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Biodiversity in fouling species at Karanja Jetty (Mumbai), west coast of India

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Abstract

The study on assessment of fouling species was carried out for a period of 16 months (February 2002–May, 2003) at Karanja jetty in Mumbai harbour (lat.18° 55' N; long.72° 50' E). The biofouling was examined with regard to its species abundance (density) species composition (diversity) and biomass (dry wt.). Forty eight species were recorded during the study period. The species recorded belonged to phylum Annelida (6 species), Ectoprocta (21), Arthropoda (3), Mollusca (4), Tunicata (3), Coelenterata (4), Porifera (2) and others 5 species. The number of species settled at Karanja ranged from 8 to 26. The highest number of species recorded was in April 2003 and lowest in March 2002. Of the 48 recorded species, 5 were new records from the region. The study revealed that the density varied significantly from month to month and season to season. The density recorded was significantly more during pre-monsoon and post-monsoon than recorded during the monsoon ($p<0.00005$ and $p< 0.005$). Pre-monsoon showed high density than post-monsoon. The species recorded during the pre-monsoon, monsoon and post-monsoon were 17 ± 4, 16 ± 4 and 19 ± 3 respectively. The species settled during pre-monsoon were significantly less than those settled in post-monsoon ($p<0.05$). Monthly variations were observed in biomass only. It varied between 3.4 and 89 g/m^2. The highest biomass recorded was 89.0 ± 34.0 g/m^2 during which as many as 21 fouling species including barnacles contributed to the biomass build-up.

Keywords: Biofouling, seasonal variations, species composition, biomass, biodiversity

Introduction

The development of macrofoulers on immersed structures or on marine machinery has now been recognised as one of the major problems and is receiving increased attention all over the world. The present investigation was mainly confined to major groups of biofouling species of bryozoans, polychaetes, cirripedes and ascidians. The individuals of these groups contribute to more than 98% of fouling assemblage developed at any time of the year in Mumbai harbour (Swami, 2003). Sufficient amount of research work on biofouling has been carried out in Indian tropical waters (Karande, 1968; Karande, 1978; Renganathan *et al*., 1982; Karande *et al*., 1986; Anil and Wagh, 1988; Karande and Swami, 1988; Nair *et al.*, 1988; Rao and Balaji, 1988; Swami and Karande, 1988, 1994; Maruthamuthu *et al*., 1990; Venugopalan and Wagh, 1990; Eashwar *et al.*, 1991; Venugopalan *et al.*, 1991; Sasikumar *et al.*, 1993; Venkat *et al*., 1995; Swami and Gaonkar, 1998 and Swami and Udhayakumar, 2004, 2010). Previous work on biofouling studies conducted at Mumbai covered only three study sites *viz*. Near-shore waters, Wet basin and Tidal basin. However, the present study site remained unexplored as it is located 4 kms off the above mentioned sites and jetty supports heavy activities of passenger boats, ships and tug movements. Aim of the work is to determine the community abundance, species composition and biomass of macrofouling organisms in relation to temporal variation.

The present site is being explored for the first time for its biota. This work would provide a basic information on biological aspects such as community structure, predominance of organisms and species diversity. The seasonal variations on the settlement

and distribution of the sedentary organisms has been examined. The data collected will remain as a source of biological information required for developing eco-friendly antifouling technology to control the fouling.

Material and Methods

Exposure site: In order to assess the settlement, distribution, species composition and seasonal variability of macrofoulers, the test coupons were exposed during February, 2002 at Karanja Jetty in Mumbai harbour (lat. 18° 55' N; long. 72° 50' E). The site (Fig. 1) is located along the west coast of the mainland near Uran township and is four km away from near-shore waters of Mumbai harbour. The water turbulence was relatively more at this site and depth of water is 10 metres. In order to assess the water quality, the samples were collected from one meter below the surface water. Hydrographical parameters such as temperature, pH, salinity, dissolved oxygen (DO) and total suspended solids (TSS) were estimated by employing standard methods (Martin, 1968). The estimation of chlorophyll '*a*' was done described by adopting the method in APHA (1980).

Exposure of the coupons: In field exposure studies for collecting data on various biological aspects, the test panels of polymethyl methacrylate (perspex) having the size of 15 x 16 x 0.4 cm were bolted on M.S. frames. The experimental frames were immersed one meter below the low tide mark. A set of 10-12 test panels was immersed at every calendar month and an equal numbers were withdrawn for examining the biota under live condition (non-destructively). The biological observations were carried out for a period of 16 months from February 2002 to May 2003.

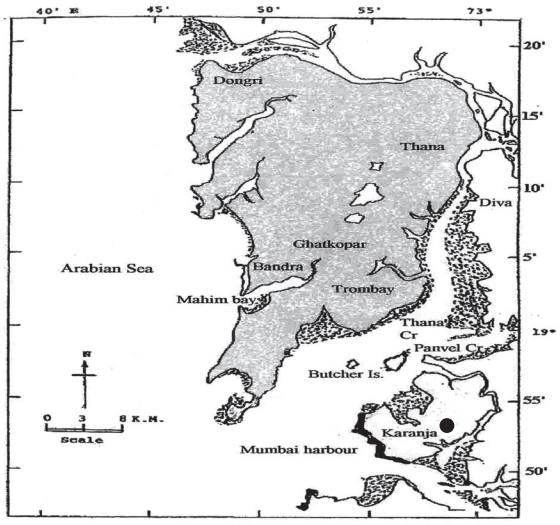

Fig. 1. Map showing the study site

Examination of the coupons: The test panels (coupons) were examined under stereo -microscope. The census of each individual was made using square grid methods (Winston and Jackson, 1984; Karande and Swami, 1988). A thin perspex sheet was engraved with squares of 1 cm mark and superimposed on the test panel. The biota assessed was characterised as density, species composition and biomass. The coupon area of 15 cm x 12 cm (180 sq. cm) was actually screened. The census was made using stereo-microscope (Ziess) to measure each individual. The data collected were statistically treated (Trivedy and Goel, 1984). After examination of the biota, fouling was scraped and wet weight was recorded. The panels were preserved in 5% formalin for 6 hours and were kept for air drying for 8-10 days to get constant weight. The test panels were weighed before immersion. The biomass was estimated accurately and expressed as g/m^2.

Results

Hydrography: Table 1 shows the hydrographical conditions recorded at Karanja jetty for the period of 16 months. The environmental parameters like temperature, salinity, DO and TSS were recorded continuously from February, 2002. Temperature ranged between 26.5° C and 32.3° C. Lowest value of 26.5° C was recorded in February, 2003 while highest value of 32.3° C was observed in June, 2002. Temperatures recorded during post-monsoon months (winter), were lower than in the summer months. pH values recorded from time to time remained almost uniform. The lowest value of 7.79 and the highest (8.02) were recorded in March 2002 and 2003 respectively. Salinity varied between 25.5 and 37.18‰. The lowest value was recorded in August, 2002 (monsoon) and highest in May, 2003 (summer). The salinity recorded during the investigation period

Table 1. Hydrographical characters and chlorophyll contents recorded at Karanja jetty

Period	Physico-chemical parameters					Chlorophyll contents		
	Temp. (°C)	PH	Salinity (‰)	DO (mg/l)	TSS (mg/l)	'a'	'b'	'c'
						mg/m^3		
				Pre-monsoon				
February '02	26.9	7.98	35.57	5.21	84.7	2.96	3.64	2.40
March	28.8	8.02	35.57	6.57	24.0	4.2	4.18	0.14
April	31.9	7.81	36.21	4.93	87.0	3.29	1.94	1.92
May	32.0	7.96	35.54	5.4	99.4	2.19	1.71	1.80
				Monsoon				
June	32.3	7.93	36.21	5.93	161.6	0.28	0.38	0.97
July	28.7	7.96	30.76	6.48	176.0	2.76	3.05	7.91
August	29.1	8.01	25.5	6.12	87.6	3.72	3.90	3.01
September	29.4	7.97	31.4	6.84	150.0	6.42	5.67	2.57
				Post-monsoon				
October	31.0	7.99	32.69	6.12	48.4	7.45	5.46	2.81
November	30.6	7.97	34.29	5.95	31.24	15.74	3.59	-
December	28.4	7.91	36.21	5.84	37.0	3.99	4.26	6.06
January 03	26.7	7.98	34.92	6.99	26.0	1.87	2.08	0.30
				Pre-monsoon				
February	26.5	7.97	35.81	5.89	54.3	2.74	2.10	1.15
March	28.6	7.79	36.21	6.20	61.6	3.64	1.72	3.31
April	32.0	7.92	36.77	6.21	51.2	2.55	1.20	2.32
May	31.8	7.91	37.18	6.20	41.2	2.03	1.69	4.53

Temp. = Temperature, DO = Dissolved oxygen, TSS = Total suspended solids

followed same profile as that of the west coast of India.

The DO ranged between 4.93 and 6.99 mg/l (Table 1). The average value remained around 5.8 mg/l, indicating pollution-free status of the water mass. The TSS values varied between 24.00 and 176.00 mg/l. The highest value was recorded during July, 2002 and lowest in March 2002. TSS values recorded during the monsoon were higher than those in non-monsoon months.

Chlorophyll: Concentrations of chl- *a* varied from 1.87 to 15.74 mg/m^3. The highest value was recorded during November 2002 and the lowest in January 2003 (Table 1). The lowest value (0.28 mg/m^3) may be attributed to the high turbidity (161.6 mg/l) caused due to the high turbulence of water mass during the monsoon. The average value remained around 2.2 mg/m^3 during entire study period.

Biological observations

Density: The number of settled organisms on each panel was counted. Table 2 shows the list of the species recorded from Karanja jetty. These species mainly belonged to phylum bryozoa, polychaeta, cirripede, mollusca and hydroids.

Table 3 shows the monthly variations in population density, species composition and biomass at Karanja jetty. It is observed that the density varied from month to month. The population density ranged between 2,246 and 20,665 no./m^2. The highest population density recorded was 20,665 no./m^2 during February 2002 and the lowest of 2,246/m^2 was recorded during June 2002.

Month-to-month variation

Observations showed that the density varied from month-to-month. During 2002 February, the density was significantly higher than in March (p<0.02). It was further observed that the density varied considerably during April to July. Monthly variations estimated were highly significant (p<0.00005). Particularly, during monsoon, monthly variations were quite high, whereas in post-monsoon season, monthly difference in density was observed to be

Table 2. The macrofouling species recorded at Karanja jetty

Name of the species	
Coelenterata	**Erect forms**
Companularia sp.	*Bugula bengalensis*
Obelia sp.	*Bugula neritina*
Sertularia sp	*Victorella pavida*
Plumularia sp.	*Amethia convoluta*
Annelida	*Nellia tenella*
Hydroides elegans	†*Electra bellula*
Hydroides operculatus	*Nolella popuenensis*
Apomatus sp.	**Cirripedes**
†*Spirorbis* sp.	*Balanus variegates*
Desycone cingulata	*Balanus reticulates*
Pseudobranchiomma orientalis	*Chirona amaryllis eumaryllis*
Bryozoans (encrusting)	**Tunicata**
Electra bengalensis	*Symplegma reptans*
Membranipora annae	*Botrylloids magnicoecum*
Membranipora tenuis	†*Ascidia molgula*
Membranipora sp.	**Mollusca**
Membranipora saverti	*Crassostrea gryphoides*
†*M. hugliensis*	*Crassostrea* sp.
Acanthodesia sp.	*Saccostrea cucullata*
Alderina arabienensis	*Oyster* sp.
Hippoporina americana	**Porifera**
Hippopodina feegeensis	*Leucosolenia* sp.
Electra crustulenta	*Sycone* sp.
Electra tenella	Amphipods, copepods & neried worms (5 sps. not identified)
†*Microporella* sp.	
Clothrudim sp.	†New records

insignificant (Table 4). Out of 15 (month-month) comparisons, at 11 occasions (73%) the '*p*' values were significant. Interestingly, during pre-monsoon and post-monsoon months of 2002 a decreasing trend in density was observed whereas in pre-monsoon of 2003, increasing trend in density was observed. The density recorded in January 2003 was (7765/m^2), which gradually increased during a span of four months and attained the peak of 14,220/m^2 in April 2003. No definite trend was observed during monsoon months.

Seasonal variations

The results showed that the density was significantly high during pre-monsoon and post-monsoon than that during the monsoon ($p<0.00005$ and $p< 0.005$). Density recorded was also high during pre-monsoon than noted in post-monsoon season. The average seasonal values recorded during pre-monsoon and post-monsoon were 14227 ± 3071 and 9270 ± 3537 respectively. Hence the difference was highly significant (Table 5).

Species composition: Table 2 lists the major macrofouling species settled on the test coupons exposed at Karanja jetty. As many as 48 species have been recorded during the investigation period. The species recorded belong to phylum - Annelida 6 species, Ectoprocta 21, Arthropoda 3, Mollusca 4, ascidians 3, hydroids 4 and others 7 species. The number of species settled at this site ranged from 8 to 26. The highest number of species was recorded in pre-monsoon month of April 2003.

Month-to-month variations

Table 4 shows monthly variations in species composition. Initially it showed highly significant difference in monthly settlement. The estimated '*p*' values remained consistent for all the four months indicated as highly significant ($p<0.00005$). During June, the number of species decreased suddenly to 13 from 22 recorded in May 2002. Subsequently the settlement remained consistent till August, and again in September, the species number increased to 21. Generally, species settlement from June 2002 to December 2002 was consistent showing no significant difference.

Seasonal variations

The statistically estimated variations in species prevalence recorded during three seasons revealed that the species settled during pre-monsoon were significantly less than those settled in post-monsoon ($p<0.05$). During monsoon, the number of species encountered was relatively less. The average species recorded during pre-monsoon, monsoon and post-monsoon were 17 ± 4 , 16 ± 4 and 19 ± 3 respectively (Table 5).

Table 3. Macrofouling intensity and its characterization at Karanja jetty

Period	Density (no/m^2) Mean ± SD	Species comp. (no/panel) Mean ± SD	Biomass (g/m^2) Mean ± SD
		Pre-monsoon	
February '02	20665 ± 5776	22 ± 1	39.12 ± 6.01
March	14596 ± 2503	8 ± 1	26.75 ± 12.0
April	13776 ± 2489	15 ± 2	31.75 ± 8.71
May	7869 ± 1515	22 ± 3	43.1 ± 10.62
		Monsoon	
June	2246 ± 1054	13 ± 2	5.62 ± 3.81
July	8506 ± 1808	14 ± 3	9.25 ± 9.64
August	10642 ± 734	14 ± 2	3.4 ± 2.13
Sept	7476 ± 2639	21 ± 3	89.0 ± 34
		Post-monsoon	
Oct	11009 ± 1908	19 ± 3	50.1 ± 10.7
Nov	9390 ± 1037	17 ± 2	16.3 ± 5.4
Dec	8860 ± 3290	17 ± 2	24.5 ± 5
Jan 03	7765 ± 879	23 ± 3	54.87 ± 7.7
		Pre-monsoon	
Feb	8460 ± 1105	25 ± 3	44.6 ± 7.3
Mar	11289 ± 2191	22 ± 2	42.87 ± 3.75
Apr	14220 ± 3186	26 ± 3	45.0 ± 9.75
May	8974 ± 2958	25 ± 3	41.0 ± 3.3

SD = Standard deviation

Biomass

Month-to-month variations

Table 4 shows the monthly variations in biomass. The observations revealed that the biomass varied from month to month. It varied between 3.4 and 89 g/m^2. During pre-monsoon months of 2002, the values ranged from 26.75 to 43.1 g/m^2, the average being 35.18 ± 9.93. The peak period for biomass build-up was in September 2002, during which 21 species were involved and the biomass recorded was 89.0 ± 34.0 g/m^2. The lowest biomass (3.4 g/m^2) was noted during August 2002. Biomass build-up was observed to be consistent in pre-monsoon months of 2003 which is correlating to the consistent occurrence in species settlement.

Seasonal variations

The biomass recorded during pre-monsoon and post-monsoon were significantly higher than the biomass recorded during the monsoon. The variations in biomass estimated between pre-monsoon and monsoon and post-monsoon and monsoon were $p<0.005$ and $p<0.00005$ respectively. Study indicated that biomass build-up was affected during the monsoon season. However, no significant difference in biomass was observed between pre-monsoon and post-monsoon (Table 5).

Discussion

The present study site is located along the west coast of the mainland near Uran town-ship. It is 4 kms away from near-shore waters of Mumbai harbour. The jetty is always busy and supports heavy traffic of passenger boats, ships and movement of tugs. The shipping and boat activity at Karanja jetty did not influence the characteristics of sea water. It is evident by the fact that all environmental parameters recorded are much within the normal limits. Average DO is around 5.8 mg/l indicating healthy status of water mass. Hence this ecosystem supported rich and varied sedentary organisms.

The macrofouling species collected from Karanja jetty mainly belonged to bryozoans, polychaetes and mollusca. Around 73% of the species belonged to

Table 4. Statistical analysis and monthly variations in macrofouling species recorded at Karanja

Period	Density (no/m^2)			Species composition (no/panel)			Biomass (g/m^2)		
Mon. - Mon.	'n'	't'	'p'	'n'	't'	'p'	'n'	't'	' p'
				Pre-monsoon					
Feb. - Mar.	16	2.70	p< 0.02	16	17.72	p< 0.00005	16	2.6	p< 0.02
Mar. - Apr.	16	0.65	NS	16	8.86	p< 0.00005	16	0.95	NS
Apr. - May	17	5.82	p< 0.00005	17	5.51	p< 0.00005	17	2.42	p< 0.05
May - June	17	9.95	p< 0.00005	17	7.08	p< 0.00005	17	9.91	HS
				Monsoon					
June - July	16	8.42	p< 0.00005	16	0.78	NS	16	0.99	NS
July - Aug.	16	3.27	p< 0.02	16	0.78	NS	16	1.68	NS
Aug. - Sept.	18	3.62	p< 0.002	18	5.93	p< 0.00005	18	8	HS
Sept. - Oct.	20	3.95	p< 0.001	20	1.49	NS	20	2.47	p< 0.005
				Post-monsoon					
Oct. - Nov.	18	3.24	p< 0.005	18	1.69	NS	18	8.74	HS
Nov. - Dec.	16	0.43	NS	16	1.0	NS	16	3.19	p< 0.01
Dec. - Jan.	16	0.41	NS	16	4.68	p< 0.005	16	9.37	HS
Jan'97 - Feb.	16	1.39	NS	17	1.69	NS	16	3.96	p< 0.002
				Pre-monsoon					
Feb. - Mar.	16	3.25	p= 005	17	2.46	p< 0.05	16	5.26	HS
Mar. - Apr.	13	1.79	NS	13	2.65	p< 0.02	13	0.46	NS
Apr. - May	13	2.97	p< 0.02	13	0.59	NS	13	0.89	NS

n = Number of samples, t = 't' test, p = level of significance, NS = Not significant and HS = Highly significant

Table 5. Seasonal settlement and variance in fouling species at Karanja jetty

Season	Density (no/m^2) Mean ± SD	Species comp. (no/panel) Mean ± SD	Biomass (g/m^2) Mean ± SD
Pre - mon.	14227 ± 3071	17 ± 4	35.18 ± 9.33
Monsoon	7172 ± 1559	16 ± 4	26.82 ± 7.2
Post - mon.	9270 ± 3557	19 ± 3	36.44 ± 7.2

Seasons	Statistical estimation and 'p' value						
	Density			Species composition		Biomass	
	'n'	't'	'p'	't'	'p'	't'	'p'
Pre-mon. x Mon.	67	11.8	p< 0.00005	1.03	NS	3.13	p< 0.005
Mon. x Post-mon.	68	3.15	p< 0.005	3.48	NS	9.62	p< 0.00005
Post-mon x Pre-mon	67	6.11	p< 0.00005	2.32	p< 0.05	0.62	NS

these groups. Like other two sites *viz*. near-shore waters and tidal basin reported in earlier study (Swami *et al.,* 2002) the density recorded at Karanja also varied from month to month and season to season. The individuals of polychaeta occurred predominantly, followed by bryozoans. The overall population of settling species was higher during pre-monsoon months. This was evident during two successive years of 2002 and 2003. Two calcareous species, namely *Hydroides elegans* and *H. operculatus* and mucilegenous species *Desycone cingulata* contributed to a great extent to the population abundance. The highest number of individuals recorded was 20,665 ± 5,776 during February 2002. Of the 15 month-to-month observations, at 11 occasions, variations were found to be significant. The density recorded during pre-monsoon and post-monsoon was significantly higher than the density recorded during the monsoon. Increasing seasonal trend was observed in monsoon.

On the contrary, during pre and post-monsoon season, a decreasing trend in density build up was observed.

At Karanja, the month-to-month variations in respect of species composition were less as compared to density. Only at 8 occasions, the variations were found to be significant. Particularly, during early pre-monsoon period, the difference in species occurrence was quite high ($p<0.00005$). The seasonal settlement was also varied. The species settled during pre-monsoon were significantly less than the species settled during post-monsoon ($p<0.05$). The species composition ranged from 8 to 26. The minimum number was recorded during March 2002. The drastic reduction in species numbers during this month could be attributed to the heavy settlement of barnacles observed on all the panels leaving very little space for other species to settle. Such kind of reduction in species due to dominance of other fouling species is common in marine environment. The maximum species (26 ± 3) settled during April 2003. April being a pre-monsoon month, the prevalence of high temperature, sufficient DO and stable salinity might have favoured maximum species occurrence. Swami and Udhayakumar (2004) have also recorded maximum number of species in the pre-monsoon month of February, 1996. Of the 48 species recorded in the present study, five are found to be new records from the west coast region. These are *Spirorbis* sp. (polychaeta), *Membranipora hugliensis*, *Microporella* sp., *Electra bellula* (bryozoa) and *Ascidia molgula* (ascidian). Bryozoa is one of the major fouling groups in Indian coasts and the present study contributed 21 species to the biofouling check-list (Table 2).

Seasonal variations in species composition were also observed. Maximum number of species settled during pre-monsoon and minimum in monsoon. Venkat *et al*. (1995) observed the maximum ascidian settlement during pre-monsoon and post-monsoon at Mangalore port located in the west coast of India. The observations made by Khandeparkar *et al*. (1995) at the same port were in agreement with those of Venkat *et al.* (1995). It indicated that seasonality brings out changes not only in species composition but also in population abundance.

Like other two characteristics, biomass also varied from month to month. It ranged between 3.4 and 89 g/m^2. The highest value was recorded during the month of September (89.0 ± 34.0 g/m^2). The shell dwelling barnacles during this month contributed to the biomass build-up. The lowest biomass, as expected, was recorded during the monsoon month of August 2002. Low salinity (25.54 ‰) and wave action affected the settlement of planktonic larvae and their subsequent growth. Parkins (1974) stated that salinity is one of the major parameters that influences the settlement and distribution of biota in the marine environment. Alam *et al*. (1988) observed a reduction in the settlement of fouling species during monsoon at Ratnagiri coast. Swami and Karande (1988) have also observed considerable species reduction during monsoon in the near-shore waters of Mumbai.

In view of the above observations, it is concluded that despite the heavy boating and shipping activities, the site supported a rich and varied fauna. Status of water mass is conducive for the settlement and growth of variety of sedentary species which includes five species as new entrants to the region. In the present study bryozoa and polychaeta are found to be the major fouling groups which indicated high biodiversity in this site.

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