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Community structure of fouling on a sunken vessel from Visakhapatnam harbour, east coast of India

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Abstract

Community structure of fouling on a sunken vessel '*Marine Victor*' that was under water for almost 10 years was analyzed. The fouling assemblage was found to comprise of 31 species making up a very rich biomass of 10.7 $kg.m^{-2}$. Among these forms, the vermetid mollusc, *Serpulorbis* sp. was found to be dominant, though oysters were major contributors to the biomass. Shannon-Wiener index (H´) indicated α-diversity to be slightly high while Simpson's dominance index (C) showed that a few organisms were dominant over the rest. Shannon's evenness index (J´) revealed unequal contribution of each species towards abundance. 'Goodness of fit' disclosed no significant difference between the distributions of the number of species observed and expected and also confirmed the log series distribution of species in the community. *Perna indica* Kuriakose and Nair, 1976 recorded from the vessel formed a new distributional record to east coast of India, though *Perna viridis* (Linnaeus, 1758) was reported earlier on different occasions.

Keywords: Biofouling, diversity, sunken vessel, Visakhapatnam harbour

Introduction

An array of benthic organisms that settle and grow on man made submerged structures in marine environment are referred to as foulers. They are viewed as a nuisance, especially from the economic angle (Nair, 1965). At times, certain foulers spread out by several means, chiefly through hull fouling to new localities and explode there leading to bioinvasion (Godwin *et al.*, 2004). Voluminous literature is available on various aspects of fouling on different substrata at several ports in India (Ganapati *et al.*, 1958; Cheriyan, 1966; Ismail and Azariah, 1978; Rao and Balaji, 1988; Srinivas *et al.*, 1992; Meena Kumari and Nair, 1994; Khandeparkar *et al.*, 1995). The fouling communities that developed on marine fishing vessels and boats in India were studied in particular by Dehadrai *et al.* (1975) and Santhakumaran and Pillai (1976, 1984). Yet, an opportunity to study the fouling communities on a long resident structure such as a sunken vessel is very rare in India.

A marine sundry vessel '*Marine Victor*' having an overall length (OAL) of 26m constructed out of mild steel and perhaps coated with antifouling paint was damaged in November 1998 and sunk in the vicinity of Visakhapatnam harbour. During the Asian Tsunami 2004, it drifted to the main navigational channel (7-10 m depth) of the fishing harbour and hindered the smooth traffic flow in the harbour. Hence, the same was salvaged by the Visakhapatnam Port Trust in May 2008. On learning this, a study was conducted on the fouling growth accumulated on the vessel over the years. Information of this kind is expected to throw light on the long term fouling phenomenon in the harbour region. Fixed harbour structures require sophistication for thorough examination in contrast to routine studies made on test panels immersed for short durations (2-3 years) or floating harbour structures repeatedly scraped off for maintenance. In order to understand the community structure and diversity of the fouling assemblage, various indices and a log series model were employed.

Material and Methods

Samples were obtained from four spots *viz.*, one from each side of the hull, one from the bottom of the hull and one from the mid interior of the hull of sunken vessel employing 30×30 cm quadrats. Fouling organisms were collected from each sampling area using a chisel and a hammer. The samples were fixed in 5% neutral formalin solution and brought to the laboratory for further analyses. Specimens obtained from each quadrat were initially sorted out group-wise and later identified as far as possible up to species level with the help of available literature (Pilsbry, 1916; Rao, 1969; Rao and Rao, 1993; Roy and Bhadra, 2005; Ramakrishna *et al.*, 2007; Dey and Ramakrishna, 2007) and distinguished into primary fouling assemblages (PFA, attached forms) and secondary fouling assemblages (SFA, free moving associates) as per Field (1982).

Quantitative estimates were made based on specimen count, species number and wet biomass. The parameters such as species richness (S), Shannon-Weiner's diversity index (H′), Simpson's dominance index (C) and Shannon's evenness index (J′) were calculated as per Magurran (1988) but '$\log_2$' was selected instead of 'ln' for easy comparison with earlier results. A rank abundance curve in respect of all species and individuals in the community was plotted following the log series model of Fisher *et al.* (1943). This log series takes the form αx, $\alpha x^2/2$, $\alpha x^3/3$, ……… $\alpha x^n/n$, where áx is a species with one individual, $\alpha x^2/2$ a species with two individuals and so on (Fisher *et al.*, 1943; Poole, 1974). In order to fit this model, the two parameters, *i.e.*, the constant (x) was estimated by iterating the term, $S/N = (1-x)/x\ [-\ln (1-x)]$ and the index of diversity (α) from the equation, $\alpha = [N (1-x)] / x$. To compile the data, all the species were first grouped into different abundance classes (in $\log_2$ form, *i.e.*, octaves or doubling abundance values) having an upper boundary raised additionally by 0.5 in each case to ensure certainty while assigning observed abundances to each class. Then, the number of expected individuals per species in each abundance class was calculated from x and α values. Finally, the distribution of the number of observed and expected species was compared through goodness of fit using Chi-Square (χ^2) test.

The data were also supplemented by important hydrographical parameters (surface sea water temperature, pH, salinity and dissolved oxygen) of the harbour waters collected/analyzed during regular research programmes of the centre.

Results

The surface sea water temperature, pH, salinity and dissolved oxygen of the site during 1999-2008 varied from 25.5 to 34.0 °C, 7.2 to 8.4, 16.90 to 35.54‰ and 1.50 to 5.74 $mg.L^{-1}$, respectively.

A total of 31 species of fouling organisms were collected from the salvaged vessel (Table 1). Of these, 20 species constituted the Primary Fouling Assemblage (PFA) while 11 species formed the Secondary Fouling Assemblage (SFA). Wet biomass of the fouling community as a whole was found to be very high, with an aggregation of 10.7 $kg.m^{-2}$.

Hydroides elegans, *Serpulorbis* sp., *Crassostrea cuttackensis*, *Saccostrea cucullata*, *Hyotisa hyotis*, *Spondylus hystrix* and *Chama reflexa* were present in all the quadrats. In contrast, one species each of an unidentified sponge, anthozoan, polychaete, barnacle and two bivalves, *Charybdis* sp., *Synalpheus brevicarpus*, *Diodora* sp., *Anachis terpsichore*, *Gyrineum natator*, *Perna viridis*, *Pinctada fucata* and *Barbatia* sp. were represented only from lone quadrats (*i.e.*, 25% frequency). In terms of abundance, *Serpulorbis* sp. with a density of 2328 individuals/m^2 occupied the first place among all the foulers followed by *C. reflexa* (775 individuals/m^2) and *H. elegans* (658 individuals/m^2). In terms of weight, the oysters, *S. cucullata*, *C. cuttackensis*, *H. hyotis* and *C. reflexa* apparently contributed the maximum.

The indices of diversity (H′), dominance (C) and evenness (J′) of the fouling community were found to be 2.398, 0.299 and 0.484, respectively (Table 1). The values of 'α' and 'x' were 5.386 and 0.99684,

Table 1. Abundance and density of fouling organisms on the salvaged vessel '*Marine Victor*' (sample: 4 quadrats)

Sl. No.	Species	No. of individuals (n_i)	Quadrats of occurrence	Frequency (%)	Abundance	Density (no/m²)	$P_i = (n_i/N)$	$P_i \log_2 P_i$	$(n_i/N)^2$
1	Sponge (Unidentified)*	6	1	25	6.0	16.7	0.00353	-0.029	0.00001247
2	Hydrozoan (Unidentified)*	2	2	50	1.0	5.6	0.00118	-0.011	0.00000139
3	Anthozoan-1(Unidentified)*	2	1	25	2.0	5.6	0.00118	-0.011	0.00000139
4	Anthozoan-2 (Unidentified)*	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
5	Polychaete (Unidentified)†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
6	*Hydroides elegans* (Haswell, 1883)*	237	4	100	59.3	658.3	0.13949	-0.396	0.01945859
7	*Balanus amphitrite amphitrite* Darwin (1854)*	6	3	75	2.0	16.7	0.00353	-0.029	0.00001247
8	Barnacle (Unidentified)*	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
9	*Charybdis* sp.†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
10	*Synalpheus brevicarpus* (Herrick, 1891)†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
11	*Diodora* sp.†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
12	*Euchelus asper* (Gmelin, 1791)†	10	2	50	5.0	27.8	0.00589	-0.044	0.00003464
13	*Anachis terpsichore* (Sowerby, 1834)†	4	1	25	4.0	11.1	0.00235	-0.021	0.00000554
14	*Gyrineum natator* (Roeding, 1758)†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
15	*Thais rugosa* (Born, 1778)†	2	2	50	1.0	5.6	0.00118	-0.011	0.00000139
16	*Cypraea pallida* Gray (1824)†	2	2	50	1.0	5.6	0.00118	-0.011	0.00000139
17	*Serpulorbis* sp.*	838	4	100	209.5	2327.8	0.49323	-0.503	0.24327713
18	*Perna viridis* (Linnaeus, 1758)*	2	1	25	2.0	5.6	0.00118	-0.011	0.00000139
19	*Perna indica* Kuriakose and Nair (1976)*	3	2	50	1.5	8.3	0.00177	-0.016	0.00000311
20	*Pinctada fucata* (Gould, 1850)*	3	1	25	3.0	8.3	0.00177	-0.016	0.00000311
21	*Isognomon legumen* (Gmelin, 1791)*	16	3	75	5.3	44.4	0.00942	-0.063	0.00008869
22	*Crassostrea cuttackensis* (Newton and Smith, 1912)*	66	4	100	16.5	183.3	0.03885	-0.182	0.00150904
23	*Saccostrea cucullata* (Born, 1778)*	138	4	100	34.5	383.3	0.08122	-0.294	0.00659738

Table 1: (Continued)

Sl. No.	Species	No. of individuals (n_i)	Quadrats of occurrence	Frequency (%)	Abundance	Density (no/m²)	$P_i = (n_i/N)$	$P_i \log_2 P_i$	$(n_i/N)^2$
24	*Hyotissa hyotis* (Linnaeus, 1758)*	46	4	100	11.5	127.8	0.02707	-0.141	0.00073304
25	*Spondylus hystrix* Roeding (1798)*	15	4	100	3.8	41.7	0.00883	-0.060	0.00007795
26	*Chama reflexa* Reeve (1846)*	279	4	100	69.8	775.0	0.16421	-0.428	0.02696632
27	Bivalvia-1 (Unidentified)†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
28	Bivalvia-2 (Unidentified)†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
29	Bivalvia-3 (Unidentified)†	1	1	25	1.0	2.8	0.00059	-0.006	0.00000035
30	Unidentified-1*	2	1	25	2.0	5.6	0.00118	-0.011	0.00000139
31	Unidentified-2*	10	2	50	5.0	27.8	0.00589	-0.044	0.00003464
	Total	1699			455.6	4719		-2.398	0.298826

Average wet biomass: 10.7 kg. m^{-2}

* - Primary Fouling Assemblage; † - Secondary Fouling Assemblage; Frequency = Quadrats represented / Total quadrats × 100; Abundance = No. of individuals / Quadrats of occurrence; Density = Organisms present in m^{-2} area; P_i = No. of individuals of a species / Total no. of individuals of all species.

respectively. The calculated value of χ^2 (15.50) (Table 2) was found to be lower than that of the Standard Table value (16.92).

Discussion

Species richness (31) of the fouling community on the vessel, although cannot be compared directly with similar values obtained in the case of various port structures and test panels together in the same harbour, falls within the range (27-99) observed by Balaji (1988) during the two years of fouling investigations. A few interesting observations were noticed from this comparison. The number of species common in the fouling assemblages in both the studies was observed to be as low as 5 represented by *H. elegans*, *Balanus amphitrite amphitrite*, *P. viridis*, *S. cucullata* and *C. cuttackensis*. Similarly, while the above author recognized *Mytilopsis sallei* was found to be dominating the communities at Eastern Quay Berth and Entrance Channel and *B. a. amphitrite* at Fishing Harbour, a vermetid mollusc *Serpulorbis* sp. not recorded earlier from the harbour

Table 2. Comparison of distribution between the number of observed and expected species through goodness of fit

Abundance class	Upper boundary of abundance class	Observed number of species	Expected number of species	χ^2
1	2.5	16	8.0	7.87
2	4.5	3	3.1	0.00
3	8.5	2	3.3	0.51
4	16.5	4	3.4	0.11
5	32.5	0	3.4	3.40
6	64.5	1	3.2	1.51
7	128.5	1	2.8	1.16
8	256.5	2	2.1	0.00
9	512.5	1	1.2	0.03
10	1024.5	1	0.4	0.90
Total		31	31.0	15.50

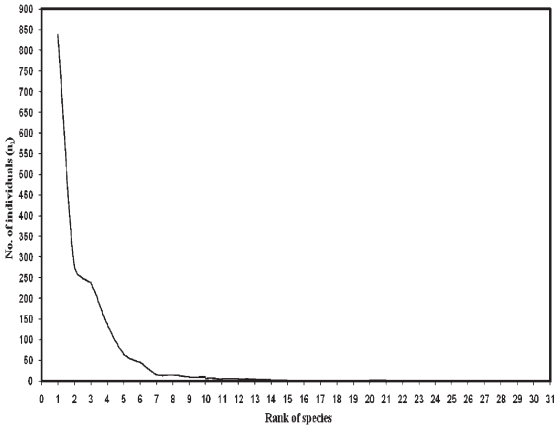

Fig. 1. Rank abundance curve

region was found to be predominant on the vessel. Similarly, *H. elegans*, *B. a. amphitrite*, *P. viridis* and *S. cucullata* were also found in the list of 43 macrofoulers reported from this harbour by Ganapati *et al*. (1958). The reason for this deviation is either due to repeated cleaning of harbour structures that removes the initial settlers or to the gradual domination of certain forms in due course of time. *Perna indica* obtained during the present collection forms a new distributional record to the east coast of India, though *Perna viridis* is a common species (Rao *et al*., 1991; Dey and Ramakrishna, 2007).

The value of H´ (2.398) reveals that α-diversity is slightly high indicating a community consisting of a variety of fouling forms. However, the α-diversity is lower than that (5.433) reported by Balaji (1988). The dominance index (0.299) denotes that a few organisms were dominant over others unlike many species sharing the dominance in the case of the earlier study (C: 0.044). Further, the index J´ (0.484) shows that contribution of each species towards abundance was not equal in contrast to that (J´: 0.820) obtained during the earlier work, where many species shared the abundance more or less equally.

Since 'Goodness of fit' indicated no significant difference between the distribution of the number of observed and expected species, log series model is regarded as a best fit to describe the data and that the rank abundance curve best represents the composition of the community in terms of abundance (Fig. 1). A steep decline in the left part of the curve indicates that the organisms (*Serpulorbis* sp., *C. reflexa*, *H. elegans*, *S. cucullata*, *C. cuttackensis* and *H. hyotis*) are more abundant than others. Further down, the steepness of the slope decreased gradually and became a plateau that represents scarce species of the community. The steeper the slope of the curve, the lesser the evenness of species and *vice versa*. In the present instance, the slope is considerably steep indicating that species evenness is less and this fact is supported by J´.

The present study indicates that fouling intensity was very high on the vessel and that the community became stable due to lack of human interference. The Shannon-Weiner's index (H´) revealed diversity of the fouling community to be fairly good. Simpson's dominance index (C), Shannon's evenness index (J´) and rank abundance plot indicated that oysters occupied most of the vessel's surface showing their good abundance in the assemblage. Biomass of the foulers reached a high proportion due to considerable weight contributed by hard shelled oysters.

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