

Marine macroalgal diversity along the Maharashtra coast: Past and present status

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A comparative study on distribution and abundance of marine macroalgae was carried out at six sites along the Maharashtra coast with the available data from 1935 onwards. The analyses and interpretation of this data revealed very interesting trends in marine macroalgal diversity. A typical cyclic change in their distribution, abundance and the reproductive features were observed in these algal forms. Although, northern part of Maharashtra is subjected to increasing industrial pollution and habitat destruction, there are some pockets wherein high macroalgal diversity occurs. This may be because of the increased tolerance to the environmental changes.

The macroalgae, one of the important component of the primary producers, contribute substantially to the carbon budget of the coastal ecosystem. Further, it provides habitat and food to a variety of invertebrate species and also plays significant role in the nutrient recycling¹. The Indian macroalgal flora² comprised of 648 species, belong to 205 genera, 61 families and 15 orders. Tamil Nadu coast (SE coast of India) was reported² to harbour 305 species followed by Gujarat (213) and then Maharashtra (91). The economically important brown and red macroalgae are being exploited from these areas since last 2 decades, for the extraction of phycocolloids.

The marine macroalgal resources along the Maharashtra coast have been studied since the beginning of this century³⁻⁷. The collections made during these studies led to believe that the macroalgal resources of the erstwhile Bombay (now Mumbai) coast were not in abundant quantity and quality. Subsequent studies, however, indicated rich as well as diverse marine algal resources along the Maharashtra coast⁸⁻¹².

Dixit⁹ reported 9 Chlorophyta, 11 Phaeophyta and 10 Rhodophyta species along the Malvan coast. Later, coordinated efforts were made to study in detail the distribution, abundance and standing stock of marine macroalgae of the Konkan coast¹⁰⁻¹². During this survey *Monostroma oxyspermum* (Kuetz.) Doty. and *Ernodesmis verticellata* (Kuetz.) Boergs were reported for the first time from this coast^{13,14}.

In the present investigation, current status of macroalgal diversity along the Maharashtra coast and changes that have been brought about over the years in their distribution, composition, biomass and associated species have been compared and discussed.

Reference has also been made to previous studies^{6,11,15} to assess the probable causes in decrease / increase in macroalgal diversity. Similarly, high diversity of macroalgae in the vicinity of polluted area has been evaluated and discussed.

Materials and Methods

The Maharashtra coast lies along the central west coast of India between the longitude 15° 43' to 20° N and latitude 72° 49' to 77° 41' E (Fig. 1). The coastline is about 760 km long indented by estuaries, creeks, small bays, headlands, promontories, cliffs etc. Most of the coastal region is of Deccan trap with the exception of pockets between Vengurla and Vijaydurg. The bays and inlets are associated with pocket beaches¹⁶.

In the present survey, entire Maharashtra coast, from Redi in the south to Dahanu in the north, was studied at 37 sites (Fig.1) for macroalgal diversity including species composition, abundance and resource evaluation. Sites having <20 macroalgal species were subsequently dropped from further studies and detailed observations were carried out bimonthly starting from September 1997 to November 1998 at Vengurla, Malvan, Ratnagiri, Shrivardhan, Thal and Colaba.

At each site, 1 m wide belt transect was laid perpendicular to the coast. The samples were collected at random by placing 0.25 m² quadrant in triplicate along 2-3 transects to have representative samples. Macroalgae from each quadrant were collected, washed with seawater to remove adhering sand particles, separated and weighed specieswise to calculate biomass (the biomass is expressed in kg/m² wet wt.). Herbarium specimens were prepared for

each species and wet samples were preserved in 5% buffer seawater formalin solution, for identification and confirming their taxonomic position. All the samples were deposited in the Reference Center of the National Institute of Oceanography, Goa. The species diversity and percentage cover were calculated using biomass values of the dominant macroalgal species from Malvan, Ratnagiri and Colaba to express abundance¹⁷.

The environmental parameters such as water temperature, salinity, pH, dissolved oxygen, nutrients and suspended load were analysed¹⁸.

The subtidal macroalgal collections were made by SCUBA diving wherever necessary. The submerged Angria Bank off Ratnagiri was studied by using a bucket dredge (0.7×0.5×0.25 m) at the depth of about 50 to 75 m.

Results and Discussion

The macroalgal distribution, species composition and dominance showed variation due to the physico-chemical factors^{19,20} as well as biological factors²¹. The range of environmental parameters of pre-post monsoon seasons at three sites is given in Table 1.

Earlier data^{7,9,11,12,22,23} on distribution, abundance, composition, standing crop biomass and diversity of macroalgae along the Maharashtra coast were examined and referred in the present investigation for comparison to assess the changes that have occurred over the years. Altogether, 91 macroalgal species belonging to 51 genera and 30 families have been recorded in the present study along the Maharashtra coast. Malvan displayed maximum diversity (69 species) followed by Colaba (64), Ratnagiri (46), Thal (38), Shrivardhan (30) and Vengurla (27).

Malvan is an open coastal ecosystem and is dominated by rocky outcrops with intermittent sandy beaches. The area surrounding the Sindhudurg fort has many submerged and exposed rocks harbouring a variety of macroalgal and invertebrate species. Totally 69 macroalgal species have been recorded from Malvan. The composition of macroalgae varied from locality to locality. The average biomass recorded at this site was 0.69 kg/m² and mainly contributed by members of Phaeophyta (55%) and Rhodophyta (32%). The comparison of the macroalgal groups with earlier studies showed that the percentage of Rhodophyta decreased from 33% in 1940 to 24% in

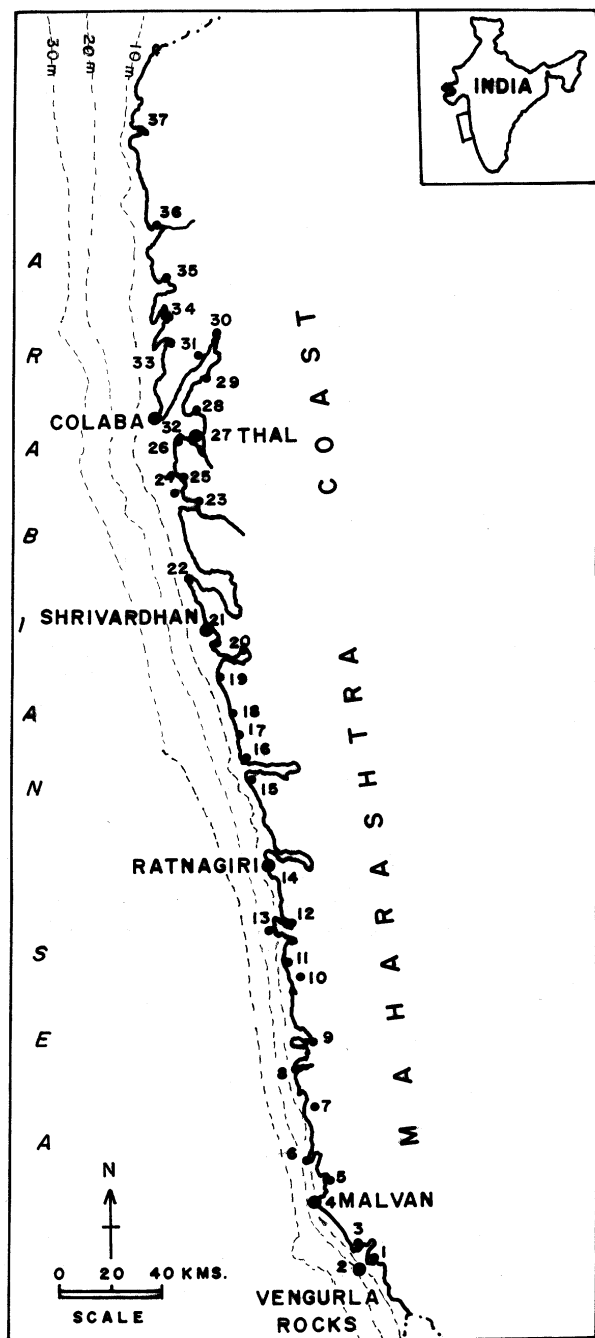


Fig. 1—Map showing number of sites studied along the Maharashtra coast

Table 1—Range of environmental parameters for pre-post monsoon seasons (1997-98) at Malvan, Ratnagiri and Colaba

Parameters	Malvan	Ratnagiri	Colaba
Temperature (°C)	26.3-27.50	23.7-27.8	26.9-27.0
Suspended solids (mg/l)	5.6-9.5	25.0-23.0	31.0-33.0
pH	7.84-7.9	7.6-8.4	7.8-8.2
Diss. oxy. (ml/l)	3.95-4.36	3.8-4.5	5.8-6.3
Salinity (‰)	31.2-34.58	29.96-33.1	30.2-35.2
PO ₄ -P (μmol/l)	0.89-1.2	0.24-0.9	3.9-6.8
NO ₃ -N (μmol/l)	1.35-2.22	1.0-3.73	1.2-5.7
NO ₂ -N (μmol/l)	0.07-0.14	0.1-0.3	0.3-1.9
NH ₄ -N (μmol/l)	0.69-0.81	0.8-1.1	0.1-1.61

1979 and later increased to 46% in 1998. In other two groups, Phaeophyta showed 39% increase in 1979, whereas, Chlorophyta showed similar percentage composition i.e. 37% in 1940 and 1979 and thereafter it decreased to 26% in 1998 (Fig. 2).

During earlier studies, some new macroalgal species such as *Monostroma* sp., *Ernodesmis verticillata*, *Acetabularia moebii* have been recorded from the Maharashtra coast^{13,14,24}. Of these, *Acetabularia moebii* Solms-Laubach was for the first time reported from Malvan²⁴. This species is small in size and grows below mean low tide level attached to the calcium encrusted basaltic rocks. It prefers sheltered rock crevices or on the leeward side of rocks sheltered from wave action. Chaugule *et al.*²⁵, collected *A. moebii* growing in the similar conditions from Malvan and Ratnagiri. The recent studies however, did not report occurrence of this species.

The comparison of present study with earlier data from the Ratnagiri coast revealed that there is a decreasing trend in number of macroalgal species within the period of 19 years from 1979 to 1998^{11,12}. It seems that increase in sedimentation is adversely influencing the algal growth. It is also possible that the macroalgal populations undergo some cyclic changeover the period. Perhaps, earlier to 1979 macroalgal populations at Ratnagiri were low and

increased during 1979 and in 1998 it showed further decrease indicating a major change in macroalgal population at Ratnagiri. It is necessary to have long-term monitoring to understand the cyclic change in macroalgal population.

The Genus *Monostroma* was reported for the first time from the mangrove swamp of Ratnagiri (Shirgao creek), Maharashtra coast by Untawale *et al.*¹³ and further the species was identified as *M. oxyspermum*²⁶. Subsequently, this species was also observed from other sites in the Konkan region. The average biomass recorded for this species in the present study was 1.73 kg/m². A large number of gastropods, particularly *Cerithidea* spp. were found associated with this alga.

Generally, macroalgal distribution is governed by the physico-chemical and biological factors²¹. The recruitment of algae in the various littoral zones depend upon the tide that exposes and inundates periodically. It was, however, observed that the macroalgal species which are found in the intertidal areas were also reported from the deeper areas. A submerged Angria Bank off Ratnagiri at the depth of 60 to 75 m harbours 57 macroalgal species, of which 44 species were also reported from the intertidal area of the Maharashtra and Gujarat coasts^{23,27}. Colaba is the southern most tip of Mumbai facing northwest and laying in a small shallow bay formed by seawall. Although, the study site is close to the city limits and despite Mumbai being most polluted, it exhibits diversified and most luxuriant marine flora and fauna. The shore has gradual slope with emerging rocks and several shallow tide pools with sandy-silty bottom. The intertidal expanse runs into few kilometers during low tide exposing vast area.

In all 64 macroalgal species have been reported from this site. The dominant group was Rhodophyta followed by Chlorophyta and Phaeophyta. Percentage-wise there was not much change since year 1935 to 1998, however, over the period a considerable variation in species composition was noticed (Figs 2,3).

At few locations macroalgae were seen in association with the coral, *Goniopora stokesi* Milne Edwards and Haime. The macroalgae associated with corals showed luxuriant growth as compared to the similar algal species growing in isolation. Perhaps, high degree of symbiotic relationship is beneficial to both, macroalgae and the coral for their growth and survival in the stress environment. The abundant macroalgal species at this site were *Caulerpa sertularioides*, *Caulerpa peltata*, *Caulerpa racemosa*, *Gracilaria corticata*, *Laurentia papillosa*, *Soliera*

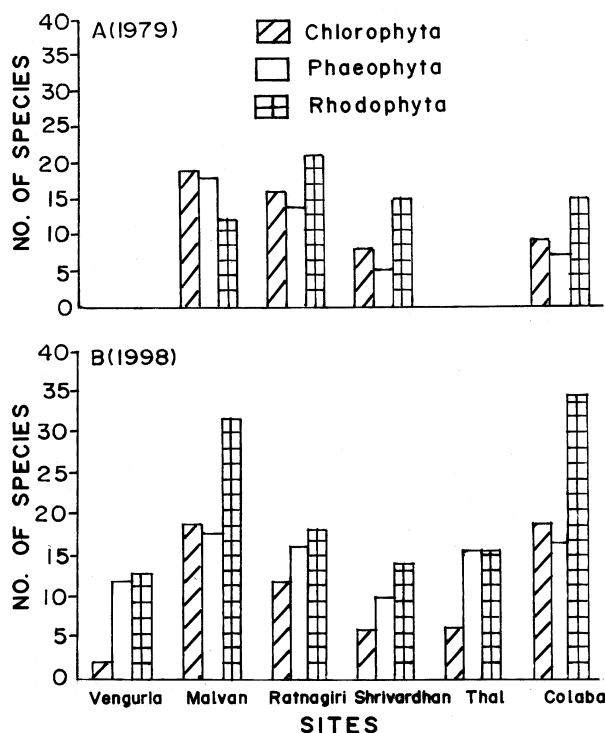


Fig. 2—Macroalgal species recorded from different sites during 1979 (A) and 1998 (B)

robusta, *Stoechospermum marginatum* etc. The average macroalgal biomass at this site was 1.33 kg/m² with Rhodophyta contributing to the tune of 48%, Phaeophyta 38% and Chlorophyta 14% to the total biomass.

The unplanned development along the coast often resulted in the degradation of marine habitat and in turn biological diversity. Along the northern part of Maharashtra, Mumbai coast in particular, industrial development has threatened biological diversity. Nevertheless, there are certain pockets along the Maharashtra coast that showed high macroalgal diversity and luxuriant growth. Perhaps, environmental conditions prevailing at these pockets are conducive to their growth or else macroalgae have developed ability to withstand change in the environmental conditions.

Comparison of the current status of macroalgal composition of the Maharashtra coast with that of earlier data since 1935 (Fig. 4) revealed that over the period of 63 years there has been series of changes in the number of species and composition of macroalgal population. In contrast, out of 73 species reported earlier⁷ from the Maharashtra coast, 31 species were not found during the present study (Table 2). The

species loss has been, however, compensated with the recruitment of new species. The variation in species composition could be attributed to the change in the water quality and sensitivity of macroalgal species to the changing environment. Perhaps, present macroalgal species are more tolerant to the environmental change than the earlier ones.

Boergesen⁷, reported four species each of *Cladophora* and *Gelidium* from the Bombay coast, however, later studies showed variations in the species composition¹¹. Similarly, species like *Gastroclonium iyengarii*, *Champia compressa*, *Solieria robusta*. etc. were not reported earlier²² from Colaba but were found growing luxuriantly during present investigation. It is also possible that earlier workers might have overlooked smaller algae. Genus *Caulerpa* was represented by four species, however, *Caulerpa scalpelliformis* was not recorded earlier from Colaba. The comparison amongst the macroalgal species from Malvan and Colaba revealed that large number of

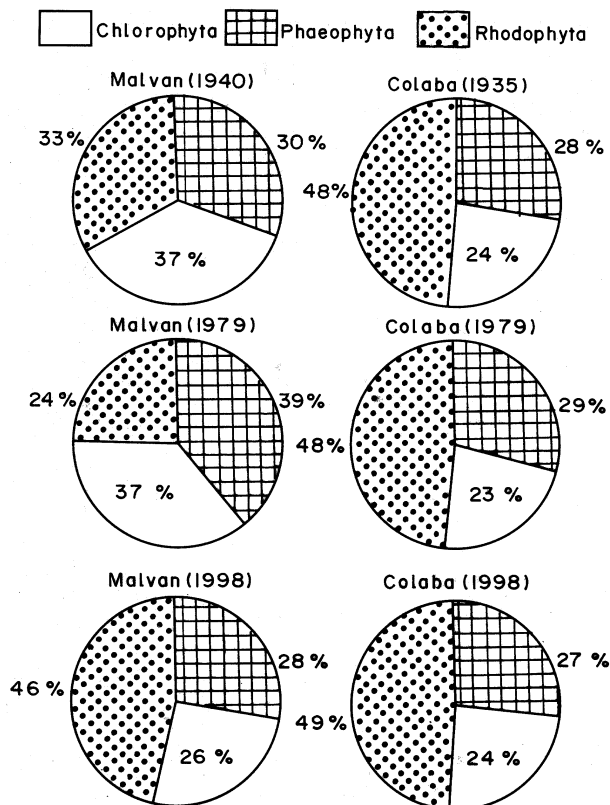


Fig. 3—Percentage of macroalgal groups during different study period at Ratnagiri and Colaba

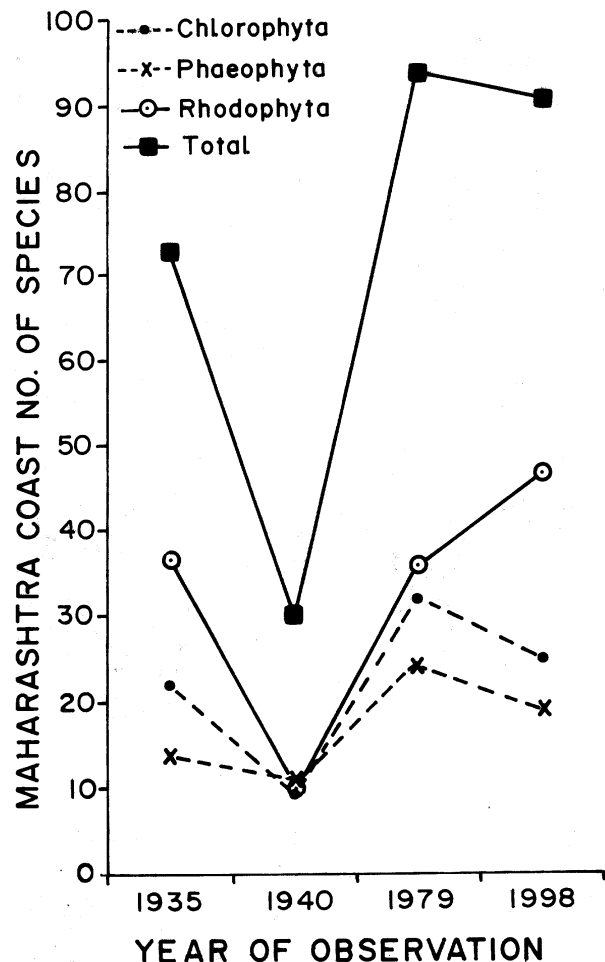


Fig. 4—Macroalgal species composition during different study period along the Maharashtra coast

species i.e. 64.50% were common to both the coasts while 18% were found only at Colaba and 17.48% at Malvan. Overall, growth of these algal species was found to be luxuriant at Colaba than Malvan which could be attributed to high nutrient levels presumably resulted from treated sewage effluent outfall at Colaba.

The coastal pollution can influence macroalgal distribution and community structure^{28,29}. At Colaba, regular discharge of treated sewage did not show any adverse effects on the macroalgal growth. Perhaps, tidal flushing dilutes sewage effluent considerably with marginal effect keeping the water quality relatively healthy³⁰.

According to Jumars & Nowell³¹, sedimentation directly affects marine benthic community structure. Large sediment load reduces light penetration as well as photosynthesis. It also changes abundance and percent cover of macroalgae³². It has been reported that high rate of sedimentation resulted in the dominance of turf forming seaweed species, whereas erect seaweed species were rare³³. At Colaba sediment load was high (Table 1) and it was observed that a majority of the species reported from Colaba showed highly branched thalli. The macroalgae might have been adapted to survive in the turbid waters in association with a dominant

Table 2—List of 31 macroalgal species that were recorded earlier⁷ but were not reported in the present study

Chlorophyta

<i>Cladophora colabanses</i> Boergs.	<i>Dictyopteris acrostichoides</i> (J. Ag.) Boergs.
<i>C. saracenic</i> Boergs.	<i>Rosenvingia orientalis</i> J. Ag.
<i>C. bombayensis</i> Boergs.	

Rhodophyta

<i>C. monumentalis</i> Boergs.	<i>Gelidium pulvinatum</i> (Kuetz.)
<i>Enteromorpha prolifera</i> (Fig. Et De Not.) J. Ag.	<i>G. heteroplatos</i> Boergs.
<i>Chaetomorpha indica</i> Kuetz	<i>G. corneum</i> (Huods) Lamour
<i>C. aerea</i> (Dillw.) Kuetz	<i>Acrochaetium sargassicolum</i> Boergs
<i>C. clavata</i> (Ag.) Kuetz	<i>Gelidiella myrioclada</i> (Boergs.) Feldman et Hamel
<i>Cladophora sudanensis</i> Reinb	<i>Peyssanelia obscura</i> Web v. Bosse
<i>Pseudobryopsis mucronata</i> Boergs.	<i>Cruosiella bicolor</i> Boergs.
<i>Lola capillaria</i> (Kuetz.) A. et G. Hamel.	<i>Hildenbrandtia prototypus</i> Nardo.
<i>Rhizoclonium kochianum</i> Kuetz.	<i>Acanthophora delilei</i> Lamour
<i>R. grande</i> Boergs.	<i>Caloglossa bombayensis</i> Boergs.
<i>Struvea delicatula</i> Kuetz.	<i>Gigartina acecularis</i> (Wulfen.) Lamour

Phaeophyta

<i>Dictyota pinnatifida</i> Kuetz.	<i>Monospora indica</i> Boergs.
<i>D. maxima</i> Zanardini	<i>Myriogramm bombayensis</i> Boergs.

coral species *Goniopora stokesi* having protruded polyps. In view of the high biodiversity of the marine flora and fauna, the site at Colaba is recommended for conservation.

As marine habitat is subjected to large environmental fluctuations, only limited amount of variability in macroalgal community can be predicted. The structure of macroalgal community as measured by the diversity indices did not show definite pattern. The data when pooled and computed as one value per station showed the trend as given in Fig.5. The Shannon - Wiener diversity index H' was highest at Colaba, whereas Simpson's index did not show much variation at all the three stations. The reciprocal of Simpson's index SI' and equally common species S were highest at Colaba than

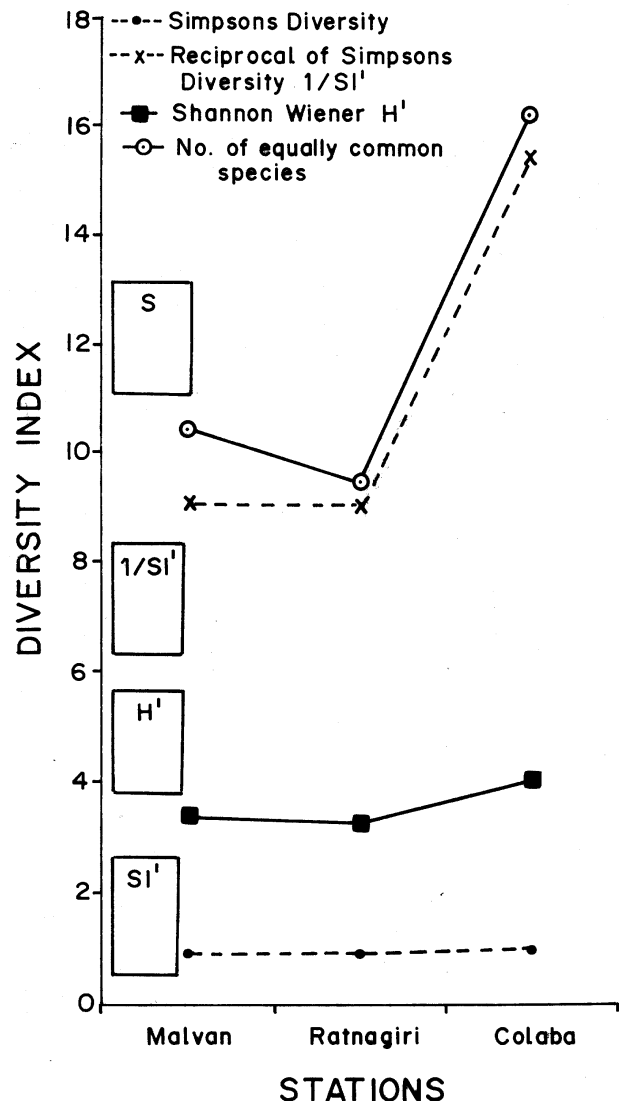


Fig. 5—Diversity indices of the three stations along the Maharashtra

Malvan, while at Ratnagiri, S was the lowest. In general, these indices were comparatively higher at Colaba that had high nutrients and dissolved oxygen than the other two stations.

On the basis of the studies carried out so far, it seems that there is no direct evidence to show that macroalgal diversity has been affected by human activities. Few studies have shown cumulative impact of pollution, siltation and habitat fragmentation on community structure³⁴. There is, however, no information on the degree of impact of pollution on dominant macroalgal species and community as a whole.

A number of surveys have been carried out to study distribution, abundance and to evaluate economic important macroalgal resources. It is, necessary to have long term monitoring program at selected sites to provide information on how biodiversity changes with space and time and whether changes are brought by natural means or by anthropogenic impacts.

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