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**ORIGINAL ARTICLE**

# Physico Chemical Factors Influencing Seaweed Colonization in Selected Coastal Areas Of Kerala, India

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Seaweeds play extremely significant ecological roles in numerous marine communities. Seaweeds belonging to Chlorophyta, Rhodophyta and Ochrophyta were collected during course of the study period from the coastal areas of Kerala. The physico-chemical factors were also monitored. The present study indicated that the various environmental factors such as temperature, salinity, PH, oxygen and nutrients have influence on the diversity and distribution of sea weeds. In this study, the seaweed biomass was high when the seawater temperature ranged between 29°C to 30°C. The pH of the study area remained within the normal range. Several species of green algae cannot grow in high salinity. At the same time, some species of red algae and brown algae cannot grow in the low salinity. Most species of seaweeds require nutrients, Carbon, Nitrogen, and Phosphorous in specific ratios. Nitrogen is the element most frequently considered to limit growth of seaweeds. In general high diversity was observed during pre monsoon and post-monsoon at all stations. These seasons favoured the algal colonization.

*Key words: Algae, Pysico chemical parameters, Sea weed colonisation*

In marine ecosystem, seaweeds can account for an overwhelming majority of nearshore production and provide critical habitat for a variety of taxa. Studies of life histories of many types of seaweed in laboratory, as well as in nature, have revealed that environmental factors like temperature, quantity and quality of light, salinity, oxygen concentration, pH, nutrients like phosphate, nitrate, substratum, etc., are important ecological parameters. The growth and distribution of seaweeds are affected by the physico-chemical characteristics of environment (Eggert, 2012). As seaweeds absorb gases as well as nutrients from the surrounding water, they rely on the continual movement of water past them to evade nutrient depletion. As seaweeds predominantly colonize rocky substratum, they survive from mechanical stress by having a strong holdfast, flexible stipes and blades and bending towards the substrate as waves move over them (Kawamata, 2001).

Presently there are 43 countries in the world engaged in the exploitation of 291 sea weeds. China holds first position in seaweed production, with *Laminaria japonica* accounting for the majority of its production, followed by Korea, Japan, Philippines, Norway, Chile, USA, France etc. However, in India, agar and alginate are produced from wild harvested seaweeds, whereas carrageenan is derived from cultivated *Kappaphycus alvarezii*. Global production of seaweeds has been estimated at 30.1 million wet tons in 2016 (Anon, 2018). About 95% seaweed production comes from culture based practices with a market worth US$ 11.7 billion (Sahu *et al.*, 2020). The most cultivated seaweed is the kelp, *Laminaria japonica*, which alone accounts for more than 60% of the overall cultured seaweed production; while *Porphyra, Kappaphycus, Undaria, Eucheuma* and *Gracilaria* make up most of the rest to a total of 99%. The most valuable alga cultivated is the rhodophycean Nori (*Porphyra* species, mainly *Porphyra yezoensis*) used as food in Japan, China and Pacific region (Sajid and Satam, 2003).

The most comprehensive estimates of seaweeds from Indian waters are 844 species belonging to 216 genera of 68 families (Oza and Zaidi, 2001). Seaweeds grow most abundantly along the Tamil Nadu (282 species) and Gujarat costs (198 species) and also around Lakshadweep and Andaman and Nicobar islands. There are rich seaweed beds around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam, Kanaykumari and Pulicat and Chilika lakes. Out of 841 species of marine algae found in both intertidal and deep water regions of the Indian coast, almost 60 species are commercially significant (Jha *et al.*, 2009; Kaliaperumal *et al.*, 2004 and Ganesan *et al.*, 2019). About 125 species seem to have never been reported outside the geographical territory of India (Mantri *et al.*, 2020).

The current investigation was undertaken to study the potential of seaweed biodiversity of Kollam coast, Kerala, India. The major objective of this study was to update the information on the monthly variation of physico chemical factors and its influence on seaweed biodiversity and abundance. The current study is the effort made to assess the seaweed potential of this vast stretches along the Kollam coast. This assessment of the seaweed resource will definitely contribute towards developing a planning utilization conservation of this resource.

## MATERIALS AND METHODS

Kerala has a vast coastline which extends to about 590 km. The current study on a detailed survey of seaweed resources of the hitherto unexplored regions of Kollam region was carried out monthly for one year. Six stations were identified as areas with different environmental conditions and magnitude of sea weed colonization (Fig. 1). The Stations selected were Thangassery (A), Sarppakuzhi (B), Thirumullavaram (C), Ozhukkuthodu Seashore (D), Sakthikulangara (E) and Neendakara Seashore (F). Seaweeds occur on natural outcrops of rocks, concrete tripods as well as on the granite blocks in Thangassery and Thirumullavaram stations, whereas at Sakthikulangara and Neendakara, they occur on natural outcrops of rocks along the sandy beach as well as over the granite blocks used as a sea wall. Station A is located at a site nearer to Thangassery light house. Here the coast is protected by rocks and cement tripods. The waves were high during monsoon season. Sewage discharge and dumping of domestic waste are prevailing around the harbor and coastal region. Station B, Sarppakuzhi is situated at the northern region of away from Thangassery here the shore line is characterized by laterite rocks which forms as a substratum for algal colonization. Drainage of municipal sewage is also found here. Station C, Thirumullavarum is ~2 km far away from the station A and is a shallow water region. The coast is protected by sea wall made up of rocks and boulders and also natural laterite formation, which support the luxuriant growth of seaweeds. Anthropogenic activities are very high here. Station D, Ozhukkuthode seashore is a region predominately of sandy nature with intermittent laterite rocks with supports high diversity of seaweeds. Human intervention and domestic waste disposal is found high in this station. Station E, Sakthikulangra is situated near to the harbour and fish market and adjacent to break water region and Ashtamudi estuarine mouth. Sea coast is partially protected by rocks and human interference and salinity fluctuations are high in this region. Station F, Neendakara seashore is near to barmouth where the Ashtamudi Lake open to the sea and also adjacent to the Neendakara harbors. This station is exposed to wastes drained from the harbor. Sea shore is protected by sea wall made up of rocks which forms the substratum for algal colonization.

For the present study, water samples for physico-chemical analyses were collected monthly for one year from the six selected stations in Kollam coastal area. The parameters such as temperature and salinity were measured at the sampling site itself. Water samples for the estimation of oxygen concentration was fixed at the site and analysed in the lab. Water samples were also collected in 2 litre borosilicate bottles and transported directly to the lab for the estimation of major nutrients. Samples were collected in duplicates for the analysis of all parameters.

The temperature was measured using precision mercury celcius thermometer with an accuracy of ±0.01°C. Salinity was analyzed using Ecoscan Salt-6 salinity meter. The hydrogen ion concentration was determined using cyber pH-14L pH meter. Oxygen concentration was estimated by Winkler's Titration Method. The water samples were filtered through Whatman GF/C filter paper (0.5 µ porosity) for the estimation of dissolved nutrients, i.e., Nitrite-Nitrogen ($NO_2^-$-N), Nitrate-Nitrogen ($NO_3^-$-N), Phosphate-Phosphorous ($PO_4^{3-}$-P), and Silicate-Silicon ($SiO_3^{2-}$-Si). Dissolved nutrients were estimated by Calorimetric Methods using Systronics 167 Spectrophotometer at appropriate wave lengths, following the standard methods described by Grasshoff *et al.,* (1999)

## RESULTS AND DISCUSSION

The atmospheric temperature showed the maximum in May (31.3ºC) and the minimum in August (26.2ºC) at Station A. Station B had comparatively greater temperature, i.e., 31.5 ºC in May and had lesser temperature, i.e., 25.2ºC in July. At Station C, the maximum temperature noted was 31.9ºC, which was observed in May and least temperature noted was 26.6ºC in September. Station D recorded a maximum temperature in March (31.6ºC) and minimum in July (26.8ºC). In the case of Station E, 31.5 ºC was the maximum temperature which was noted in November, and 27.1ºC was the minimum value noted which was in September. Station F recorded the maximum temperature of 31.1ºC in the month of October and the minimum temperature noted in Station F was 27.4ºC, noted in August (Fig. 2).

Hydrogen ion concentration of surface water at station A varied from 6.8 in March to 7.8 in December. At Station B, pH value varied from 6.8 in March and September to 7.9 in October and December. At station C the data showed a difference in pH value between 6.9 (March) and 7.7 (November and December). PH value of surface water at station D varied from 6.6 in March to 8.0 during November and December. At Station E the pH value varied from 6.6 in March to 7.9 in December. Similarly the pH value of surface water at station F varied from 6.6 in February to 7.9 in December (Fig.3).

At station A, the highest salinity was observed during March (32.6 PSU) and the lowest during June (28.3 PSU) while at station B the maximum value was observed in October (32.9 PSU) and the minimum value was observed in September (30.7 PSU) . At station C the salinity ranged from 30.2 PSU (July) to 32.9 PSU (January). At station D the lowest of 28.1 PSU (January) and the highest of 32.9 PSU (March) were observed. The salinity at Station E varied in between 30.6 PSU (June) and 32.9 PSU (January) whereas in Station F it fluctuated in between 14.8 PSU (November) and 22.0 PSU (October) (Fig.4).

At station A significantly higher (5.29 mg/L) and lower (3.21mg/L) value of oxygen were observed in July and May respectively. The low value of oxygen concentration was observed at Station B was 3.1 mg/L (February) and the high value observed was 5.85 mg/L (June). In the case of Station C, the oxygen was the highest in June (5.05 mg/L) and was the least in March (3.21 mg/L). At station D the oxygen varied from 3.4 mg/L (March) to 4.95 mg/L (September). While at station E it was lowest (3.02 mg/L) observed during April and the highest (4.89 mg/L) was noted during October whereas in station F the concentration of oxygen varied in between 3.12 mg/L and 4.12 mg/L (Fig. 5).

At station A, the monthly value of nitrite ranged from 0.12 µmol/L (December) to 0.55 µmol/L (February). The concentration of nitrite varied in between 0.15 µmol/L (January) and 0.81 µmol/L (February) in Station B. In station C, station D and station E the values ranged from 0.21 µmol/L (March) to 0.55 µmol/L (October), 0.18 µmol/L (February) to 0.99 µmol/L (January) and from 0.16 µmol/L (August) to 0.67 µmol/L (January) respectively. The nitrite concentration recorded a maximum of 0.21 µmol/L (March) and a minimum of 0.88 µmol/L (October) at station F (Fig. 6).

Maximum concentration of nitrate observed was 12.57 µmol/L (July) at Station A and the minimum value noted was 2.44 µmol/L (February). In the case of station B the highest and the lowest value noted were 12.57 µmol/L (July) and 2.44 µmol/L (February) respectively. The highest and the lowest amount of nitrate recorded at station C were 9.62 µmol/L (October) and 2.03 µmol/L (February) respectively. At station D maximum (8.88 µmol/L) nitrate concentration was noted during October and minimum (2.7 µmol/L) was observed during January. The concentration of nitrate at station E and station F were in the range of 1.66 µmol/L to 6.39 µmol/L (March and October) and from 3.763 µmol/L to 11.9 µmol/L (January and October) respectively (Fig.7).

The concentration of phosphate ranged from 0.24 µmol/L (January) to 5.04 µmol/L (May) in Station A. The minimum concentration of phosphate in station B was same as that of Station A (January) and maximum observed was 3.88 µmol/L (July). The monthly values of phosphate in station C, station D, station E and station F varied from 0.44 µmol/L (January) to 4.57 µmol/L (July); 0.16 µmol/L (January) to 3.45 µmol/L (July); 0.76 µmol/L (August) to 3.47 µmol/L (July); and 0.69 µmol/L (March) to 3.34 µmol/L (October) respectively (Fig. 8).

At station A the concentration of silicate fluctuated between 1.31 µmol/L (December) and 5.21 µmol/L (June). In the case of station B, the highest and the lowest values of silicate was observed during June and April, the values being 8.95 µmol/L and 1.11 µmol/L respectively. At stations C, D and E the silicate levels ranged from 1.56 µmol/L (December) to 7.33 µmol/L (June); 2.04 µmol/L (April) to 8.29 µmol/L (June) and from 1.08 µmol/L (April) to 6.44 µmol/L (June) respectively whereas, Station F showed the variation of concentration from 2.27 µmol/L (February) to 15.06 µmol/L (June) (Fig.9).

The high diversity and abundance of seaweeds belonging to the Chlorophyta, Rhodophyta and Ochrophyta along the Kollam coast indicate that the prevailing conducive environmental conditions, particularly of the physico-chemical parameters are favourable for the growth of seaweed communities in this region. According to Lobban and Harrison (1997), diversity, abundance and distribution of seaweeds are influenced by many environmental factors such as rainfall in the region, temperature, salinity, pH, oxygen concentration and nutrients viz., nitrate and phosphate. Hence in the current study various physico-chemical parameters of seawater were monitored to assess the influence of such factors on the distribution, abundance and diversity of seaweeds.

Temperature is a factor of prime importance in the physical environment of an organism. It is one of the important factors affecting water and controlling the distribution of animals and plants (Alabaster and Lloyd, 1980). Temperature determines the life of seaweeds, and indeed most of the organisms, at the enzymatic processes and metabolism (Raven and Geider, 1988; Lobban and Harrison, 1997). Light and temperature are considered as the important environmental factors that affect the capability of seaweeds to absorb nutrients, which, consequently, regulate seaweed growth and productivity (Roleda and Hurd, 2019). According to Hoek, (1987) temperature influences seaweed distribution and also affects the life history of seaweeds. In the current study, the seaweed biomass was high when the seawater temperature ranged between 29°C to 30°C. High temperature observed during the summer season resulted in the bleaching of the colonized algae which may be due to the exposure of algae to prolonged higher temperature leading to desiccation and resultant reduction in the abundance of seaweeds. In the current study, the seaweed biomass was high when the seawater temperature ranged between 29°C to 30°C.

PH of seawater and concentration of $CO_3^{2-}$ have been reducing due to anthropogenic $CO_2$ emissions (~30%) happening for the past 270 years which is called as ocean acidification. Long-term monitoring of pH in the seawater show that it declines on an average of about 0.002 units per year (Lauvset *et al.*, 2015) and it already declined by 0.1 units since the start of the industrial time (Bopp *et al.*, 2013), which may affect primary production, nitrogen fixation and calcification of organisms (Gattuso *et al.*, 2014). Month-wise analysis of hydrogen ion concentration at various stations in Kollam coast showed wide fluctuations. The seasonal mean value showed maximum pH concentration at premonsoon and minimum at monsoon. The pH of the study area remained within the normal range. In general the pH was low during January and high during May. This is in agreement with the observations made by Johny Thomas and Ragothaman (1987) in the Hajiira coast. Rainfalls, river discharge, exchange from the sea and flow from retting zone are important factors that influence pH variation in Sea water (Nair *et al.*, 1984). Hoq *et al.*, (2002) also recorded a range of pH at 7.4 to 8.1 at Sunderban mangrove, Bangladesh.

Salinity has an important effect on the organisms living in the marine ecosystem. High salinity values observed during pre-monsoon can be attributed to low rainfall. Low salinity values observed during monsoon may be due to the rainfall and increased river discharge. The minimum value observed in the month of June (monsoon) and maximum during the month of March (pre-monsoon). This may be due to the effect of monsoon (Sanilkumar, 1995). Madhukumar and Anirudhan (1995) also observed high salinity during the non-monsoon months (October to May). This is also in conformity with the earlier observations (Ayyappan Nair, 1978; Arunachalam *et al.,* 1982 and Nair *et al.,* 1984). Several species of green algae cannot grow in high salinity. At the same time, some species of red algae and brown algae cannot grow in the low salinity. Some of the warm water species also has a wider tolerance to salinity (Dring, 1974; Luning, 1980; Fralick and Mathieson, 1978).

Oxygen in natural water is of prime importance both as a regulator of metabolic process of floral and faunal community and it is also an indicator of the health of seawater condition. The observed data on monthly variation of oxygen concentration in the coastal waters of Kollam coast revealed that the maximum concentration of oxygen was observed during monsoon. This may be due to the increasing river discharge during monsoon and terrigenous sediment deposits (Madhukumar and Anirudhan, 1995 and Kumar *et al.,* 2009). The high concentration of oxygen in other location may be due to high rate of primary production by phytoplankton and benthic macro algae, mixing of freshwater and also air sea exchange (Nair *et al.,* 1984). During the monsoon months, due to upwelling, the hydrographical features of coastal water in certain areas are subjected to changes like depletion of dissolved oxygen, enrichment of nutrients and fall in temperature (Qasim, 1965).

For optimal growth, most species of seaweeds require nutrients, Carbon, Nitrogen, and Phosphorous in specific ratios. Nitrogen is the element most frequently considered to limit growth of seaweeds. Nitrogen is available in the inorganic forms nitrate ($NO_3^-$) and ammonium ($NH_4^+$) and the organic form urea. The relative preference index can be used to determine the preference of seaweed for $NO_3^-$ vs $NH_4^+$ vs urea, for example, between different seasons (Phillips and Hurd, 2003). The level of tissue nitrogen range from 0.2% to 4.2% with an average varying from of 0.6%-2.2% (Duarte, 1992). When nitrogen is available in low concentration, slow-growing species dominate, but as nitrogen concentration increases, species growing fast which requires higher concentration of nitrogen can overgrow leading to the decline in the diversity (Worm *et al.*, 2002).

The distribution of nitrite and nitrate showed monthly variations. The high concentration of nitrate was observed during monsoon period. This may be due to the leaching of nitrogen from the sediment and run off. Sreedharan and Salih (1974) also reported high concentration of nitrate during the monsoon in Cochin backwaters due to nitrate leaching from sediment. The high nitrite and nitrate concentrations during monsoon period could also be correlated with the larger amount of fertilizers used in neighbouring agricultural fields and subsequent speciation during the season. Mathew *et al.,* (1984) observed higher concentration of nitrite in the water media during the monsoon period. From south west coast of India, the level of nitrite ($NO_2^-$) and nitrate ($NO_3^-$), were reported to be the lowest of all seasons during the pre-monsoon (Nair *et al.*, 2013).

The Kollam coast is a laterite rocky shore enriched with several species of marine algae. In general, distribution of phosphate in the surface water showed wide fluctuations. The increase in phosphate content at Quilon coast during monsoon period may be due to the runoff reaching the coastal waters. Revichandran *et al.,* (2012) reported that the tidal mixing during the monsoon and pre-monsoon seasons, lead to transportation of high concentrations of dissolved inorganic phosphate to the seawater from runoff and shelf region. Monthly values of phosphate varied from 1.15 to 3.46 g/L at Vizhinjam (Nair *et al.,* 1988) and from 1.40 to 3.78 g/L at Cape Comorin (Dhevendaran and Praseetha, 2004). Madhukumar and Anirudhan (1996) also observed high values of phosphorous in the retting zone in Edava-Nadayara and Paravur back water system.


**Figure 1.** Study area

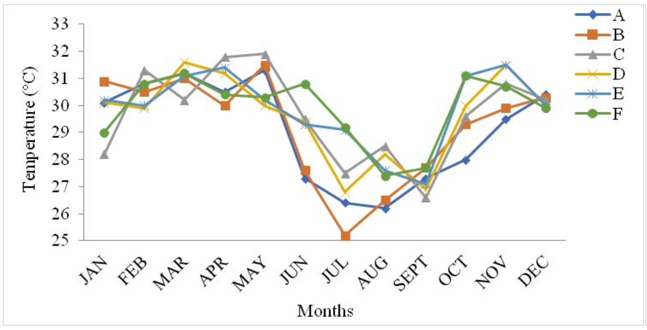


**Figure** 2. Monthly variation of water temperature.

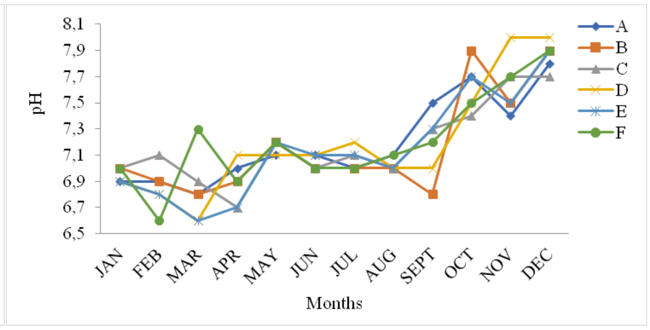


**Figure** 3. Monthly variation of pH.

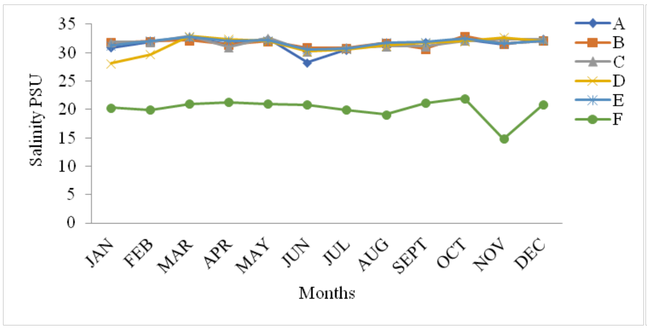


**Figure** 4. Monthly variation of Salinity.

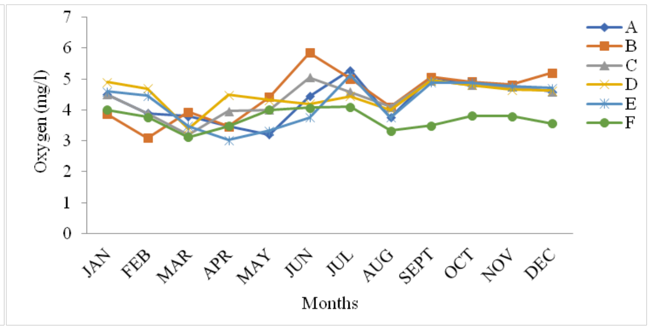


**Figure** 5. Monthly variation of Oxygen concentration.

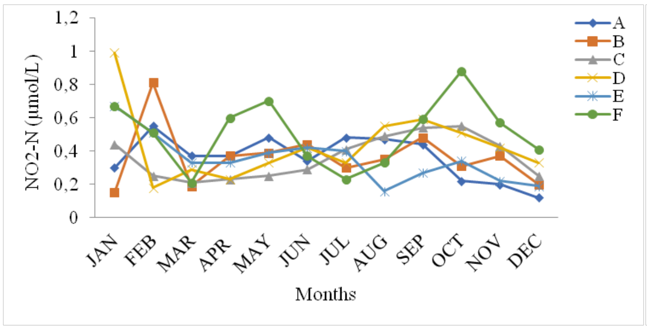


**Figure** 6. Monthly variation of Nitrite.

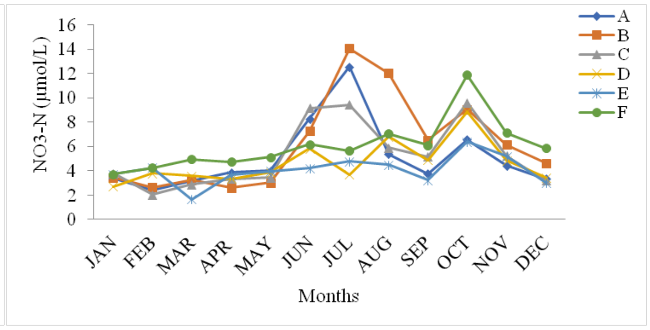


**Figure** 7. Monthly variation of Nitrate.

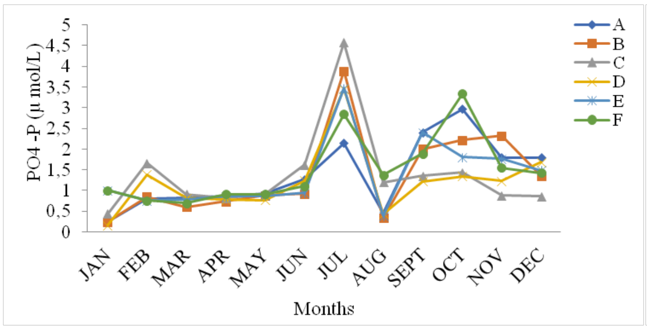


**Figure** 8. Monthly variation of Phosphate.

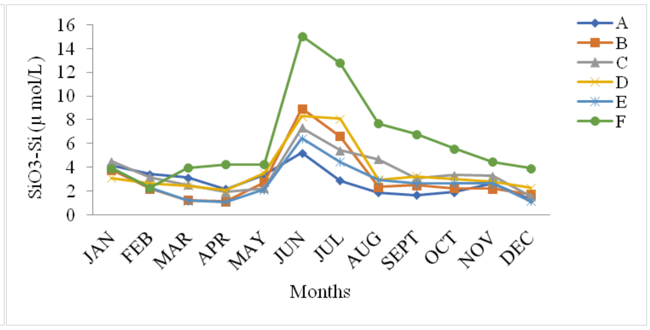


**Figure** 9. Monthly variation of Silicate.

**Table 1**: Correlation coefficient between water quality parameters and Seaweeds biomass

| Stations | Sea weed | Temp | pH | Salinity | Oxygen | $NO_3$ | $NO_2$ | $PO_4$ | $SiO_3$ |
|---|---|---|---|---|---|---|---|---|---|
| S1 | Green algae | -0.263 | 0.463 | 0.349 | -0.095 | -0.192 | -0.134 | 0.018 | -0.448 |
| | Red algae | -.641* | 0.085 | 0.008 | 0.266 | 0.409 | 0.312 | 0.269 | -0.349 |
| | Brown algae | .596* | 0.048 | 0.228 | -0.297 | -0.48 | -0.239 | -0.255 | -0.022 |
| S2 | Green algae | -0.464 | -0.008 | -0.375 | 0.552 | 0.365 | -0.414 | 0.012 | 0.42 |
| | Red algae | 0.062 | 0.531 | 0.11 | 0.439 | 0.057 | -0.242 | -0.079 | 0.025 |
| | Brown algae | 0.318 | 0.093 | 0.562 | -.649* | -0.249 | 0.457 | -0.159 | -.646* |
| S3 | Green algae | -0.011 | 0.504 | -0.159 | 0.443 | 0.059 | 0.082 | 0.106 | -0.245 |
| | Red algae | 0.763 | 0.371 | 0.14 | 0.015 | 0.385 | 0.232 | 0.662 | 0.519 |
| | Brown algae | .713** | 0.306 | 0.555 | -0.219 | -0.219 | -0.149 | -0.508 | -0.33 |
| S4 | Green algae | .-913 | 0.654 | 0.497 | 0.867 | 0.434 | 0.495 | 0.208 | 0.089 |
| | Red algae | 0.072 | .584* | 0.176 | 0.117 | .-216 | -0.147 | 0.179 | -0.208 |
| | Brown algae | 0.156 | 0.104 | 0.294 | -0.438 | -0.181 | -0.296 | 0.462 | 0.39 |
| S5 | Green algae | 0.082 | 0.555 | 0.148 | 0.108 | .581* | -.601* | 0.186 | -0.075 |
| | Red algae | -0.071 | -0.279 | 0.123 | 0.182 | 0.006 | 0.389 | -0.176 | -0.089 |
| | Brown algae | 0.074 | -0.499 | 0.444 | -.797** | -0.423 | -0.22 | -0.448 | -0.403 |
| S6 | Green algae | -0.205 | .685* | -0.106 | -0.152 | 0.130 | 0.003 | -0.031 | -0.189 |

*Correlation is significant at the 0.05 level (2 tailed); **Correlation is significant at the 0.01 level (2 tailed))

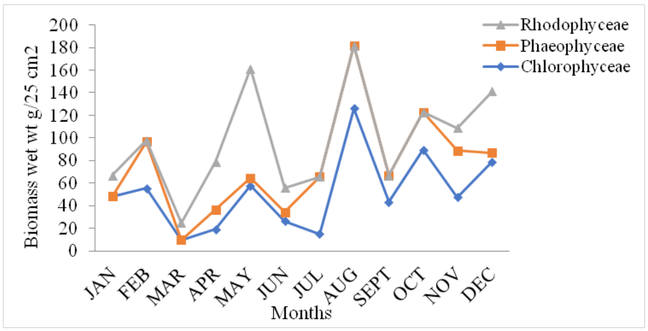


**Figure** 10. Variations of sea weed biomass at station A.

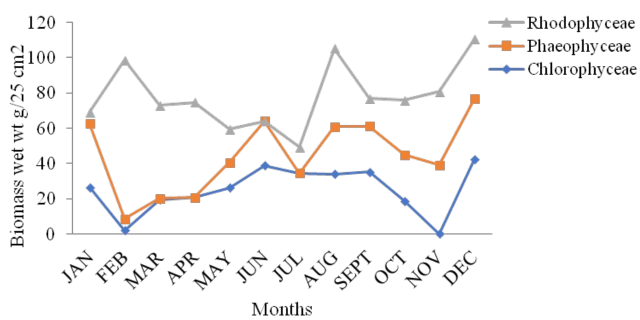


**Figure** 11. Variations of sea weed biomass at station B.

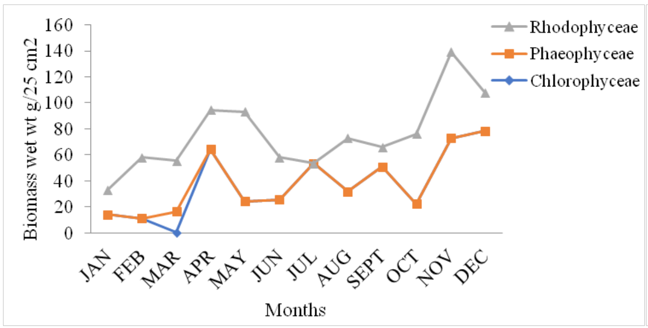


**Figure** 12. Variations of sea weed biomass at station C.

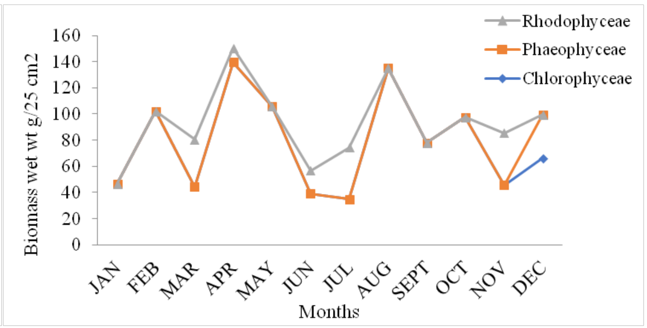


**Figure** 13. Variations of sea weed biomass at station D.

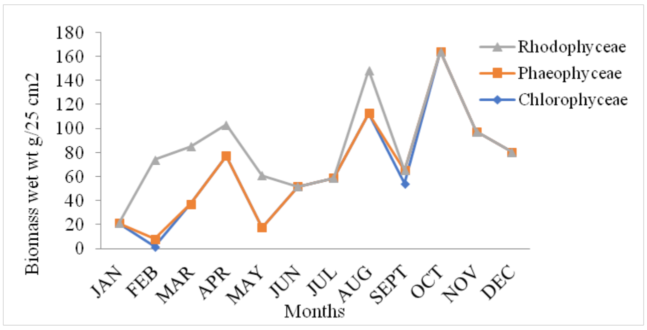


**Figure** 14. Variations of sea weed biomass at station E.

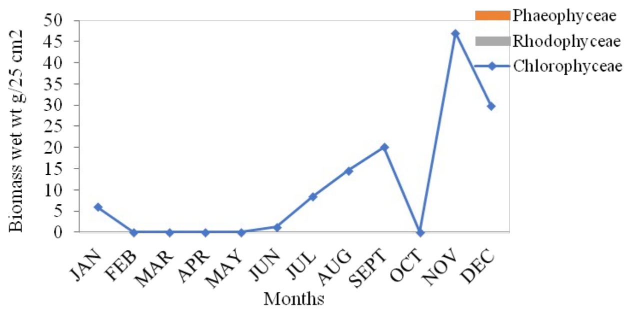


**Figure** 15. Variations of sea weed biomass at station F.

With regard to nutrients, the requirement for silicon by plants is not to the level of the need for phosphorus or nitrogen. Most of the dissolved silicate is utilized by phytoplankton. Silicate concentration in the in the surfaces water of the study area showed wide fluctuations over different study area. According to River run off and fresh water flow is a primary source of silicate in estuaries and coastal waters and its concentration is inversely related to salinity and increase with suspended solids (Purushothaman and Venugopalan, 1972; Sankaranarayanan *et al.,* 1986). Correlation coefficient analysis indicates significant positive correlation between temperature and red algae & temperature and brown algae. Significant negative correlation between oxygen and brown algae & silicate and brown algae were observed. But such relationships were not observed uniformly between stations and species.

## CONCLUSION

The different physico-chemical factors of coastal waters, such as temperature, salinity, pH, oxygen concentration, and nutrients i.e., phosphate, nitrite, nitrate and silicate were monitored during the period of study. The pH varied from 6.6 (March) to 8.0 (November and December). The oxygen concentration fluctuated between 3.02 mg/l (April) and 5.85 mg/l (June). The lowest salinity (14.8 PSU) was noticed during November and the highest (32.9 PSU) was observed during March and October. The concentration of $NO_3$-N varied from 1.66 µmol/l (March) to 14.06 µmol/l (July) and the $NO_2$-N fluctuated between 0.12 µmol/l (December) and 0.99 µmol/l (January). The dissolved phosphate ranged from 0.16 µmol/l (January) to 3.88 µmol/l (July). The concentration of Silicate varied from 1.08 µmol/l (April) to 15.06 µmol/l (June 2006). In general comparatively greater algal density was observed during the month of August (192.23g) and September (181.73g**)** for which the major contributors were *Ulva intestinalis*, *Chnoospora minima* and *Ulva fasciata.* In the case of algal diversity, the maximum was observed during the month of December, during which the total number of species observed was 14, which included seven species of Chlorophyceae, two species of Phaeophyceae and five species of Rhodophyceae. The station F recorded the least density and diversity among all the stations monitored. The substantial diversity and distribution of seaweeds belonging to Chlorophyceae, Rhodophyceae and Phaeophyceae from the Quilon coast indicates that the prevailing environmental conditions particularly the physico-chemical parameters favorable for the growth of seaweed communities. Efforts must be taken to exploit the resources and enforce conservation measures for sustainable management.

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## CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

## REFERENCES

Alabaster, J.S., and R. Lloyd. (1980). Water quality criteria for freshwater fish. European Inland

Fisheries Advisory Commission Report (FAO). Buttersworth, London. 297 pp.

Anon. (2018). The State of World Fisheries and Aquaculture-Meeting the Sustainable Development Goals; FAO: Rome, Italy.

Arunachalam, M., Divakaran, O., Nair, N.B., and N.K. Balasubramanian. (1982). Seasonal variation of zooplankton of the Veli lake, South-west coast of India. *Arch. Hydrobiol.*, 93:359-374.

Ayyappan Nair. (1978). Production ecology of a tropical sandy beach at Benaulim, Goa. *Indian J. Mar. Sci.*, 7: 163-167.

Bopp, L., Resplandy, L., Orr, J.C., Doney, S.C., Dunne, J.P., Gehlen, M., Halloran, P., Heinze, C., Ilyina, T., Seferian, R., Tjiputra, J., and Vichi, M. (2013). Multiple stressors of ocean ecosystems in the 21st century: Projections with CMIP5 models. *Biogeosciences*, 10(10): 6225-6245.

Dhevendaran, K., and Praseetha, P.K. (2004). Studies on streptomycetes associated with seaweed of Cape Comorin, Tamilnadu. *Seaweed Res. Utiln.*, 26:245–252.

Duarte, C.M. (1992). Nutrient concentration of aquatic plants: patterns across species. *Limnology and Oceanography*, 37: 882–889.

Fralick, R.A., and Mathieson, A.C. (1978). Physiological ecology of four Polysiphonia species (Rhodophyta, Ceremiales). *Mar. Biol.*, 29: 29-36.

Ganesan, M., Trivedi, N., and Gupta, V. (2019). Seaweed resources in India – current status of diversity and cultivation: Prospects and challenges. *Bot. Mar.* 62, 463–482.

Gattuso, J.P., Hansson, L., and Gazeau, F. (2014). Ocean acidification and its consequences, In: Ocean in the Earth System, eds. A. Monaco and P. Prouzet, John Wiley, Hoboken, N. J. pp. 189-253.

Grasshoff, K., Ehrhardt, M., and Kermiling, K. (1999). Methods of Sea Water Analysis. Wiley-VCH Verlag GmbH, 600pp.

Hoek van den, C. (1987). The possible significance of long-range dispersal for the biogeography of seaweeds. *Helgoliinder Wiss. Meeresunters.*, 41: 261-272.

Hoq, M.E., Islam, M.L., Paul, H.K., Ahmed, S.U., and Islam, M.N. (2002). Decomposition and seasonal changes in nutrient constituents in mangrove litter of Sundarbans mangrove, Bangladesh. *Ind. J. Mar. Sci.*, 31(2):130–135.

Jackson, G.A. (1983). The physical and chemical environment of a kelp community. *J. Exp. Mar. Biol. Ecol.*, 6: 11-37.

Jha, B., Reddy, C.R.K., Thakur, M.C., and Rao, M.U. (2009). Seaweeds of India. The Diversity and Distribution of Seaweeds of Gujarat Coast; Springer: Dordrecht. p. 215.

Johny Thomas., and Ragothaman, G. (1987). Studies on the hydrography of Hajira coast. *Proc. Natn. Sem. Estuarine Management, Trivandrum*, 138-142.

Kaliaperumal, N., Kalimuthu, S, J.R., and Ramalingam. (2004). Present scenario of seaweed exploitation and industry in India. *Seaweed Res. Util.*, 26:47–53.

Kawamata, S. (2001). Adaptive mechanical tolerance and dislodgement velocity of the kelp Laminaria japonica in wave-induced water motion. *Mar. Ecol. Prog. Ser.*, 211,89 -104.

Lauvset, S.K., Gruber, N., Landschützer, P., Olsen, A., and Tjiputra, J. (2015). Trends and drivers in global surface ocean pH over the past 3 decades. *Biogeosciences*, 12(5): 1285-298.

Lobban. C.S., and Harrison, P.J. (1997). Seaweed Ecology and Physiology. Cambridge University Press, New York, 366pp.

Luning, K. (1980). Critical levels of light and temperature regulating the gametogenesis of three Laminaria species (Phaeophyceae). *J. Phycol*. 16: 1-15.

Madhukumar, A., and Anirudhan, T.S. (1995). Phosphate distribution in sediments of Edava-Nadayara and Paravur lake systems along the south west coast of India. *Indian J. Mar. Sci.*, 24: 186-191.

Madhukumar, A., and Anirudhan. T.S. (1996). Hydrographic features and chemical characteristics of edava- nadayara and paravur backwaters. *Poll. Res.*, 15: 79-84.

Mantri, V., Kavale, M., and Kazi, M.A. (2020). Seaweed Biodiversity of India: Reviewing Current Knowledge to Identify Gaps, Challenges, and Opportunities. *Diversity*, 12(1):13.

Mathew, K.J., Regunathan, A., Gopinathan, C.P., Rao, D.S., and Murthy, A.V.S. (1984). Ecology of mud banks - The current system. *Mar. Fish. Res. Inst. Bull.*, 31:46-59.

Nair, A., Mohanty, U.C., and Acharya, N. (2013). Monthly prediction of rainfall over India and its homogeneous zones during monsoon season: a supervised principal component regression approach on general circulation model products. *Theoretical and Applied Climatology*, 111, 327-339.

Nair, N.B., Dharmaraj, K., Abdul Aziz, P.K., and Arunachalam, M. (1984). A study on the ecology of soft bottom benthic fauna in kadinamkulam backwater, South-West coast of India. *Proc. Indian Natn. Sci. Acad.*, 50(B): 473-482.

Nair, N.B., Sobha, V., Chandra, R., Rathiammal, M., Maya, S., and Sankaranarayanan, H. (1988). Algal resources of Kerala cost II, An update list of Indian marine algae. *Aquat. Biol.*, 6: 25-52.

Oza, R.M., and Zaidi, S.H. (2001). A Revised Checklist of Indian Marine Algae; Central Salt and Marine Chemicals Research Institute: Bhavnagar, India. p. 296.

Phillips, J.C., and Hurd, C.L. (2003). Nitrogen ecophysiology of intertidal seaweeds from New Zealand: N uptake, storage and utilization in relation to shore position and season. *Marine Ecology Progress Series*, 264: 31–48.

Purushothaman, A., and Venugopalan, V. K. (1972). Distribution of dissolved silicon in the Vellar estuary. *Indian J. Mar. Sci.*, 1: 103-105.

Qasim, S.Z. (1965). Fisheries hydrography. *Fish. Technol.*, 2 (2): 155-157.

Raven, J.A., and Geider, R.J. (1988). Temperature and algal growth. *New Phytol.*, 110:441– 61.

Revichandran, C., Srinivas, K., Muraleedharan, K.R., Rafeeq, M., Shivaprasad, A., Vijayakumar, K., and Jayalakshmy, K.V. (2012). Environmental set-up and tidal propagation in a tropical estuary with dual connection to the sea (SW Coast of India). *Environmental Earth Sciences*. 66: 1031-1042.

Roleda, M.Y., and Hurd, C.L. (2019). Seaweed nutrient physiology: application of concepts to aquaculture and bioremediation, *Phycologia*, 58:5, 552-562.

Sahu S.K., Ingle K.N., and Mantri V.A. (2020). Epiphytism in Seaweed Farming: Causes, Status, and Implications. In: Gothandam K., Ranjan S., Dasgupta N., Lichtfouse E. (eds) *Environmental Biotechnology Vol. 1. Environmental Chemistry for a Sustainable World, Vol. 44.* Springer, Cham. Pp 227-242.

Sajid, I.K., and Satam, S.B. (2003). Seaweed mariculture: scope and potential in India. *Aquaculture Asia*, 8(4):26-29.

Sanilkumar, K.V. (1995). Some aspects of oceanic variability in the upper layers of the Bay of Bengal. Ph.D. Thesis, Cochin University of Sci. and Tech. 105 pp.

Sankaranarayanan, V.N., Udayavarma, P., Balachandran, K.K., Pylee, A., and Joseph, T. (1986). Estuarine characteristics of the lower reaches of the River Periyar. *Indian J. Mar. Sci.*, 15: 166- 170.

Sreedharan, M. and Salih, M. (1974). Distribution characteristics of nutrients in the estuarine complex of Cochin. *Indian J. Mar. Sci.*, 5: 125-130.

Worm, B., Lotze, H. K., Hillebrand, H., and Sommer, U. (2002). Consumer versus resource control of species diversity and ecosystem functioning. *Nature*, 417: 848-851.