

## Impact of sewage on the distribution, abundance and community structure of rocky intertidal macroalgae of the Colaba coast, Mumbai, India

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### ABSTRACT

Three transects T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> in the intertidal area of Colaba were sampled for macroalgal distribution, abundance, species composition, diversity and standing stock estimation during 1997-98. Transect T<sub>2</sub> was in the vicinity of the sewage discharge point and T<sub>1</sub> and T<sub>3</sub> were on either side of T<sub>2</sub> at a distance of about 800m. Comparatively, less number of species and different pattern of macroalgal assemblages were recorded at the discharge point, while transects distance from discharge point showed more number of species, luxuriant growth and well developed macroalgae. The opportunistic species such as *Ulva fasciata*, *Enteromorpha* spp., *Cladophora vagabunda*, etc. were abundant at the vicinity of the discharge point T<sub>2</sub>. Highly branched, coarse and calcareous species like *Laurentia papillosa*, *Solieria robusta*, *Gracilaria corticata*, *Caulerpa* spp, *Cheilosporum spectabile*, *Amphiroa fragilissima* etc. were found abundantly at T<sub>1</sub> and T<sub>3</sub>. These species, although contribute substantially to the biomass, their composition differs at all the three transects and also at the littoral level. Highest biomass of 1.43 kg m<sup>-2</sup> was recorded at T<sub>1</sub> while lowest of 0.76kg m<sup>-2</sup> was at T<sub>2</sub>. There was a shift in the composition of macroalgal species from biotically competent to stress tolerant and opportunistic at T<sub>2</sub>. The factors responsible for structuring macroalgal communities at Colaba were distance from the sewage discharge point, degree of tidal flushing and tolerance capacity of the macroalgae to sewage.

### Introduction

Metropolitan cities like Mumbai, produce large quantities of sewage effluent which is released into the coastal waters after preliminary treatment. Treated sewage is comprised of a complex mixture of nitrogenous compounds, ortho-phosphates, synthetic detergents, trace metals, residual

chlorine, hydrocarbon, microorganisms and organic particulate (Andrews, 1976; Doblin and Clayton, 1995). All these compounds can have deleterious effect on marine organisms. The effect of treated sewage was mainly observed on species composition and is often associated with a shift in dominance and community complexity (Munda, 1982; Brown *et. al*, 1990).

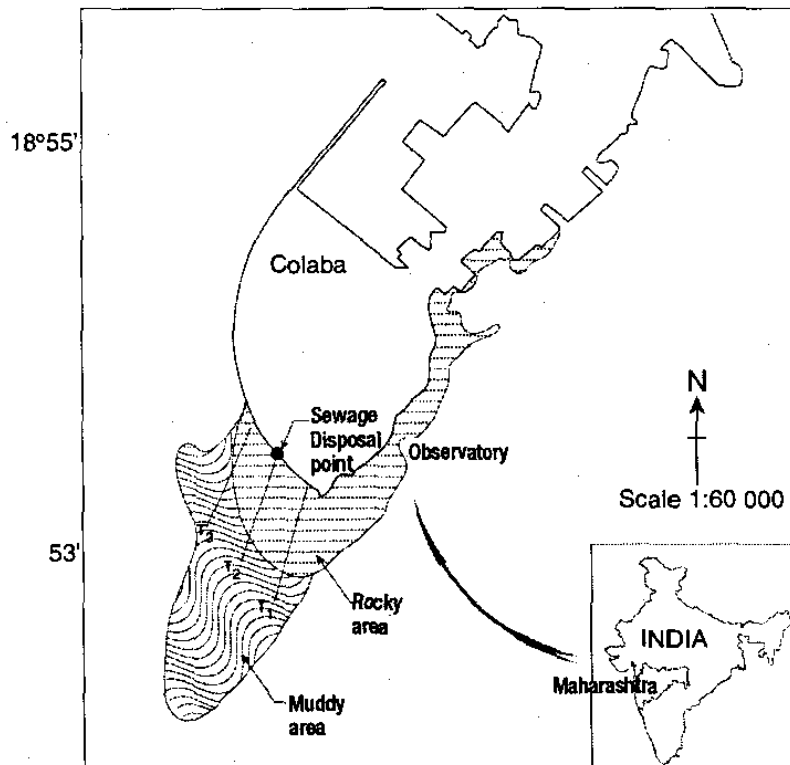


Fig. 1. Rocky intertidal area of Colaba showing three sampling transects and sewage disposal point

Exposure of macroalgae to sewage effluent results in the reduction in number of macroalgal species and increase in the standing stock of the opportunistic species (Souza, 1980; Littler *et al.*, 1983). The effect of the treated sewage on benthic macroalgal assemblages have been studied by Littler and Murray (1975), May (1981), Munda (1982), Murray and Littler (1984), Tiwari and Joshi (1988), Brown *et al.* (1990) Fairweather (1991) and others. The aim of the present study was to evaluate the impact of treated sewage on the macroalgal distribution, abundance and community composition in the vicinity of a discharge point and away from the discharge point. The occurrence of a number of well developed macroalgae in the polluted water of Colaba has also been discussed.

#### Study site

Colaba is the southern most tip of Mumbai, lies in between Lat.  $18^{\circ} 52' 50''$

to  $18^{\circ} 55' 00''$  N and Long.  $72^{\circ} 47' 40''$  to  $72^{\circ} 49' 52''$  E (Fig. 1). It encloses a sheltered beach facing north west in a small shallow bay formed by a seawall. The shoreline has a gradual slope with emerging rocks enclosing several shallow rock pools. Rocks extend downwards to the level of MLWS below which the bottom of the bay consists of soft clayey mud.

#### Materials and Methods

Three transects were selected for macroalgal studies. The sewage discharge point is at supra littoral zone near the transect  $T_2$  as shown in Fig.1. Transects  $T_1$  and  $T_3$  are on the either side of  $T_2$  at a distance of about 800 m (Fig. 1). The length of each transect was about 300 meters. In order to study macroalgal distribution and composition along the three transects, the area is further divided into upper, mid and lower littoral for convenience. At each transect, 1 m wide belt transect was laid

perpendicular to the coast. Macroalgae were sampled at random by placing 0.25 m<sup>2</sup> quadrant in triplicate to have representative samples. Macroalgae from each quadrant were collected, washed with seawater, sorted, counted and weighed species-wise to calculate biomass (kg m<sup>-2</sup>, wet weight).

Macroalgal distribution, community composition, biomass, species diversity were studied during the post and pre - monsoon seasons in 1997 and 1998 respectively. Species diversity was calculated based on the biomass values of the dominant macroalgae (Pielou, 1966).

### Results and Discussion

Primary treated sewage is discharged in the coastal waters of Mumbai at the rate of about 80 x 10<sup>6</sup> L day<sup>-1</sup>. The general quality of sewage generated at Mumbai and water quality parameters for the post and pre-monsoon of 1997-98 at Colaba are given in Table 1. In all, 64 macroalgal species have been recorded from Colaba area (Table 2). Rhodophyta

dominates at all the three transects followed by Phaeophyta and Chlorophyta except at T<sub>2</sub> where Rhodophyta is followed by Chlorophyta and then Phaeophyta. Of the total species recorded, 82.81 % species were present at T<sub>1</sub> 57.81 % at T<sub>2</sub> while T<sub>3</sub> had 73.43 %. These differences noticed in the species composition on the transect in the vicinity of the sewage discharge point (T<sub>2</sub>) and away from the discharge points (T<sub>1</sub> & T<sub>3</sub>) may be due to the physico-chemical conditions of the sewage and biological factors present in the region (Lubchenco and Gains, 1981). Some of the Phaeophyta members that are sensitive to sewage pollution were absent in the vicinity of the polluted area (T<sub>2</sub>) while opportunistic and turf forming species were abundant at sewage discharge point.

At T<sub>1</sub> macroalgae, such as *Caulerpa sertularioides*, *C. peltata*, *C. racemosa*, *Laurencia papillosa*, *Gracilaria corticata*, *Solieria robusta*, *Sargassum swartzii* and *S. ilicifolium* were abundant in the lower littoral zone. The numerous shallow rock pools

Table 1. Constituents of the preliminary treated sewage effluent discharged at Mumbai and environmental parameters for post and pre monsoon seasons (1997-98) at Colaba, Mumbai

Constituents	* Mumbai	Parameters	** Colaba
Dissolved solids (mg/l)	1500	Temperature (°C)	26.9-27.0
Suspended solids (mg/l)	235	Suspended solids (mg/l)	31.0-33.0
pH	7.0	pH	7.8-8.2
BOD (mg/l)	250	Dissolved Oxygen (ml/l)	5.8-6.3
COD (mg/l)	350	Salinity (‰)	30.2-35.2
Total nitrogen (mg/l)	35	P <sub>04</sub> -P (µmol/l)	3.9 - 6.8
Total phosphorus (mg/l)	6.0	NO <sub>3</sub> -N (µmol/l)	1.2-5.7
Chromium (mg/l)	0.02	NO <sub>2</sub> -N (µmol/l)	0.3-1.9
Copper (mg/l)	0.08	NH <sub>4</sub> -N (µmol/l)	0.1 -1.61
Zinc (mg/l)	0.2		
Cadmium (mg/l)	0.01		

Source: \* M. D. Zingde (Personal communication), \*\* Zingde *et al.* (1998)

Table 2. List of marine macrophytes recorded at Colaba

Name of the species	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>
<b>CHLOROPHYCEAE</b>			
<i>Ulva fasciata</i> Delile	+	+	+
<i>U. lactuca</i> Linnaeus	-	+	-
<i>Enteromorpha clathrata</i> (Roth) Greville	-	+	+
<i>E. flexuosa</i> (Wulf) J. Ag.	+	+	-
<i>E. intestinalis</i> (Linn.) Nees	+	+	+
<i>Chaetomorpha antennina</i> (Bory de Saint Vincent) Kuetz.	-	+	-
<i>C. linum</i> (Muell) Kuetz.	+	+	-
<i>Cladophora vagabunda</i> (Linn.) Van den Hauck	+	+	+
<i>Caulerpa verticillata</i> J. Ag.	+	+	-
<i>C. sertularioides</i> (Gmel.) Howe	+	+	+
<i>C. recemosa</i> (Forssk.) Weber v. Bosse	+	+	+
<i>Caulerpa</i> sp.	+	-	-
<i>C. peltata</i> Lamour.	+	+	-
<i>Bryopsis plumosa</i> (Hudson) C. Ag.	-	+	-
<i>B. hypnoides</i> Lamour.	-	+	+
<i>Ernodesmis verticillata</i> (Kuetz.) Boerg.	-	+	+
<i>Avrainvillea</i> sp.	-	-	+
<i>Struvea anastamosans</i> (Harvey) Piccone and Grunow ex Piccone	+	-	-
<b>PHAEOPHYCEAE</b>			
<i>Feldmannia irregularis</i> (Kuetz.) Hamel	+	-	+
<i>Hincksia mitchelliae</i> (Harv.) P. Silva	+	-	+
<i>Sphacelaria rigidula</i> Kuetz.	+	+	+
<i>Dictyota dichotoma</i> (Huds.) Lamour.	+	+	+
<i>Dictyopteris australis</i> (Sonder) Askenasy	+	-	+
<i>Lobophora veriegata</i> (Lamour.) Womersley ex Olivieae	+	-	-
<i>Padina gymnospora</i> (Kuetz.) Sonder	-	-	+
<i>P. tetrastrumatica</i> Hauck	+	+	+
<i>Ralfsia expansa</i> (J. Agardh) J. Agardh	+	-	+
<i>Stoechospermum marginatum</i> (C. Ag.) Kuetz.	+	-	+
<i>Spatoglossum asperum</i> J. Ag.	+	-	+
<i>Colpomenia sinuosa</i> (Mertens ex Roth) Derbes and Solier	+	-	+
<i>Sargassum swartzii</i> C. Ag.	+	+	+
<i>S. cinereum</i> J. Ag.	+	+	-
<i>S. ilicifolium</i> (Turn.) J. Ag.	+	-	+
<b>RHODOPHYCEAE</b>			
<i>Porphyra vietnamensis</i> Tanaka and Phar Hoang Ho	+	+	+
<i>Scinaia hatei</i> Boergs.	+	-	-
<i>Grateloupia lithophila</i> Boergs.	-	+	+
<i>G. filicina</i> (Lamour.) C. Ag.	-	-	+
<i>Hydrolithon farinosum</i> (Lamour.) Penrose and Chamberlain	-	+	+
<i>Amphiroa fragilissima</i> (Linn.) Lamour.	+	+	+
<i>Jania adhaerens</i> Lamour.	+	+	+
<i>Cheilosporum spectabile</i> Harvey ex Grunow	+	+	+

Table 2. continued...

Name of the species	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>
<i>Lithophyllum</i> sp.	+	-	+
<i>Gelidium pusillum</i> (Stackh.) Le Jolis	+	+	+
<i>Gelidiopsis variabilis</i> (J. Ag) Schmitz	+	-	-
<i>Sarconema filiforme</i> (Sond.) Kylin	+	-	+
<i>Solieria robusta</i> (Grev.) Kylin	+	+	+
<i>Gracilaria corticata</i> (J.Ag) J. Ag.	+	+	+
<i>G. verrucosa</i> (Huds.) Papenfuss	+	+	-
<i>Hypnea valentiae</i> (Turn.) Montagne	+	+	+
<i>H. spinella</i> (C. Ag.) Kuetz.	+	+	+
<i>Champia parvula</i> (C. Ag.) Harvey	+	-	+
<i>Castroclonium</i> sp.	+	-	+
<i>Ceramium cimbricum</i> H. Peterson	+	+	+
<i>Spyridia fusiformis</i> Boergs.	+	-	+
<i>Laurencia obtusa</i> (Huds.) Lamour.	+	-	-
<i>L. papillosa</i> (C. Ag.) Greville	+	+	+
<i>Chondria armata</i> (Kuetz.) Okamura	+	-	-
<i>C. tenuissima</i> C. Ag.	+	-	+
<i>Rhodymenia palmata</i> (Linn.) Kuntze	+	-	+
<i>Polysiphonia platycarpa</i> Boergs.	+	+	+
<i>P. denudata</i> (Dillwyn) Greville	+	-	-
<i>Centroceras clavulatum</i> (C. Ag.) Montagne	+	+	+
<i>Acanthophora spicifera</i> (Vahl.) Boergs.	+	-	+
<i>Caloglossa leprieurii</i> (Mont.) Mertens	+	+	+

Legends: T<sub>1</sub> - Transect towards lighthouse; T<sub>2</sub>-Transect towards the centre near disposal point  
T<sub>3</sub> - Transect towards TIFR

at this transect had abundantly growing macroalgae in association with coral *Goniopora stokesi*, which occupied about 23% of the littoral zone. Similar species composition and community structure were noticed at mid-littoral zone.

Differences were also noted in the size of the plants where growth was maximum. Macroalgae from T<sub>1</sub> were larger and better developed than that from other two transects. Large and better developed macroalgae at this transect, perhaps, could be attributed to the nitrogenous waste present in the sewage. Nitrogen is generally considered to be a critical factor limiting macroalgal growth (Rhyther and

Dunstan, 1971). Rosenberg and Ramus (1984) demonstrated that the uptake of ammonium and nitrate is positively correlated with surface area to volume ratio (S:V) of the macroalgal thallus. The morphologies of macroalgae may facilitate uptake of nitrogenous nutrients allowing more rapid growth. These macroalgae contribute substantially to the biomass (1.43 kg m<sup>-2</sup> wet weight) recorded at T<sub>1</sub> (Fig. 2).

Upper littoral zone was dominated by filamentous macroalgae like *Enteromorpha clathrata*, *E. flexuosa*, *E. intestinalis*, *Cladophora fascicularis*, *Chaetomorpha antennina*, *Ernodesmis verticillata* and *Ceramium cimbricum*.

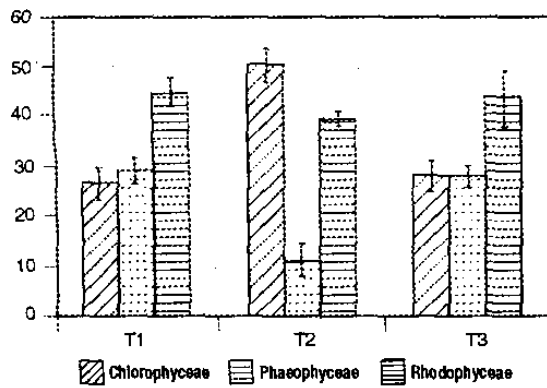


Fig. 2. Group wise biomass (%) of the three transects at Colaba, Mumbai.

Chlorophyta dominates this zone. The rocky boulders at this transect were found covered with the chlorophyta members forming a green carpet. Well developed green macroalgae at this transect indicated that the rate of sewage dilution at T<sub>1</sub> is beneficial to these algae.

At T<sub>2</sub>, composition of macroalgae varied from upper littoral to lower littoral. The total number species recorded at this transect was 37 with dominance of Rhodophyta (45.94 %) followed by Chlorophyta (40.54 %) and Phaeophyta (13.51 %). Chlorophyta members such as *Ulva fasciata*, *Enteromorpha* spp. *E. verticillata* etc., dominated with few Rhodophyta members such as *Ceramium cimbricum* and *Gelidium pusillum* at the upper littoral zone. The lower percentage of Phaeophyta indicated that although considerable flushing takes place at this transect, the rate of dilution is not effective as compared to the other two transects.

Although, the mid-littoral had different macroalgal composition, it showed predominance of Chlorophyta (43.8%) followed by Rhodophyta (36.36%)

and Phaeophyta (19.83 %). The main constituents of Rhodophyta were comprised of jointed coralline macroalgae such as *Amphiroa fragilissima*, *Cheilosporum spectabile*, *Jania adhaerens* etc. The overall growth of coralline macroalgae at this zone was found to be stunted. Perhaps, comparatively high phosphate concentration in the sewage in the vicinity of discharge point acts as crystal inhibitors of calcification (Brown *et. al*, 1977). Calcareous articulated coralline macroalgae are regarded as a relatively long lived or perennials and they are also biotically competent species (Murray and Littler, 1984).

Lower littoral had mixed macroalgae such as *Caulerpa* spp., *Cheilosporum spectabile*, *Amphiroa fragilissima*, *Gracilaria corticata*, *Dictyota dichotoma*, *Stoechospermum marginatum*, *Sargassum* spp. etc. Although Phaeophyta members contributed less to the biomass at T<sub>2</sub> (Fig. 2) in lower and mid-littoral zones, they showed comparatively good growth at a distance of about 150 m from the discharge point. This indicates that considerable sewage dilution takes place at this transect away from the discharge point, which is evident from the presence of *Sargassum* spp. at lower littoral zone. The reduced number of macroalgae or absence of some macroalgae common to other two transects suggest that this zone is experiencing a situation where species present are able to withstand extra stress exerted by the presence of sewage.

On the basis of the strategy model developed by Vermeji (1978) and applied to rocky intertidal population by Seapy and Littler (1982) and Littler *et al* (1983), the macroalgal population at T<sub>2</sub> has been categorized as opportunistic, stress

tolerant and biotically competent species. *Ulva fasciata* and *Enteromorpha* spp. with high reproductive output, short life span and high dispensability have been categorized as opportunistic species. Species like *Caulerpa* spp., *Hypnea spinella*, *Gracilaria corticata*, *Laurancia papillosa*, *Dictyota dichotoma* can tolerate physiological stress, slow in growth and poor competitors are categorized as stress tolerant species, while, *Amphiroa fragilissima*, *Cheilosporum spectabile*, *Jania adhaerens* with long life, good competitors and having mechanism to reduce predation have been categorized as biotically competent species. The species distribution and composition of macroalgal communities indicated that there is a shift in the composition of the macroalgal species from biotically competent to stress tolerant and opportunistic species, contributing substantially to the algal biomass at T<sub>2</sub>. Life history characteristics, such as the frequency of reproduction, number of modes of reproduction and life span are probably some of the important factors that may explain species shift (Brown *et. al.*, 1990; Doblin and Clayton, 1995). Opportunistic sewage tolerant macroalgae such as *Ulva fasciata* and *Enteromorpha* spp. can increase their reproductive output in the nutrient rich waters (Bellgrove *et. al.*, 1997). These species are fertile throughout the season and produce 2 to 3 times more propagules, regenerate vegetatively from basal tissue and they possess characteristically rapid growth rate with high productivity (Littler and Murray, 1975) unlike most of the Phaeophyta and Rhodophyta having complex reproductive cycles.

At T<sub>3</sub> total number of species recorded was 47, with 19.15 % represented by Chlorophyta, 27.65 % by Phaeophyta and 53.19 % by Rhodophyta. The macroalgal

assemblages such as *Cheilosporum spectabile*, *Padina tetrastrumatica*, *Grateloupia lithophila*, *Caulerpa* spp. were predominant at T<sub>3</sub> in the lower littoral zone. Mid - littoral had *Padina tetrastrumatica*, *Grateloupia filicina*, *Amphiroa fragilissima*, *Stoechospermum marginatum* in varying composition. These species were found in association with the coral *Porites* spp. Upper littoral assemblage was dominated by Chlorophyta members like *Ulva fasciata*, *Enteromorpha* spp., *Chaetomorpha antennina*, *Ernodesmis verticillata*. Rhodophyta member, *Caloglossa lepreurii* formed thick carpet on the boulders.

Rock pools in the mid-littoral zone at T<sub>3</sub> also showed luxuriant growth of crustose macroalga *Melobesia farinosa* covering about 58% of the rock surface. Stony coral, *Porites* spp. were present only at this transect in association with *Grateloupia lithophila*, *Cheilosporum spectabile*, *Caulerpa* spp., *Padina tetrastrumatica* etc. and some sponges. The maximum contribution to biomass at this transect (1.04 kg m<sup>2</sup>) was from these macroalgae. The two transects (T<sub>1</sub> & T<sub>3</sub>), although had high biomass they differ in their species composition and community structure.

Data on macroalgal standing stock was also analysed in terms of functional groups using four categories i.e. macroalgae were classified based on thallus morphology as sheet forming, filamentous, coarsely branched and calcareous forms. The significant contribution to macroalgal biomass at T<sub>1</sub> and T<sub>3</sub> was from coarsely branched macroalgae such as, *Caulerpa* spp., *Laurencia papillosa*, *Gracilaria corticata*, *Solieria robusta*, *Grateloupia lithophila*, *Sargassum* spp. etc., and calcareous macroalgal forms such as

*Cheilosporum spectabile*, *Amphiroa fragilissima*, *Jania adhaerens* etc. However, species composition at these two transects varied. Opportunistic species showed slightly higher composition at T<sub>2</sub> and T<sub>3</sub>, while sheet forming did not show significant difference (Fig. 3). This indicates that in the polluted waters, thallus structure of macroalgae plays a very significant role for survival, growth and reproduction.

The study indicated that the dilution of the sewage is the most important factor for the survival of macroalgae in the polluted area. Dhargalkar (1986) in the experimental studies on the effect of treated sewage on eight macroalgal species from the Goa

coast showed that at 5 % dilution of treated sewage resulted in good growth in *Ulva fasciata*, *Chetomorpha antennina*, *Gracilaria verrucosa*, *Padina tetrastratica*, *Stoechospermum marginatum* and *Spatoglossum asperum* while *Sargassum* sp. was found to be least tolerant to sewage. Flushing out of the effluent at Colaba is so rapid that there is hardly any deleterious effect on macroalgal growth (Zingde *et al*, 1998) except in the close vicinity of the sewage discharge point at T<sub>2</sub>. The composition, distribution and diversity of macroalgae near discharge point and away from discharge point not only depend on the dilution factor but also on the sensitivity of macroalgae to the level of dilution.

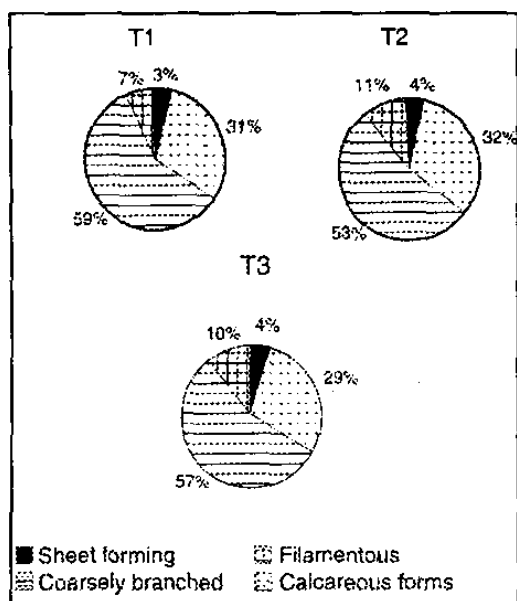


Fig.3. Percentage of functional groups at three transects

The structure of macroalgal community as measure of diversity indices showed that T<sub>2</sub> had low diversity and reduced number of larger species which were replaced by more tolerant species like *Ulva fasciata*, *Enteromorpha spp.*, *Cladophora sp.* etc. The data when pooled and computed as one value per transect showed highest diversity index at T<sub>1</sub>. This indicates that water quality at this transect is conducive for macroalgal growth. Transect T<sub>3</sub> is intermediate between T<sub>1</sub> and T<sub>2</sub>. Although good growth was seen in some of the macroalgae, dilution of the sewage is not that effective. Shannon-Wiener and Simpson's diversity indices and equally common species showed similar pattern (Table 3).

Table 3. Diversity indices of the three transects at Colaba, Mumbai

Parameters	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>
Simpson's Diversity	0.926	0.885	0.91
Reciprocal of Simpson's Diversity	13.539	8.663	11.120
Shannon Wiener Diversity	3.967	3.272	3.616
No. of equally common species	15.64	9.66	12.26



Information on the sewage tolerance capacity and rate of nutrient uptake of the individual macroalgal species is not available. Data on these lines are required to be generated by undertaking experiments to decipher the relationship between macroalgae and sewage. This data will definitely assist in planning, management and monitoring strategies of sewage in the coastal waters.

### Acknowledgement

Authors thank the Director, NIO, Goa for encouragement and colleagues for helping in the field collection.

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