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(RESEARCH ARTICLE)

Physicochemical Characteristics of Surface Waters in the Habitats of *Enhalus acoroides* and *Halodule uninervis* in Palk Bay, Tamil Nadu, India

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Abstract

Background: Hydrological studies are essential for understanding the interactions among various trophic levels and the structure of food webs. In recent years, significant attention has been devoted to analyzing the physicochemical parameters of coastal waters to assess water quality and the biodiversity of seagrass meadows.

Aim: This study aimed to investigate the seasonal changes of physicochemical parameters of selected seagrass meadows in the Kattumavadi, Palk Bay, India.

Methods: Field collections were carried out over a two-year period, from June 2011 to June 2013, at monthly intervals to record various physicochemical parameters in two selected seagrass meadows (*Enhalus acoroides* and *Halodule uninervis*). The observations were categorized into four seasons: post-monsoon (January–March), summer (April–June), pre-monsoon (July–September), and monsoon (October–December), using standard methods.

Results: The seasonal analysis revealed elevated concentrations of nitrate, nitrite, phosphate, and particulate organic carbon (POC) in the seagrass meadows. Results revealed that there is no difference in the physico-chemical variables between the micro-habitats of the two species and there are clear differences in the physico-chemical variables between the seasons. The water quality of Palk Bay at Kattumavadi remains within normal limits, with no evidence of coastal pollution despite the recent development of aquaculture in the region.

Conclusion: Continuous, long-term monitoring and assessment are crucial to safeguard the health, safety, and sustainability of the region's flora and fauna, thereby ensuring the preservation of ecosystem biodiversity.

Keywords: Seagrass; Water quality; Palk Bay; Pollution; Seawater

1. Introduction

Many of the unique features of the ocean are attributed to the intrinsic properties of water. Hydrological studies are therefore essential to understand the relationships among trophic levels and food webs [1]. Environmental factors such as temperature, dissolved oxygen, salinity, and nutrient availability largely determine the composition and distribution

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of marine biota. Water quality is commonly assessed through physical, chemical, and biological parameters [2]. According to Chester [3], more than 60 elements have been identified in seawater, which primarily consists of sodium, magnesium, calcium, and strontium, along with sulphates, chlorides, fluorides, carbonic acid, and boric acid. Economically, the oceans are often regarded as a "treasure house" of valuable minerals. In addition, seawater contains essential plant nutrients such as phosphorus and nitrogen [4]. Maintaining good water quality is therefore crucial for sustaining a balanced marine environment [5].

Excessive inputs of nitrates and phosphates into rivers can lead to eutrophication [6, 7]. In severe cases, nutrient overloading in coastal regions results in the proliferation of opportunistic macroalgal blooms on a large scale [8, 9]. The hydrographical parameters of coastal ecosystems such as mangroves and seagrass meadows vary considerably and are influenced by climatic conditions, tidal fluctuations, and freshwater inflow. The availability of Nutrients in the surrounding environment had influences on the morphology and seasonal cycling of seagrass communities [10]. Seagrasses play a vital role in stabilizing sediments, producing particulate organic matter, and transporting it to adjacent ecosystems, thereby enhancing secondary productivity [11].

Assessment of water quality in any region is fundamental for sustainable developmental activities. Palk Bay, located along the southeast coast of India, represents one of the country's most important marine resource zones due to its biological richness and hydrographical potential [12]. Hydrographic investigations in this region have been carried out by several researchers, including Jayaraman [13], Kannan and Kannan [14], Kumar and Manivannan [15], Vankataraman and Wafar [16], Sundaramanickam et al. [17], Sridhar et al. [11], Sitik et al. [18], and Ramkumar et al. [19].

However, modern human activities often exert significant pressure on coastal ecosystems. Industrial development, urbanization, and the discharge of untreated effluents have contributed to coastal pollution [20]. In Palk Bay, anthropogenic influences—including the release of untreated sewage from coastal towns—have placed severe stress on aquatic ecosystems, particularly on seagrass habitats. This, in turn, poses a continuous threat to fishery resources [21]. In this context, the present study was undertaken to investigate the seasonal variations in physicochemical parameters at Kattumavadi (Palk Bay).

2. Materials and methods

Field collections were undertaken for a period of two years from June 2011 to June 2013 at monthly intervals to record various physico – chemical parameters at the two selected seagrass (*Enhalus acoroides* and *Halodule uninervis*) meadows. For the sake of convenience and easy interpretation a calendar year of study was divided into four seasons viz., Post-monsoon (January - March), Summer (April - June), Premonsoon (July - September) and Monsoon (October - December).

The atmospheric temperature and sea surface water temperature were measured by using standard mercury filled centigrade thermometer. Light penetration in the water column was measured with the help of secchi disc and light extinction coefficient (LEC) was calculated using Pool and Atkins [22] formula. The water pH was determined using an 'ELICO' pH meter (Model LC- 120). Salinity was estimated by using 'ATAGO' hand refractometer (Model LC-120). Dissolved oxygen concentration was measured using the modified Winkler's method as described by Strickland and Parsons [23].

For analysis of nutrients, water samples were collected using plastic containers every month during low tide and transferred to the pre-cleaned polypropylene bottles and kept in an icebox and transported immediately to the laboratory. Water samples were filtered using a GFC Millipore Filtering System (MFS). Filtered samples were kept in deep freeze and the nutrients were analyzed. Analysis of Inorganic phosphate, Nitrite, Nitrate, Silicate, Total Nitrogen were carried out according to the methods given by Strickland and Parsons [23]. Concentration of Particulate Organic Carbon (POC) was determined by wet washing method [24].

2.1. Data analysis

In the present study mean, Pearson correlation coefficient, Cluster analysis (CA), MDS, ANOSIM (Two-Way Crossed Analysis) and Linktree were used for distinguishing physico chemical parameters in two seagrass meadows. The results were statistically analyzed using computer-aided packages like PRIMER-E version 6 and Microsoft EXCEL.

3. Results and discussion

3.1. Atmospheric temperature (°C)

The minimum and maximum atmospheric temperature recorded in *Enhalus acoroides* meadows ranged between 26.3°C – 37.7°C during Monsoon 2012 and Postmonsoon 2012. The mean value ranged from 28.6 °C – 35 °C in Monsoon 2012 and Summer 2012. Similarly atmospheric temperature in *Halodule uninervis* meadows ranged from 26.4 °C – 35.6°C in Monsoon 2011 and Summer 2012. The mean value ranged from 27.9 °C – 33.9 °C in Monsoon 2012 and Summer 2012.

3.2. Surface Water Temperature (°C)

The minimum and maximum surface water temperature recorded in *Enhalus acoroides* meadows ranged between 23.8°C – 35.4°C during Monsoon 2012 and Postmonsoon 2012. The mean value ranged from 25.4°C – 34.2°C in Monsoon 2012 and Summer 2012. Similarly surface water temperature in *Halodule uninervis* meadows ranged from 21.5 °C – 34.2°C in Monsoon 2012 and Summer 2011. The mean value ranged from 25.4°C – 31.7°C in Monsoon 2012 and premonsoon 2011.

3.3. Salinity (‰)

The minimum and maximum salinity recorded in *Enhalus acoroides* meadows ranged between 26.7°C – 37.5°C during Monsoon 2011 and Summer 2012. The mean value ranged from 27.8°C – 36.1 °C in Monsoon 2012 and Summer 2012. Similarly salinity in *Halodule uninervis* meadows ranged from 25.3°C – 38.1°C in Monsoon 2012 and Summer 2013. The mean value ranged from 26.7 °C –37.2°C in Monsoon 2012 and Summer 2013.

3.4. Hydrogen ion concentration (pH)

The minimum and maximum pH recorded in *Enhalus acoroides* meadows ranged between 7 – 8.6 during Postmonsoon 2013 and Summer 2012. The mean value ranged from 7.5 – 8.5 in Summer 2011 and Summer 2012. Similarly surface water temperature in *Halodule uninervis* meadows ranged from 7 – 8.6 in Monsoon 2012 and premonsoon 2012. The mean value ranged from 7.1 – 8.1 in Summer 2011 and Summer 2012.

3.5. Light extinction coefficient (LEC)

The minimum and maximum LEC recorded in *Enhalus acoroides* meadows ranged between 1.8 – 5.1 during Monsoon 2011 and Summer 2013. The mean value ranged from 2.5 – 4.9 in Monsoon 2011 and Summer 2013. Similarly LEC in *Halodule uninervis* meadows ranged from 2.1 – 4.7 in Monsoon 2012 and Summer 2013. The mean value ranged from 2.6 –4.4 in Monsoon 2011 and Summer 2012.

3.6. Dissolved oxygen (DO) mg/L

The minimum and maximum dissolved oxygen recorded in *Enhalus acoroides* meadows ranged between 4.4 – 8.1 during Summer 2012 and Monsoon 2011. The mean value ranged from 4.5 – 7.7 in Summer 2012 and Monsoon 2011. Similarly dissolved oxygen in *Halodule uninervis* meadows ranged from 4.1 – 7.8 in Summer 2012 and Monsoon 2012. The mean value ranged from 4.7 – 7.2 in Summer 2011 and Monsoon 2012.

3.7. Nitrate (µM)

The minimum and maximum nitrate recorded in *Enhalus acoroides* meadows ranged between 3.8 – 18.4 during Summer 2013 and Monsoon 2011. The mean value ranged from 4.0 – 16.5 in Summer 2013 and Monsoon 2011. Similarly nitrate in *Halodule uninervis* meadows ranged from 2.1 – 7.5 in Summer 2013 and Monsoon 2011. The mean value ranged from 2.5 – 15.7 in Summer 2013 and Monsoon 2011.

3.8. Nitrite (µM)

The minimum and maximum nitrite recorded in *Enhalus acoroides* meadows ranged between 1.5 – 6.9 during Summer 2012 and Monsoon 2011. The mean value ranged from 2.0 – 6.2 in Summer 2012 and Monsoon 2011. Similarly nitrite in *Halodule uninervis* meadows ranged from 1.3 – 6.5 in Summer 2013 and Monsoon 2011. The mean value ranged from 1.5 – 6.1 in Summer 2011 and Monsoon 2011.

3.9. Phosphate (µM)

The minimum and maximum phosphate recorded in *Enhalus acoroides* meadows ranged between 4.9 – 20.1 during Summer 2012 and Monsoon 2011. The mean value ranged from 5.7 – 18.9 in Summer 2012 and Monsoon 2011. Similarly phosphate in *Halodule uninervis* meadows ranged from 5.7 – 20.2 in Summer 2011 and Monsoon 2012. The mean value ranged from 5.7 – 18.7 in Summer 2011 and Monsoon 2011.

3.10. Silicate (µM)

The minimum and maximum silicate recorded in *Enhalus acoroides* meadows ranged between 4.3 – 18.6 during Summer 2011 and Monsoon 2011. The mean value ranged from 4.3 – 18.1 in Summer 2011 and Monsoon 2011. Similarly silicate in *Halodule uninervis* meadows ranged from 6.1 – 18.7 in Summer 2012 and Monsoon 2012. The mean value ranged from 6.5 – 17.2 in Summer 2011 and Monsoon 2012.

3.11. Free Ammonia (µM)

The minimum and maximum free ammonia recorded in *Enhalus acoroides* meadows ranged between 0.1 – 0.5 during Summer 2012 and Monsoon 2011. The mean value ranged from 0.1 - 0.4 in Summer 2012 and Summer 2011. Similarly free ammonia in *Halodule uninervis* meadows ranged from 0.2 – 0.3 in Summer 2011 and Summer 2013. The mean value ranged from 0.09 – 0.43 in Summer 2012 and Monsoon 2012.

3.12. Total Nitrogen (µM)

The minimum and maximum nitrogen recorded in *Enhalus acoroides* meadows ranged between 3.8 – 12.3 during Summer 2012 and Monsoon 2012. The mean value ranged from 4.6 – 10.8 in Summer 2012 and Monsoon 2011. Similarly nitrogen in *Halodule uninervis* meadows ranged from 2.4 – 12.4 in Summer 2012 and Monsoon 2012. The mean value ranged from 3.5 – 11.8 in Summer 2012 and Monsoon 2012.

3.13. Particulate Organic Carbon (POC) (µM)

The minimum and maximum POC recorded in *Enhalus acoroides* meadows ranged between 0.3 – 4.2 during Summer 2013 and Monsoon 2012. The mean value ranged from 0.7 – 3.8 in Summer 2012 and Monsoon 2012. Similarly POC in *Halodule uninervis* meadows ranged from 1.1 – 3.6 in Summer 2012 and Monsoon 2012. The mean value ranged from 1.2 - 3.0 in summer 2013 and Monsoon 2012.

Atmospheric temperature was positively correlated with surface water temperature, salinity, pH and light extinction coefficient. It was negatively correlated with nutrients and particulate organic carbon. Similarly dissolved oxygen was positively correlated with nutrients and particulate organic carbon (Fig 1).

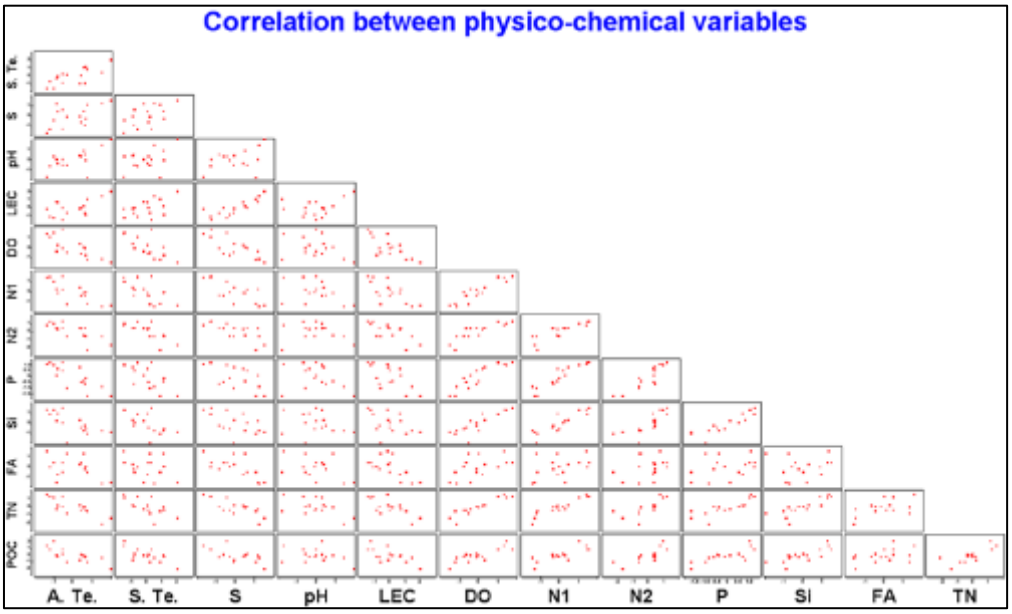
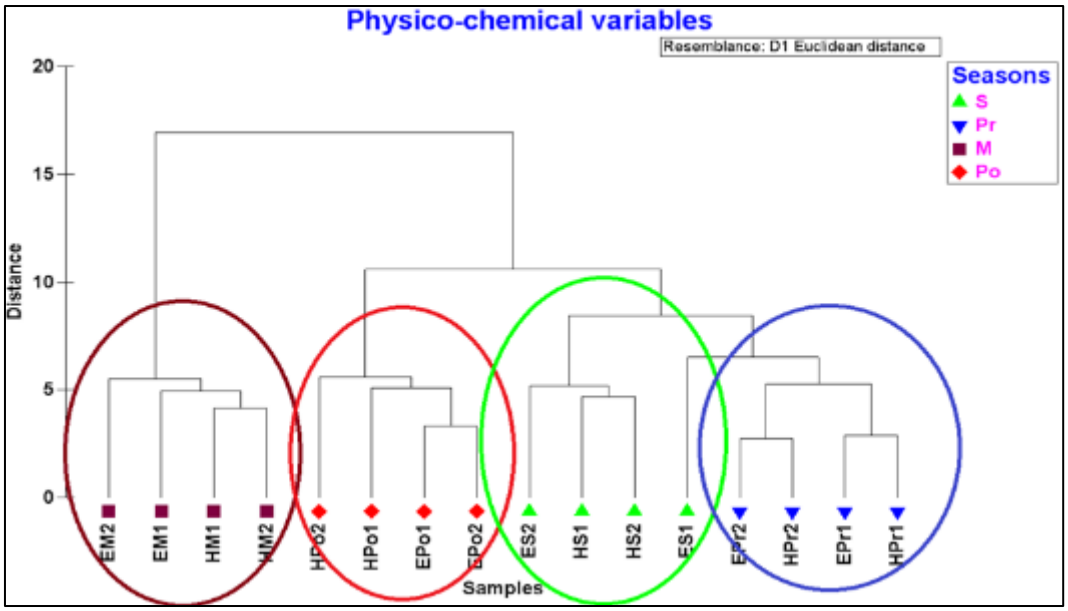


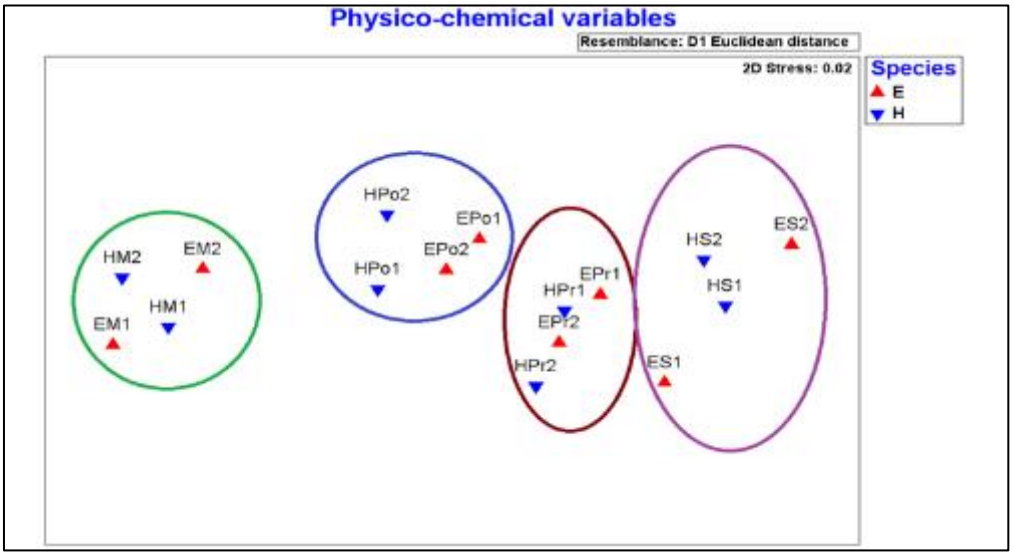
Figure 1 Draftsman plot showing the correlation between various physico-chemical variables in Kattumavadi, Palk Bay, India

In the dendrogram (Fig 2) drawn for physico-chemical variables collected from the study area during various seasons, 5 groups were found – one each during the seasons monsoon, postmonsoon and summer and two groups during the postmonsoon season. The dendrogram revealed two striking patterns: 1. No difference in the physico-chemical variables between the micro-habitats of the two species and 2. Clear differences in the physico-chemical variables between the seasons. Clearly the samples collected during the seasons monsoon, postmonsoon, summer and premonsoon formed larger groups. In only one instance a sample collected during the summer season (ES1) joined with the groups formed by samples of the premonsoon season (EPr2 and Hpr2 & EPr1 and HPr1). However as the cluster analysis has the criticism of not revealing the interrelationship of the samples, the non – metric multi dimensional scaling (MDS) plot was drawn. It however revealed very clearly the interrelationship of the samples (same grouping as recognized in the dendrogram). The stress value, which overlie on the top right corner of the plot was also found to be minimum (0.02) vouching for the goodness of fit of the variables collected from the study area (Fig 3).



EM – *Enhalus* Monsoon; **ES –** *Enhalus* Summer; **HS –** Halodule Summer;
EPr – Enhalus Pre Monsoon; **EPo –** Enhalus Post Monsoon; **HPr –** Halodule Pre Monsoon; **HPo –** Halodule Post Monsoon; **1 –** 2011; **2 –** 2012.

Figure 2 Dendrogram representing the Clustering of Physicochemical Variables in the study area



EM – *Enhalus* Monsoon; **ES –** *Enhalus* Summer; **HS –** Halodule Summer;
EPr – Enhalus Pre Monsoon; **EPo –** Enhalus Post Monsoon; **HPr –** Halodule Pre Monsoon; **HPo –** Halodule Post Monsoon; **1 –** 2011; **2 –** 2012.

Figure 3 Non – metric Multi Dimensional Scaling (MDS) for the physico-chemical variables of the study area

The statistical significance of the grouping found in the dendrogram and MDS was tested using ANOSIM. In the histogram drawn for the seasons, the R value varied from – 0.5 to + 1. The Null hypothesis tested showed no significant differences between the seasons. The global R value of +0.91 fell away from the histogram (Fig 4). Therefore the Null hypothesis was rejected and the alternate hypothesis of significant differences was accepted at 0.02%. In the ANOSIM done to find out the differences between the species, the R value in the histogram varied from – 0.4 to+0.5 (Fig 5). The global R value of 0 fell very much in the Null distribution (within the histogram) suggesting no difference in the physico-chemical variables of micro-habitats of the two species (significance 55.6%).

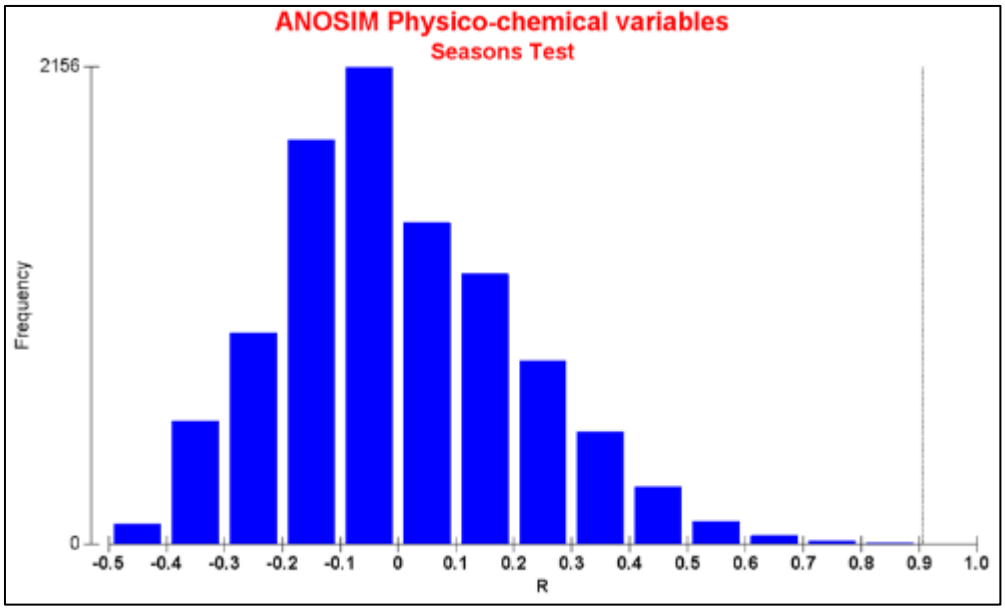


Figure 4 ANOSIM Histogram to compare the physico-chemical variables between the seasons

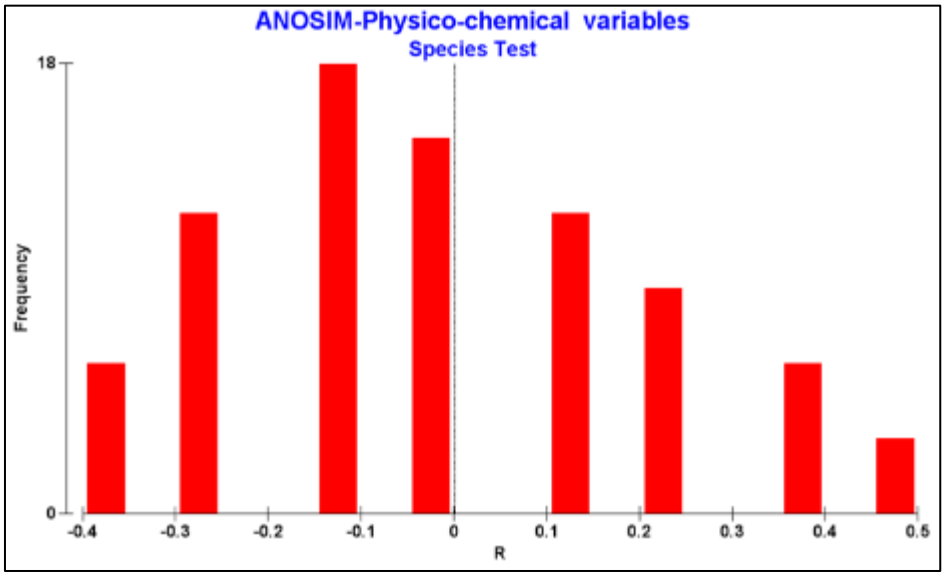
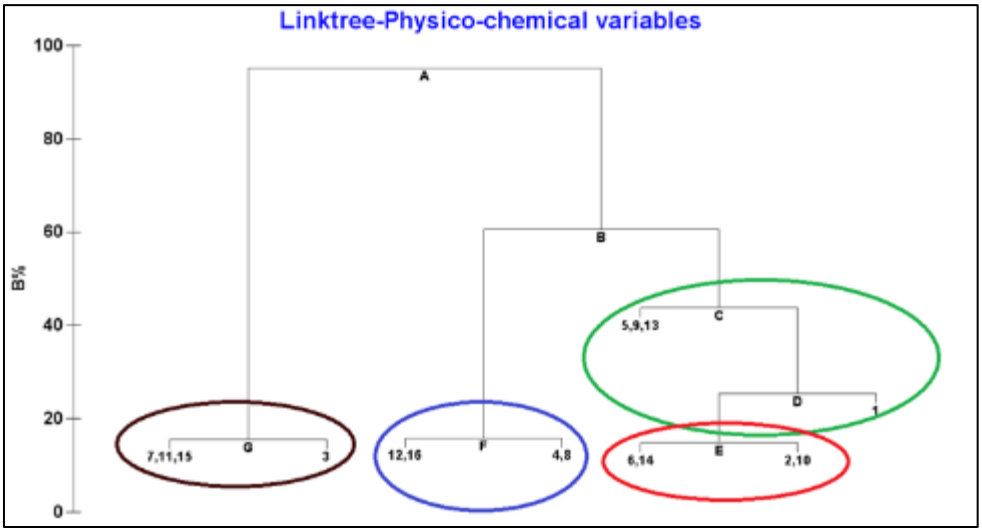


Figure 5 ANOSIM Histogram to compare the physico-chemical variables of the microhabitats between the species

The linktree (Fig 6) clearly brought out the differences between the seasons. First it separated the monsoon season (A) from others. All the other three seasons went with branch B. It was based on higher levels of total nitrogen (more than 10.5), oxygen (more than 6.83), nitrite (more than 12.8) or POC (more than 2.5), nitrate (more than 5.23) or pH levels (more than 17.2). This separation has an ANOSIM R of 0.87 and absolute measure of group difference (B%) of 95%.



(1-*Enhalus* Summer 2011 ; 2- *Enhalus* Premonsoon 2011; 3 - *Enhalus* Monsoon 2011 ; 4 - *Enhalus* Postmonsoon 2011 ; 5 - *Enhalus* Summer 2012 ; 6 - *Enhalus* Premonsoon 2012 ; 7 - *Enhalus* Monsoon 2012 ; 8 - *Enhalus* Postmonsoon 2012 ; 9 - *Halodule* Summer 2011 ; 10 - *Halodule* Premonsoon 2011 ; 11 - *Halodule* Monsoon 2011 ; 12 - *Halodule* Postmonsoon 2011 ; 13 - *Halodule* Summer 2012 ; 14 - *Halodule* Premonsoon 2012 ; 15 - *Halodule* Monsoon 2012 ; 16 - *Halodule* Postmonsoon 2012).

Figure 6 Linktree for the physico-chemical variables

In branch B having the other three seasons such as postmonsoon, summer and premonsoon, first the postmonsoon season (F) got separated. It was based on oxygen level of more than 5.97 on the left side (12, 16) and less than 5.7 on the right side (4,8); P of more than 15.1 on the right side and less than 14.1 on the right side; salinity of less than 32.5 on the left side and higher than 33.1 on the right side; TN of more than 7.7 on the left side and lower than 7.3 on the right side; POC of less than 1.7 on the left side and higher than 1.8 on the right side or Si of more than 11.3 on the left side and lower than 10.9 on the right side. This separation had an ANOSIM R of 0.50 and absolute measure of group difference of 16 %.

Among the remaining samples of B, samples of summer season got separated first (C, D). It was based on the LEC of more than 3.3. on the left side and less than 3.3 on the right side or S of more than 34.6 on the left side and less than 32.8 on the right side or oxygen of less than 4.77 on the left side and higher than 5.09 on the right side or FA lower than 0.2 on the left side and more than 0.23 on the right side or A. Te of more than 32.2 on the left side and less than 32 on the right side. This separation had an ANOSIM R of 0.86 and absolute measure of group difference of 44 %.

Finally the premonsoon season got separated (E). It was based on S.Te of less than 29.1 on the left side and higher than 31.6 on the right side or N2 of more than 4.5 on the right side and lower than 3.3 on the right side or salinity of less than 29.5 on the left side and 30.5 on the right side or N1 of less than 6.67 on the left side and more than 7.4 on the right side or Si of more than 8.4 on the left side and 7.87 on the right side or P of less than 9.5 on the left side and 9.8 of the right side. This separation had an ANOSIM R of 1.00 and absolute measure of group difference of 15%.

Temperature variation is an important factor in the coastal ecosystem which influence the physicochemical parameters of coastal waters to a greater extent triggering the growth, breeding and metabolic activities of marine biota [17, 25]. In the present study the observed surface water temperature was high in summer seasons and it was low in monsoon seasons in both stations. Kalaiarasi *et al.,* [26] recorded 28.0°C in monsoon season and 32.8°C in summer season in Manamelkudi which is near to Kattumavadi (Palk Bay).

Researchers reported that [27, 28, 29, 30] the surface water temperature is influenced by the intensity of atmospheric conduction, solar radiation, evaporation, fresh water influx and cooling, mixing up of water currents with the ebb and flow from adjoining neritic water. The minimum water temperature being observed during the monsoon at the meadows of *Enhalus acoroides* and *Halodule uninervis* may be due to the heavy North- East monsoon rainfall received

at the Kattumavadi Bay, thus influencing the atmospheric temperature and surface water temperature to be at the lowest.

Salinity is one of the important limiting factors that regulate the functional physiology, reproductive activity and the distribution of flora and fauna in the marine ecosystem [31]. From the present study, the higher values recorded during the monsoon season can be attributed to the high degree of evaporation of surface water in the shallow areas, less wave and tidal action with minimal rate of fresh water inflow and drainage [17]. The low salinity values during the monsoon season could be due to the dilution of sea water by heavy rainfall.

The pH of water is a precious indication of its quality and provides an important piece of information in many types of geochemical equilibrium or solubility calculations [32]. The surface waters in both the study areas remained alkaline with a very narrow range of variation (7.1-8.6) throughout the study period, this alkaline nature of sea water is controlled by the buffering action of carbonates [26]. Generally, the H_2 ion concentration fluctuations can be attributed to the changes in temperature, salinity and biological activity, removal of carbondioxide by photosynthesis through bicarbonate degradation of organic matter [29, 30]. The reason for pH for being low during the monsoon is due to the dilution of saline water, influence of fresh water influx, reduction of salinity and temperature [17] while the recorded higher pH values during summer might be due to the influence of high biological activity and occurrence of high photosynthetic activity [30].

Light extinction coefficient is a measure of the reduction of light intensity in a vertical column of water in the euphotic zone [25]. There was a marked difference of 2 meter water depth in *Enhalus acoroides* habitat and a comparatively shallow water depth of 0.5 meter in *Halodule uninervis* habitat. LEC is influenced by wave action, tides, wind agitation, fresh water discharges, re suspending settled particles and fine sand or mud particles in shallow areas as that of the present study area [30, 33]. The flow of water and removal of sand causing disturbance at the bottom were the main factors governing light penetration in mangrove ecosystem [25].

The higher values of dissolved oxygen recorded during monsoon season in *Enhalus acoroides* (8.1 mg/L) and *Halodule uninervis* (7.8 mg/ L) meadows might be due to low temperature and low salinity values which enhances the level of dissolved oxygen content in H_2O, the cumulative effect of higher wind velocity coupled with heavy rainfall and resultant fresh water mixing [29]. The lowest values of dissolved oxygen in *Enhalus acoroides* (4.4 mg/L) and *Halodule uninervis* (4.1 mg/ L) meadows could be due to the decrease in O_2 solubility because of increase in temperature and salinity of the water column during the summer season [33]. According to EMECS [34] if the concentration of DO is less than 5mg/L, fish growth is affected.

The highest nitrate value was observed in monsoon in *Halodule uninervis* (17.5 µM) and *Enhalus acoroides* (18.4 µM). The increased nitrate value could be attributed to higher activity of oxidation of ammonia, fresh water inflow, mangrove leaves (litter fall) decomposition of planktonic detritus present in the environment [35]. These nitrates have been utilized by the phytoplankton during their peak period of production. The recorded low nitrate values during the summer season could be due to utilization by phytoplankton as evidenced by high photosynthetic activity and also due to shallow water dominance which contained only negligible amount of nitrate [36].

In *Enhalus acoroides* and *Halodule uninervis* the higher concentration (6.8 µM and 6.5 µM) of nitrites observed in monsoon meanwhile the lowest concentration (1.3 µM to 1.8 µM) was recorded in summer. The higher concentration of nitrite and seasonal variation could be attributed to the variation of phytoplanktonic excretion, oxidation of ammonia, reduction of nitrate (denitrification) and by air- sea interaction of exchange of chemical elements.

Phosphorus occurs naturally in rock formations in the earth's crust as poly-phospates or organically bound phosphates, all will degrade to ortho or reactive phosphates with time. The increased phosphate concentration observed during the monsoon season in *Halodule uninervis* (20.2µM) and in *Enhalus acoroides* (20.1µM) may be due to fresh water inflow [36] release of phosphate from the sediments due to high wind action during this season. Similarly the lower phosphate concentration observed during the summer season in *Halodule uninervis* (5.7µM) and in *Enhalus acoroides* (4.9µM) could be attributed to the utilization of the nutrient by phytoplankton which occurred in higher densities during the post monsoon and summer seasons. The variation of phosphate values may be due to processes like adsorption, buffering action of sediment under varying environmental conditions.

Silicate concentration was high during monsoon season 18.7µM might be due to addition of silica material by land run off caused by flooding during monsoon season, leading to the available silicates present in the bottom sediments to go into the upper water layers and the agitated wind action leaches silicate out of the rocks [37]. The depletion of silicate

level observed during summer in *Enhalus acoroides* (4.3 µM)) and *Halodule uninervis* (6.1µM) could be attributed to the utilization by phytoplanktons, diatoms with siliceous tests and reduction in the fresh water input [28].

The concentration of ammonia ranged from 0.1µM – 0.5 µM in both the stations. According to Thirunavukkarasu [37], higher concentration of ammonia could be partly due to death and subsequent decomposition of phytoplankton, high ammonia content may be related to the excretion of ammonia by planktonic organisms.

Nitrogen content varied from 3.8 µM – 12.3 µM for *Enhalus acoroides* and 2.4 µM -12.4 µM for *Halodule uninervis* with the minimum during summer season and the maximum during monsoon season. The low values of nitrogen observed during the summer season might be due to the lesser amount of fresh water inflow and higher salinity [37]. During high levels of nitrogen algal blooms will occur. Nitrogen level controls the primary production, hence the growth of macrophytes and phytoplanktons is stimulated principally by nutrients such as phosphorus and nitrogen.

The high POC content was recorded during the monsoon season in *Halodule uninervis* (3.6 µM) and *Enhalus acoroides* (4.2 µM). Similarly the lowest POC content recorded during summer season in *Enhalus acoroides* (0.3 µM) and in *Halodule uninervis* (1.1 µM). According to Sridhar *et al*., [33] the higher POC content recorded during the monsoon season could be due to the fresh water inflow due to the heavy monsoon rainfalls.

Coastal water plays an important role in fisheries as nursery grounds for marine fish, prawn and as habitats for a wide variety of aquatic flora and fauna. The temperature and nutrient concentration of Palk Bay had increased compared to the previous years [11]. Temperature plays an important role in distribution of fauna and metabolic activities. The increased nutrient levels will favour epiphytes to grow in seagrass ecosystem.

According to Central Pollution Control Board, India [38] the water quality criteria for marine life are pH (5.5 to 9.0), ammonia (<5.0 mg/l), dissolved phosphates (<5.0 mg/l), nitrate nitrogen (<20 mg/l) and Dissolved oxygen (>5.0 mg/l), respectively. Comparing the standards with the present study all the parameters except dissolved oxygen, the pH, temperature, salinity, dissolved oxygen, nitrite, nitrate and silicate levels were safe for marine life.

4. Conclusion

As the season changes there is a fluctuation in the physicochemical characters of the water, this will be due to ebb and flow, flushing of rain water, change in the temperature and salinity as season changes. The present information of the physico-chemical characteristics of water would form a useful tool for further ecological assessment and monitoring of these coastal ecosystems. And, it is concluded that the water quality of the Palk Bay at Kattumavadi is in normal condition and there is no indication of any coastal pollution even after the development of aquaculture industry in this region at present. Hence the regular monitoring and assessment of Palk Bay for a longer span could ensure the safety, quality and quantity of flora and fauna, thereby sustaining biodiversity in the ecosystem.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed

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