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Fouling communities of the static substrata in a tropical Indian harbour

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Abstract

The community structure of foulers on various substrata in different regions of the Visakhapatnam harbour was analyzed. The results indicate that community composition differed from season to season and station to station within each season (2 to 17). Species richness at various stations during each season was found to be generally higher (10 to 17) in the outer harbour than in the inner harbour (2 to 13). The diversity and evenness indices were high and dominance indices low at almost all the stations during premonsoon season relative to postmonsoon season in the outer harbour whereas these indices remained the same during both the seasons in the inner harbour. Reasons for such variations are discussed. Fouling biomass among the stations ranged from 2.3 to 11.0 $kg.m^{-2}$ during postmonsoon season and 1.5 to 8.8 $kg.m^{-2}$ during premonsoon season. The foulers *Dynamenella dianae*, *Acanthochitona mahensis* and *Isognomon legumen* formed new records to Visakhapatnam harbour and *Siphonaria kurracheensis* to the east coast of India.

Keywords: Harbour structures, fouling organisms, community composition, diversity index, Visakhapatnam harbour

Introduction

Benthic organisms confined to submerged marine structures as foulers, pose serious threat to shipping and coastal industrial activities leading to several economic losses. Hence, studies related to these animal groups are very important to ports, navy and shore-based establishments. Generally, fouling on static substrata like piles, piers and wharves is neither a hindrance to maritime activities nor an economic burden to the ports. However, fouling on these structures not only discloses the long term scenario of the communities in a harbour, but also reveals their potential in acting as biological reservoirs in perpetuating the phenomenon. Around the world, fouling on permanent harbour structures were studied by Scheer (1945), Kashin *et al*. (2000), Huang (2003) and Qvarfordt *et al*. (2006) and in India particularly by Ismail and Azariah (1978) and Panigrahy *et al*. (2006). At Visakhapatnam, studies of this kind were those of Ganapati *et al*. (1958) and Balaji (1988). Yet, the basic information generated by these authors is neither sufficiently exhaustive nor specific to the static harbour structures. Further to this, manifold increase in marine traffic coupled with development of port infrastructure over the years would have had influence in changing the physico-chemical environment as well as biological nature of the harbour. Increased traffic and ballast water exchanges would have played their role in translocating several species (Godwin *et al*., 2004; Karande, 2005). A classic example of such effect is the invasion, perhaps through hull fouling of the black striped mussel, *Mytilopsis sallei* and its subsequent establishment in highly polluted regions of the Visakhapatnam harbour (Ganapati *et al.*, 1971), Bombay harbour (Karande and Menon, 1975) and Kakinada canal (Satyanarayana Rao *et al.*, 1989). An attempt is made to analyse the community structure of the foulers on various static substrata in different regions of Visakhapatnam harbour so that the changed scenario can be understood.

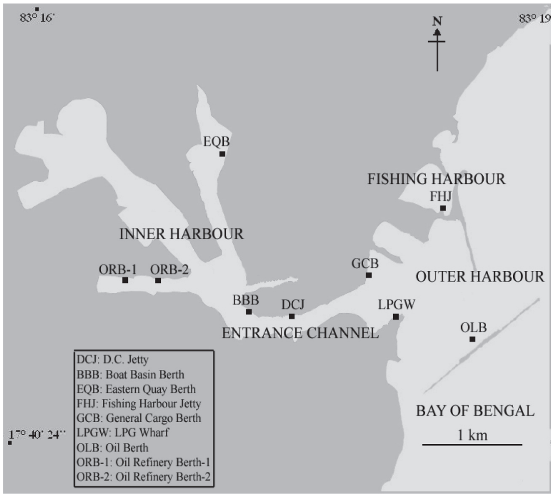

Fig. 1. Map of Visakhapatnam Port indicating 9 stations

Material and Methods

The salient features of the study area, 17º 40´ N lat. and 83º 16´ E long. (Fig. 1) were described by Balaji and Satyanarayana Rao (2004). For the present study, random sampling was done four times from reinforced concrete cement (RCC) harbour structures in a span of 2 years in Visakhapatnam harbour. Of these, matching samples could be obtained for two seasons from 9 stations and hence this data alone were utilised for analysis. One biotic sample each was collected by scraping 30 cm^2 area at 0 m depth from the RCC structures of each of the 9 stations, namely, Eastern Quay Berth, Oil Refinery Berth-1, Oil Refinery Berth-2, Boat Basin Berth and D. C. Jetty in the inner harbour and General Cargo Berth, LPG Wharf, Oil Berth and Fishing Harbour Jetty in the outer harbour during postmonsoon (November 2007) and premonsoon (April 2008) seasons. The animals collected were initially preserved in 5% neutral formalin. Subsequently, all macrofoulers were sorted out into different groups, identified to species level, quantified and various community indices (H´, C and J´) were derived following Magurran (1988). Bray Curtis similarity indices were estimated for the two seasons separately as dendrograms using Primer 6 software and ANOVA by Microsoft Office Excel 2003.

Results

Although the community composition differed slightly between postmonsoon and premonsoon seasons, near equal count of fouling species (32 and 33, respectively) were noticed on the static substrata during the two seasons (Tables 1 and 2). However, the total number of organisms recruited on each structure during each season as well as that on a particular structure during the two seasons was usually different. The number of species present on D.C. Jetty and LPG Wharf (13), Fishing Harbour Jetty and Oil Berth / Oil Refinery Berth-1 (11) during postmonsoon; LPG Wharf and Oil Berth (17) in premonsoon; Boat Basin Berth (6) in both the seasons were equal, but the species composition between each pair was different.

A total of 32 species were encountered during postmonsoon and 33 in premonsoon on the harbour structures. Twenty species, namely, *Metridium* sp., *Dasychone cingulata*, *Hydroides elegans*, one nereid, *Polydora* sp., *Balanus amphitrite amphitrite*, *Cirolana willeyi*¸ *Dynamenella dianae*, *Dynoides* sp., *Corophium triaenonyx*, *Metapograpsus messor*, *Acanthochitona mahensis*, *Euchelus circulatus*, *Littoraria scabra scabra*, *Siphonaria kurracheensis*, *Crassostrea cuttackensis*, *Modiolus striatulus*, *Mytilopsis sallei*, *Isognomon legumen* and *Saccostrea cucullata* were common during both the seasons, while 12 species occurred exclusively during postmonsoon and 13 taxa during premonsoon. The species exclusively found during postmonsoon were one species each of a polychaete, nereid, sphaeromatid, and gobiid, three brachyurans, *Chthamalus malayensis*, *Cirolana fluviatilis*, *Parisocladus* sp., *Metapograpsus maculatus* and *Morula granulata*. The species exclusively found during premonsoon were two nereids, one species each of polychaete, mytilid, echiurid, sipunculid and gobiid, *Serpula vermicularis*, *Dynamenella* sp., *Sphaeroma walkeri*, *Euchelus* sp., *Littoraria undulata* and *Trapezium* sp.

The ubiquitous species *B. amphitrite amphitrite* was the only organism found on all structures without any exception during both the seasons, though its abundance varied from structure to structure and from season to season on the same structure. During

Table 1. Abundance of fouling organisms (number of individuals. m^{-2}) on various hard substrata at Visakhapatnam harbour during postmonsoon

	Outer harbour				Inner harbour				
Fouling organisms	Fishing Harbour Jetty	General Cargo Berth	LPG Wharf	Oil Berth	D.C. Jetty	Boat Basin Berth	Eastern Quay Berth	Oil Refinery Berth-1	Oil Refinery Berth-2
Metridium sp.	0	56	0	44	0	0	0	156	67
Polycladidae (Unidentified)	89	33	0	11	0	0	0	0	22
Dasychone cingulata	0	0	0	0	11	0	0	0	0
Hydroides elegans	0	0	0	0	11	0	0	0	0
Polydora sp.	311	0	444	0	0	0	833	0	0
Nereidae (Unidentified-1)	0	11	0	0	0	0	56	33	0
Nereidae (Unidentified-2)	0	0	0	0	0	0	0	11	0
Balanus amphitrite amphitrite	7267	356	400	689	367	7556	667	1556	311
Chthamalus malayensis	33	0	0	0	0	0	0	0	0
Cirolana fluviatilis	0	0	0	0	133	178	0	0	0
Cirolana willeyi	0	133	11	22	44	100	33	0	22
Dynamenella dianae	0	0	22	0	0	0	0	0	0
Dynoides sp.	0	0	0	156	0	0	0	0	0
Sphaeromatidae (Unidentified)	67	0	0	0	0	0	0	0	0
Parisocladus sp.	0	0	11	0	0	0	0	0	0
Corophium triaenonyx	156	0	0	0	0	0	0	0	0
Metapograpsus maculatus	33	0	11	0	0	0	0	0	0
Metapograpsus messor	0	0	0	0	56	0	0	11	0
Crab (Unidentified-1)	0	0	0	0	11	0	0	0	0
Crab (Unidentified-2)	0	0	0	0	11	0	0	0	0
Crab (Unidentified-3)	0	0	0	0	0	0	0	11	0
Acanthochitona mahensis	0	0	0	11	0	0	0	0	0
Euchelus circulatus	0	0	33	0	0	0	0	0	33
Littoraria scabra scabra	467	33	89	0	22	33	0	0	44
Morula granulata	0	0	0	11	0	0	0	0	0
Siphonaria cf. kurracheensis	0	0	11	89	0	0	0	0	0
Crassostrea cuttackensis	200	533	244	478	333	44	0	467	1889
Modiolus striatulus	0	0	0	11	0	0	0	11	0
Mytilopsis sallei	0	44	44	0	244	6333	1200	11	0
Isognomon legumen	0	89	67	0	156	0	0	178	156
Saccostrea cucullata	378	422	467	89	2311	0	0	2422	933
Gobiidae (Unidentified-1)	11	0	0	0	0	0	0	0	0

postmonsoon, *C. cuttackensis* occurred on 8 structures, *C. willeyi* and *S. cucullata* on 7, *L. scabra scabra* and *M. sallei* on 6, *I. legumen* on 5, *Metridium* sp. and polyclads on 4 and *Polydora* sp. and nereid on 3 structures while others on 1 or 2 structures, but with different intensities on each structure (Table 1). During premonsoon, *H. elegans*, *Polydora* sp., *C. willeyi*, *C. cuttackensis*, *M. sallei*, *I. legumen* and *S. cucullata* occurred on 5 structures, *S. kurracheensis* on 4, *Metridium* sp., *S. vermicularis*, *D. dianae* and *Dynamenella* sp. on 3 structures while others on 1 or 2 structures, but with varied abundance on each structure (Table 2).

The most dominant forms in terms of individual count during both the seasons were *B. amphitrite amphitrite* at Boat Basin Berth, Fishing Harbour Jetty and Oil Berth and *M. sallei* at Eastern Quay Berth. During postmonsoon, the most dominant animals were *S. cucullata* at D. C. Jetty, LPG Wharf and Oil Refinery Berth-1 and *C. cuttackensis* at General Cargo Berth and Oil Refinery Berth-2. During

Table 2. Abundance of fouling organisms (number of individuals. m^{-2}) on various hard substrata at Visakhapatnam harbour during premonsoon

Fouling organisms	Outer harbour				Inner harbour				
	Fishing Harbour Jetty	General Cargo Berth	LPG Wharf	Oil Berth	D.C. Jetty	Boat Basin Berth	Eastern Quay Berth	Oil Refinery Berth-1	Oil Refinery Berth-2
Metridium sp.	0	22	89	44	0	0	0	0	0
Dasychone cingulata	156	0	0	0	0	0	0	0	0
Hydroides elegans	44	11	22	22	0	67	0	0	0
Serpula vermicularis	89	22	0	0	0	44	0	0	0
Polydora sp.	1333	222	1111	333	0	6222	0	0	0
Nereidae (Unidentified-1)	33	0	67	0	0	0	0	0	0
Nereidae (Unidentified-3)	0	0	0	0	0	0	0	0	44
Nereidae (Unidentified-4)	0	0	0	67	0	0	0	0	0
Polychaeta (Unidentified)	0	0	11	11	0	0	0	0	0
Balanus amphitrite amphitrite	5333	244	778	422	3778	10444	822	9111	222
Cirolana willeyi	444	44	100	0	56	22	0	0	0
Dynamenella dianae	11	0	0	22	0	0	0	0	89
Dynamenella sp.	22	0	0	22	0	0	0	0	944
Dynoides sp.	0	0	0	144	0	0	0	0	0
Sphaeroma walkeri	0	11	0	0	0	0	0	0	0
Corophium triaenonyx	0	111	0	0	0	0	0	0	0
Metapograpsus messor	0	0	11	0	0	0	0	0	0
Acanthochitona mahensis	0	0	0	11	0	0	0	0	0
Euchelus circulatus	0	0	11	22	0	0	0	0	0
Euchelus sp.	0	0	0	0	0	0	0	0	11
Littoraria scabra scabra	11	0	0	0	11	0	0	0	0
Littoraria undulata	0	33	0	0	0	0	0	0	11
Siphonaria cf. kurracheensis	0	11	111	156	0	0	0	0	133
Crassostrea cuttackensis	67	178	311	156	0	0	0	0	178
Modiolus striatulus	22	0	0	178	0	0	0	0	0
Mytilopsis sallei	0	156	133	0	222	356	3756	0	0
Isognomon legumen	22	56	156	133	0	0	0	0	44
Saccostrea cucullata	133	533	711	356	0	0	0	0	533
Trapezium sp.	0	0	22	0	0	0	0	0	0
Mytilidae (Unidentified)	11	0	0	0	0	0	0	0	0
Echiuridae (Unidentified)	0	0	11	0	0	0	0	0	0
Sipunculid (Unidentified)	0	0	0	11	0	0	0	0	0
Gobiidae (Unidentified-2)	0	0	11	0	0	0	0	0	0

premonsoon, the predominant species were *B. amphitrite amphitrite* at D. C. Jetty, Oil Refinery Berth-1, *Polydora* sp. at LPG Wharf, *Dynamenella* sp. at Oil Refinery Berth-2 and *S. cucullata* at General Cargo Berth.

Total wet biomass of foulers was the highest at Fishing Harbour Jetty (11.033 kg.m^{-2}) followed by Oil Refinery Berth-1 (8.902 kg.m^{-2}), but the lowest at Boat Basin Berth (2.282 kg.m^{-2}) and Eastern Quay Berth (2.497 kg.m^{-2}) during postmonsoon, while it was the highest at Oil Refinery Berth-1 (8.826 kg. m^{-2}) followed by LPG Wharf (5.188 kg.m^{-2}), but the lowest at Eastern Quay Berth as well as General Cargo Berth (1.528 kg.m^{-2} each) during premonsoon (Table 3).

Discussion

Species richness of foulers at the four stations in the outer harbour was relatively high during premonsoon season than the postmonsoon season

Table 3. Wet biomass, species richness and diversity, dominance and evenness indices of hard substratum fouling communities

Zone	Station	Season	Wet Biomass (kg.m^{-2})	Species Richness (S)	Shannon-Wiener's Diversity index (H´)	Simpson's Dominance index (C)	Shannon's Evenness index (J´)
Outer	Fishing	Postmonsoon	11.033	11	0.862	0.657	0.359
harbour	Harbour Jetty	Premonsoon	3.789	15	1.096	0.510	0.405
	General Cargo	Postmonsoon	4.758	10	1.780	0.213	0.773
	Berth	Premonsoon	1.528	14	2.066	0.171	0.783
	LPG Wharf	Postmonsoon	2.756	13	1.889	0.189	0.736
		Premonsoon	5.188	17	1.990	0.187	0.702
	Oil Berth	Postmonsoon	3.100	11	1.557	0.280	0.649
		Premonsoon	3.897	17	2.329	0.122	0.822
Inner	D.C. Jetty	Postmonsoon	7.664	13	1.388	0.379	0.541
harbour		Premonsoon	2.885	4	0.302	0.866	0.218
	Boat Basin Berth	Postmonsoon	2.282	6	0.818	0.479	0.457
		Premonsoon	3.681	6	0.796	0.503	0.444
	Eastern Quay	Postmonsoon	2.497	5	1.197	0.332	0.744
	Berth	Premonsoon	1.528	2	0.471	0.705	0.680
	Oil Refinery	Postmonsoon	8.902	11	1.271	0.362	0.530
	Berth-1	Premonsoon	8.826	1	0.000	1.000	0.000
	Oil Refinery	Postmonsoon	8.353	9	1.280	0.378	0.583
	Berth-2	Premonsoon	2.153	10	1.649	0.263	0.716

(Table 3). On the contrary, species richness at five stations in the inner harbour was comparatively low during premonsoon than the postmonsoon at three stations, equal at one station and high at another station. Coinciding with these, the diversity and evenness indices were high and dominance low at almost all the stations during premonsoon than postmonsoon in the outer harbour and *vice versa* at all the stations in the inner harbour except at Oil Refinery Berth-2. However, ANOVA revealed that among various parameters (S, H′, C and J′) species richness alone was significantly different between the two seasons that too in the outer harbour only (Table 4).

Within each of the two seasons, species richness in general was higher at various stations of the outer harbour than that of the same at different stations of the inner harbour. In accordance with these observations, the diversity and evenness indices were comparatively high and dominance low at various stations of the outer harbour than that of the same at different stations of the inner harbour. However, ANOVA substantiated that only species richness, diversity and dominance of foulers during premonsoon season were significantly different between the outer and inner harbours (Table 4).

Although such spatial and temporal differences in fouling compositions are well known (Brown and Swearingen, 1998; Kocak, 2007), variations noticed

Table 4. Summary of ANOVAs ($p \leq 0.05$) of various community parameters of fouling at Visakhapatnam harbour

Parameter	Between outer and inner harbours		Between post and premonsoons	
	Postmonsoon	Premonsoon	Outer harbour	Inner harbour
S	1.88	33.37**	21.13**	3.68
H′	2.05	9.53**	0.97	3.35
C	0.26	6.29**	0.39	4.47
J′	0.35	2.30	0.13	1.22
$F_{critical}$	5.59	5.59	5.99	5.32

** Significant

in the present instance are perhaps due to seasonal changes in the water quality of the outer and inner harbours as pointed out by Tripathy *et al*. (2005) during their studies on plankton in the region. They found an improvement in water quality coupled with increase in species diversity of phytoplankton from polluted inner channels of the harbour towards the nearshore environment. Highly polluted waters in the inner harbour region (Raman and Ganapati, 1983) remain more or less stagnant during premonsoon due to scanty freshwater input, but are diluted and flushed out more or less to a large extent by the run off from Mehadrigedda stream during monsoon. These relatively clean waters in all likelihood favour the spread of a number of animals including biofoulers in the ensuing postmonsoon. On the contrary, as freshwater discharge from the stream slows down, the water in the inner harbour becomes stagnant and polluted during premonsoon and turns again non-conducive for the spread of biota. As flushing of inner harbour waters nearly ceases during premonsoon, the influence of bay waters in the outer harbour probably increases to a large extent and as a result, a number of stenohaline species (such as sipunculid and echiurid exclusively encountered during premonsoon on structures in the outer harbour alone) may find way into the region. But all such new entrants are likely to perish off during the monsoon season leading to a decline in the number of populations during postmonsoon. Thus, much similar to the observations of Koutsoubas *et al.* (2000) and Mistri *et al.* (2001), three kinds of fouling species, *viz.*, (1) marine species commonly found in low water dynamic environment, (2) opportunistic species with different degrees of tolerance to organic enrichment and (3) typical euryhaline (brackishwater) species do exist in Visakhapatnam harbour.

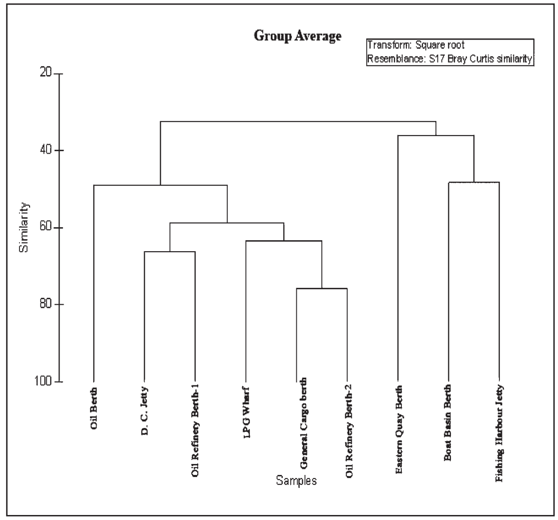

Fig. 2. Bray Curtis Similarity in the postmonsoon season

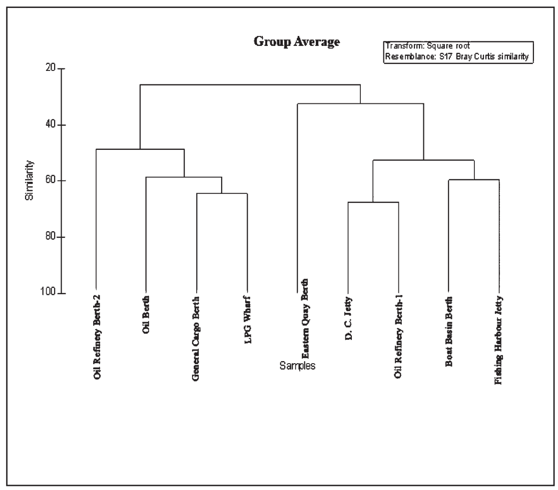

Fig. 3. Bray Curtis Similarity in the premonsoon season

Table 5. ANOVA of wet biomass and abundance of major foulers of fouling communities ($p \leq 0.05$)

	Biomass			*Polydora* sp.		*Balanus amphitrite amphitrite*		*Crassostrea cuttackensis*		*Mytilopsis sallei*		*Saccostrea cucullata*	
	df	SS	F	SS	F	SS	F	SS	F	SS	F	SS	F
Seasons	1	18	2.89	3237099	1.50	7985192	1.96	605000	4.21	588813	0.23	1256406	2.22
Stations	8	80	1.63	15854129	0.92	168913800	5.19*	1511824	1.31	26113580	1.27	3265734	0.72
Error	8	49		17293086		32546722		1150617		20553964		4529273	
Total	17	147		36384314		209445713		3267442		47256358		9051413	

* Significant

Cluster analysis of the data showed that high degree of similarity existed between fouling compositions and abundance at General Cargo Berth and Oil Refinery Berth-2 in contrast to low similarity between Boat Basin Berth and Fishing Harbour Jetty during postmonsoon season (Fig. 2). During the same season, Eastern Quay Berth in the inner harbour formed a distinct group perhaps due to high pollution levels prevailing there (Tripathy *et al.*, 2005). Oil Berth also formed another distinct group in the outer harbour, probably due to larger influence of bay waters.

Similarly, a high degree of similarity prevailed during premonsoon season between D. C. Jetty and Oil Refinery Berth-1 possibly due to the presence of fewer fouling species coupled with dominance of *B. amphitrite amphitrite* (Fig. 3). Like-wise to that in postmonsoon season, a lower degree of similarity was noticed between Boat Basin Berth and Fishing Harbour Jetty during premonsoon season also. During this season, Eastern Quay Berth and Oil Refinery Berth-2 of the inner harbour formed distinct groups unlike the other stations.

Although fouling biomass among various stations ranged from 2.3 $kg.m^{-2}$ to 11.0 $kg.m^{-2}$ during postmonsoon and 1.5 $kg.m^{-2}$ to 8.8 $kg.m^{-2}$ during premonsoon, no significant difference was noticed either between the two seasons or among the nine stations (Table 5). Two-way ANOVA employed on the abundance of the five major fouling forms, *viz.*, *Polydora* sp., *B. amphitrite amphitrite*, *C. cuttackensis*, *M. sallei* and *S. cucullata* revealed no significant difference in biomass between the two seasons and among the nine stations except in the case of biomass of *B. amphitrite amphitrite* among the stations.

Among various foulers collected during the present work, *Dynamenella dianae*, *Acanthochitona mahensis*, *Siphonaria kurracheensis* and *Isognomon legumen* formed new records to Visakhapatnam harbour while *Siphonaria kurracheensis* represented a new record to the east coast of India.

It may be concluded that static substrata in Visakhapatnam port support a rich assemblage of fouling organisms during both postmonsoon and premonsoon seasons with species richness on structures at each station chiefly governed by the prevailing water quality and aid in perpetuating the spread of biofoulers to ships, fishing craft and other marine vessels navigating in the region. Regular monitoring of species composition of foulers in the harbour helps in deciphering the temporal and spatial changes taking place in the entire community in the region thereby unraveling any untoward introductions.

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