

Ecology of intertidal benthic algae of northern Karnataka coast

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The intertidal benthic marine algal flora has been studied for distribution, phenology, biomass and zonation along with the environmental conditions. About 65 species belonging to 42 genera of Chlorophyta, Phaeophyta and Rhodophyta have been recorded. Rhodophyta is dominant followed by Chlorophyta and Phaeophyta. Biomass of the dominant and perennial algal species is monitored. Maximum biomass is obtained during December to February. *Ulva fasciata*, *U. lactuca*, *Enteromorpha intestinalis*, *Padina tetraströmatica*, *Spatoglossum asperum*, *Stoechospermum marginatum*, *Dictyota dichotoma*, *Sargassum* spp, *Porphyra vietnamensis*, *Gracilaria corticata* and *Amphiroa fragillissima* are dominant. About 26 species have been recorded for the first time from this coast.

Various estimates and inventories of marine algae have been prepared earlier¹⁻⁷. The information available on the central west coast algal flora is restricted only to the distribution^{8,9}. Therefore an attempt has been made to study seasonal variation in distribution, zonation, biomass and phenology of the benthic algae to assess the effects of some ecological factors of the marine environment over these algae along the Karnataka coast.

Study Area

The Karnataka coast is about 300 km long with major rivers like Kali, Kollur and Netravati. The coast is sandy with emergent shoreline towards the southern part, while north is rocky with interspersed sandy beaches. Most of the solid formations are mainly granites and laterite rocks. The present study area lies between lat. 11°12'-18°12'N and long. 43°48'-78°18'E.

Climatically this region shows 3 seasons—premonsoon (March-May), monsoon (June-September) and postmonsoon (October-February). Along the coast the tides are of mixed type with unequal heights of low and high levels.

St 1 (Karwar head)—The sampling station situated on the southwest side of Karwar harbour, is at the foot of high cliff towering over the sea with a sandy beach on either side. The shore is densely covered with massive to moderate size boulders of both granite and laterite, providing numerous sheltering areas. Intertidal expanse is < 15 m due to steep slope. The impact of wave action is moderate to strong. Mean tidal level is 1.74 m at spring and 0.3 m at neap. Annual average rainfall is 2818 mm.

St 2 (Honavar)—It is located 11 km south of Honavar town at the foot of a high cliff towering over the sea. The intertidal region consists of huge boulders of granite as well as laterite with gradual slope. The rocky coast is interrupted by pockets of sandy beaches in between rock promontories. Many of the rocks are terraced possessing a number of rock pools which harbour a variety of flora and fauna. The wave action is moderate. Mean tidal level is 1.76 m at spring and 10.44 at neap. Annual average rainfall is 3202 mm.

St 3 (Bhatkal)—It is located at the foot of the light house. The intertidal region consists of irregular platforms, some with gently sloping surfaces and some with steep or almost vertical sides. Many of the platforms rise a few meters above the levels of high water, while the adjacent rock extends several meters high. The intertidal region is very narrow and wave action is intense on open coast. Mean tidal level is 1.16 m at spring and 0.12 m at neap.

Materials and Methods

Monthly samples for biomass were collected by placing 0.25 m² quadrant randomly at different levels in the intertidal region during January to December 1985. Samples were cleaned with seawater as well as with fresh water and fresh weight (biomass) per unit area was determined for the abundant plants occurring throughout the year. Vertical occurrence of the algae in relation to the zonation was determined from the vegetation present along the boulders at each station. In addition to this, monthly floristic studies were made at each station. The samples collected were preserved in 5% seawater.

ter-formalin and to study the phenology of different algae.

Ambient seawater samples were analysed for nutrients¹⁰ and pH. For the latter few drops of chloroform were added to seawater, as a preservative. The temperature and dissolved oxygen (DO) of surface water were measured at the time of collection.

Results

Environmental parameters—The environmental parameters in the nearshore waters along the Karnataka coast (Fig. 1) followed a seasonal cycle. Temperature decreased from May to August and increased till December at all stations. On the other hand, DO registered higher values during May to August when temperature was low. pH did not vary largely except in July. Salinity decreased from May to June at Honavar and in July at Bhatkal and thereafter registered gradual increase up to November. Nutrients NO₃-N and PO₄-P, showed 2 distinct peaks during the investigation. NO₃-N showed highest values in June and November whereas PO₄-N in July and October. NO₂-N registered irregular trends.

Distribution of algae—The intertidal flora like in any other tropical shore showed single growing season in a year. The vegetation is luxuriant in winter

and early spring whereas in summer months (May and June) it was almost negligible. During the period of investigation different benthic algae showed spatial and temporal variation in their occurrence. The distribution of algal taxa in the intertidal zone at all stations is given in Table 1. About 65 species belonging to 42 genera were recorded and 26 new species of different groups were also recorded for the first time from Karnataka coast. Maximum number of species was represented by Rhodophyta members (25) followed by Chlorophyta (23) and Phaeophyta (17). Maximum species were observed at Honavar (55) followed by Karwar (50) and Bhatkal (39). The green alga *Rhipidodesmis ceaspitosa* Aet E.S. Gepp was recorded for the first time from the west coast at Honavar.

Algal zonation—The present observations on the zonation or vertical distribution of intertidal algae along rocky shores is based on pooled data from all the 3 stations (Fig. 2). Although the tidal range was small, 3 basic zones were seen in the vertical distribution of flora agreeing with the universal scheme of zonation¹¹.

Karwar: The shoreline showed very small intertidal expanse. The supralittoral fringe was dominated by *Ulva*, *Cheatomorpha* and *Enteromorpha*. In monsoon *Porphyra* and *Bangia fuscopurpurea* were

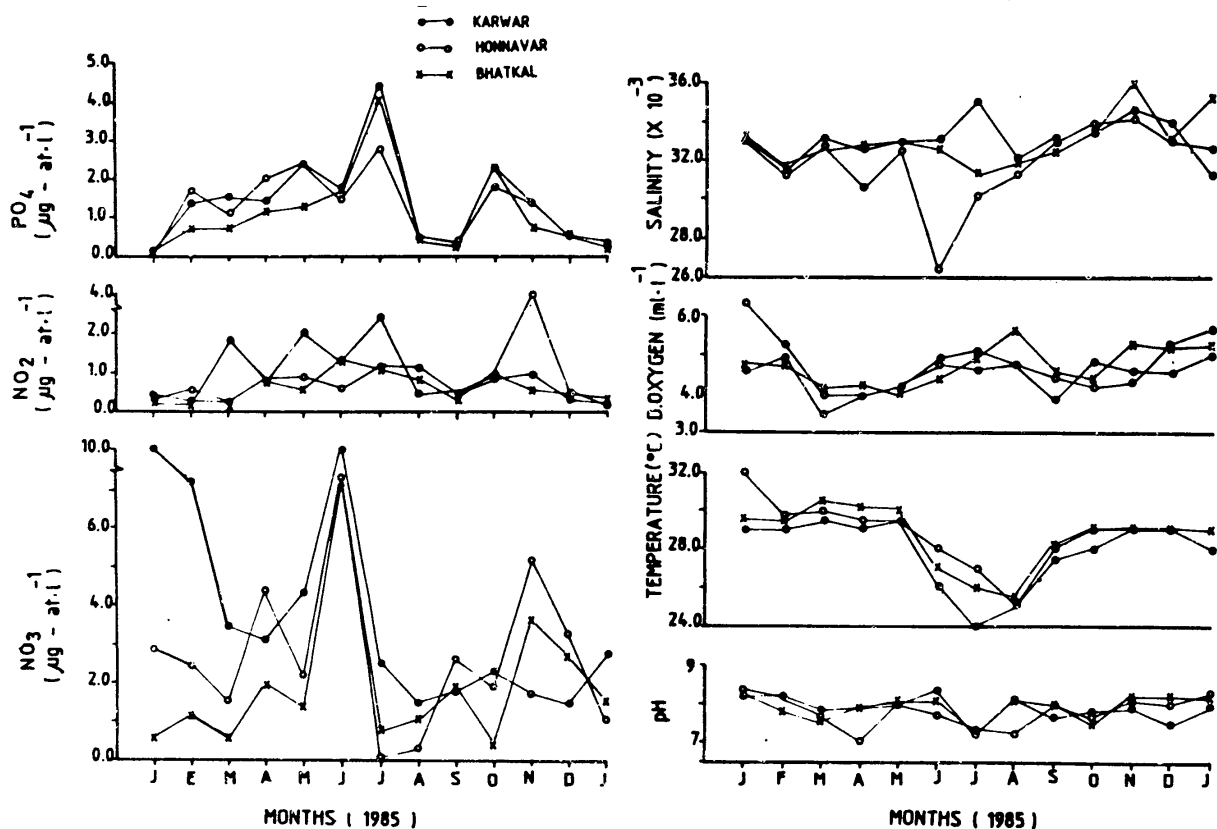


Fig. 1—Environmental data of the stations studied along the Karnataka coast

Table 1—Seasonal distribution of marine algae
 (Stations : 1-Karwar, 2-Honavar, 3-Bhatkal)

* New record for India; ** New record for West coast of India; + = recorded; - = not recorded

Sl. No.	Name of species	St.No.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
CHLOROPHYTA																
1	<i>Ulva fasciata</i> Delile	1,2,3	+	+	+	-	-	+	+	+	+	+	+	-	-	+
2	<i>U. lactuca</i> (Linn) Le Jolis	1,2	+	+	+	-	-	+	+	+	+	+	-	-	+	+
*3	<i>U. rigida</i> C. Ag.	3	+	+	+	-	-	+	+	+	+	+	+	+	+	+
4	<i>U. reticulata</i> Forssk.	1,2	+	+	+	+	-	-	-	-	+	+	+	+	+	+
*5	<i>Enteromorpha tubulosa</i> Kutz.	2,3	-	-	+	+	+	-	-	-	+	+	+	+	-	-
6	<i>E. flexuosa</i> (Wulf) J. Ag.	1,2	-	-	-	-	-	-	-	-	+	+	+	+	-	-
7	<i>E. intestinalis</i> (L.) Link	1,2	-	-	+	+	-	-	-	-	+	+	+	+	-	-
*8	<i>E. clathrata</i> (Roth) J. Ag.	1	+	+	+	+	+	+	+	-	-	-	-	+	+	+
9	<i>Monostroma</i> sp.	1	-	+	-	-	-	-	-	+	+	+	-	-	-	+
10	<i>Cladophora fascicularis</i> (Mertens) Kutz.	1,2	+	+	-	-	-	+	+	+	+	+	+	+	+	+
*11	<i>C. prolifera</i> (Roth) Kutz.	1,2	+	+	-	-	-	-	-	-	-	-	+	+	+	+
*12	<i>Spongomorpha</i> sp.	1,2,3	+	-	-	-	-	-	-	+	+	+	+	+	+	-
13	<i>Chaetomorpha media</i> (C. Ag.) Kutz.	1,2,3	+	+	+	+	-	+	+	+	+	+	+	+	+	+
14	<i>C. linum</i> (Muller) Kutz.	2	+	+	-	-	-	-	-	-	-	-	+	+	+	+
15	<i>Caulerpa sertularioides</i> (Gmel.) Howe	1,2,3	+	+	-	-	-	-	-	-	-	-	+	+	+	+
16	<i>C. scalpelliformis</i> (R. Br) V. Bosse	2	+	+	+	-	-	-	-	-	-	-	-	+	+	+
17	<i>C. peltata</i> Lamour	1,2,3	+	+	+	+	-	-	-	-	-	-	-	+	+	+
18	<i>C. racemosa</i> (Forssk.) J. Ag.	1	+	+	+	+	+	+	-	-	-	-	+	+	+	+
19	<i>Ermodesmis verticillata</i> (Kutz.) Boerps.	2,3	+	+	-	-	-	-	+	+	+	+	+	+	+	+

Contd.

Table 1—Seasonal distribution of marine algae—Contd.
(Stations : 1-Karwar, 2-Honavar, 3-Bhatkal)

* New record for India; ** New record for West coast of India; + = recorded; - = not recorded

Sl. No.	Name of species	St. No.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
20	<i>Struvea</i> sp.	1,2,3	+	+	-	-	-	-	-	-	+	+	+	+	+	+
21	<i>Bryopsis plumosa</i> (Hudson) C. Ag.	2	+	+	-	-	-	-	-	-	-	-	+	+	+	+
**22	<i>Rhipidodermis caespitosa</i> Aet. E.S. Gepp	2	+	+	+	+	-	-	-	-	-	-	+	+	+	+
**23	<i>Avrainvillea amadelpha</i> Gepp	2	+	+	+	-	-	-	-	-	-	-	-	+	+	+
PHAEOPHYTA																
* 1	<i>Giffordia michellae</i> (Harv.) Lam.	1,2,3	+	-	-	-	-	-	-	+	+	+	+	-	-	-
2	<i>Sphacelaria furcigera</i> Kutz	1,2,3	+	+	-	-	-	-	-	-	-	+	+	+	+	+
*3	<i>Ralfsia</i> sp.	1,2	+	+	+	+	-	-	-	-	-	-	-	+	+	+
4	<i>Dicyota dichotoma</i> (Huds.) Lamour.	1,2	+	+	+	+	-	-	-	-	-	-	+	+	+	+
5	<i>D. bariayresiana</i> Lamour.	1,2,3	+	+	+	+	-	-	-	-	-	-	-	+	+	+
*6	<i>Dilophus fasciola</i> (Roth) Hauck	1,2,3	+	+	-	-	-	-	-	-	-	+	+	+	+	+
*7	<i>Lobophora variegata</i> (Lamour.) Papenf.	1,2	+	+	+	+	+	-	-	-	-	-	-	+	+	+
8	<i>Padina gymnospora</i> (Kutz.) Vick.	1,2	-	+	+	+	+	+	-	-	-	-	-	-	-	-
9	<i>P. tetrastromatica</i> Hauck	1,2,3	+	+	+	+	-	-	-	-	-	+	+	+	+	+
10	<i>Dicypoteris australis</i> Sonder	1	+	+	+	-	-	-	-	-	-	-	+	+	+	+
11	<i>Stoechospermum marginatum</i> (C. Ag) Kutz	1,2,3	+	+	+	+	-	-	-	-	-	-	+	+	+	+
*12	<i>Spatoglossum asperum</i> J. Ag.	1,2,3	+	+	+	+	+	-	-	-	-	-	-	+	+	+
*13	<i>Sargassum cinereum</i> J. Ag.	1,2,3	+	+	+	+	-	-	-	-	-	-	+	+	+	+
14	<i>S. tenerinum</i> J. Ag.	1,2,3	+	+	+	+	-	-	-	-	-	-	+	+	+	+
15	<i>Sargassum</i> sp.	2	+	+	+	+	-	-	-	-	-	-	+	+	+	+

Contd.

Table 1—Seasonal distribution of marine algae—Contd.
(Stations : 1-Karwar, 2-Honavar, 3-Bhatkal)

Sl. No.	Name of species	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
3	16 <i>S. wightii</i> Greville	+	+	+	+	-	-	-	-	-	-	+	+	+	+
1,2,3	17 <i>S. ilicifolium</i> (Turn) J. Ag.	+	+	+	+	-	-	-	-	-	-	+	+	+	+
1,3	* RHODOPHYTA	-	-	-	-	-	-	+	+	+	-	-	-	-	-
1,2,3	*1 <i>Bangia fuscopurpurea</i> (Dill) Lyng	-	-	-	-	-	-	+	+	+	+	+	-	-	-
1,2,3	2 <i>Prophyra vietnamensis</i> Tanaka et Ho	-	-	-	-	-	-	+	+	+	+	+	-	-	-
1,2,3	3 <i>Grateloupia filicina</i> (Wulf.) C. Ag.	+	+	+	+	-	-	-	-	-	+	+	+	+	+
1,2,3	4 <i>G. lithophila</i> Boerg.	+	+	+	+	-	-	-	-	-	+	+	+	+	+
1,2,3	5 <i>Cheilosporum spectabile</i> Harvey	+	+	+	+	+	+	-	-	-	+	+	+	+	+
1,2,3	*6 <i>Amphiroa</i> sp.	+	+	+	+	+	+	-	-	+	+	+	+	+	+
1,2	*7 <i>A. fragilissima</i> (L.) Lamour	+	+	+	+	-	-	-	+	+	+	+	+	+	+
1	*8 <i>Jania adharence</i>	+	+	-	-	-	-	+	+	+	+	+	+	+	+
1	*9 <i>Melobesia</i> sp.	+	+	-	-	-	-	+	+	+	+	+	+	+	+
1,2,3	10 <i>Gelidium pusillum</i> (Stack) Le Jolis	+	+	+	+	-	-	-	-	-	-	-	+	+	+
2	11 <i>G. micropterianum</i> Kutz	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1,2,3	12 <i>Gracilaria coricata</i> J. Ag.	+	+	-	-	+	+	-	-	-	-	+	+	+	-
1,2,3	13 <i>Gelidiopsis variabilis</i> (Grev.) Schmitz	+	+	+	+	-	-	+	+	+	+	+	+	+	+
1,2,3	14 <i>Hypnea musciformis</i> (Wulf) Lam.	+	+	+	+	-	-	-	-	-	-	+	+	+	+
1,2,3	*15 <i>H. valentiae</i> (Turn) Mont.	+	+	+	+	-	-	-	-	-	-	+	+	+	+
3	*16 <i>H. cervicornis</i> J. Ag.	+	+	+	+	-	-	-	-	-	+	+	+	+	+
1,2,3	*17 <i>Rhodomyenia australis</i> Sonder	+	+	+	+	-	-	-	-	-	+	+	+	+	+

Contd.

Table 1—Seasonal distribution of marine algae—Contd.
(Stations : 1-Karwar, 2-Honavar, 3-Bhatkal)

* New record for India; ** New record for West coast of India; + = recorded; - = not recorded

Sl. No.	Name of species	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
*18	<i>Champia parvula</i> C. Ag. (Harv.)	+	2	-	-	-	-	-	-	-	-	+	+	+	+
19	<i>Centroceros clavulatum</i> (C. Ag.) Mont.	+	+	+	+	-	-	-	-	-	-	-	+	+	+
20	<i>Ceramium fastigiatum</i> (Roth) Harv.	+	+	-	-	-	-	-	-	-	-	+	-	-	-
21	<i>Anithamnion</i> sp.	-	-	-	-	-	-	-	-	+	+	+	+	-	-
22	<i>Chondria armata</i> Kurz.	+	+	+	+	-	-	-	-	-	-	+	+	+	+
23	<i>Laurencia papillosa</i> (Forssk.) Grev.	+	+	+	-	-	-	-	-	-	-	+	+	+	+
24	<i>Polysiphonia</i> sp.	+	-	-	-	-	-	-	-	-	-	+	+	+	-
25	<i>P. macrocarpa</i> Harv.	+	+	-	-	-	-	-	-	-	-	+	+	+	+

dominant in this zone. The midlittoral showed dominance of *Dictyota*, *Stoechospermum marginatum*, *Hypnea*, and *Gelidium*. The infralittoral fringe was dominated by *Gracilaria*, *Sargassum* and *Amphiroa*.

Honavar: The supralittoral fringe showed *Enteromorpha* and *Porphyra* dominance. *Ulva fasciata* was observed in supra and mid littoral zones. Many tide pools were observed in the midlittoral zone with *Padina*, *Hypnea cervicornis*, *Dictyota dichotoma* and *Avrainvillea* sp. The infralittoral fringe showed *Sargassum*, *Cheilosporum* and *Amphiroa* sp. dominance.

Bhatkal: Compared to the other two, this station showed poor quality of flora. Due to steep slope, the intertidal expanse was very small. At the supralittoral zone *Ulva* and *Enteromorpha* were predominating. The midlittoral zone showed pools as at st 2 and the flora was *Ulva rigida*, *Stoechospermum marginatum*, *Spatoglossum asperum* and *Dictyota* sp. *Sargassum* was observed growing in the lower region of midlittoral zone.

Biomass—The monthly biomass values for *Ulva fasciata*, *Gracilaria corticata* and *Sargassum* spp. are shown in Fig. 3. There was considerable difference in the biomass of each species at different stations. The biomass of *Ulva fasciata* and *Sargassum* spp. showed gradual decrease from January and by May it had completely disappeared from the shore. Similarly *Ulva fasciata* showed declining trend from January to May. Unlike *Sargassum* spp., *Ulva fasciata* registered peak values in July and September besides January. The biomass of *Gracilaria corticata* at Honavar and Bhatkal showed 2 peaks (December and April). The maximum biomass was estimated during October to January.

Phenology—The preliminary observations on the phenology of few selected dominant algal species of different groups is given in Table 2. The dominant species occurred from October to April except *Porphyra* which was dominant only in the monsoon. *Ulva fasciata* and *Gelidium pusillum* were found growing almost throughout the year.

Discussion

Some algae showed marked seasonal changes in pattern of distribution, which varied from complete disappearance of visible thalli in some seasons (e.g. *Porphyra*, *Bangia*) to stunted basal parts (e.g. *Sargassum* and *Gracilaria*). Seasonal changes in the pattern of distribution of different algae from October to January could be possible due to seasonal variability of reproduction/recruitment of species¹³. Increase in the species number of different algae dur-

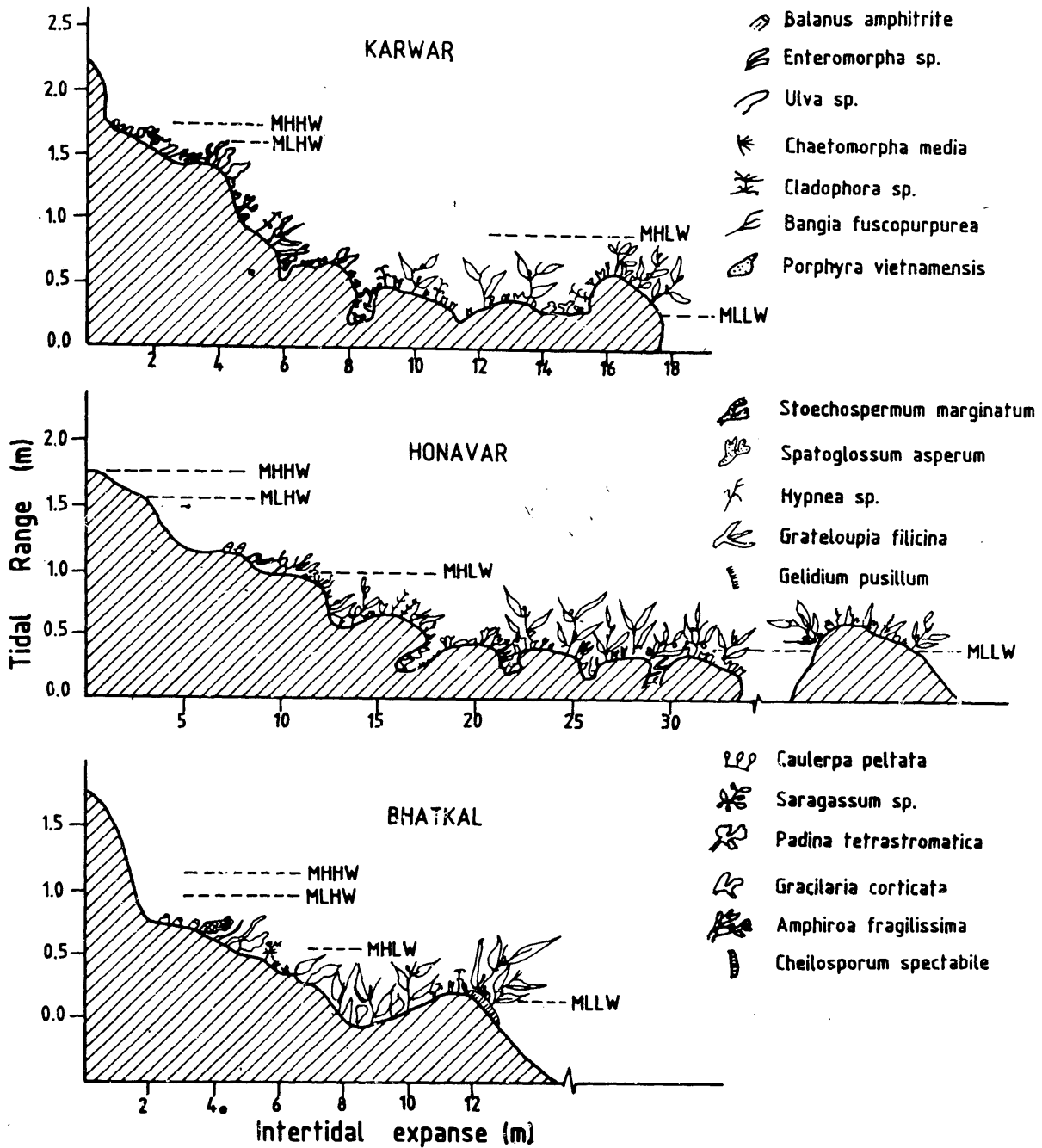


Fig. 2—Shore profiles showing algal distribution

ing this period correlated with the increase in temperature and salinity (Fig. 1).

Despite narrow intertidal region along Karnataka coast, a different algal zone was observed in littoral zone, and the algal zones were less extensive. A distinct barnacle line occurred in the upper region of midlittoral zone and *Gracilaria* and *Sargassum* were the two dominant band forming algae in the lower part of the intertidal region. As emphasized by Ste-

phenson and Stephenson¹¹ any break in the distribution of the intertidal organisms was not evident in the present study except a barnacle line on the top of midlittoral zone. The rock pool community was more as the rock pools provide sheltered areas.

Among the 3 dominating algae, *Sargassum* and *Gracilaria* were present for longer time (till April), while *Ulva* crop started disintegrating from January onwards. This may be due to the latter growing to-

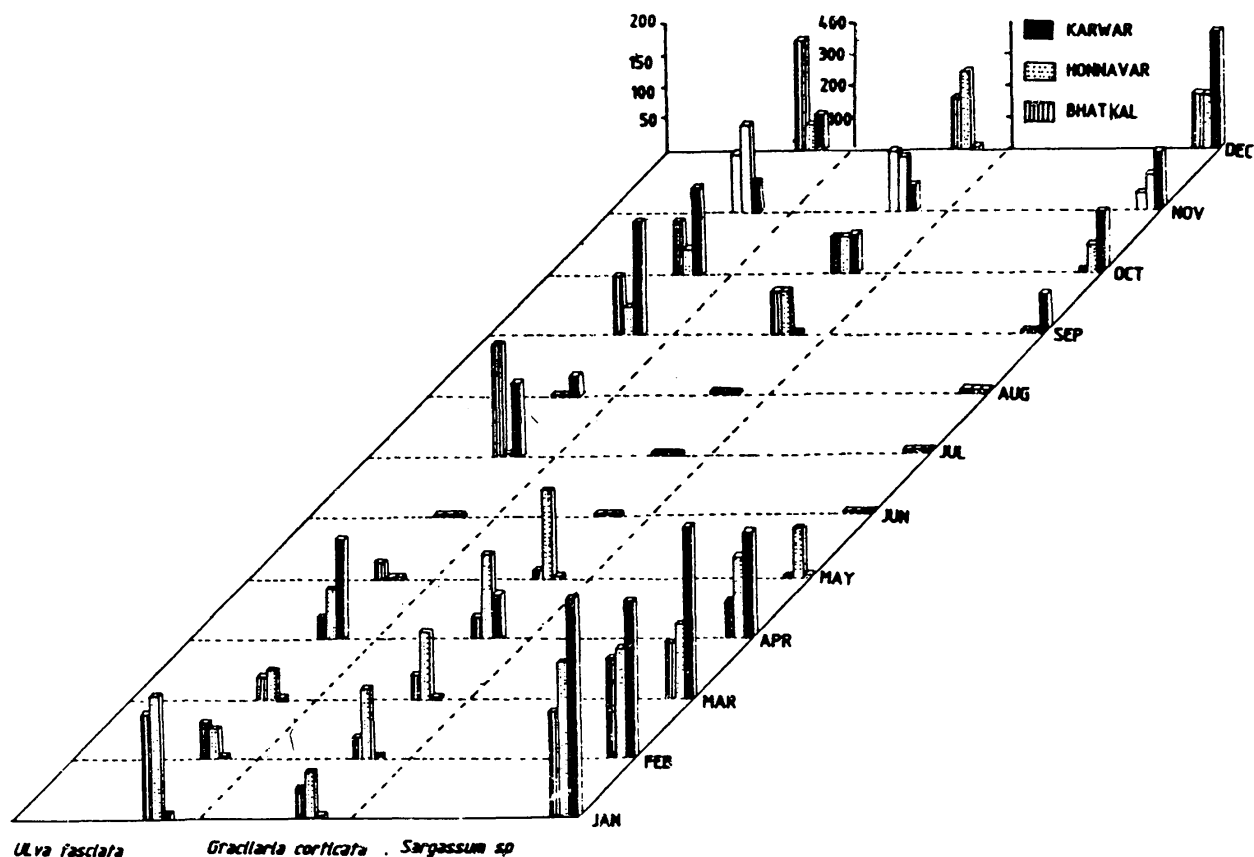


Fig. 3—Monthly variations in biomass for algal species at Karwar, Honavar and Bhatkal

Table 2—Phenology of reproductive structures of some dominant benthic algae

Name of species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Ulva fasciata</i>	z	+	+	+	+	+	+	+	g	g	+	z
<i>Chaetomorpha media</i>	+	+	z	z	—	—	+	+	g	g	+	+
<i>Padina tetrastrum</i>	g/sp	g	g	g	—	—	—	+	+	sp	sp/g	sp/g
<i>Dictyota dichotoma</i>	g	g	g	g	+	—	—	+	+	+	sp	sp
<i>Stoechospermum marginatum</i>	g/sp	g/sp	g	—	—	—	—	—	+	+	+	sp/g
<i>Spatoglossum asperum</i>	sp	sp	g	g	+	—	—	—	+	+	sp/g	sp/g
<i>Sargassum ilicifolium</i>	g	g	g	+	—	—	—	—	+	+	g	g
<i>Porphyra vietnamensis</i>	—	—	—	—	—	+	+	sp	sp	+	—	—
<i>Gelidium pusillum</i>	t	t	t	t	t	—	+	+	+	+	+	t
<i>Grateloupia filicina</i>	s/c	s	t	t/c	—	—	—	+	+	+	+,t	s/c
<i>Gracilaria corticata</i>	t	s/c	t	t,c	+	—	+	+	c/s	c/s	c	t,c
<i>Gelidiopsis</i> sp.	c/s	c/s	t	t,c	—	—	—	+	+	+	t/sp	c
<i>Hypnea cervicornis</i>	c	s/c	+	+	—	+	t	t	+	+	c/s	c/s
<i>Rhodymenia australis</i>	c	c	c	+	—	—	—	—	+	+	t	c/s
<i>Centroceras clavulatum</i>	c	t	t	+	+	+	+	+	+	+	s/c	s/c
<i>Laurencia obtusa</i>	+	+	t	t	+	—	—	—	+	+	s/c	s/c

+, veg.; —, absent; z, zoospores; g—gametes; t—tetrasporic; s—spermatangia; c—cytocarps; sp—sporangia.

wards the supralittoral fringe and getting exposed more to the sunlight resulting in bleaching.

Maximum algal growth and occurrence of reproductive stages in November-December showed the nutritional requirements of the marine algae. Among the red algae, the tetrasporangiate thalli were more than the cystocarpic plants. Similar observations were made in *Hypnea*¹⁴ and *Gelidium*¹⁵. The tendency of asexual reproduction (in many cases vegetative) may be due to grazing of the thalli of either sex or nonavailability of both the gametes at the same time. The spermatangial thalli were not easily identified because of their early discharge soon after the maturation.

From the foregoing account it is difficult to conceptualise the mechanism by which the zonation, distribution and biomass of littoral vegetation changes. The environmental parameters, along with the substratum and associated fauna may be affecting these changes.

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