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Factors affecting marine algae diversity and distribution along the Indian coastal region

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Abstract
Marine algae are primitive non-flowering photosynthetic plants inhabiting in seas and oceans that occupy 71% of the globe and they are natural renewable resources. They formed part of human life from time immemorial as food, besides their used as feed, fodder and manure. Marine algae are key space occupiers of rocky shores and interact with other organisms and hence play a key role in overall coastal biodiversity. They are found on rocks in the intertidal zone as a giant underwater forest. Marine algae grow abundantly along the Indian coastline particularly in rocky shore regions. The diversity and distribution of marine macro algal resources of Indian waters are affected since early 1970s due to over exploitation, sediment deposition and discharge of effluents, changes in the environmental factors, water temperature, light intensity, tidal waves, cyclones and consequence of bottom trawl fishing. As a result, there is decrease in algal production in Gulf of Mannar, Andhra coast and Kerala coast. On the other hand, there is rising demand for the phycocolloids viz. agar, algin, carrageenan and others. In this context there is an urgent need for conservation and better exploitation of the resources. Regulation of exploitation, control of pollution by domestic and industrial effluents, conducting algal culture are proposed as measures to overcome the damage to natural algal stocks to enable conservation and sustained production.

Keywords: biodiversity, marine algae, conservation, intertidal, renewable resources, environmental factors

1. Introduction
Marine algae are considered as ecologically and biologically important component in the marine ecosystems. Marine algae make a substantial contribution to marine primary production and provide habitat for nearshore benthic communities. The important and use of marine algae for various purposes in gaining momentum world over with bright prospects for future growth. Marine macro algae otherwise called "Sea vegetables" (or) Marine Vegetables are traditionally consumed in Asia. Marine algae had been used as human food from 600 to 800 BC. In china they had been used from prehistoric time. In china and Japan, they had been used as a staple diet for human beings for centuries. Fresh, dried and processed seaweeds are utilised for human consumption. Many types of seaweeds are used as human food in Japan, China, Philippines and other countries of Indo-pacific region. Moreover they are eaten as salad curry soup or jam. The marine macroalgae form a unique renewable resource of the Oceans as they have all the beneficial characteristics in one group of plants in the form of nutraceutical and pharmaceutical values. The marine macroalgae contain minerals, trace elements, iodine, bromine, proteins, carbohydrates, lipids etc. They are also a good source of vitamins, amino acids, growth hormones, bioactive substances and polysaccharides and have medicinal properties too (Renn, 1984; Chennubhotla *et al.*, 1987, 2013b; Ramalingam *et al.*, 2003; Krishnamurthy, 2011 Anantharaman *et al.*, 2011; Kaliaperumal, 2011; Umamaheswara Rao, 2011, Sarojini *et al.*, 2013) [36, 9, 32, 1. 9, 37]. In view of their importance as food, fodder, fertilizer, manure and as a raw material for extraction of phycocolloids like agar, algin and carrageenan etc. Earlier studies on mapping the macroalgae around the world have been restricted to aerial photography. Studies have been conducted in Great Barrier Reef using Landsat TM digital, SPOT and aerial data, mostly for inventorying macroalgal beds.

2. Commercial use of marine algae
In the recent past, marine macroalgae are also finding a place in integrated aquaculture systems (Umamaheswara Rao, 2011) [6]. Some polysaccharides (agar, carrageenan and alginate) extracted from brown and red algae are employed in various industries especially for culturing microbial organisms, genetic engineering, pharmaceutical, textile, food industry and in a host of other items (Kaliaperumal, 2011; Chennubhotla *et al*, 2013b) [36, 9]. Some of the marine algae exhibit antimicrobial, antifungal, antiviral, diuretic, spasmolytic, hypertensive, anti-fertility properties and also used in the treatment of goiter and as ichthyotoxic compound (Anantharaman *et al.*, 2011; Umamaheswara Rao, 2011; Kalaiyarasi and Rajasulochana, 2014) [1, 6, 19]. The other medicinal properties of marine algae are in combating tuberculosis, cancer, influenza and in ulcer therapy and also as a laxative for intestinal and stomach disorders, as vermifuge etc (Chennubhola *et al.*, 1987; Anantharaman *et al*:, 2011) [1]. Commercial use of concentrated marine algal extracts in seed treatment and for root and foliar application have become popular by brand names Algifert, Sm3, Seaspray etc (Anantharaman *et al.*, 2011; Venkataraman Kumar, 2011) [1, 4].

3. Marine Algae used for small-scale fishing communities
Marine macroalgae are collected from southeast coast of India, especially from Gulf of Mannar area as a means of livelihood; since algal collection plays a major role in the living of small-scale fishing communities. More than 5,000 women are directly

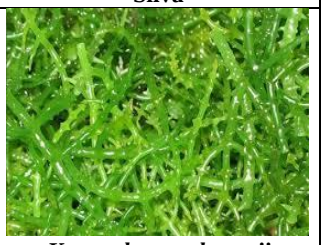
Involved in algal collection from the fishing villages in the Rameswaram Island and those in the Kilakkarai area, of the Gulf of Mannar. Another 5,000 people are dependent on seaweed related activities and industries in the region and each person collect about10-15 kg of seaweed per day.

Marine Algae of Commercial Importance

Gracilaria corticata* (J. Agardh) J. Agardh *var cylindrica

***Gracilaria edulis* (S. Gmelin) P. Silva**

***Sargassum tenerrimum* J. Agardh**



Kappaphycus alvarezii

The price for the seaweeds (in dried condition) varies from species to species depending upon the moisture content *Gelidiella. acerosa* at 70-75/ per kg; *Gracilaria edulis*at 20 to 22/ per kg.; *Sargassum and Turbinaria* sp. at Rs.12 to 15/- per kg. And *Kappaphycus alvarezii* at Rs. 30 per kg (Ramya Rajagopalan, 2008) [33] the species collected in large quantities are *Gelidiella acerosa*, *Gracilaria Certicata* (agarophytes) and species of *Sargassum, Turbinaria* (alginophytes) (Plate-1). These species grown the shallow waters around the 21 islands in the Gulf of Mannar area. The collection is seasonal. The suitable seasons for harvest of *Gelidiella corticataa* and *Gracilaria sp are* from January-March and July-September. For species of *Sargassum, Turbinaria* and *Hypnea*, October to December / January are recommended (Kaliaperumal, 2007) [9]. The women earn approximately Rs. 400/- to 450/- per day, when they sell the seaweeds on an average of Rs15/kg. In dry form. These seaweeds are sold to the agar processing industries located in Madurai, a city 120 km away from Ramanathapuram (Ramya Rajagopalan, 2008) [33]. It is estimated that the marine algal based industries in India produce about 80- 100 tonnes of agar, 350-400 tonnes of algin and 250 tonnes of carrageenan from cultured *Kappaphycus alvarezii* (Plate-1) annually and utilized for various industrial requirements mentioned above. (Anon, 2003; Kaliaperumal, 2011) [2, 9].

4. Loss of algal diversity

The decline in algal diversity in recent decades is matter of great concern (Tillman *et al*., 1997; Hopper *et al.,* 2005. Raja Saravanan *et al*., 2015) [30]. The algal diversity is being lost by natural threats like storms and tidal waves in some years and during monsoon periods the excess fresh water runoff kills many of the fauna and flora in semi enclosed bays and lagoons by lowering salinity and depositing large amounts of sediments and nutrients. The increasing tourist traffic also is one of the causes of disturbing the biodiversity. There is tremendous change in the marine environment due to urbanization and construction activity in addition to industrial pollution and illegal mining of coral reefs in the coastal areas. The biodiversity and density of marine algae of Gulf of Mannar have come down gradually over a period of years (Krishnamurthy, 2006; Kannan and Thangaradjou, 2006; Kaliaperumal, 2007) [24, 22, 9]

The gradual rise in temperature, impact of anthropogenic activity, release of sewage are cited as factors for changes in diversity of algae and extensive reduction in number of species up to 50% at Visakhapatnam (Sarojini *et al.*, 2013) [37]. These findings were corroborated by the works of Wood and Zeiman, 1969; Lubchenko and Graines, 1981 [26] and Chi Chung *et al.*, 2007 [10]. The rise in temperature led to heavy mortality of *Kappaphycus alvarezii* crop in some villages of Tamil Nadu during August - September, 2013 (Gopakumar *et al.*, 2014) [14]. In the laboratory experiments conducted at the Regional Centre of CMFRI, Mandapam Camp by these authors with *Kappaphycus alvarezii* has indicated that in culture tanks having water temperature of 31°C and above have started to lose pigments and finally became bleached. Hence, regular monitoring of water temperature by algal farmers is essential to protect the crop until harvesting.

The influence of industrial wastes and other pollutants on the physiological processes of 9 marine macro algae of Visakhapatnam coast was studied by Umamaheswara Rao and Murthy (2011) [7]. They found that exposure to lower concentrations of industrial effluents from Hindustan zinc and Alum factory even for one day was enough for impairing the metabolic activities of the algae. These findings are in agreement with the observations of Hellenbrand (1977) [17], Gutknecht (1961) [16], Reed and Moffet (1983) [34] and Rai *et al.*, (1981). Marked inhibition in photosynthesis and respiration and inactivation of enzyme systems operating the biochemical processes of the algae due to exposure to industrial pollutants released in to the marine environment, were observed by Murthy and Umamaheswara Rao (2003) [7] in the experiments conducted for 25 days.

The gradual disappearance of marine algae along Visakhapatnam coast by disturbances created by discharge of effluents, environmental factors, tidal waves, cyclones is well. Evidenced by the studies of Umamaheswara Rao and Sreeramulu (1963) [6] and Sarojini *et al.* (2013) [37].

Who reported 80 species and 40 species respectively? Similarly, the rich algal flora (200 species) once recorded in Gulf of Mannar in 1970s have become scarce (80 species) after 1980 due to indiscriminate collection of algae in the region.

The species which are endangered and facing extinction in that region (Kaliaperumal, 2007) [9] are listed in the Table-1.

Table 1: List of some marine macro algae facing extinction

Green Algae	
1.	Neomeris annulata
2.	Avrainvillea erecta
3.	Boodlea composita
4.	Microdicty ontenuis
5.	Valonia aegagrophila
6.	Dictyosphaeria cavernosas
7.	Iyengaria stellata
Brown Algae	
9.	Dictyopteris delicatula
Red Algae	
10.	Liagora albicans
11.	Gelidium micropterum
12.	Grateloupia filicina
13.	Pterocladia heteroplatos
14.	Gracilaria arcuata
15.	G. Textorii
16.	G. Verrucosa
17.	Dictyurus Purpurascens
18.	Martensia fragilis
19.	Leveillea junger mannioides
20.	Vanvoorsia spectabilis

5. Conservation measures for preserving marine algae diversity.

The industry has to conduct harvesting of marine algae from natural beds during season of peak growth for which time tables are available with CMFRI. Training programmes have to be organized periodically for fishermen, farmers and industry personnel to impart knowledge regarding the methods of harvesting and favourable period for harvesting the required raw material.

- Department of wildlife should strictly implement the regulations on the exploitation of marine algal resources.
- Algal diversity can be enhanced through introduction of exotic species but must be done after sufficient experimentation only, to prevent causing any imbalance in the ecosystem
- The industries located along the coast must follow strict effluent treatment procedures before discharging the effluents in to the marine environment.
- The Pollution Control Authorities should use ulmost discretion while granting permission to start an industry along seashore.
- Planning of Marine National Parks where the marine living resources (germplasm & biodiversity) are conserved and protected for the future generations.

Marine National Parks: (Dorairaj and Soundarrajan, 1997; Melkani *et at.*, 2006, Ramya Rajagopalan, 2008; Chennubhotla e/a/., 2011) [33].

- In order to control the disturbances, the Government of India has established marine protected areas (Marine National Parks) for conservation of flora and fauna (germ plasm and biodiversity) to protect marine algae and other biota.
- Great Nicobar Island was declared as a Reserve in January, 1989. It incorporates two National parks of India namely Campbell Bay National Park on the northern part of the island and Galathea National Park on the southern part and contains 109 species of marine algae apart from other biota.
- Gulf of MannarNational Park to protect 148 species of marinealgae.
- Marine National Park in the Gulf of Kutch with 108 species of marinealgae.
- Mahatma Gandhi marine national park, Wandoor, Andaman Nicobar Islands - The algal coverage was represented by *Gracilaria*, *Turbinaria, Sargassum, Padina* and *Halimeda.*
- The marine ecosystem of Malvan: The Malvan Marine Wildlife Sanctuary with 49 species of marine algae. The NIO has investigated the ecology and biotain the sanctuary
- These national parks must be maintained and monitored regularly for preserving the algal diversity in the region.

Recommendations

Remote sensing tools such as aerial photography, airborne and satellite imagery are appropriate for surveying and classifying marine habitats (Guillaumont *et al,* 1993; Kracker, 1999) [15, 23] in the tidal zone. Acoustic methods are suitable to remotely sample seafloor texture and depth in waters as deep as 200 meters (Brown *et al.,* 2002) [4]. Usually some combination of environmental parameters is assumed to control the distribution of species and habitat types (Day and Roff, 2000) [11]. The key parameters usually used are depth, roughness of seabed, nature of substratum, exposure to waves, temperature and current strength. (Baxter, 2003) [3]. Studies based on the above aspects may be taken up in Indian coastal waters also to assess the deep water marine algal resources.

- Installation of Artificial Reef structures in the coastal waters by submerging suitable additional substrata for settlement & recolonization of algae.
- Biotechnological techniques such as somatic cell hybridization and protoplast fusion must be taken up to get improved varieties of algae of economic importance.
- Cultivation of highly priced varieties such as *Kappaphycus alvarezii* has to be taken up and training imparted to fish farmers on farming of this important carrageenophyte. At

present Aquagri (P) Ltd. is culturing this marine alga using raft method along Tamil Nadu coast.

- Regular monitoring of fluctuations in salinity and water temperature must be carried out in the culture farms, as they play an important role in healthy growth of algae. Any increase in these factors will lead to large scale mortality of the marinealgae.
- Spore culture of economically important species like *Gracilaria edulis* also proved successful and needs further studies for taking to commercial scale (Reeta Jayasankar and Kaliaperumal, 1991; Reeta Jayasankar, 1992 P.V. Subbarao *et al*., 2016) [9, 35, 29]. Thus there is enormous potential to augment algal production through culture practices from the present level which will enable to meet the ever rising demand in various countries.
- The bottom trawl and shore seine fishing must be banned in the areas between Gulf of Mannar islands and main land and also in and around the islands upto 4 m. depth where marine macroalgae grow abundantly.

6. Conclusion

Marine ecologists have a long history of using artificial substrate and habitats to test hypothesis about sessile plants and animals. The marine algae biomass on test panels was high during pre-monsoon & monsoon seasons. The observed pattern of seasonal distribution is likely to be related to the life history of the algae, particularly the dispersal abilities of its spores. The supply from macroalgal propagule may influence the abundance of algae in literal hesitate. As the test panels provide limited spaces for the settlement of marine organism including seaweeds, the seasonal biomass of only a few species could be observed. Gradual rise in the arthropogenic influence, impact of the possible thermal discharge from the emerging nuclear power station and the indiscriminate collection of algae. Marine algal are under threat in developing countries, where they are being disturbed by a variety of human activities. Increasing concern on destruction of seaweeds resources and alteration in the diversity of various life forms make it necessary the studies on taxonomy and species diversity for a better management of marine algae. From the foregoing account it can be seen that marine algae play a very important role in frontier areas of science, industry and livelihoods. Hence efforts must be made by the concerned Agencies and Organizations to protect and safeguard this valuable resource by enforcing strict conservative measures.

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