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RESEARCH ARTICLE

SPATIAL VARIABILITY IN DISTRIBUTION OF SEAGRASSES ALONG THE TAMILNADU COAST

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ABSTRACT

Seagrasses are one of the predominant groups of marine flora that grows in tidal and subtidal region of the shallow coastal environment. Spatial variability of seagrass distribution, biomass, canopy height, productivity and environmental parameters were recorded at 24 stations all along the Tamilnadu coast during 2011 and 2012. Thirteen seagrass species of six genera were recorded, among which *H. ovalis* was found to be distributed all along the coast of Tamilnadu, and *C. serrulata* was found densely populated in the shallow coastal regions of Palk Bay and Gulf of Mannar (GOM). *H. beccarii* is the rare species found only in Vellar estuary of Parangipettai. Biomass (36.2 gfr.wt.m^{-2} - 1218 gfr.wt.m^{-2}), productivity (0.01 g C m^{-2} d^{-1} - 4.34 g C m^{-2} d^{-1}) and canopy height (0.28cm -107.73 cm) of seagrass species varied among all species of seagrasses. Correlation coefficient indicate that the local environmental parameters, particularly inorganic phosphate and total phosphorus are two important nutrients and sediment texture play a prominent role in influencing seagrass biomass, productivity and canopy height by enhancing the growth of seagrasses. Hence the present study suggests continuous monitoring of ecological and biological variables in time and space is highly required for managing the resources efficiently.

INTRODUCTION

Seagrasses are one of the most widespread vegetation that grows in tidal and subtidal region of the shallow coastal environment. Seagrasses characteristically forms monospecific meadows in temperate and multispecific in tropical and subtropical regions (Hemminga and Duarte, 2000). They perform physical, chemical and biological functions in the shallow coastal waters and act as an ecological engineer (Wright and Jones, 2006) by performing important physical functions such as filtering of coastal waters, dissipating wave energy (Green and Short, 2003) and protecting the shoreline from erosion. Their chemical and biological functions improves the water quality by cycling nutrients and mitigating ocean acidification and its detritus supports higher tropic levels including commercially important species (Hemminga and Duarte, 2000; Deegan *et al.*, 2002; Marba *et al.*, 2006), and thereby regulates benthic metabolism by decomposing and remineralysing organic matter in seagrass environment. Seagrass meadows have greater ecological importance and are recognized for high primary and secondary productivity all over the world contributing 1% of the net primary production and 12% of the net ecosystem production in the ocean (Duarte, 1999). Higher primary production rates of seagrasses leads to the increased fish assemblages and are significant contributors to the coastal productivity (Kannan and Thangaradjou, 2007). Seagrasses also play important role in the carbon cycle in the ocean, being responsible for a significant fraction of net CO_2 uptake (Thangaradjou *et al.,* 2010). Nutrient cycle in the marine sediment and the surrounding water column is mediated by the presence of seagrass, which provide the link between sediment and overlying water column nutrients (Spalding *et al.,* 2003). Seagrasses uptake the essential nutrients from the water column through leafs and sink to the sediment through rhizome (Terrados and Williams, 1997) and also partly transfer to the autochthonous and allochthonous materials to the other ecosystem (Kennedy *et al.*, 2010) thereby regulates biogeochemical cycle in their ecosystem. The physical structure of the seagrass canopy modifies the water column velocity, enhances the sedimentation of suspended particles (Koch *et al.,* 2001) thereby anchoring the sediments (Green and short 2003). Seagrass biomass provides food and shelter for different organisms and profoundly serves as a nursery and spawning area for a diverse biota (Nagelkeran *et al.,* 2001; Dahlgren *et al.,* 2006). It also serves as the primary food source for dugongs and green turtles and several fishes (McKenzie *et al.*, 2010). Such important coastal resource is subject to variation with space and time over the years due to natural and anthropogenic causes. Tamilnadu coast is bestowed with all fourteen seagrass species of the country, representing Palk Bay

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and Gulf of Mannar (GOM) as the luxuriant seagrass destinations. Distribution of seagrasses along Tamilnadu coast was studied in detail (Jagtap, 1991; Parthasarthy *et al*., 1991 and Rammamurthy *et al*., 1992). Later, few intermittent sites specific studies in GOM (Ganesan and Kannan 1995; Thangaradjou and Kannan, 2010; Manikandan *et al.,* 2011a) and Palk Bay (Kannan and Kannan, 1996; Manikandan *et al.,* 2011b; Govindasamy and Arulpriya 2012; Govindasamy, 2013; Govindasamy *et al.,* 2013, Nisha D' Souza *et al.,* 2013) were carried out at different time periods. However, a holistic spatial survey on seagrasses along Tamilnadu coast is largely missing for the past two decades. Hence, the present study aimed to assess the spatial variation of seagrass distribution along Tamilnadu coast with respect to local environmental parameters.

MATERIALS AND METHODS

Sampling Strategy

In situ ecological and biological parameters were recorded at 24 stations all along the Tamilnadu coast during 2011 and 2012. Based on the richness, seagrass meadows of Marakkaanam, Vellar and Pazhaiyar estuaries, Pichavaram mangrove and Velivayal, Mallipattinam, Manora, Paasipattinam, Thondi, Thirupalakudi, Mullimunai, and Devipattinam in Palk Bay, Chinnapaalam, Shingle, Krusadai, Manoli, Manoliputti and Hare islands in Gulf of Mannar Biosphere reserve and Uvari, Edinthakarai, Aarockiapuram, Leepuram, Sangentheri and Chinnamuttam in Kanyakumari region were covered for the present survey.

Seagrass distribution and biology

Sampling was carried out during low tide regime at intertidal regions by skin diving method. Seagrass distribution was assessed using line transects (100 m) made perpendicular to the coast randomly (10 transects per site). Presence of different species of seagrasses along all transects were recorded. Seagrass samples were identified following the field key of Kannan and Thangaradjou (2006) and confirmed in the laboratory with the help of literature (Rammamurthy *et al.,* 1992, den Hartog, 1970). Seagrass samples were collected randomly by using a quadrate ($0.25m^2$) and washed thoroughly with the ambient seawater to remove sediment and debris. Moisture from the samples was removed using adsorbent paper and weighed to get the total biomass. The mean of ten quadrate sampling per site was considered for quantifying seagrass biomass and the mean value was expressed in terms of gram fresh weight per square meter (g fr. wt. m^{-2}). Canopy height of seagrass species was measured by picking a hand full of leaves from the samples collected for biomass estimation whilst the length was measured using 30cm scale. Dissolved oxygen was measured by following the method of Strickland and Parsons (1972) and the photosynthetic productivity of seagrasses was estimated by following the methods of Qasim *et al.* (1972), and modified by Kannan and Thangaradjou (2006).

Physico- Chemical characteristics of seagrass environment

Atmospheric and water temperature was measured using a digital multistem thermometer of 0.1°C accuracy. Salinity was recorded using a hand-held refractometer (Atago hand refractometer, Japan) and the pH and Eh was measured using a pH meter (WTW PH 3110, Germany) with the accuracy of ± 0.1. Light intensity was estimated using LUX meter (TES 1332A Digital LUX meter) and the values were expressed as irradiance by using a conversion factor of Lux*0.0135. Surface water samples were collected using polypropalene containers and stored in the ice box after adding 1 ml of saturated mercury chloride to avoid the degradation of nutrients and transported to the laboratory. Samples were filtered using a Millipore filtering system using 0.45 µm GF/C filter paper. Pre-weighed filter papers were used for filtration and dried at 75°C for 24 hours and weighed again to estimate the suspended sediment concentration (SSC) in terms of mg^{-1} (Gray *et al.,* 2000). Dissolved micronutrients such as the nitrite (NO_2), nitrate (NO_3), total nitrogen (TN), inorganic phosphate (PO_4), total phosphorus (TP) and reactive silicate (SiO_3) were measured by following the method of Strickland and Parsons (1972) by using a UV-VIS- Spectrophotometer (Shimatzou UV-2450). Dried sediment samples were subjected to size fraction analysis following the procedure of Udden modified by Wentworth (1922). The sediment samples which passed through the 62 µ sieve were the silt and clay. The silt and clay fractions were then separated by means of pipette method, described by Lindholm, (1987) and all the values were expressed in terms of percentage (%). Sediment pH and Eh were measured using WTW PH 3110 meter (Germany) immediately after sampling.

Statistical Analysis

All the statistical analysis was carried out using SPSS version 16.0 in Windows 7 software. Pearson coefficient was used to derive the relationships among biomass, productivity, canopy height with physico-chemical parameters of water and sediment.

RESULTS AND DISCUSSION

Seagrasses, the very unique habitats of the marine environment plays vital ecosystem services thereby supporting wide variety of marine organisms. Distribution and growth of seagrass are regulated by a variety of environmental parameters such as temperature, salinity, nutrient and substrate uniqueness (Dennison and Krikman, 1996). Present study on the distribution of seagrasses all along the coast of Tamilnadu, covering 24 stations provides details on the status of seagrasses and physico-chemical properties prevailing in the region, thereby confers a clue on the influence of these parameters on the growth and productivity of seagrasses along the stations.

Seagrass distribution

Seagrass of 13 species belonging to 6 genera (*E. acoroides, H. beccarii, H. ovalis, H. ovalis* subsp. *ramamurthiana, H. ovata, H. stipulacea***,** *T. hemprichii***,** *C. rotundata, C. serrulata, H. pinifolia, H. uninervis, H. wrightii and S. isoetifolium*) were recorded in the sampling stations. Seagrass distribution in all stations varied spatially, none of the 24 stations were found similar with the other in the distribution of seagrasses. *H. ovalis* was found distributed in 17 stations, and *H. beccarii*, the rare species was found only at Parangipettai. Higher seagrass diversity in terms of number of species was recorded at Chinnapaalam (10 species), followed by Devipattinam and Manoli island (9 species each). Low species diversity was recorded at Pitchavaram and Edinthakarai (Table 1).

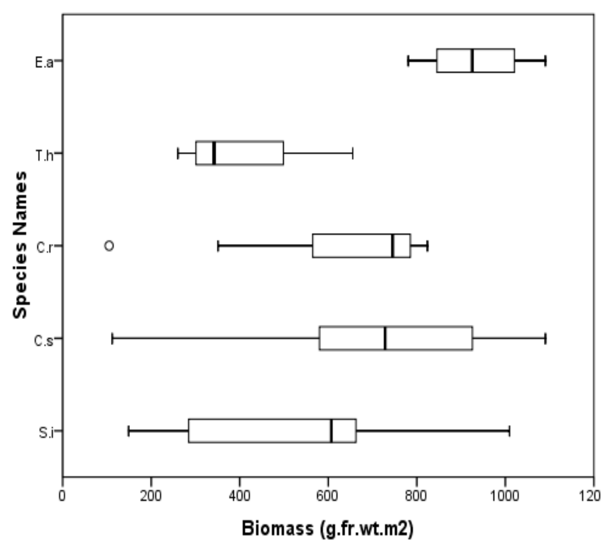
Table 1. Distribtuion of seagrass all along the Tamilnadu

S.No.	Seagrasses	Marakkaanam	Parangipettai	Pitchavarm	Pazhaivar	Mallipattinam	Manora	Paasipattinam	Thondi	Thirupaalakudi	Mullimunai	Devipattinam	Chinnapaalam	Shingle	Krusadai	Manoli	Manoliputti	Hare island	Velivayal	Uvari	Edinthakarai	Aarockiapuram	Leepuram	Sangentheri	Chinnamuttam
1.	*E.acoroides*								+			+	+		+	+		+							
2.	*H.ovalis*	+	+	+	+		+	+	+	+	+	+	+	+	+	+		+		+					+
3.	*H.ovata*						+			+		+	+	+	+	+		+							
4.	*H.stipulacea*							+		+															
5.	*H.beccarii*		+																						
6.	*H.ovalis rammamurthiana*	+									+														
7.	*T.hemprichii*								+			+	+			+									
8.	*S.isoetifolium*					+	+		+			+	+		+	+		+	+	+	+	+	+	+	+
9.	*C.serrulata*					+	+	+	+	+		+	+	+	+	+	+	+	+	+		+	+	+	+
10.	*C.rotundata*								+			+	+			+	+	+		+				+	+
11.	*H.pinifolia*		+			+	+	+	+			+	+	+	+	+	+	+	+						
12.	*H.uninervis*								+				+		+	+	+	+							
13.	*H.wrightii*				+							+	+											+	+
	Total	2	3	1	2	3	5	4	8	4	2	9	10	4	7	9	4	8	3	4	1	2	2	4	5

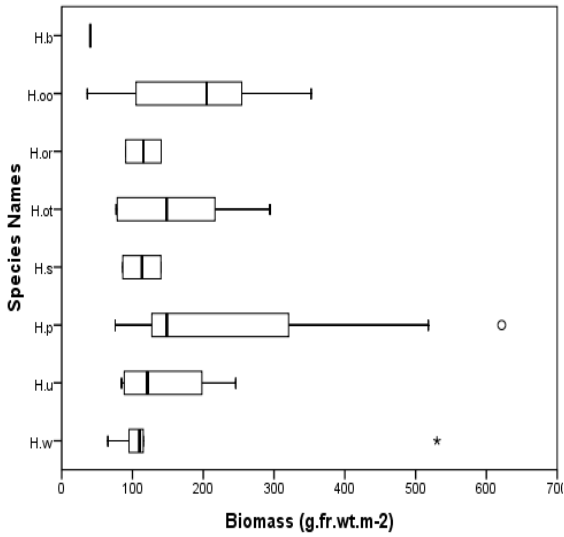
Though, *H. ovalis* was found distributed at many of the stations of Tamilnadu, *C. serrulata* was found dominant in shallow coastal regions of Palk Bay and Gulf of Mannar. Though the population trend of *H. decipiens* is said to be increasing globally (Short *et al.*, 2011), it was not recorded in any of the stations. The distribution of the species along the stations seems to be decreasing trend and not able to record. However, extensive survey in deeper waters is required to confirm the status of *H. decipiens*.

Seagrass Biology

Maximum seagrass biomass was recorded by *E. acoroides* (1218 g fr.wt.m^{-2}) at Chinnapaalam and *C. serrulata* at Thondi (1090.5 gfr.wt.m^{-2}) and the minimum biomass was recorded by *H. ovata* (36.2 gfr.wt.m^{-2}) at Manora during 2011. *H. beccarii* was recorded only at Parangipettai with a biomass of 40.5 gfr.wt.m^{-2} whereas, the biomass of *H. ovalis ramamurthiana* recorded at Marakkaanam and Mullimunai varied between 90.4 and 140.5 gfr.wt.m^{-2}. Interestingly, *H. stipulacea* was recorded for the first time at Paasipattinam and Thirupalakudi with a biomass of 86.4 and 140.2 gfr.wt.m^{-2}, respectively (Fig. 1a and b). Significant difference in biomass of seagrasses was observed when compared to earlier studies. Biomass of *E. acoroides* recorded at Chinnapaalam in the present study was found 4 times lower than that of 5000 gfr.wt.m^{-2} (Thangaradjou and Kannan, 2010) and 4080 gfr.wt.m^{-2} (Susila *et al.,* 2012) recorded at Gulf of Mannar. Productivity of seagrasses not varied widely among species of various stations. Maximum seagrass productivity was recorded by *C. serrulata* at Krusadai (4.34 g C m^{-2} d^{-1}) and minimum was recorded by *H. ovalis* at Pazhaiyar, *H. pinifolia* at Mallipatinam and *H. wrightii* in Devipattinam (0.01 g C m^{-2} d^{-1}) (Fig. 2a and b). However, productivity of *C. serrulata* and *H. ovalis* (4.34 g C m^{2} d^{-1} and 0.01 g C m^{2} d^{-1} respectively) recorded in the present study was found very low compared to earlier records (14.97 g C m^{2} d^{-1} and 2.54 g C m^{-2} d^{-1} respectively) in Gulf of Mannar (Thangaradjou *et al.*, 1998). Seagrass canopy play a vital ecological role in determining the benthic and pelagic organism composition (Nagelkerkan *et al.,* 2001). Canopy height of seagrass showed clear variation, with maximum canopy height recorded by *E. acoroides* at Chinnapaalam (107.73 cm) and minimum by *H. ovata* at Manoli (0.28 cm) (Fig. 3a and b). Seagrasses such as *E. acoroides, C. serrulata, C. rotundata* and *S. isoetifolium* with large canopy height were found growing comparatively at higher depth that provides stable environment not disturbed by other sources and hence producing continuous seagrass coverage and high productivity. Fast growing and rapidly colonizing species are often small (e.g., *Halophila*) whereas, slow growing climax species are often large (e.g., *Enhalus acoroides* and *Posidonia spp*.) (den Hartog, 1977; Hillman *et al.*, 1989) suggesting that difference in plant size may help to explain productivity difference among seagrass species. Present study revealed that the biomass, productivity and canopy height of all 13 seagrass species varied clearly with respect to the size of the leaf.

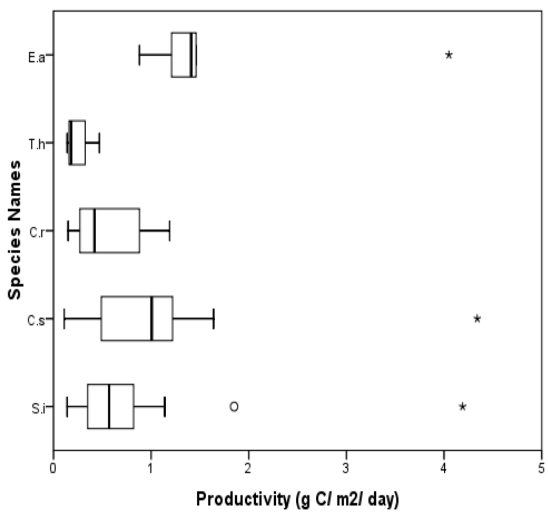


(a)

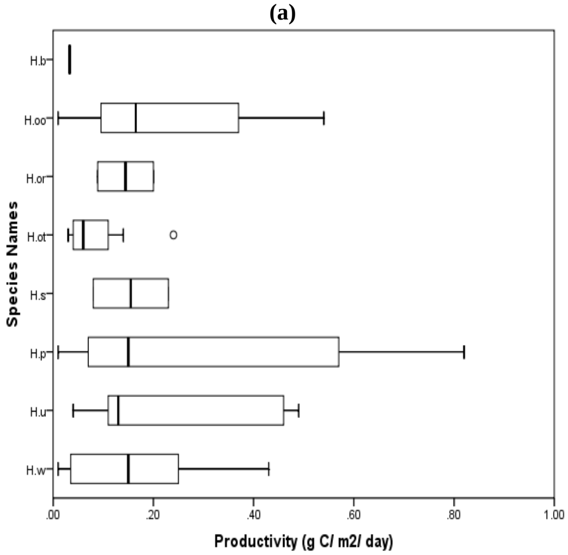


(b)

Fig 1. (a and b) Biomass of seagrasses recorded along the stations

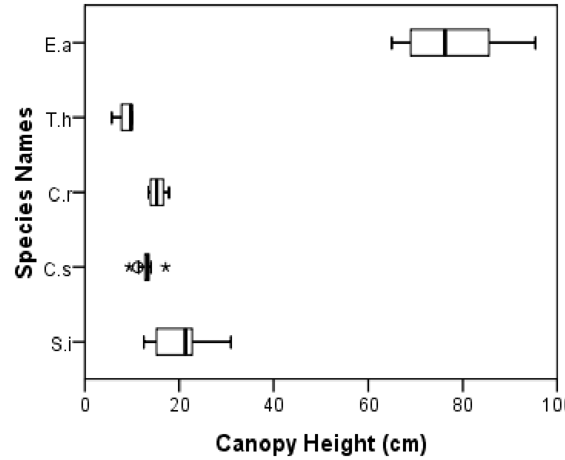


(a)

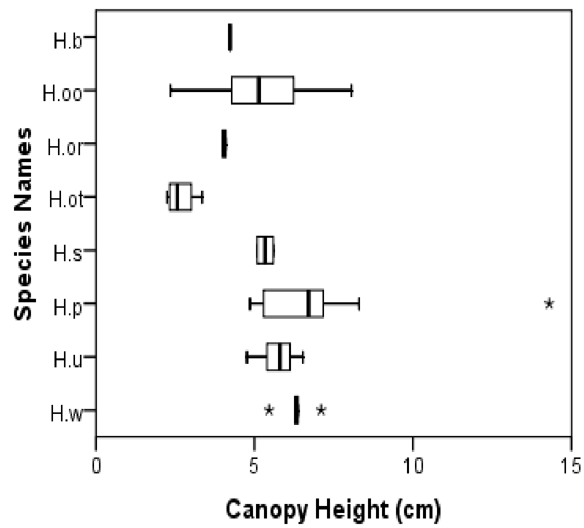


(b)

Fig 2. (a and b) Primary productivity of seagrasses recorded along the stations



(a)

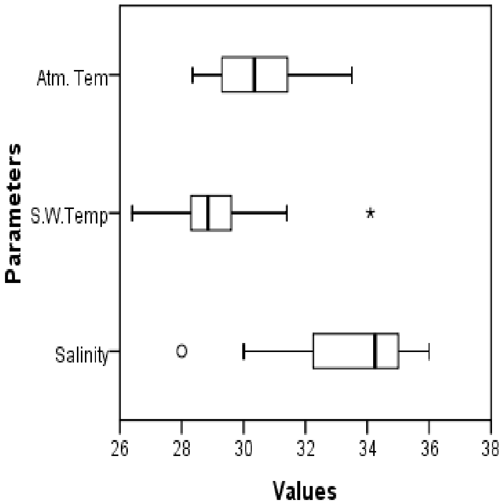


(b)

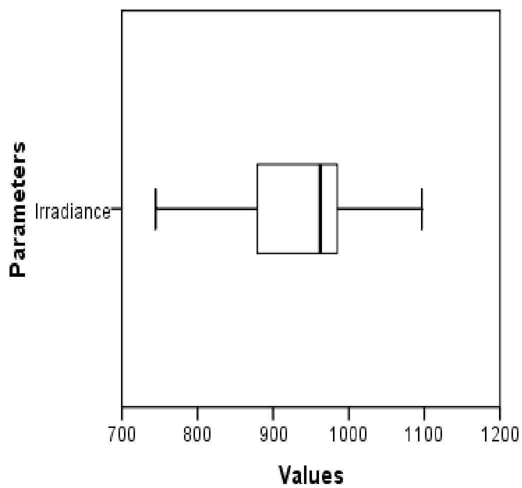
Fig 3. (a& b) Canopy height of seagrasses recorded along the stations

Physico-chemical characteristics of seagrass environment

Temperature is the important factor that influences highly the geographical distribution of world seagrasses (Walker and Prince, 1987). Atmospheric temperature varied between 28.3 and 33.5° C, and surface water temperature varied between 26.4 and 34.1° C (Fig. 4a). The range of surface water temperature recorded (25-31.5° C) was found to be greater when compared to that of the earlier report (Sridhar *et al.*, 2008). This increasing trend of temperature is capable to alter biology, physiology and ecology of the seagrass ecosystem, thus affecting seagrass community structure (Paynter *et al.*, 2001) and this might be one of the reasons for the comparatively low productivity recorded at the sampling stations. Salinity is one of the important parameters that influences the function, physiology and reproductive activities of the organism (Pramasivam and Kannan, 2005). Salinity varied between 28 and 36 ppt, recording the minimum at Parangipettai and maximum at Chinnapaalam, Manoliputti and Hare islands (Fig. 4a).



(a)



(b)

Fig 4. (aand b) Range of physical factors recorded in the sampling stations

It is well proved that seagrass can grow at salinities ranging between 5 and 45 ppt thereby well adapted to changes in salinity (Greve and Binzer, 2004), and hence the present range of salinity might not influence the seagrasses literally. Primary productivity of seagrass environment is regulated by underwater irradiance and sediment (Lee and Dunton, 2000). Irradiance varied between 744.5 and 1096.5 µ mol^{-2} s^{-1} with the minimum at Chinnapalam and maximum at Edinthakarai (Fig. 4b), sometimes high irradiance such as found in the tropical intertidal regions, can limit the growth and productivity of seagrasses by photo inhibition, which lowers photosynthesis rates (Beer and Bjork, 2000). Seagrasses are sensitive to light levels and requires high irradiance for photosynthesis; therefore, light deprivation generally leads to a decline in seagrass health and loss of habitat (Ralph *et al.*, 2006). Hydrogen ion concentration (pH) of water not showed much variation among all the stations, with the minimum at Devipattinam and Manora (7.1), and maximum at Krusadai (8.2) (Fig. 5).

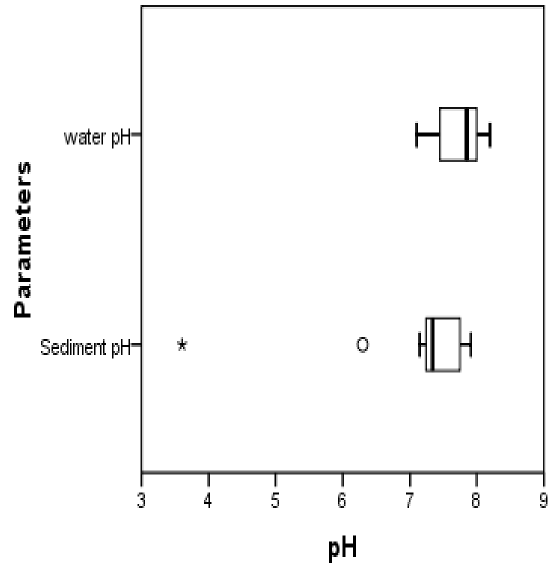


Fig 5. Sediment and Water pH recorded in the sampling station

pH was alkaline throughout the stations due to removal of CO_2 by photosynthesis and liberation of oxygen into the water column. Water Eh was minimum (5.8 MV) in Velivayal and maximum in Aarockiapuram (80.85 mV) (Fig. 6). Nutrients are linked to almost all the ecological process, especially in the seagrass ecosystem and it plays a vital role in distribution and abundance of seagrasses (Dawes, 1998). Nutrients varied differentially along the sampling stations, such as nitrite (0.08 - 1.24 µM); nitrate (0.67 - 13.28 µM); TN (3.12 µM – 14.09 µM); IP (0.27 µM - 3.29 µM); TP (1.02 - 4.006 µM) and reactive silicate (0.12 - 16.80 µM) (Fig. 7). Nutrient such as nitrite (0.08-1.24 µM) and nitrate (0.67 to 13.28 µM) concentration were moderate. Higher nitrate and nitrite concentration in the seagrass environment is a common phenomenon as nitrogen fixation is generally more active in the seagrass bed sediment rather than the carbonate sediments of the coral reef environment (Raja, 2009; Sridhar *et al.*, 2008).

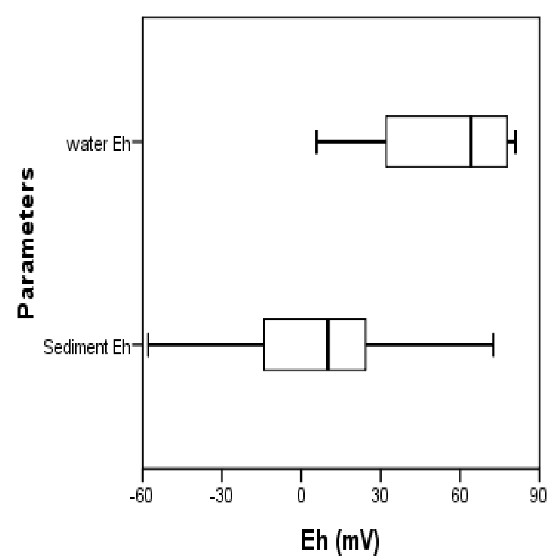


Fig 6. Sediment and Water Eh recorded in the sampling station

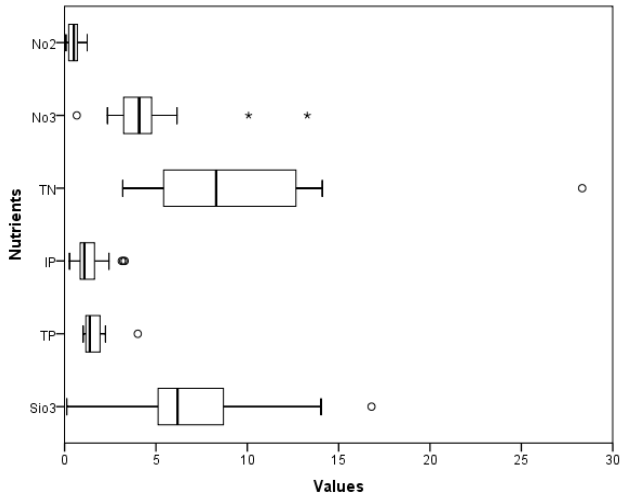


Fig 7. Concentrations of nutrients recorded in the sampling stations

Nitrite showed positive correlation with biomass of *H. pinifolia* (No_2; r = 0.505, p<0.05) and *H. wrightii* (No_2; r = 0.406, p<0.05) and canopy height of *H. ovalis* (No_2; r = 0.454, p<0.05), *H. ovata* (No_2; r = 0.447, p<0.05) and negative correlation with canopy height of *S. isoetifolium* (No_2; r = -0.433, p<0.05). Total nitrogen ranged from 3.12 to 14.09 µM in the water column because nitrogen fixation in the seagrass environment is one of the significant phenomena in nutrient cycling as in any system, which provides with substantial inputs of nitrogen in the rhizosphere of marine macrophytic communities (Capone and Taylore, 1980). Higher densities of bacteria could play a major role in determining the local nitrogen cycle in the seagrass environment (Raja *et al.*, 2012) and seagrasses ability to recycle the sediment and water nutrients through roots and leaves might have resulted in higher water TN. IP ranged from 0.27 to 3.29 µM and is found to be low when compared to that of the earlier record of 0.21- 4.1 µM (Sridhar *et al.*, 2008). The lower nutrient content in the seagrass meadows could be attributed to their utilization by the seagrasses and seaweeds, and low retention by loose and unstable sediments (Sankaranarayana, 1973). This was also evidenced by the positive correlation obtained between IP and TP with seagrass biomass in the study, *E. acoroides* (IP; r = 0.518, p<0.05), *S. isoetifolium* (IP; r = 0.467, TP; r = 0.564, (p<0.05) *C. serrulata* (IP; r = 0.505, p<0.05), *C. rotundata* (IP; r = 0.412, p<0.05), *H. pinifolia* (IP; r = 0.540, p<0.05), *H. wrightii* (IP; r = 0.494, p<0.05), canopy height of *E. acoroides* (IP; r = 0.470, p<0.05), *H. ovata* (IP; r = 0.458, p<0.05) and productivity of *E. acoroides* (IP; r = 0.459, p<0.05) *S. isoetifolium* (TP; r = 0.431, p<0.05). Silicate is not an essential nutrient for the seagrasses but important elements for the associated organism especially diatoms which often encrusts the seagrass leaves (Sridhar *et al.*, 2008) thereby plays a critical role in the community productivity of seagrasses. Silicate (0.12 to 16.80 µM) was higher than other nutrients and also with that of earlier reports (Thangaradjou *et al.*, 2012).

Sediment texture analysis

An appropriate sediment fraction plays a vital role in determining the seagrass species distribution in the region. Sediment texture of soil samples collected at different station

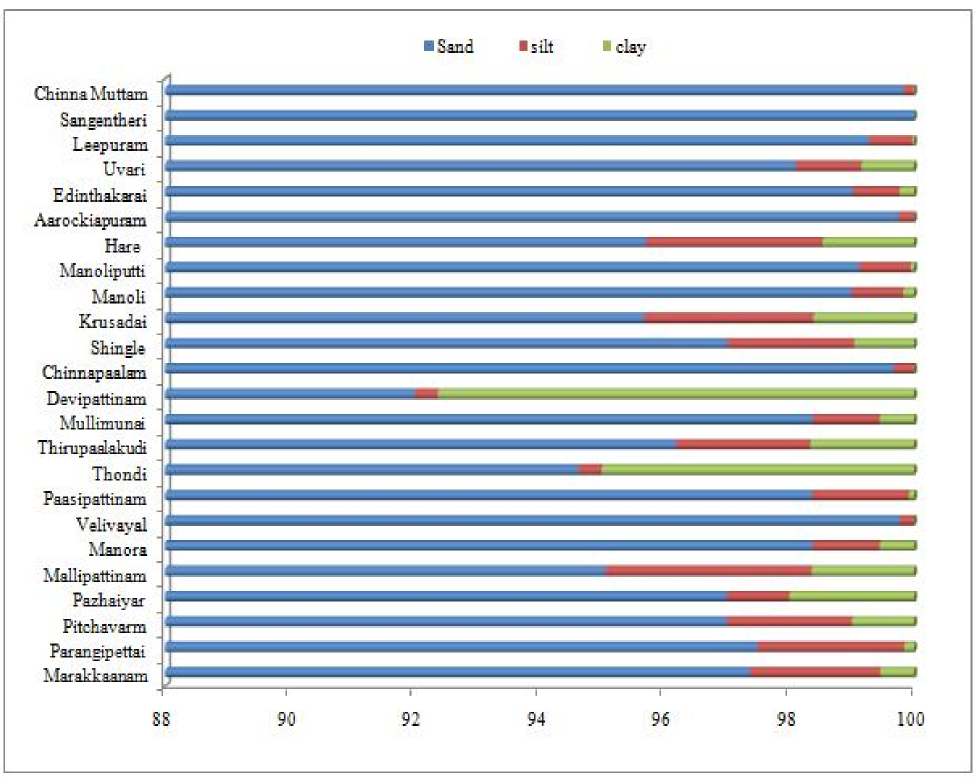


Fig 8. Sediment texture recorded at the sampling stations (%)

of seagrass meadows showed wide variation. Sand composition varied between 92 and 100% with the minimum at Devipattinam and maximum at Sangentheri followed by silt composition (0 and 3.31 %) with the minimum at Sangentheri and maximum at Mallipattinam. Clay composition ranged between 0 and 7.63%, with the minimum at Sangentheri and maximum at Devipattinam respectively (Fig. 8). Sand composition (92 to 100%) was higher compared to that of earlier records of seagrass sediment in Gulf of Mannar (Rajeswari and Kamala, 1987; Vinithkumar *et al.,* 1999; Thangaradjou and Kannan, 2007 and Arumugam *et al.*, 2013) and Lakshadweep islands (Jagtap and Untawale, 1984). During the present study, silt (0 – 3.31%) and clay (0-7.63%) was found to be lower when compared to that reported for Gulf of Mannar sediments; silt: 7.52 - 3.7 % and 12.42-3.10%, clay: 3.7 - 1.07% and 5.65-1.60% (Thangaradjou and Kannan, 2005; Thangaradjou and Kannan, 2007). Clay showed positive correlation with the biomass of *E. acoroides* ($r = 0.612$, $p<0.05$), *T. hemprichii* ($r = 0.716$, $p<0.05$), productivity of *T. hemprichii* ($r = 0.676$, $p<0.05$), canopy height of *E. acoroides* ($r = 0.685$, $p<0.05$), *T. hemprichii* ($r = 0.807$, $p<0.05$). Sediment hydrogen ion concentration (pH) ranged between 3.6 and 7.9 registering the minimum at Pazhaiyar and maximum at Hare and Sangentheri (Fig.5). The sediment pH range is comparatively neutral to alkaline compared to pH range of Gulf of Mannar; 6.5-6.9 (Thangaradjou and Kannan, 2005), and 6.3 - 7.1 (Arumugam *et al.*, 2013). Sediment Eh recorded minimum (-57.75 mV) in Hare island and maximum in Sangentheri (72.5 mV) (Fig. 6). Redox potential of the sediments and the sediment water interface also play an important part in determining nutrient bioavailability (Nayar *et al.,* 2006). Such higher redox potential in the root layer of seagrasses modifies the geochemistry of the sediment as hypothesized (Hemminga, 1998).

However, increase in redox potential derived from seagrass activity, conversely, may enhance phosphate binding to iron, and hence reduce the availability of sediment phosphorus for plant growth (Marba and Duarte, 2001). Correlation factors obtained indicate that the seagrass biomass, productivity and canopy height of seagrass (*E. acoroides, S. isoetifolium, C. serrulate, C. rotundata, H. pinifolia, H. wrightii, H. ovalis, H. ovata* and *T. hemprichii*) varied spatially in response to change in certain physico-chemical parameters like nitrite, IP and TP. Among all the nutrients, nitrite, IP and TP are important parameters which enhance the growth of seagrass species. From the correlation analysis it has been found that clay as one of the parameters influencing the growth of seagrasses (*E. acoroides* and *T. hemprichii*) and sediment texture play a vital role in determining the species diversity. Nutrients play specific role in determining the growth of different species.

Conclusion

From the result it is evident that there is a spatial variability of seagrass biomass, canopy height, and productivity concurrent with environmental parameter of seagrass along the Tamilnadu coast. It is vital to note that nitrate is comparatively higher and phosphate is lower than the previous reports warning about possible over growth of seaweeds on the seagrass meadows. Local environmental parameters, particularly inorganic phosphorus and TP are two important nutrients, play a prominent role for influencing seagrass biomass, productivity and canopy height. However, it is also important to note that these relationships are subject to change if site specific independent analysis is carried out, as the biological and ecological parameter recorded in the sampling stations varies spatially. Hence, continuous monitoring of ecosystem process is an important management option for monitoring the seagrasses of the region.

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