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Marine macroalgal resources from nine beaches along the Kerala coast, India

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Original Article

Abstract

Estimates of number, density and wet biomass of seaweed resources and their availability for exploitation for phycocolloid extraction along the Kerala coast in relation to water quality were studied using the data collected at quarterly intervals from nine stations during 1998 and 1999. A total of 37 species of seaweeds were collected and out of these, 13 were grouped under Class Chlorophyceae (green seaweeds), 7 under Phaeophyceae (brown seaweeds) and 17 under Rhodophyceae (red seaweeds). Agar yielding seaweeds were represented by seven species and the major resources were *Gracilaria corticata, G. foliifera, Gelidiopsis variabilis* and *Gelidium pusillum* during 1998 and 1999 besides the species of *Pterocladia* during 1999. Alginophytes were represented by *Sargassum wightii, S. duplicatum, S. tenerimum, Stoechospermum marginatum, Dictyota dichotoma* and *Padina* spp. The carrageenan yielding red seaweeds were more in number (nine species) belonging to seven Genera. Out of them, *Hypnea musciformis, H. valentiae, Grateloupia filicina, G. lithophila* and a new resource *Gracilariopsis lemaneiformis*, from Dhalavapuram and Kannur stations were available in considerable quantities. The richest diversity of seaweeds was observed at Mullur (Vizhinjam) and Thikkodi (Calicut) followed by Thirumallavaram (Quilon).

Keywords*: Seaweeds, resource assessment, Kerala coast, hydrography, agarophytes*

Introduction

All macroscopic algae occurring in the marine, coastal and brackish water habitats are termed as seaweeds. They are autotrophic non-flowering plants and grow either as free floating in the sea surface or attached on rocks, shells or on dead corals in intertidal and subtidal regions. In India luxuriant growth of several species of seaweeds occur along the southeast coast of Tamilnadu, Gujarat, Lakshadweep (Laccadives) and Andaman-Nicobar Islands (Umamaheswra Rao, 1969; Chennubhotla, 1996; Kaliaperumal, 1993). Indian coastline is endowed with 844 species of marine algae comprising 216 species of Chlorophyta, 191 species of Phaeophyta, 434 species of Rhodophyta and 3 species of Xanthophyta (Oza and Zaidi, 2001). From the seaweed resource surveys carried out in the intertidal and shallow water areas of east and west coasts and also the archipelago of Laccadives and Andamans so far by CMFRI Cochin, CSMCRI Bhavnagar and NIO Goa, it could be estimated that total standing crop of all the seaweeds in Indian waters is more than 2,60,876 tonnes (wet weight) consisting of 6% of agar yielding red seaweeds, 16% of algin yielding brown seaweeds, 8% of carragenophytes and the remaining edible and other seaweeds (Devaraj *et al.*, 1999). Recent developments on

seaweed resources, their culture and utilization in India were reviewed by Baby Ushakiran *et al.* (2014).

Marine algal resources of southern Kerala coast including Ashtamudi Lake, Quilon and Trivandrum coasts were assessed qualitatively by Balakrishnan Nair *et al.* (1982, 1986, 1986a, 1990, 1993). Chennubhotla *et al.* (1988) conducted an extensive resource assessment survey along the Kerala coast and brought out the details of availability of economically important resources for the first time. Occurrence of *Porphyra kanyakumariensis* was reported from the southern Kerala coast by Chennubhotla *et al.* (1990). *Gracilariopsis lemaneiformis*, a long thalloid red alga has been reported from the Kumbala backwaters near mangrove patches along Kerala coast (Kaladharan, 2005). In this communication an attempt is made to assess the seaweed resources, density and their availability for exploitation for phycocolloid extraction along the Kerala coast in relation to water quality during 1998 and 1999.

Material and methods

Nine study sites as shown in Fig. 1 were selected along the Kerala coast after visiting the entire coast. Main criteria for selecting the study sites were approach through road and the presence of hard substratum for seaweed growth. The geographical locations of the study sites were marked with the help of hand held geographical positioning system (GPS mp 76 CSX, Garmin model). Seaweeds were collected from the above sites at quarterly intervals during 1998 &1999 at low tide as recorded in the Indian Tide Table when the beach was exposed. The seaweeds collected from each sites were cleaned with seawater and brought to the laboratory separately for further observations. Density of macroscopic seaweeds from each study sites was estimated using a quadrate ($1m^2$). Five quadrats were laid randomly at each site to estimate the standing crop. Seaweeds present in each quadrat harvested were pooled together, washed thoroughly with seawater, brought to shore, and the wet biomass was estimated using a top pan balance, spread in a sheet, sorted by species and weighed separately. Afterwards, each species was put in separate polyethylene covers and brought to laboratory for processing. Based on the wet weight and density, the dominant species in a particular period from each study site was identified. Species were identified using the identification key prepared by Umamaheswara Rao (1987).

Standing stock of seaweed was estimated using the following formula.

$$W = \frac{w}{a}$$

where *w* is the standing stock of a particular species of a particular site,

w is the wet biomass of seaweed harvested from 5 quadrates

a is the total area studied i.e. 5 m^2.

The hydrographic parameters such as water temperature (SST), pH, salinity, dissolved oxygen and the dissolved nutrients like phosphate and nitrate from the study sites were estimated quarterly using standard procedures (APHA, 1998; Parsons *et al.*, 1984). Dissolved Phosphate was determined according to Murphy and Riley (1962). Nitrate dissolved in seawater was estimated according to the method of Morris and Riley (1963). The data collected were statistically analysed using SPSS software (version 13.0). For the comparison of different locations with respect to the harvestable biomass of different species of seaweeds, one way analysis of variance (ANOVA) were carried out using SPSS software (version 13.0). Seasonal difference in the harvestable biomass of different species of seaweeds was also tested using ANOVA.

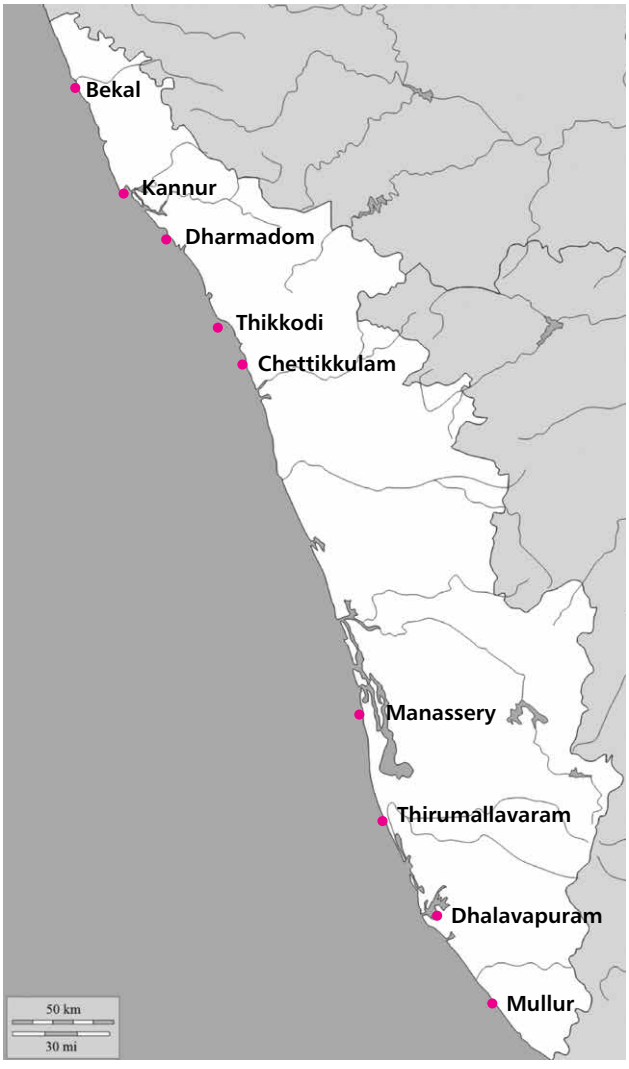

Fig.1 Sampling locations along Kerala coast

Table 1. Annual mean of wet biomass of seaweed resources at nine stations along the Kerala coast (g/m^2) during 1998 and 1999

Seaweeds	Mullur		Dhalavapuram		Thirumallavaram		Manassery		Chettikulam		Thokkodi		Dharmadom		Kannur		Bekal	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Bryopsis plumosa	0	2.5	0	0	0	0	0	0	0	0	0	0	3.75	2.5	0	0	0	6.25
Caulerpa cupressoides	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulerpa peltata	3.75	5	0	0	1.25	0.75	0	0	0	0	0	3	0	0	0	0	0	0
Caulerpa racemosa	11.25	8.75	0	0	3.75	0	0	0	0	0	0	4.5	0	0	0	0	0	0
Caulerpa sertularioides	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Chaetomorpha antennina	8.75	13	0	0	8.25	22	30.3	26.75	22.5	23.8	12.5	3.75	42.5	8.75	35	18.8	24.5	10
Chaetomorpha linum	0	0	20	10	0	0	0	0	0	0	3.75	3.75	0	0	0	0	0	0
Cladophora fascicularis	1.5	3.75	0	0	0	0	0	0	0	0	3	2.5	0	0	0	0	0	6.25
Enteromorpha compressa	0	0	58.75	25	0	0	0	0	0	0	2.5	0	0	0	0	0	0	2.5
Enteromorpha intestinalis	0	0	0	0	0	0	0	0	8.75	15			0	0	0	5	0	3.75
Ulva facsiata	26.25	6.25	0	0	43.75	7.5	0	0	11.8	3.75	8.75	7.5	16.3	3.75	3.75	8.75	15	10.3
Ulva lactuca	5.75	35.5	0	0	7.5	0	0	0	14.3	27.5	2.5	2.5	0	2.5	0	0	0	0
Ulva reticulata	0	0	25	16.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyota dichotoma	0.75	0	0	0	0	1.5	0	0	0	3.75	3.75	0	0	7.5	0	0	0	0
Padina gymnospora	7.75	2.5	0	0	1.25	0	0	0	2.5	0	6.25	5.5	0	5	0	0	0	0
Padina tetrastromatica	4.5	5.5	0	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0
Sargassum duplicatum	0	3.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum tenerimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum wightii	108.8	141	0	0	2.5	65	0	0	0	0	6.25	25	0	0	0	0	6.25	0
Stoechospermum marginatm	0	0	0	0	0	10	0	0	0	0	4.5	13.3	0	0	0	0	0	0
Acanthophora spicifera	4	4	0	0	0	0	0	0	3.75	0	0	0	7.5	5	0	0	6.25	10.5
Amphiroa anceps	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	2	0
Asparagopsis taxifomis	48.5	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centroceros clavulatum	0	3.75	0	0	0	9.25	6.25	3.75	10.5	6.25	5.75	10	0	7.5	3.75	10	3.75	5
Chondrus sp.	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Gelidium pusillum	3	6	0	0	5.75	40	0	0	8.25	8.75	7.5	10	2.5	7.5	0	5	1.75	0
Gelidiopsis variabilis	10	2	0	0	6.25	2	0	0	0	0	4.25	6.25	0	2.5	0	0	0	0
Gracilaria corticata	57.5	48.8	0	0	71.25	115	0	0	50	35	41.3	20	51.3	47.5	42.5	32.5	17.5	28.8
Gracilaria foliifera	11.25	3.75	0	0	20	0	0	0	5	0	4.5	3.75	0	0	0	0	0	10
Gracilariopsis lemaneiformis	0	0	65	130	0	0	0	0	0	0	0	0	0	0	38.8	38.8	0	0
Grateloupia filicina	0	0	0	0	2.5	0	9.25	15	0	6.25	0	0	10	0	0	0	0	3.75
Grateloupia lithophila	0	0	0	0	15	1.25	16.8	5	8.75	11.3	0	0	8.75	0	5	0	3.75	0
Hypnea musciformis	2.5	2.5	3.75	0	5	0	0	0	0	0	10	10	2.5	0	0	0	11.3	12
Hypnea valentiae	25.5	16.8	0	0	42.5	25	0	0	3.75	0	3.75	11.3	0	8.75	0	3.75	5	3.75
Jania rubens	0	0	0	0	2	0	0	0	0	0	0	1.25	0	0	0	0	0	1.25
Laurencia paniculata	17.5	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterocladia sp.	0	0	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0
Total (g/m^2, wet weight)	359	344	173	181.3	238.5	299.25	62.5	50.5	150	141	133	161	145	108.8	129	125	97	114

Results

Annual mean of wet biomass of seaweeds harvested from each collection sites (Fig. 1) along the Kerala coast during the four quarters of 1998 and 1999 are presented in Table 1 and the species of seaweeds collected from these sites are listed in Table 2.

Mullur

Mullur is a rocky coast and hence serves as an excellent substratum for seaweed growth. During the year 1998, Mullur coast registered 359 g/m^2 average wet biomass of seaweeds that can be harvested, ranging from 451 g/m^2 in March to 270 g/m^2 in December. Red seaweeds such as *Hypnea valentiae* (25.5 g/m^2), *Asparagopsis taxiformis* (48.5 g/m^2), *Gracilaria corticata* and *G. foliifera* (73.75 g/m^2) and brown seaweeds such as *Sargassum wightii* (109 g/m^2) were present throughout the year in appreciable quantities. However, the year 1999 registered an average wet biomass of 344 g/m^2 seaweeds ranging from 307 g/m^2 in March to 495 g/m^2 during June with only 6 species of seaweeds. Although during December the number of species increased to 17, the harvestable biomass was only 315 g/m^2 (Table 1). During June 1999 luxurient growth of green seaweed *Ulva fasciata* (100 g/m^2) could be harvested. Mullur was identified as an excellent site in Kerala for collecting *Sargassum wightii* (140.75 g/m^2), the raw material for alginic acid production throughout the year.

Dhalavapuram

Dhalavapuram is a brackish water area in the Ashtamudi Lake system harbouring rich growth of red alga *Gracilariopsis lemaneiformis*. A total of five species of seaweeds could be collected during the study period (Table 1). The average seaweed biomass that could be harvested from Dhalavapuram was estimated to 173 g/m^2 during 1998 and 181 g/m^2 during 1999. During March 1998, 180 g/m^2 of *Gracilariopsis lemaneiformis* was found growing along with the carrageenan yielding *Hypnea musciformis* and green seaweed *Enteromorpha compressa*. The last quarter also registered rich biomass of seaweeds (200 g/m^2) comprising fairly dense vegetation of *Gracilariopsis lemaneiformis, Enteromorpha compressa* and *Chaetomorpha linum*. Subdominant species were *Enteromorpha compressa* (60 g/m^2 in June and 50 g/m^2 in December) and *Ulva reticulata* (40 g/m^2 in June). Another green seaweed, *Chaetomorpha linum*, was encountered during December in appreciable quantity (40 g/m^2).

Thirumallavaram

Thirumallavaram coast is characterized by laterite rocky substratum extending to shallow sea and known to harbour rich diversity (17 species) of seaweeds especially dense vegetation of carrageenan yielding *Hypnea valentiae* (160 g/m^2) and *Ulva fasciata* (140 g/m^2) during December 1998 (mean wet biomass 238.5 g/m^2) and considerable wet biomass of agar yielding *Gelidium pusillum, Gracilaria corticata* (100 g/m^2 each) as well as 150 g/m^2 of *Sargassum wightii* in December 1999 (mean wet biomass 299 g/m^2). However, during 1999 the number of species

Table 2. List of seaweeds collected from Kerala coast during 1998 and 1999

Sl.No	Species
Chlorophyceae	
1	*Bryopsis plumosa*, C. Agardh.
2	*Caulerpa cupressoides*, C. Agardh.
3	*Caulerpa peltata*, Lamour.
4	*Caulerpa racemosa*, Forsskal
5	*Caulerpa sertularioides*, F. Brevioes
6	*Chaetomorpha antennina*, (Borey.) Kuetz.
7	*Chaetomorpha linum* (O. F.Muller) Kuetz.
8	*Cladophora fascicularis*, (Merteos) Kuetz.
9	*Enteromorpha compressa*, (Linn.)Grev.
10	*Enteromorpha intestinalis*, Kuetzing
11	*Ulva facsiata*, Delila
12	*Ulva lactuca*, Linn.
13	*Ulva reticulata*, Forsskal
Phaeophyceae	
14	*Dictyota dichotoma*, (Huds.) Lamour.
15	*Padina gymnospora*, (Kuetz.) Vickers
16	*Padina tetrastromatica*, Hauck.
17	*Sargassum duplicatum*, J. Agardh.
18	*Sargassum tenerimum*, J. Agardh.
19	*Sargassum wightii,* Grev.
20	*Stoechospermum marginatum*, (C. Agardh.) Kuetz.
Rhodophyceae	
21	*Acanthophora spicifera*, (Vahl.) Boergesen
22	*Amphiroa anceps*, (Lamk.) Decsne.
23	*Asparagopsis taxifomis*, Delila
24	*Centroceros clavulatum*, C. Agardh.
25	*Chondrus* sp.
26	*Gelidium pusillum*, Stackhouse
27	*Gelidiopsis variabilis*, (Grev.) Schmitz
28	*Gracilaria corticata*, J. Agardh.
29	*Gracilaria foliifera*, (Forsskal) Boergesen
30	*Gracilariopsis lemaneiformis*, (Borey) Dawson
31	*Grateloupia filicina*, J. Agardh.
32	*Grateloupia lithophila*, Boergesen
33	*Hypnea musciformis*, (Wulf.) Lamour.
34	*Hypnea valentiae,* Mont.
35	*Jania rubens*, (Linn.) Lamour.
36	*Laurencia paniculata*, J. Agardh.
37	*Pterocladia* sp.

that could be collected reduced to only 12 although a rarely occurring alginic acid yielding brown seaweed *Stoechospermum marginatum* was encountered during December (Table 1).

Manassery

Manassery coast is protected with seawall made of granite boulders and this substratum harboured very few seaweed species. The year 1998 registered a mean harvestable biomass of 62.5 g/m^2 belonging to 4 species and in 1999 these four species of seaweeds registered mean biomass of 50.5 g/m^2 (Table 1). Economically important resources were carrageenan yielding red weeds such as *Grateloupia filicina* (9.25 g/m^2 in 1998 and 15 g/ m^2 in 1999) and *Grateloupia lithophila* (16 g/m^2 in 1998 and 5 g/m^2 in 1999). Other resources were *Chaetomorpha antennina* (30.25 g/m^2 in 1998 and 26.75 g/m^2 in 1999) and *Centroceros clavulatum* (6.5 g/m^2 in 1998 and 3.75 g/m^2 in 1999).

Chettikulam

Chettikulam coast is armoured with many patches of laterite rock formations which serve as ideal substratum for seaweeds and green mussels. During 1998 the mean seaweed biomass that could be harvested was150 g/m^2 constituted by 12 species and only 141 g/m^2 during 1999 comprising 11 species. Dominant vegetation here was *Gracilaria corticata* (50 g/m^2) ranging from 25 - 80 g/m^2 during 1998 and 35 g/m^2 during 1999 showing maximum during December 1998. The subdominant species were green seaweeds *Chaetomorpha antennina* (22.5 g/m^2) and *Ulva* (14.25 g/m^{2}of *Ulva lactuca* and 11.75 g/m^2 of *Ulva fasciata*). No *Sargassum* sp were encountered during our study period. However, 35 g/m^2 density of *Grateloupia lithophila* during June 1998, 15 g/m^2 of *Hypnea valentiae* during September 1998 and 23 g/m^2 of *Gelidium pusillum* during December1998 were obtained from this coast. During the year 1999, in addition to *Grateloupia lithophila, G. filicina* was also encountered (Table 1).

Thikkodi

Thikkodi coast also has very good laterite rocky substratum to support dense vegetation of seaweeds, estimated with an mean annual wet biomass of 133 g/m^2 during 1998 constituted by 19 species and a mean biomass of 161 g/m^2 during 1999 with 23 species. Rarely occurring red seaweed, *Pterocladia* sp. (8 g/ m^2) during December 1998 and during September 1999 (20 g/ m^2), *Chondrus* sp. (20 g/ m^2) during December 1999 and brown seaweed *Stoechospermum marginatum* (18 g/m^2 during December 1998, 35 g/m^2 during June 1999 and 18 g/m^2 during December 1999) were observed from Thikkodi coast. Maximum in the annual biomass of individual species was registered by *Gracilaria corticata* (41.25 g/ m^2 during 1998) and by *Sargassum wightii* (25 g/ m^2 during 1999; Table 1).

Dharmadom

Dharmadom station is in the vicinity of Dharmadom estuary. Here the seaweed species diversity was not so rich as that of Thikkodi and the annual mean harvestable biomass of seaweeds ranged from 108 g/ m^2 during 1999 comprising 13 species to 145 g/ m^2 during 1998 formed of only nine species. The dominant species occurring throughout the study period was *Gracilaria corticata* (51 g/m^2 during 1998 and 47.5 g/ m^2 during 1999). The subdominant species was *Chaetomorpha antennina*. Green seaweed *Bryopsis plumosa* was recorded during September 1998 as well as during December1999. Considerable quantity of carrageenan yielding red seaweeds *Grateloupia filicina* and *G. lithophila* were observed during December 1998 and *Hypnea valentiae* (35 g/ m^2) during December 1999 (Table 1).

Kannur

Kannur station is characterized by the Mopla Bay housing the Kannur Fisheries Harbour inside and the rocky beach on the northern side. Long thalloid form of red seaweed, *Gracilariopsis lemaneiformis* was available in the Bay area during March and December of both the years. The annual mean harvestable biomass of seaweeds during 1998 was 129 g/m^2 constituted by 6 species including 38.75 g/m^2 of *Gracilariopsis lemaneiformis* and 42.5 g/m^2 of *Gracilaria corticata* (Table 1). Similarly the annual mean harvestable biomass of seaweeds during 1999 was 125g/m^2 comprising 9 species dominated by 38.75 g/m^2 of *Gracilariopsis lemaneiformis* (120 g/m^2 during December) and 32.5 g/m^2 of *Gracilaria corticata*. Among the carrageenophytes, *Grateloupia lithophila* was observed during December 1998 (20 g/m^2) while, *Hypnea valentiae* was recorded during December 1999.

Bekal

Bekal station is situated close to the Bekal Fish Landing Centre and the Bekal Fort surrounded by rock formations which showed mean biomass of 97 g/m^2 during 1998 constituted by 11 species of seaweeds and 114 g/ m^2 during 1999 comprising 14 species. While the dominant species during 1998 was *Chaetomorpha antennina* (24.5 g/ m^2), during 1999 it was *Gracilaria corticata* (28.75 g/ m^2). Coralline red algal species *Amphiroa anceps* was recorded during September 1998 and *Jania rubens* during December 1999. Carrageenophytes of Bekal during 1998 were represented by four species such as *Acanthophora spicifera* (June and December), *Grateloupia lithophila* (December), *Hypnea musciformis* (except during September) and *Hypnea valentiae* during September. Similarly carrageenan yielding seaweeds during 1999 were *Hypnea musciformis, Acanthophora spicifera* during September - December and *Grateloupia filicina* as well as *Hypnea valentiae* during December only (Table 1).

Distribution of seaweed resources along the Kerala coast

From the nine selected stations along the Kerala coast (Fig. 1), a total of 37 species of seaweeds could be collected during

Table 3. Annual mean of water quality parameters of seaweed beds of Kerala coast during 1998 and 1999.

Stations	Temperature (°c)	pH	Salinity (ppt)	DO (ml/l)	PO_4 (μg at/l)	NO_3 (μg at/l)
Mullur	28.84 ± 1.96	7.57 ± 0.40	29.95 ±2.50	3.69 ± 0.31	1.33 ± 0.58	1.57 ± 0.95
Dhalavapuram	29.84 ± 0.87	6.95 ± 0.41	21.09 ±3.39	3.51± 0.32	1.457 ± 0.66	2.79 ± 1.54
Thirumallavaram	27.01 ± 2.09	7.98 ± 0.07	29.86 ±1.95	3.88 ± 0.36	1.45 ± 0.37	0.44 ± 0.19
Manassery	28.85 ± 1.11	7.65 ± 0.69	29.53 ±3.68	3.68 ± 0.45	0.72 ± 0.42	0.67 ± 0.36
Chettikulam	29.81 ± 1.47	7.97 ± 0.71	33.15 ±1.10	4.05 ± 0.65	1.24 ± 0.66	1.32 ± 1.05
Thikkodi	30.39 ± 1.79	8.08 ± 1.03	30.4 ± 1.06	4.03 ± 0.21	1.0 ± 0.25	1.3 ± 0.55
Dharmadom	27.65 ± 1.87	7.96 ± 0.14	30.04 ±5.28	4.08 ± 0.19	0.58 ± 0.6	2.38 ± 1.89
Kannur	28.56 ± 1.76	7.89 ± 0.21	29.81 ±1.74	3.98 ± 0.30	0.353 ± 0.23	2.0 ± 0. 93
Bekal	29.2 ± 0.78	7.9 ± 0.32	30.1 ± 2.38	3.93 ± 0.68	0.18 ± 0.3	0.71 ± 0.37

mean ± SD, n=8

1998 and 1999 and they were enlisted in Table 2. Out of the 37 species 13 were grouped under Class Chlorophyceae, 7 under Phaeophyceae (brown seaweeds) and 17 under Rhodophyceae (red seaweeds). Agar yielding seaweeds or the agarophytes that can be harvested for extraction of agar were represented by seven species and the major resources were *Gracilaria corticata, G. foliifera, Gelidiopsis variabilis* and *Gelidium pusillum* during 1998 and 1999 besides the species of *Pterocladia* during 1999. Alginophytes were represented by *Sargassum wightii, S. duplicatum, S. tenerimum, Stoechospermum marginatum, Dictyota dichotoma* and *Padina* spp. The carrageenan yielding red seaweeds were more in number (nine species) belonging to seven Genera. Out of them, *Hypnea musciformis, H. valentiae, Grateloupia filicina, Grateloupia lithophila* and a new resource *Gracilariopsis lemaneiformis* from Dhalavapuram and Kannur stations were available in appreciable quantities (Table 1).

Hydrography of seaweed beds of Kerala coast

The quarterly observation on the seawater quality parameters such as seawater surface temperature (SST), pH, dissolved

Table 4. Pearson Correlation of six hydrographic variables of nine stations

		Temp.	pH	Salinity	DO	PO_4	NO_3	Seaweed biomass
Temp	Pearson Correlation	1	0.160	0.249*	0.214	-0.204	0.019	-0.059
	Sig. (2-tailed)		0.181	0.035	0.071	0.086	0.871	0.625
	N	72	72	72	72	72	72	72
pH	Pearson Correlation	0.160	1	0.819**	0.422**	-0.360**	-0.395**	-0.059
	Sig. (2-tailed)	0.181		0.000	0.000	0.002	0.001	0.625
	N	72	72	72	72	72	72	72
Salinity	Pearson Correlation	0.249*	0.819**	1	0.432	-0.244*	-0.586**	0.012
	Sig. (2-tailed)	0.035	0.000		0.000	0.039	0.000	0.919
	N	72	72	72	72	72	72	72
DO								
	Pearson Correlation	0.214	0.422**	0.432**	1	-0.260*	-0.106	-0.006
	Sig. (2-tailed)	0.071	0.000	0.000		0.027	0.375	0.961
	N	72	72	72	72	72	72	72
PO_4	Pearson Correlation	-0.204	-0.360**	-0.244	-0.260	1	0.071	0.422**
	Sig. (2-tailed)	0.086	0.002	0.039	0.027		0.553	0.000
	N	72	72	72	72	72	72	72
NO_3	Pearson Correlation	0.019	-0.395**	-0.586**	-0.106	0.071	1	-0.049
	Sig. (2-tailed)	0.871	0.001	0.000	0.375	0.553		0.683
	N	72	72	72	72	72	72	72
Sea weed biomass	Pearson Correlation	-0.059	-0.059	0.012	-0.006	0.422**	-0.049	1
	Sig. (2-tailed)	0.625	0.625	0.919	0.961	0.000	0.683	
	N	72	72	72	72	72	72	72

* 5% level of significance , ** 1% level of significance

oxygen, dissolved phosphates and nitrates determined for a period of two years from nine seaweed growing areas along the Kerala coast are presented as annual mean in Table 3. Annual mean of SST registered maximum of 30.39° C in Thikkodi (32.9°C during March 1999 to 27.9° C during September 1998) and minimum of 27.01°C at Thirumallavaram with a range of 29.2°C during March 1999 to 24.2° C during June 1998. Similarly pH also registered maximum of 8.08 in Thikkodi and a minimum of 6.95 in Dhalawapuram. Dhalawapuram, being the estuarine station registered highest annual mean values of dissolved nitrate and phosphate levels. The northern stations of Kerala coast recorded gradual reduction in phosphate levels (Table 3).

When the hydrographic data from the seaweed growing sites was statistically analysed, very high significant positive correlation could be observed between salinity and pH. Though not high, there was significant positive correlation between pH and dissolved oxygen as well as salinity and dissolved oxygen ($p < 0.01$). There was also significant negative correlation (Table 4) between pH and PO_4, pH and NO_3 and Salinity and NO_3 ($p < 0.01$), Salinity and PO_4, O_2 and PO_4 ($p < 0.05$).

Discussion

Water quality plays an important role in the occurrence and distribution of seaweeds. Seawater quality parameters such as sea surface temperature (SST), pH, dissolved oxygen, dissolved phosphates and nitrates were determined quarterly for a period of two years from nine seaweed growing areas along the Kerala coast. The mean values of SST showed a minimum at Thirumallvaram and the maximum at Thikkodi. Higher mean value of SST at Thikkodi than in other locations might be due to the depth and rocky nature of coast. Since Dhalavapuram is a brackish water station, the mean values of pH and salinity recorded were minimum and matched with the higher PO_4 and NO_3 levels received from the upstream areas.

The southwest monsoon plays a major role in deciding the hydrographic parameters of Arabian Sea in general and the sea adjoining Kerala coast extending to the Laccadive Sea in particular. Highest temperatures were observed in the Laccadive Sea before and after the south west monsoon period, whereas during the monsoon period the SST was low (Sewel, 1929). Observations of SST near Calicut by Chidambaram (1950), George (1953), Sheshappa and Jayaraman (1956) and Kasturirangan (1957) indicated that after an annual maximum of SST in April/May of about 30° C, there is a reduction in June although in some years the monthly average temperature began to decrease by May itself. In the present investigation also similar pattern was exhibited along the Kerala coast. Maximum SST was observed in April (Table 3) as understood by Sankaranarayanan and Qasim (1969) and Pillai (1991).

The salinity of seawater showed a decline during the southwest monsoon period as reported that the variation in the sea water salinity during monsoon in the intertidal region is mainly brought about by rainfall and river runoff (Pillai, 1991). The dissolved oxygen levels observed were normal and remained well aerated. However, in the off sea near the continental shelf the presence of low oxygen concentrations between Kasaragod and Quilon during the south west monsoon period was reported by Pillai (1993). Upwelling is a process normally associated with the south west monsoon which brings in nutrient rich subsurface waters to the sea surface. Besides upwelling, nutrient enrichment in coastal waters does occur through river runoff and land runoff during the monsoon period (Atkins, 1923) which is significant in the enrichment of seawater near the river mouths. In the present study most of the stations registered higher nutrient NO_3 and PO_4) status during the south west monsoon period (June-September) which is well supported by the findings of earlier studies (George, 1953; Seshappa and Jayaraman, 1956; Jayaraman and Seshappa, 1957; Sankaranarayanan and Qasim, 1969). This monsoon induced hike in dissolved PO_4 and NO_3 supports the blooming of phytoplankton along the west coast (Balachandran *et al*., 1997) is applicable in the present study also that postmonsoon period of both 1998 and 1999 registered considerable increase in the harvestable biomass of seaweeds.

From the nine selected Stations along the Kerala coast, a total of 37 species of seaweeds could be collected. Although Balakrishnan Nair *et al.* (1982) claimed to have recorded 44 species of marine algae from southern Kerala coast including the Ashtamudi Lake systems, two were identified as seagrasses (marine angiosperms). Chennubhotla *et al* (1988) observed 34 species of marine algae from entire Kerala coast during the seaweed assessment survey they conducted. He and his team later added one more species of red seaweed *Porphyra kanyakumariensis* from Kerala coast (Chennubhotla *et al*., 1990) which was not encountered during the present study. Later Kaliaperumal and Chennubhotla (1997) described only 35 species belonging to 28 genera and 18 families after conducting seaweed resource assessment survey along the Kerala coast from 15 localities.

Recently Nettar and Panikkar (2009) described two new species from the Family Ralfsiaceae, *Hapalospongidion thirumullavaramensis* and *Pseudolithoderma thangasseriensis*, collected from the Quilon coast of Kerala. The taxonomy of four species of *Feldmannia* collected from different parts of Kerala such as *F. collumellaris, F. irregularis* and two new species: *F. sahnienii* and *F. renienii* was also reported by Nettar and Panikkar (2009a). Nettar and Panikkar (2009b) reported five species of *Hincksia* collected from different parts of Kerala and these include, *H. clavata* (Krishnamurthy and Baluswami) Silva, *H. rallsiae* (Vickers) Silva, *H. sandriana* (Zanardini) Silva, *H. mitchelliae* (Harvey) Silva and *H. turbinariae* (Jaasund) Silva. Among these, *H. rallsiae* is a new report to the Indian marine

flora. Nettar (2009) described with illustrations the occurrence of *Hecatonema: H. sargassicola* Boergesen and *H. terminale* (Kuetzing) Kylin, collected from Kerala and Tamil Nadu.

Agar yielding seaweeds or the agarophytes that can be harvested for extraction of agar from Kerala coast were represented by seven species and the major resources were *Gracilaria corticata, G. foliifera, Gelidiopsis variabilis* and *Gelidium pusillum* during 1998 and 1999 besides the species of *Pterocladia* during 1999. Alginophytes were represented by *Sargassum wightii, S. duplicatum, S. tenerimum, Stoechospermum marginatum, Dictyota dichotoma* and *Padina* spp. The carrageenan yielding red seaweeds were *Hypnea musciformis, H. valentiae* and a new resource *Gracilariopsis lemaneiformis* from Dhalavapuram and Kannur stations.

The nine sampling locations were compared using ANOVA followed by SNK test for testing their significant difference in the harvestable biomass production of two species of seaweeds, *Chaetomorpha antennina* and *Gracilaria corticata* which occurred in all the locations and almost throughout the study period. This analysis revealed that the harvestable biomass of *Chaetomorpha antennina* was significantly different ($p<0.01$) between different sampling locations which can be grouped into two homogenous groups. In the first grouping, among the eight marine locations, Dharmadam stations was significantly different from all other locations with regard to occurrence of *Chaetomorpha antennina*, whereas in the second grouping Thirumallavaram, Mullur andThikkodi were significantly different from rest of the study locations.

In the case of *Gracilaria corticata* ANOVA results have shown that all locations are homogenous with respect to biomass availability. Multiple regression analysis carried out to examine predictability of harvestable seaweed biomass with the help of water quality variables such as SST, salinity, DO and dissolved nutrient levels yielded low but significant R^2 (0.198, $p< 0.05$) and the regression coefficient was significant only for phosphate which is corroborated by observations made by Chennubhotla *et al.* (1990). It could be inferred that a synergistic effect of all these parameters existing in a water body can be held responsible for seasonal and spatial variation in the seaweed biomass production along the Kerala coast.

Seaweed resource assessment carried out from Mullur to Bekal along the Kerala coast indicated rich quantity (70-75%) of non commercially important species such as *Chaetomorpha antennina, Ulva reticulata, Ulva fasciata, Ulva lactuca, Caulerpa peltata, C. racemosa, Bryopsis plumosa, Enteromorpha compressa* and *Chaetomorpha linum*. Similar estimates made from five States including Lakshadweep islands (Umamaheswara Rao, 2011) unraveled that the resources available for agar, algin and carrageenan production are about 9% of the total seaweed resources of our country and the remaining 91% are either unutilized or underutilized. However, these underutilized seaweed resources can be utilized for the production of nutraceuticals, manure and cattle feed.

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