown in Fig. 10. There is significant positive correlation (p<0.01) between total suspended solids and nitrate.

Maximum ammonia level was in Sangumal 29.3 µmol l^{-1} followed by Thonithurai 16.78 µmol, Farm pond 11.18 µmol and Kundhukaal point 3.81 µmol l^{-1} in November 2006, December 2007, December 2006 and December 2007 respectively. Maximum ammonia (29.3 µmol l^{-1}) was observed during monsoon followed by premonsoon (10.228 µmol l^{-1}), post monsoon (3.2 µmol l^{-1}) and summer (2.16 µmol l^{-1}) seasons. ANOVA showed significant (p<0.001) difference in seasonal ammonia levels. There is significant positive correlation (p<0.01) of ammonia with phosphate, silicate and total suspended solids (p<0.05).

Atkinson and Smith (1983) observed that succession of macrophytes and microphytes depends on the optimum N:P ratio which is about 30:1 vs 16:1 for phytoplankton (Redfield, 1958). Thus phytoplankton blooms can occur only in summer where N: P ratios of water is lower than 20:1. In Palk Bay and Gulf of Mannar, phytoplankton blooms are observed in summer as well as in the premonsoon season. The low level of phosphate in Kundhukaal point and Farm pond when compared to Sangumal and Thonithurai indicates that phosphorous plays a key role as a limiting factor and influences the productivity of the region. It was observed that Sangumal has the lowest dissolved oxygen concentration and the highest nitrite in premonsoon, which may be due to decomposition of algae by microorganisms. Thonithurai, which is the most diverse seagrass site with 10 species, had less fluctuation in dissolved oxygen compared to the other sites. The study indicates that nutrient input, wind velocity and direction, rainfall and current changes influence the productivity of seagrass beds in Palk Bay and Gulf of Mannar.

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