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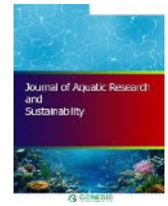

Original Research

Seasonal dynamics and implications of macroalgae species composition in Pulicat Lagoon, India

Nimish Mol Stephen[1*], Muthupandi Kalaiarasan[2], Sangaralingam Mariappan[3], Ponesakki Ganesan[4]

[1] *Department of Fish Processing Technology, Dr. MGR Fisheries College and Research Institute, Tamil Nadu Dr. J Jayalalithaa Fisheries University, Ponneri – 601 204, India*
[2] *Directorate of Incubation and Vocational Training in Fisheries, Tamil Nadu Dr. J Jayalalithaa Fisheries University, Ramanathapuram – 614 904, India*
[3] *Department of Fishing Technology & Fisheries Engineering, Fisheries College and Research Institute, Tamil Nadu Dr. J Jayalalithaa Fisheries University, Thoothukudi – 628 008, India*
[4] *Department of Biochemistry and Biotechnology, CSIR-Central Leather Research Institute, Adyar – 600 020, India*

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Abstract

Macroalgae are the valuable bioresources in the marine ecosystem. These renewable resources phase several challenges for its existence due to industrial and anthropological activities. Thus, the present study aimed to examine the seasonal patterns of the marine macroalgal species in Pulicat Lagoon, Tamil Nadu. The study was conducted from July 2015 to June 2016. Fresh algal samples were collected once in a month from three different sites at a depth of around 0.5 m. The collected samples were identified and analysed for species variation and distribution. Totally, 15 species of marine macroalgae were noticed during the entire study period. Among them, the phylum Rhodophyta (Red algae) ranked the maximum with 6 species followed by Chlorophyta (Green algae) with 5 species, and Phaeophyta (Brown algae) with 4 species. Maximum species variations (9) were observed from July 2015 to August 2015. *Ulva intestinalis* was found to be dominant throughout the study, followed by *Enteromorpha compressa*. The changes in the macroalgal species composition noticed at different seasons indicate the influence of environmental factors such as temperature and salinity. This study describes for the first time, the diversity of marine algal species in Pulicat Lagoon in different seasons. Our data provide the present status of macroalgal biodiversity in the Pulicat Lagoon and emphasize the importance of preserving those renewable resources.

1. Introduction

The marine ecosystem harbours exceptionally abundant and promising sources of biological importance. Among the diverse marine sources, marine macroalgae are considered as important renewable resources that contain a wide range of nutritional and health beneficial molecules with a broad spectrum of biological activities (Kumar *et al*., 2009; Shahidi and Rahman, 2018; Pradhan *et al*., 2021). A previous report reveals that researchers isolated approximately 7000 marine natural products, of which 25 % are from marine macroalgae (Kijjoa and Sawangwong, 2004). Moreover, components isolated from marine macroalgae exhibited antioxidant, anti-inflammatory, antiobesity, and anticarcinogenic activity (Ganesan *et al*., 2008; Ganesan *et al*., 2011; Yogendra Prasad *et al*., 2019; Manabe *et al*., 2020). It was reported that seaweed-derived extracts in the form of carrageenan, agar, and alginates make up almost 40 % of the world's hydrocolloid market in terms of food (Khan and Satam, 2003). Among marine macroalgae, red and brown algae are mostly considered food and industrially important resources in Asia. These data provide economic importance to marine macroalgae for its exploitation in chemical, food and pharmaceutical industries.

****Corresponding authors***
Email address: nimish@tnfu.ac.in (Nimish Mol Stephen)

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In 2015, the total world marine macroalgae/seaweed production was 30.4 million tonnes (wet weight), with culture and capture production of 29.4 million tonnes and 1.1 million tonnes, respectively (Ferdouse *et al*., 2018). This value of total production increased to 35 million tonnes in the year 2019 (FAO, 2021). Chile, China, Norway, and Japan were the top four wild seaweed producers in 2015. Chilean Kelp (*Lessonia nigrescens*) is the dominant species (22 %) harvested from the wild, followed by *L. trabeculata* (7 %) and *Gracilaria* sp. (5 %). However, Indian seaweed market is mostly focused on the natural stock of agar-yielding red algae, *Gelidiella acerosa* and *Gracilaria edulis*, and alginate-yielding brown algae, *Sargassum* spp. and *Turbineria* sp. (Ganesan *et al*., 2019).

India is a tropical country in South Asia with around 7500 km of coastline interspersed with sandy and rocky beaches, mudflats, estuaries, and lagoons (Mukhopadhyay and Karisiddaiah, 2014). Around 830 species of marine macroalgae have been recorded from the Indian coast, of which the maximum number of species belongs to the phylum Rhodophyta (422), followed by Chlorophyta (217) and Phaeophyta (191) (Oza and Zaidi, 2001). Most Indian marine algal flora is defined as tropical and has a distinct seasonal periodicity. However, global warming, associated climate change, and disrupted rainfall could potentially affect this seasonal periodicity and the yield of marine algal production. Studies emphasized that climatological and extreme environmental events bring new drifted marine macroalgae, and such events might have occurred on the Indian coast (Hirata *et al*., 2003; Thakur *et al*., 2008; Rani *et al*., 2025). The southeast coast of Indian Peninsula has large deltas formed by rivers due to abundant sediment supply, and receives rainfall from the retreating monsoon during the winter. Pulicat Lagoon, a brackish waterbody lying between the land-sea interfaces separated from the Bay of Bengal is a rich natural and fragile ecosystem. It had experienced many drastic changes due to a range of natural and human-driven activities leading to decreased productivity and increased pollution levels (Jeba Kumar and Natesan, 2015). Though the availability of marine algal resources in coastal lines of Tamil Nadu, India had been investigated earlier (Kaliaperumal *et al*., 1998; Sahayaraj *et al*., 2014), minimal data on the seasonal variations in the species composition of marine macroalgae is available for the last two decades. Moreover, the status of distribution of marine macroalgal species in the Tamil Nadu coastal region of Pulicat Lagoon, India's second largest brackish water lagoon, is poorly understood. With these backgrounds, this study aimed to systematically examine the seasonal variation in species composition of marine macroalgae along the Tamil Nadu region of Pulicate Lagoon.

2. Materials and Methods

2.1 Ethical approval

Not applicable.

2.2 Study area and design

Pulicat Lagoon (13° 24'-13° 47' N latitude; 80° 03'- 80° 18' E longitude) is formed by the backwater of the Bay of Bengal, which is situated in the states of Andhra Pradesh and Tamil Nadu (Figure 1). This lagoon is the second largest brackish water ecosystem situated on the Coromandel Coast of the Indian subcontinent. It constitutes an area of 720 sq. km, of which 84 % falls in Andhra Pradesh and the remaining 16 % in Tamil Nadu. The lagoon has a length of about 60 km, and its breadth varies from 0.2 to 17.5 km. It is a shallow lake with a depth of around a meter, with a north-to-south and west-to-east slope connected with an estuary mouth of 200 m (Sanjeeva Raj, 2006; Saraswathy and Pandian, 2016). The study area is humid (up to 90%) and tropical, with temperatures ranging from 18 °C to 40 °C. It receives rainfall mainly from the North-east Monsoon (October-December) and slightly from South-west Monsoon (June-September). Pulicat is often exposed to extreme weather events like depressions and cyclones during the onset of the two monsoons and receives an annual rainfall of around 1,200 mm. During the summer season (March to September), the temperature in this area soars to the maximum of over 40 °C. The salinity values of the lagoon were reported to vary from zero (during a monsoon season) to about 52 ppm (during the post and pre-monsoon seasons). The wind throughout the year is majorly from the southwest (Kannan *et al*., 2008; Saraswathy and Pandian, 2016).

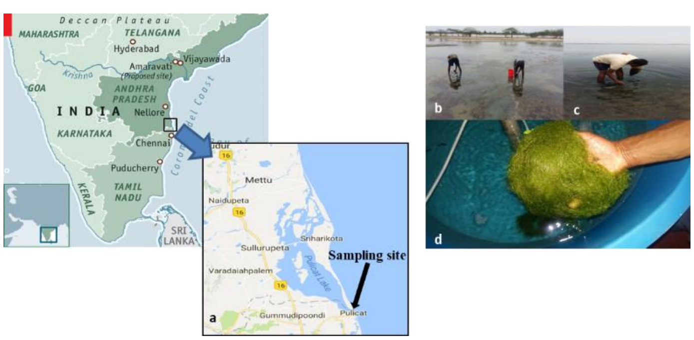

Figure 1. (a) Map showing the study site of Pulicat Lagoon, India; (b and c pictures of the sample collections on site) (d) sample processing at the laboratory.

2.3 Sampling period

The sampling period was designed based on the influence of land-atmospheric parameters on intra-seasonal variability as reported by earlier studies (Jana *et al*., 2016; Ghosh *et al*., 2018; Deb Burman *et al*., 2020). It was classified as July to August 2015 (monsoon 1), September to November 2015 (monsoon 2), December 2015 to February 2016 (winter), March to May 2016 (summer), and June 2016 (late summer). The sampling was done at the end of each month, and the data were collected for species variation and distribution analysis.

2.4 Sampling

Three sampling sites were identified along the shore of the Pulicat Lagoon, which was located on the Tamil Nadu coastal estuary mouth (Figure 1a). Each sampling location was situated about one kilometre away from the other. The intertidal marine macroalgae collection procedure was followed as described by Dhargalkar (2004). Briefly, sampling was conducted out once a month for one year, from July 2015 to June 2016. Fresh samples were collected at a depth of around 0.5 m, about 30 to 50 m off the shore (Figure 1b and c). The samples collected were transported to the laboratory with proper labelling under chilled conditions and cleaned thoroughly with clean water to remove extraneous matters (Figure 1d). A portion of the samples was preserved with 5 % formalin for identification in the laboratory

2.5 Species identification

The species were first recognized by studying their morphological features using botanical approaches by the taxonomist. They were identified based on gross morphology and internal features of the respective species following genera algarum-1 and published taxonomic references (Krishnamoorthy and Baluswamy, 2010; Krishnamoorthy and Ezhili, 2013; Dixion *et al*., 2014). Gross morphological characteristics used in this study are the type of the holdfast, shape of the branches, vesicles, leaves, nature of cryptostomata, and receptacles.

2.6 Statistical analysis

The SPSS statistical package for social science 26 (SPSS, 2020) was used to analyse the data. One-way analysis of variance (One Way ANOVA) was carried out to justify the significant difference between different treatments. Tukey's multiple range tests were performed at $p < 0.05$. The values are expressed as mean ± standard deviation.

3. Results and Discussion

Pulicat Lagoon is considered an excellent storehouse of biological resources rich in flora and fauna that support active commercial fishery activity in those areas. It is a well-known nursery and breeding ground for many species of coastal-marine fauna and serves as a prime livelihood source for a large population through fishing. Since the lagoon is becoming a fragile ecosystem with polluted sediment and water columns due to sustained anthropogenic pressure, we examined seasonal variation in the composition of marine macroalgal species as they contribute directly or indirectly to the nutritional status of the human population.

The species composition of marine macroalgae in Pulicat Lagoon from July 2015 to June 2016 is presented in Table 1. Fifteen species of marine macroalgae belonging to the three phyla, viz. Rhodophyta, Chlorophyta, and Phaeophyta, were identified during the entire study period. A previous study by Sahayaraj *et al*. (2014) observed that red algae are dominantly distributed over green and brown algae on the coast of four southern districts of Tamil Nadu from July 2009 to July 2010. Similarly, we found a higher number of red algae (6 species) followed by green (5 species) and brown (4 species) algae. The genus *Gracilaria* belongs to red algae and had three species during the study period, viz. *Gracilaria crassa*, *G. edulis*, and *G. verrucosa*.

Table 1. Marine macroalgae identified in Pulicat Lagoon, Tamil Nadu during July 2015 to June 2016.

Type of algae	Total number of species identified	Name of the species
Red algae (Rhodophyta)	6	*Gracilaria crassa* *Gracilaria edulis* *Gelidium corticata* *Gelediella indica* *Gracilaria verrucosa*

		Kappaphycus alvarezii
Brown algae (Pheophyta)	4	*Sargassum wightii* *Turbinaria conoides* *Padina tetrastromatica* *Dictyota dichotoma*
Green algae (Chlorophyta)	5	*Ulva lactuca* *Chaetomorpha linoides* *Enteromorpha compressa* *Caulerpa sertularioides* *Ulva intestinalis*

The season-wise species composition of marine macroalgae in Pulicat Lagoon is given in Table 2. A maximum species variation (9) was observed between July 2015 and August 2015 (monsoon 1), followed by September and November 2015 (monsoon 2) with eight species. The green algal species dominated during the winter (December 2015 to February 2016) through the summer (March 2016 to May 2016). No brown algal species were noticed from winter to summer; however, they appeared from late summer (June 2016). The distribution frequency of marine macroalgae of Pulicat Lagoon at different seasons is shown in Figure 2. As shown in Figure 2b and 2c, the frequency of macroalgae distribution varies with different seasons. The highest distribution frequency of red and green algae was observed during Monsoon 1 (July to August 2015). In contrast, the highest distribution of brown algae was observed in Monsoon 2 (September to November 2015). Interestingly, *Ulva* species were identified throughout the sampling period. It was reported that *Ulva* is a commonly found genera of chlorophytes worldwide (Riddin and Adams, 2008). Earlier studies identified that salinity plays a critical role in the natural environment, and decreased salinities limit the distribution of macroalgae by reducing its photosynthetic rate, and in turn, the growth rate (Kamer and Fong, 2000; Biber and Irlandi, 2006). It was reported that species belonging to the genera *Ulva* and *Enteromorpha* are likely to grow at a wide range of salinities. This might be why *Ulva* sp., the filamentous euryhaline species, is found throughout our study, followed by *Enteromorpha* sp. These submerged macrophytes are long-known algal species of Pulicat Lagoon (Kannan and Krishnamurthy, 1978). In addition, we found the presence of *Chaetomorpha linoides* and *Caulerpa sertularioides* as other green algal species. The lower distribution of macroalgae from the winter to summer might be due to heavy rainfall and flooding during those seasons in India. It was reported that sea level rise reduces the distribution and abundance of macroalgae (Sunny, 2017). Our study indirectly provides the background knowledge of the conditions required for the growth of different types of macroalgae. Further, it allows future studies to identify various physical, chemical, and nutritional compositions at different seasonal conditions to better corroborate this present investigation.

Table 2. Changes in the distribution of marine macroalgae in Pulicat Lagoon, Tamil Nadu, India at different seasons.

Type of algae	**Total number of species identified**	**Name of the species**
July 2015 to August 2015 (Monsoon 1)		
Red algae (*Rhodophyta*)	4	*Gracilaria crassa* *Gracilaria edulis* *Gelidium corticata* *Gelediella indica*
Brown algae (*Pheophyta*)	2	*Sargassum wightii* *Padina tetrastromatica*
Green algae (*Chlorophyta*)	3	*Ulva lactuca* *Chaetomorpha linoides* *Enteromorpha compressa*
September 2015 to November 2015 (Monsoon 2)		
Red algae (*Rhodophyta*)	2	*Gracilaria edulis* *Gracilaria verrucosa*
Brown algae (*Pheophyta*)	4	*Sargassum wightii* *Turbinaria conoides* *Padina tetrastromatica* *Dictyota dichotoma*
Green algae (*Chlorophyta*)	2	*Ulva lactuca* *Caulerpa sertularioides*
December 2015 to February 2016 (Winter)		
Green algae (*Chlorophyta*)	2	*Enteromorpha compressa* *Ulva intestinalis*
March 2016 to May 2016 (Summer)		
Red algae (*Rhodophyta*)	1	*Kappaphycus alvarezii*
Green algae (*Chlorophyta*)	2	*Ulva intestinalis* *Enteromorpha compressa*
June 2016 (Late summer)		
Red algae (*Rhodophyta*)	2	*Gracilaria edulis* *Kappaphycus alvarezii*
Brown algae (*Pheophyta*)	1	*Sargassum wightii*
Green algae (*Chlorophyta*)	2	*Enteromorpha compressa* *Ulva lactuca*

One of the abiotic factors that primarily contribute to the assemblages of macroalgae in estuaries is the flow rate, as water mobility brings and circulates nutrients and other elements into the system (Kang *et al.*, 2011). Moreover, faster flow rates increased macroalgal species diversity in estuaries due to increased nutrient exchange and decreased sedimentation (Bunn and Arthington, 2002). A previous study identified a large number of brown algae in the Gulf of Mannar region from July to November, when a strong sea breeze was observed (Rani *et al.*, 2015). Likewise, we also noticed a maximum number of brown algae (four species out of five) during this period in Pilicat Lagoon (Figure 2b). The present study observed a maximum number of red algae (five species out of six) during the sampling period from July to November, which indicate the influence of increased flow rate. The green algae observed during this period are *Ulva lactuca*, *Chaetomorpha linoides*, *Enteromorpha compressa*, and *Caulerpa sertularioides*.

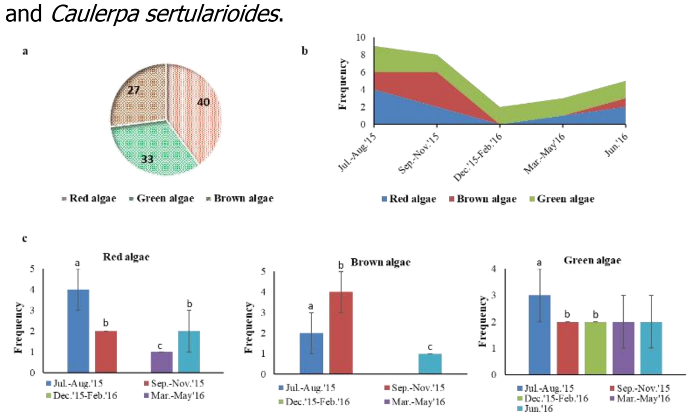

Figure 2. (a) Percentage macroalgal distribution; (b and c) distribution frequency of macroalgal types in Pulicat Lagoon, Tamil Nadu from July 2015 to June 2016.

During summer, the mouth of the estuary closed, affecting the tidal exchange between the lake and the sea. This changes the water quality and salinity, vastly affecting the lake's biodiversity (Mantri *et al.*, 2011; Saraswathy and Pandian, 2016). In our study, the composition of marine algal species was considerably reduced from March to June with two red algae (*Kappaphycus alvarezii* and *Gracilaria edulis*), three green algae (*Ulva intestinalis*, *Ulva lactuca,* and *Enteromorpha compressa*) and only one brown alga (*Sargassum wightii*). This reduction might be due to changes in the salinity and nutritional content that do not favour the growth of marine algae. The period from October to December is referred to as the Monsoon season over peninsular India. It has been reported that the diversity and biomass of algal species decline towards the end of the monsoon due to the fluctuation of salinity (Rani *et al.*, 2015). Another study found the monsoon period as a lean period with the scanty growth of a few species (Thakur *et al.*, 2008). Consistent with the previous observations, the present study did not find any brown or red algal species from December to February. Still, we noticed the occurrence of two green algal species, *Ulva intestinalis,* and *Enteromorpha* *compressa*. The representative pictures of two significant marine algae from each phylum (Red, brown and green algae) collected from Pulicat Lagoon, Tamil Nadu, from July 2015 to June 2016 are presented in figure 3. It is noticed through this study that monsoon season might not provide favourable ecosystem for macroalgal growth at Pulical Lagoon, Tamil Nadu, India.

Figure 3. Pictures of two major macroalgae of each phylum collected at Pulicat Lagoon, Tamil Nadu.

4. Conclusions

This study report the seasonal pattern data for the occurrence of macroalgae from India's second-largest brackish water ecosystem for the first time. We found a marked seasonal variation in the frequency of occurrence of most dominant macroalgal species belong to the family Rhodohyceae (red algae), Phaeophyceae (brown algae) and Chlorophyceae (Green algae). Green algal species, *Ulva intestinalis* and *Enteromorpha compressa* were the dominant algae throughout the seasons at Pulicat Lagoon. The present study emphasizes sensitity of the marine macroalgae to seasonal changes. Since this valuable ecosystem is fragile due to anthropogenic pressure, steps toward protecting biodiversity are urgently needed to maintain the balance of nature and preserve these renewable resources for future generations. As India has recently started cultivating marine macroalgae in certain coastal districts of the Tamil Nadu state, this report directly or indirectly provide an information on conceivable ecosystem for macroalgal growth.

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Data availability

The first author can provide the data upon reasonable request.

Informed consent statement

Not applicable.

Conflict of interest

The authors declare that they have no conflicts of interest.

Authors' contribution

Conceptualization: Nimish Mol Stephen; **Data collection:** Muthupandi Kalaiarasan and Sangaralingam Mariappan; **Data analysis:** Nimish Mol Stephen; **Figure preparation:** Nimish Mol Stephen and Ponesakki Ganesan; **Manuscript writing:** Nimish Mol Stephen; **Manuscript review and editing:** Nimish Mol Stephen and Ponesakki Ganesan. All the authors critically reviewed the manuscript and agreed to submit a final version of the article.

References

Biber PD and Irlandi EA, 2006. Temporal and spatial dynamics of macroalgal communities along an anthropogenic salinity gradient Biscayne Bay, Florida, USA. Aquatic Botany, 85: 149-155. https://doi.org/10.1016/j.aquabot.2006.02.002

Bunn S and Arthington A, 2002. Basic principles and ecological consequences of altered flow regimes for aquatic deflation basin lakes. Journal of Environmental Management, 30: 492-507. https://doi.org/10.1007/s00267-002-2737-0

Deb Burman PK, Sarma D, Chakraborty S, Karipot A and Jain AK, 2020. The effect of Indian summer monsoon on the seasonal variation of carbon sequestration by a forest ecosystem over North-East India. SN Applied Sciences, 2: 154. https://doi.org/10.1007/s42452-019-1934-x

Dhargalkar VK, 2004. Seaweeds: A field manual. In: Verlecar XN and Karlekar D (Eds.), National Institute of Oceanography (pp. 1-36), India.

Dixon RRM, Mattio L, Huisman JM, Payri CE, Bolton JJ and Gurgel FD, 2014. North meets South – Taxonomic and biogeographic implications of a phylogenetic assessment of Sargassum subgenera Arthrophycus and Bactrophycus (Fucales, Phaeophyceae). Phycologia, 53: 15–22. https://doi.org/10.2216/13-173.1

FAO (Food and Agriculture Organization of the United Nations), 2021. Global aquaculture production. In: Fisheries and Aquaculture. Italy.

Ferdouse F, Holdt SL, Smith R, Murua P and Yang Z, 2018. The global status of seaweed production, trade and utilization. In: FAO Globfish Research Programme (pp. 1-120). Volume. 124. Rome, Italy.

Ganesan M, Trivedi N, Gupta V, Madhav SV, Reddy CR and Levine IA, 2019. Seaweed resources in India – Current status of diversity and cultivation: Prospects and challenges. Botanica Marina, 62: 463-482. https://doi.org/10.1515/bot-2018-0056

Ganesan P, Kumar CS and Bhaskar N, 2008. Antioxidant properties of methanol extract and its solvent fractions obtained from selected Indian red seaweeds. Bioresource Technology, 99: 2717-2723. https://doi.org/10.1016/j.biortech.2007.07.005

Ganesan P, Noda K, Manabe Y. Okubo T, Tanaka Y, Maoka T, Sugawara T and Hirata T, 2011. Siphonaxanthin, a marine carotenoid from green algae, effectively induces apoptosis in human leukemia (HL-60) cells. Biochimca et Biophysica Acta (BBA)-General Subjects, 1810: 497-503. https://doi.org/10.1016/j.bbagen.2011.02.008

Ghosh R, Chakraborty A and Nanjundiah RS, 2018. Relative role of pre-monsoon conditions and intraseasonal oscillations in determining early-vs-late Indian monsoon intensity in a GCM. Theoritical and Applied Climatology, 131: 319–333. http://dx.doi.org/10.1007/s00704-016-1970-z

Hirata T, Tanaka J, Iwami T, Dazai A, Aoki M, Ueda H, Tsuchiya Y, Sato T and Yokohama Y, 2003. Ecological studies on the community of drifting seaweeds in the south-eastern coastal waters of Izu Peninsula, central Japan. II: Seasonal changes in plants showing maximum stipe length in drifting seaweed communities. Phycology Research, 51: 186-191. https://doi.org/10.1046/j.1440-1835.2003.00309.x

Jana A, Maiti S and Biswas A, 2016. Seasonal change monitoring and mapping of coastal vegetation types along Midnapur-Balasore Coast, Bay of Bengal using multi-temporal Landsat data. Modeling Earth Systems and Environment, 2: 7. https://doi.org/10.1007/s40808-015-0062-x

Jeba Kumar E and Natesan U, 2015. Status and critical knowledge gaps for integrated lagoon management – Pulicat lagoon, India. Journal of Coastal Conservation, 19: 475–489. https://doi.org/10.1007/s11852-015-0401-0

Kaliaperumal N, Chennubhotla V, Kalimuthu S, Ramalingam J, Pillai S, Muniyandi K, Rao KR, Rao P, Thomas PC, Zaidi SH and Subbaramiah K, 1998. Seaweed resources and distribution in deep waters from Dhanushkodi to Kanyakumari, Tamil Nadu. Seaweed Research and Utilization, 20: 141-151.

Kamer K and Fong P, 2000. A fluctuating salinity regime mitigates the negative effects of reduced salinity on the estuarine macroalga, *Enteromorpha intestinalis* (L.) link. Journal of Experimental Marine Biology and Ecology, 254: 53-69. https://doi.org/10.1016/S0022-0981(00)00262-8

Kang JC, Choi HG and Kim MS, 2011. Macroalgae species composition and seasonal variation in biomass on Udo, Jeju Island, Korea. Algae, 26: 333-342. https://doi.org/10.4490/algae.2011.26.4.333

Kannan I and Krishnamurthy K, 1978. A survey of the algae of the Porto-Novo region (Coromandel Coast. Bay of Bengal). Seaweed Research and Utilization, 5: 1-4.

Kannan V, Manakadan R, Rao P, Mohapatra KK, Sivakumar S, Santharam V, 2008. The water birds of Pulicat Lake, Andhra Pradesh-Tamil Nadu, India, including those of the adjoining wetlands and heronries. The Journal of the Bombay Natural History Society, 105: 162-180.

Khan SI and Satam SB, 2003. Seaweed mariculture: Scope and potential in India. Aquaculture Asia, 8: 26-29.

Kijjoa A and Sawangwong P, 2004. Drugs and cosmetics from the Sea. Marine Drugs, 2: 73-82. https://doi.org/10.3390/md202073

Krishnamoorthy V and Baluswamy M, 2010. Ectocarpales, Sphacelariales, Dictyotales, Chordadariales and Scytosiphonales. In: Phaeophyceae of India and Neighbourhood (pp. 1-193). Volume 1. Koeltz Botanical Books, Germany.

Krishnamoorthy V and Ezhili R, 2013. The Fucales. In: Phaeophyceae of India and Neighbourhood (pp. 1-156). Volume 2. Krishnamurthy Institute of Algology, India.

Kumar CS, Ganesan P and Suresh PV, 2009. Seaweeds as a source of nutritionally beneficial compounds-a review. Journal of Food Science and Technology, 2009, 45: 1-13.

Manabe Y, Takii Y and Sugawara T, 2020. Siphonaxanthin, a carotenoid from green algae, suppresses advanced glycation end product-induced inflammatory responses. Journal of Natural Medicine, 74: 127-134. https://doi.org/10.1007/s11418-019-01354-z

Mantri VA, Singh RP, Bijo AJ, Kumari P, Reddy CRK and Jha B, 2011. Differential response of varying salinity and temperature on zoospore induction, regeneration and daily growth rate in *Ulva fasciata* (Chlorophyta, Ulvales). Journal of Applied Phycology, 23: 243–250. https://doi.org/10.1007/s10811-010-9544-4

Mukhopadhyay R and Karisiddaiah SM, 2014. The Indian coastline: Processes and landforms. In: Kale V (Ed.), Landscapes and Landforms of India - World Geomorphological Landscapes (pp. 91-101). Springer, Netherlands. https://doi.org/10.1007/978-94-017-8029-2_8

Oza RM and Zaidi SH, 2001. A revised checklist of Indian marine algae. In: CSMCRI Publication (pp. 1-296). Bhavnagar, India.

Pradhan B, Nayak R and Patra S, 2021. Bioactive metabolites from marine algae as potent pharmacophores against oxidative stress-associated human diseases: A comprehensive review. Molecules, 26: 1-37. https://doi.org/10.3390/molecules26010037

Rani V, Jawahar P and Jeya Shakila R, 2015. Seasonal variation in biomass and distribution of brown seaweeds (phaeophyceae) in Gulf of Mannar, Tamil Nadu, India, The Bioscan, 10: 1123-1129.

Riddin T and Adams JB, 2008. Influence of mouth status and water depth on the macrophytes in a small temporarily open/closed estuary. Estuarine, Coastal and Shelf Science, 79: 86-92. https://doi.org/10.1016/j.ecss.2008.03.010

Sahayaraj K, Rajesh S, Asha AN, Rathi JM and Raja P, 2014. Distribution and diversity assessment of the marine macroalgae at four southern districts of Tamil Nadu, India, Indian Journal of Geo-Marine Science, 43: 607-617.

Sanjeeva Raj PJ, 2006. Macro fauna of Pulicat Lake. In: National Biodiversity Authority, NBA Bulletin No. 6 (pp. 1-67). India.

Saraswathy R and Pandian PK, 2016. Pulicat Lake: A fragile ecosystem under threat. Slovak Journal of Civil Engineering, 24: 8-18. https://doi.org/10.1515/sjce-2016-0012

Shahidi F and Rahman MJ, 2018. Bioactives in seaweeds, algae, and fungi and their role in health promotion. Journal of Food Bioactives, 2: 58-81. https://doi.org/10.31665/JFB.2018.2141

Sunny AR, 2017. A review on effect of global climate change on seaweed and seagrass. International Journal of Fisheries and Aquatic Studies, 5: 19-22.

Thakur MC, Reddy CRK and Jha B, 2008. Seasonal variation in biomass and species composition of seaweeds stranded along Port Okha, northwest coast of India, Journal of Earth System Science, 117: 211-218.

Yogendra Prasad K, Deepika UR, Sowmya Shree G, Arpitha HS, Nimish Mol S, Kannan R and Ganesan P, 2019. β-carotene isolated from the marine red alga, *Gracilaria* sp. potently attenuates the growth of human hepatocellular carcinoma (HepG2) cells by modulating multiple molecular pathways. Journal of Functional Foods, 52: 165-176. https://doi.org/10.1016/j.jff.2018.11.015

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