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RECRUITMENT DYNAMICS OF IMPORTANT FOULERS AT VISAKHAPATNAM HARBOUR, INDIA

DINÁMICA DE RECLUTAMIENTO DE BIOINCRUSTADORES IMPORTANTES EN VISAKHAPATNAM HARBOUR, INDIA

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ABSTRACT

Biofouling is a serious problem in marine waters particularly in tropical countries like India. Knowledge on recruitment of foulers is highly essential for estimating fouling potential. Hence, monthly recruitment patterns of important foulers namely, *Polydora* sp., *Dasychone cingulata* (Grube, 1878), *Hydroides elegans* (Haswell, 1883), *Amphibalanus amphitrite amphitrite* (Darwin, 1854) and *Mytilopsis sallei* (Récluz, 1849) were studied using wooden test panels at three stations (Slipway Complex, Ore Berth and Marine Foreman Jetty) in Visakhapatnam harbour from February 2007 to January 2009. In general, each of these five species not only exhibited independent recruitment pattern from one another but also depicted variable trend both spatially and temporally. While *Polydora* sp. exhibited continuous and higher recruitment at Marine Foreman Jetty and Slipway Complex, *Dasychone cingulata* and *Hydroides elegans* showed continuous and highest recruitment at Slipway Complex only. *Amphibalanus amphitrite amphitrite* recruited continuously at all the three stations, the highest being at Ore Berth and lowest at Marine Foreman Jetty. Recruitment of the invasive bivalve *Mytilopsis sallei* was not only dominant but also very significant at Marine Foreman Jetty whereas at the other two stations its recruitment was discontinuous and sporadic, yet alarming.

Key words: Fouling, Harbour, Pollution, Recruitment, Tropical

RESUMEN

El bioencrustamiento es un problema grave en las agua marinas particularmente de países tropicales como India. Conocer el reclutamiento de los organismos incrustadores es esencial para estimar el potencial de incrustación. Por lo tanto, los patrones mensuales de reclutamiento de incrustadores importantes como: *Polydora* sp., *Dasychone cingulata* (Grube, 1878), *Hydroides elegans* (Haswell, 1883), *Amphibalanus amphitrite amphitrite* (Darwin, 1854) and *Mytilopsis sallei* (Récluz, 1849) fueron estudiados en ensayos sobre paneles de madera en tres estaciones (Slipway Complex, Ore Berth and Marine Foreman Jetty) en el puerto de Visakhapatnam desde febrero del 2007 a enero del 2009. Por lo general cada una de estas cinco especies no solo exhiben un patrón de reclutamiento independiente el uno del otro, sino que también muestran una tendencia espacial y temporal variable. Mientras que *Polydora* sp. exhibió un reclutamiento continuo y elevado en Marine Foreman Jetty y en Slipway Complex, el reclutamiento de *Dasychone cingulata* y *Hydroides elegans* sólo fue continuo y elevado en Slipway Complex. El reclutamiento de *Amphibalanus amphitrite amphitrite* fue continuo en las tres estaciones, con el mayor valor en Ore Berth y el menor valor en Marine Foreman Jetty. El reclutamiento del bivalvo invasivo *Mytilopsis sallei* no sólo fue dominante sino también muy significativo en Marine Foreman Jetty, en tanto que en las otras dos estaciones su reclutamiento fue discontinuo y esporádico, aunque todavía alarmante.

Palabras clave: Contaminación, Incrustación, Puerto, Reclutamiento, Tropical

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INTRODUCTION

Biofouling is a ubiquitous problem in marine environment affecting all moving and stationary engineered structures irrespective of the nature and type of material employed. Fouling accumulations on any marine vessel/craft fundamentally lead to frictional resistance thereby depleting propeller efficiency, reducing vessel/craft speed and increasing manpower requirement/fuel consumption further to malfunctioning of acoustic systems, etc. (Yan and Yan 2003). In the case of stationary structures, the phenomenon accelerates corrosion of metallic surfaces and increases wave/hydrodynamic load. These troubles in turn manifest in the form of periodical maintenance costs, loss of fishing/navigation time, loss of man days, etc. The magnitude of fouling in tropical countries like India is very high (Nagabhushanam and Alam 1988) and hence recurring expenditure is involved in dry docking and associated maintenance of vessels. However, no comprehensive inventory of the economic losses involved in this pretext has been recorded from the country. Economic losses, especially by the fishing sector in India run to approximately 30 million rupees/year (Nair, 2002).

Fouling differs not only spatially but also varies temporally (Brown and Swearingen 1998). Study on recruitment pattern of foulers is an important aspect in biofouling as such knowledge is essential for estimating the fouling potential within a given area (Satheesh and Godwin Wesley 2008a). Seasonal variation of foulers on submerged structures in Indian waters has been documented in a number of studies (Daniel 1954; Ganapati *et al.* 1958; Cheriyan 1966; Nair 1967; Swami and Karande 1988; Sasikumar *et al*. 1989; Rajagopal *et al.* 1997; Swami and Udhayakumar 2004; Satheesh and Godwin Wesley 2007 and 2008b; Sahu *et al.* 2011).

Visakhapatnam Harbour, which is an important gateway for trade is not immune to fouling activity (Balaji, 1988). Physical, chemical and biological changes due to anthropogenic activities have been taking place within the harbour since the last couple of decades. This study was thus designed to determine the recruitment dynamics of the important foulers namely, *Polydora* sp. (Spionidae), *Dasychone cingulata* (Grube, 1878) (Sabellidae), *Hydroides elegans* (Haswell, 1883) (Serpulidae), *Amphibalanus amphitrite amphitrite* (Darwin, 1854) (Balanidae) and *Mytilopsis sallei* (Récluz, 1849) (Dreissenidae) at Visakhapatnam Harbour to assess the current situation.

MATERIAL AND METHODS

The investigation was carried out at three test stations namely, Slipway Complex (SWC), Ore Berth (OB) and Marine Foreman Jetty (MFJ) of Visakhapatnam harbour (17° 40′N and 83° 16′E) (Figure 1) for two years from February 2007 to January 2009. The harbour has two distinct areas namely, outer harbour and inner harbour inter-connected by a narrow entrance channel. The Slipway Complex and Ore Berth are located in the outer harbour while the Marine Foeman Jetty is located in the inner harbour. A pollution gradient is known to exist between the inner harbour and outer harbour (Tripathy *et al*. 2005).

In order to study monthly recruitment patterns, *Bombax ceiba* wooden test panels of dimensions 150×80×20mm were drilled at the centre with a 4mm bit and fastened with a 3mm nylon rope into vertical ladders containing 6 panels each. One such ladder was deployed in the beginning of every month at each of the three test stations in such a way that the uppermost panel was kept in the intertidal zone and the rest well below lowest low water mark with a gap of 100mm in between each of them. After retrieval of ladders, the panels were separated from the rope, gently washed with seawater to remove any adhering mud and silt while taking care not to lose any animal and brought to laboratory in individual seawater containers. At the laboratory, fouling taxa were enumerated through the random sampling method employing 4cm^2 grids. Ten random grids per panel were sampled thus making a total of 60 grids from one ladder. Average count from the 60 grids represents the density (individuals m^{-2}) of fouling species for that month.

RESULTS

Recruitment of *Polydora* sp.

Recruitment density of *Polydora* sp. at Slipway Complex was least (42 and 167 individuals m^{-2}, respectively) during February and April to June of the 1st year (Figure 2) and November of the 2nd year (Figure 3) whereas maximum recruitment density (7042 and 53042 individuals m^{-2}, respectively) was noticed during October of the 1st year and March

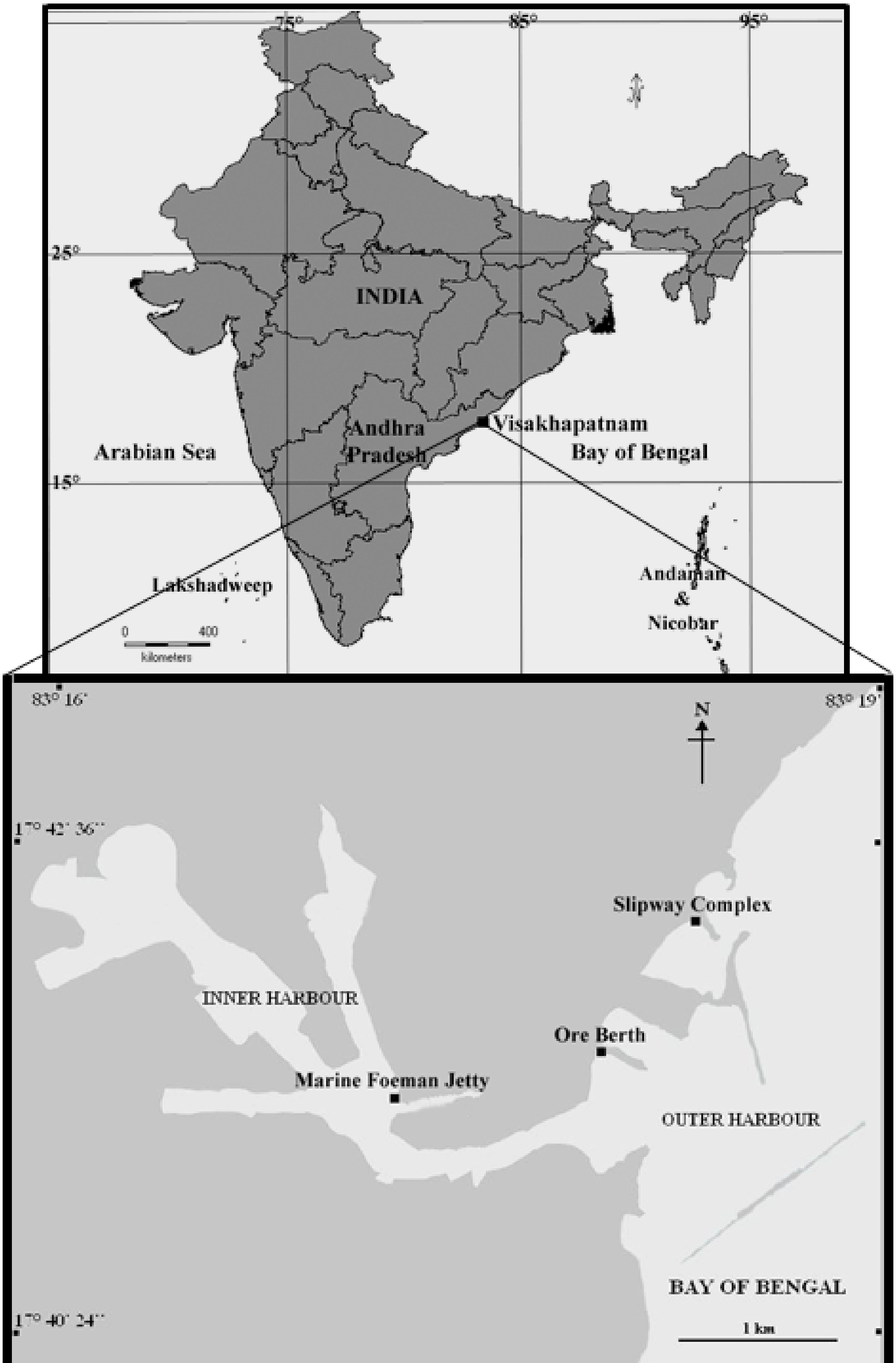

Figure 1. Map of Visakhapatnam harbour.

Table 1. Density (range and mean ± S.D) of important foulers at Visakhapatnam harbour.

		1st year		2nd year	
		Range	Mean ± S.D	Range	Mean ± S.D
Polydora sp.	SWC	42–7042	1953 ± 2416	0–53042	13432 ± 17655
	OB	417–4583	2604 ± 1761	0–833	120 ± 291
	MFJ	0–15292	6303 ± 6017	0–35625	8396 ± 11558
Dasychone cingulata (Grube, 1878)	SWC	42–9250	2773 ± 3010	42–7833	2447 ± 2222
	OB	166–5292	2115 ± 2368	0–1000	266 ± 349
	MFJ	0–125	20.8 ± 45	0–0	0 ± 0
Hydroides elegans (Haswell, 1883)	SWC	0–5254	1656 ± 1619	0–7263	1047 ± 2109
	OB	334–6233	1992 ± 2846	0–2031	301 ± 701
	MFJ	0–42	4.2 ± 13.3	0–0	0 ± 0
Amphibalanus amphitrite amphitrite (Darwin, 1854)	SWC	42–10375	3073 ± 3034	83–7463	3099 ± 2777
	OB	4708–32708	21844 ± 12618	0–10708	5922 ± 3768
	MFJ	0–19634	4802 ± 6573	0–7625	1786 ± 2570
Mytilopsis sallei (Récluz, 1849)	SWC	0–917	153.5 ± 265.8	0–333	106.1 ± 146.9
	OB	458–4583	2010 ± 1856	0–500	110 ± 186
	MFJ	0–56000	19036 ± 19203	0–36833	11896 ± 11461

S.D: Standard Deviation; SWC: Slipway Complex; OB: Ore Berth; MFJ: Marine Foreman Jetty of the 2nd year. Though continuous recruitment of this fouler took place at this station, it's recruitment was comparatively high from March to October during the 2nd year than the corresponding months of the 1st year, but vice-versa from November to January during the 2nd year than the corresponding months of the 1st year. At Ore Berth, recruitment density of this species increased from 417 to 4583 individuals m^{-2} during the four months of the 1st year in contrast to its low density (125 and 833 individuals m^{-2}, respectively) during August and October of the 2nd year. At the Marine Foreman Jetty, low (667 and 1708 individuals m^{-2}, respectively) recruitment of this polychaete took place during June of the 1st year and January of the 2nd year. High recruitment density (15292 and 35625 individuals m^{-2}, respectively) occurred on the panels in November of the 1st year and October of the 2nd year. Recruitment of this species was almost continuous at this station during both the years. Highest recruitment of this annelid was registered at Marine Foreman Jetty during the 1st year and at Slipway Complex during the 2nd year, and lowest recruitment was noticed at Slipway Complex during the 1st year and at Ore Berth during the 2nd year (Table 1).

Recruitment of *Dasychone cingulata*

At Slipway Complex, low (42 individuals m^{-2}) recruitment of *D. cingulata* took place during February/June of the 1st year (Figure 4) and January of the 2nd year (Figure 5) while maximum recruitment density was recorded (9250 and 7833 individuals m^{-2}, respectively) on the panels during December of the 1st year and August of the 2nd year. The overall recruitment of this species was however, relatively higher during the second half of the 1st year, but vice-versa during the same period of the 2nd year at the same station. At Ore Berth, recruitment of this species varied from 166 to 5292 individuals m^{-2} during the four months of the 1st year and recruitment densities ranged from 83 individuals m^{-2} in July to 1000 individuals m^{-2} in November during the eight months of the 2nd year. At Marine Foreman Jetty, the recruitment was low (83 and 125 individuals m^{-2}, respectively) during May and June of the 1st year and no recruitment during the 2nd year. Recruitment of this species showed decreasing densities from Slipway Complex through Ore Berth to Marine Foreman Jetty during the study period (Table 1).

Recruitment of *Hydroides elegans*

Recruitment of *H. elegans* at Slipway Complex was minimum (166 and 75 individuals m^{-2}, respectively) during October of the 1st year (Figure 6) and September of the 2nd year (Figure 7) while maximum recruitment density (5254 and 7263 individuals m^{-2}, respectively) was recorded during July of the 1st year and March of the 2nd year. Recruitment of the serpulid at this station was almost continuous during both the years, but was generally higher during the 1st year as compared to the 2nd year. At Ore Berth, recruitment of this species ranged between 334 and 6233 individuals m^{-2} during the four months of the 1st year and varied from 42 individuals m^{-2} in December to 2031 individuals m^{-2} in November during the eight months of the 2nd year. At Marine Foreman Jetty, this species was recruited only once during December in low density (42 individuals m^{-2}) during the 1st year and was absent on panels during the 2nd year. The recruitment of *H. elegans* demonstrated highest recruitment at Ore Berth during the 1st year and at Slipway Complex during the 2nd year whereas lowest recruitment was found at Marine Foreman Jetty during both the years (Table 1).

Recruitment of *Amphibalanus amphitrite amphitrite*

The recruitment of *A. a. amphitrite* at Slipway Complex, though continuous, found to be low in density (42 and 83 individuals m^{-2}, respectively) occurred during both the years in June while higher densities (10375 and 7463 individuals m^{-2}, respectively) were recorded on panels during July of the 1st year and August of the 2nd year (Figures 8 and 9). The recruitment densities varied from month to month during the 1st year whereas the recruitment was relatively high during the second half of the 2nd year at this station. Recruitment of this species was relatively high (20167 to 32708 individuals m^{-2}) during April, May and June of the 1st year while its recruitment varied between 2250 individuals m^{-2} in August to 10000 individuals m^{-2} in January during the 2nd year at Ore Berth. Recruitment of the balanid was rather continuous during both the years at Marine Foreman Jetty. Low (250 and 42 individuals m^{-2}, respectively) recruitment of the species at this station was found during October of the 1st year and June of the 2nd year while higher densities (19634 and 7625 individuals m^{-2}, respectively) were recorded

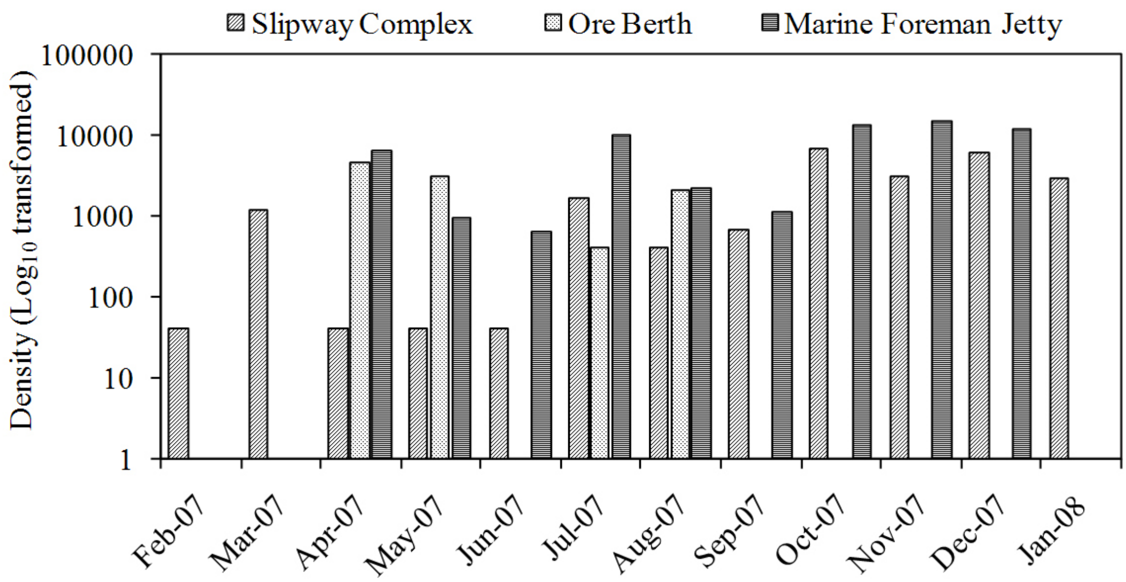

Figure 2. Monthly recruitment of *Polydora* sp. at Visakhapatnam harbour from February '07 to January '08

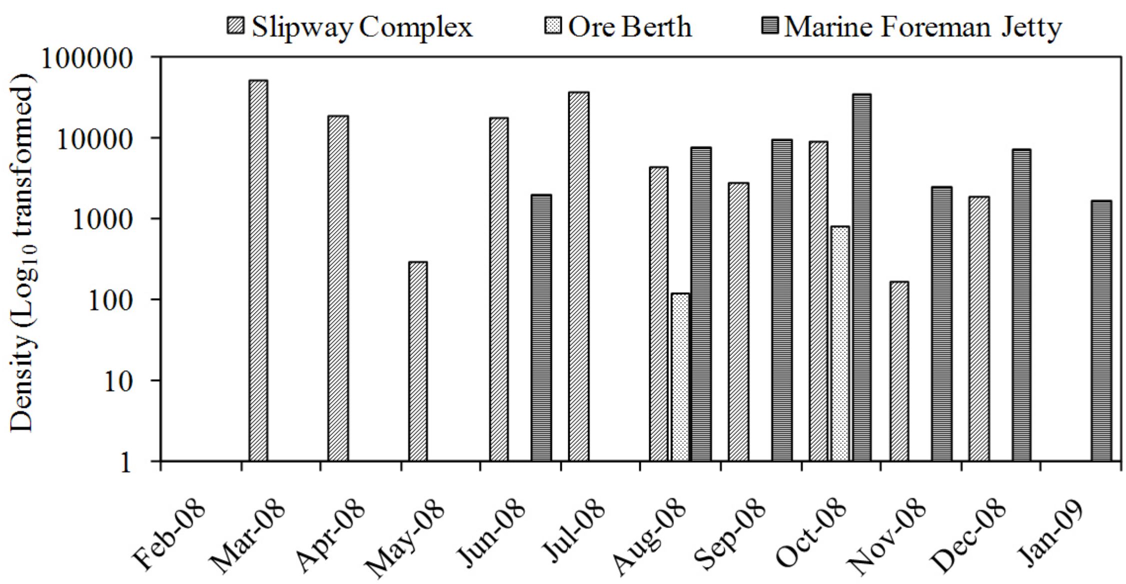

Figure 3. Monthly recruitment of *Polydora* sp. at Visakhapatnam harbour from February '08 to January '09

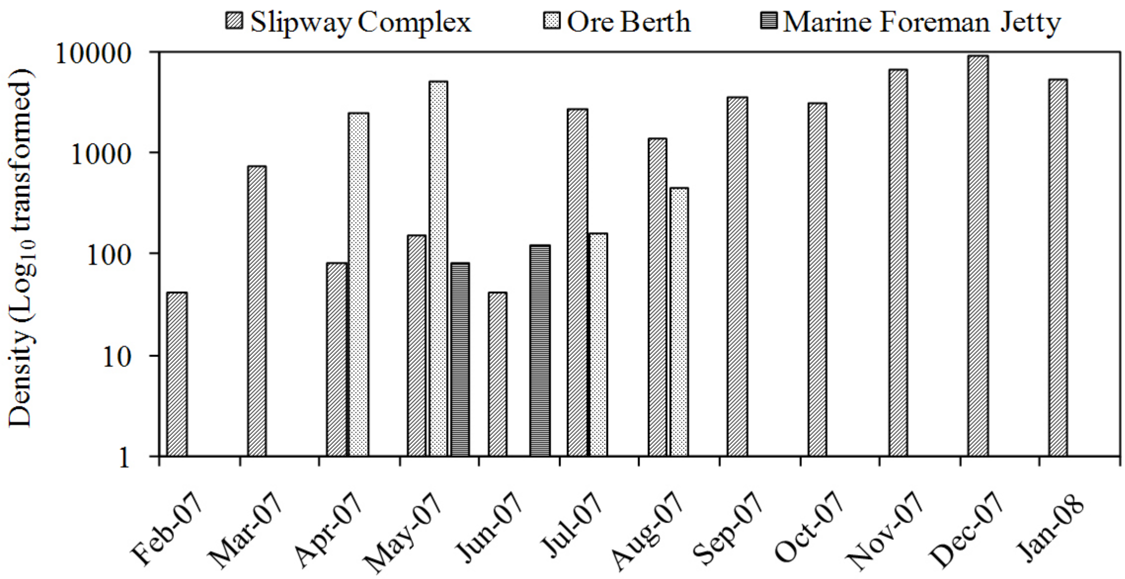

Figure 4. Monthly recruitment of *Dasychone cingulata* at Visakhapatnam harbour from February ’07 to January ’08

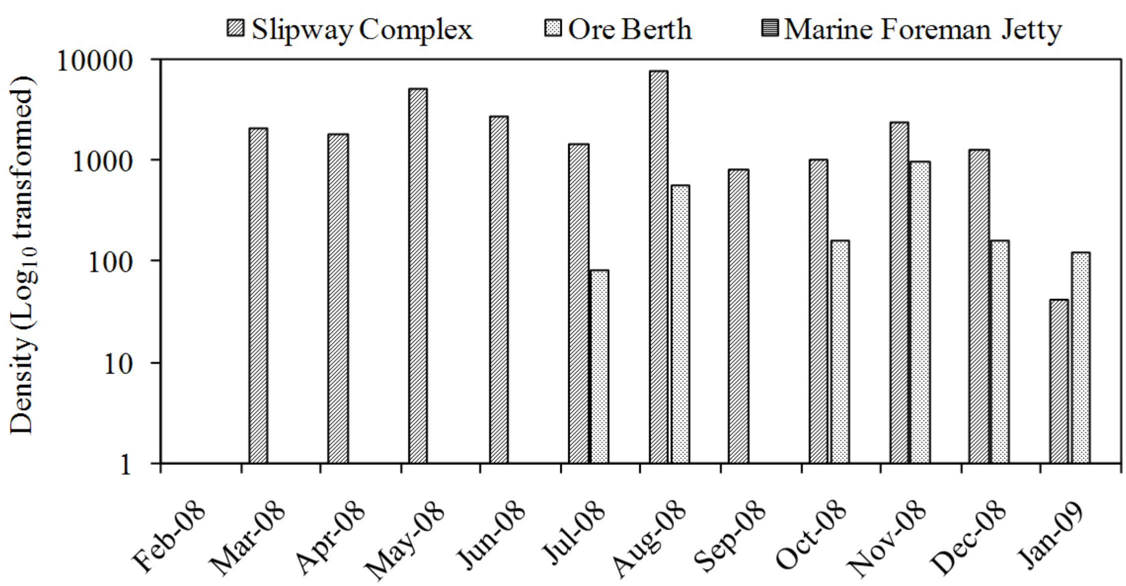

Figure 5. Monthly recruitment of *Dasychone cingulata* at Visakhapatnam harbour from February ’08 to January ’09

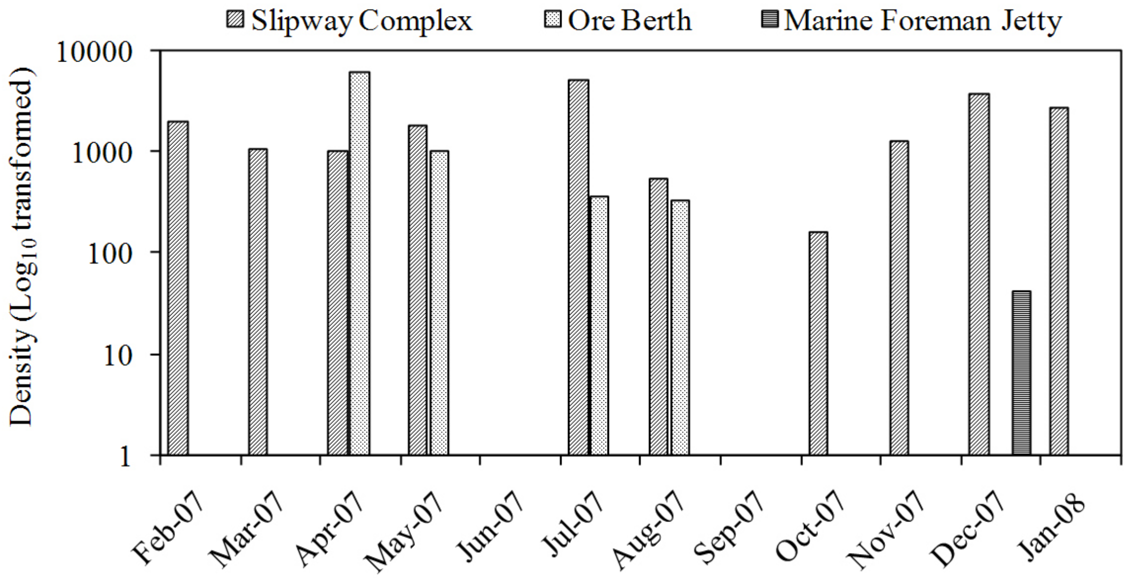

Figure 6. Monthly recruitment of *Hydroides elegans* at Visakhapatnam harbour from February ’07 to January ’08

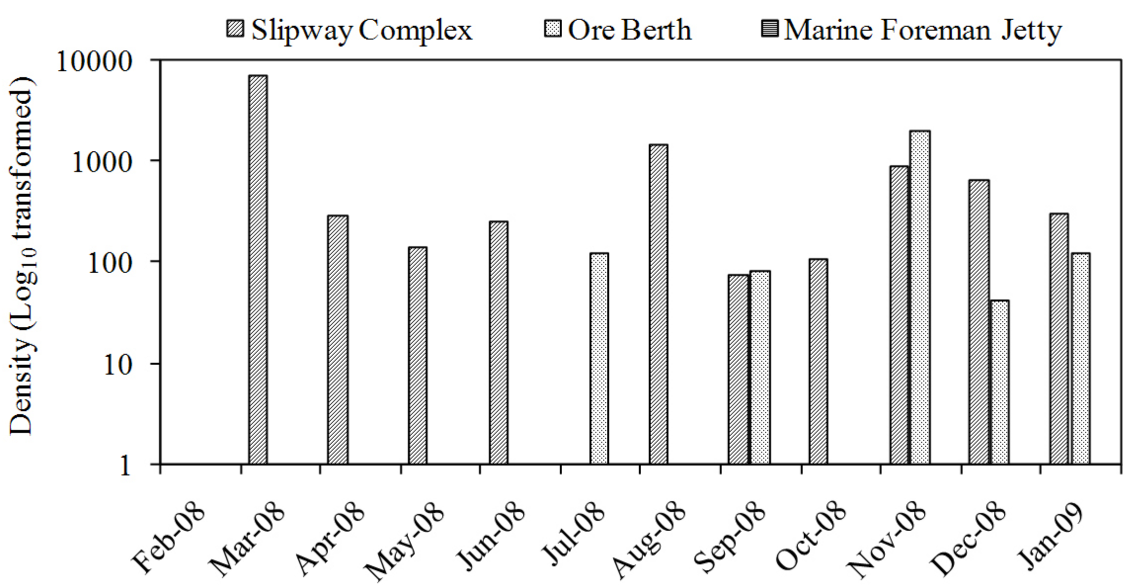

Figure 7. Monthly recruitment of Hydroides elegans at Visakhapatnam harbour from February ’08 to January ’09

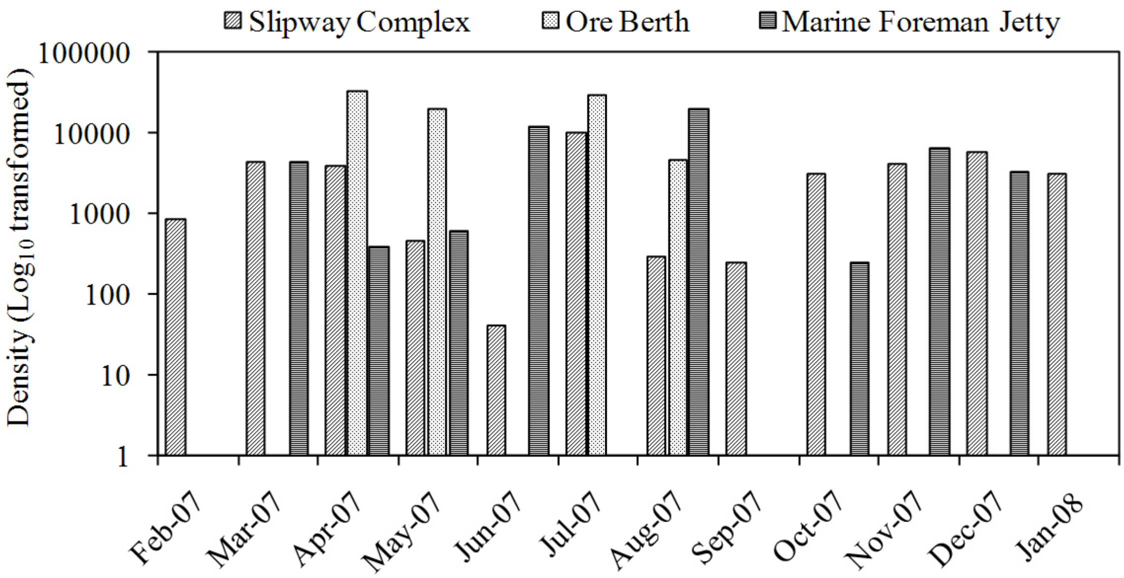

Figure 8. Monthly recruitment of *Amphibalanus amphitrite amphitrite* at Visakhapatnam harbour from February ’07 to January ’08

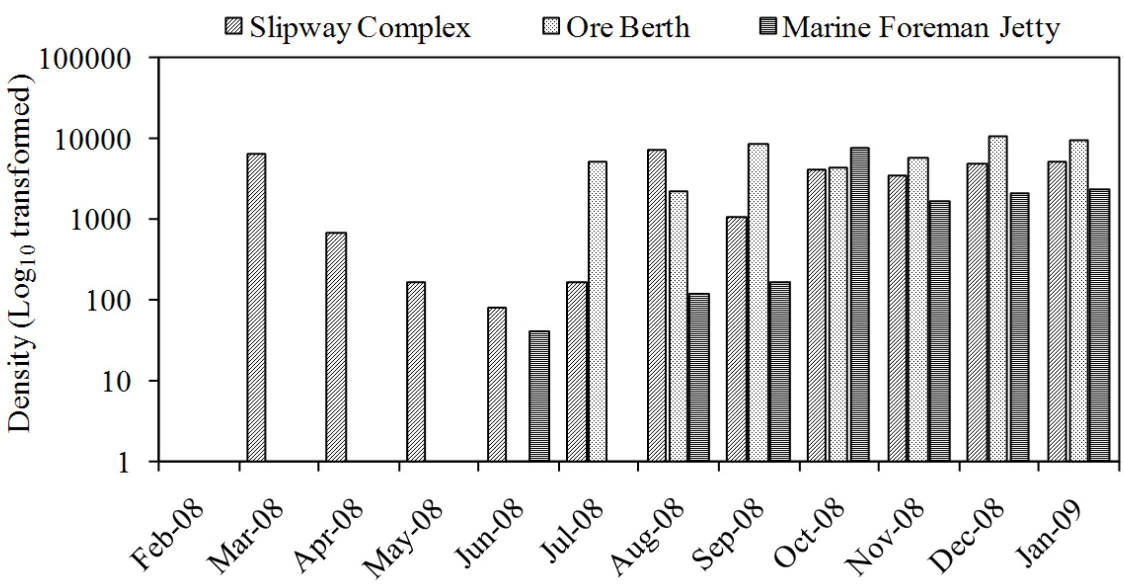

Figure 9. Monthly recruitment of *Amphibalanus amphitrite amphitrite* at Visakhapatnam harbour from February ’08 to January ’09

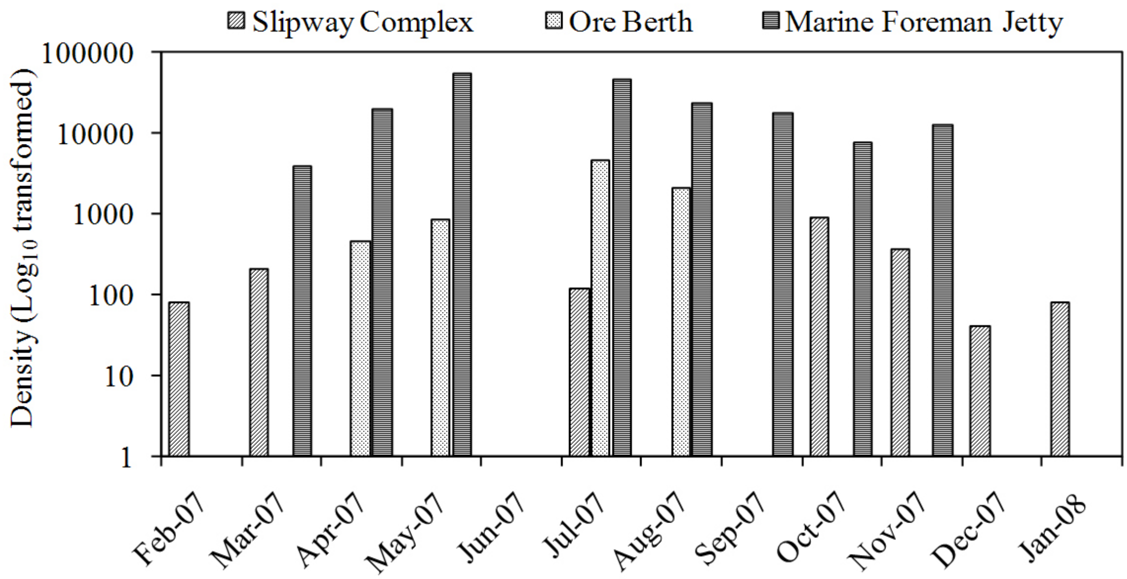

Figure 10. Monthly recruitment of *Mytilopsis sallei* at Visakhapatnam harbour from February ’07 to January ’08

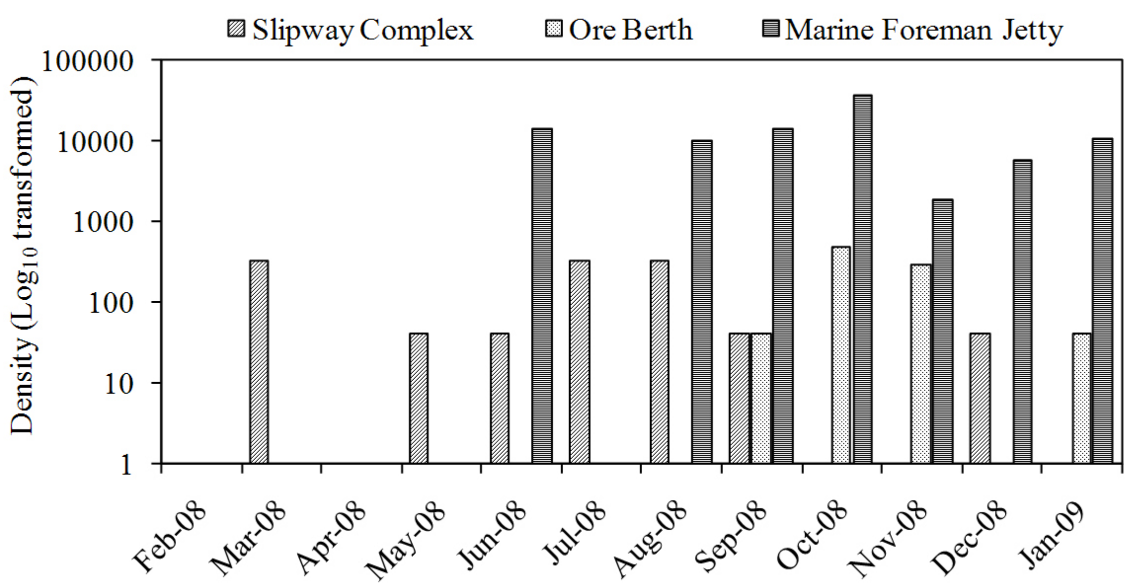

Figure 11. Monthly recruitment of *Mytilopsis sallei* at Visakhapatnam harbour from February ’08 to January ’09

during August of the 1st year and October of the 2nd year. Among the three stations, recruitment of *A. a. amphitrite* was highest at Ore Berth during both the years, and lowest at Slipway Complex during the 1st year and at Marine Foreman Jetty during the 2nd year (Table 1).

Recruitment of *Mytilopsis sallei*

Recruitment of *M. sallei* at Slipway Complex was somewhat discontinuous during the 1st year than in the 2nd year (Figures 10 and 11). Low densities of the bivalve (42 individuals m^{-2}) were recorded during December of the 1st year and during May, June, September and December of the 2nd year whereas high recruitment (917 and 333 individuals m^{-2}, respectively) were observed during October of the 1st year and during March, July and August of the 2nd year. At Ore Berth, recruitment of this species was relatively low (458 and 875 individuals m^{-2}, respectively) during April and May than during July and August (4853 and 2125 individuals m^{-2}, respectively) of the 1st year. Low recruitment (42 to 500 individuals m^{-2}) of this species was recorded during September, October, November and January of the 2nd year. At Marine Foreman Jetty, recruitment of this dreissenid was usually very high and more or less continuous during both the years. Low densities (3958 and 1917 individuals m^{-2}, respectively) were recorded during March of the 1st year and November of the 2nd year. High densities (56000 and 36833 individuals m^{-2}, respectively) were shown on the panels during May of the 1st year and October of the 2nd year. Recruitment of *M. sallei* was comparatively higher at Marine Foreman Jetty than at the other two stations during the study period (Table 1).

DISCUSSION

Since complex demographic processes occur during the recruitment of various foulers on suspended anthropogenic substrata as noted by Brykov *et al*. (2000), it is rather difficult to comprehend the recruitment patterns of even the five fouling forms studied for the aspect. However, the possible reasons were elucidated.

Recruitment of *Polydora* sp.

Variation in recruitment of *Polydora* sp. was observed from year to year at all the stations. Recruitment of this species was relatively low during the 1st year in Visakhapatnam harbour except at Ore Berth. Spatial variation noticed in the recruitment of *Polydora* sp. is again different from year to year. In general, recruitment of this species is more or less continuous in Visakhapatnam habour with no clear pattern of temporal and spatial variations. This indicates pollution may not be an important factor for settlement of this fouler since recruitment of the species was high at Marine Foreman Jetty.

Recruitment of *Dasychone cingulata*

Dasychone cingulata showed definite temporal and spatial variations. Recruitment of this species was found to be high during 1st year. High and continuous recruitment of this species at Slipway Complex during both the years; low and discontinuous recruitment at Ore Berth and very low density that to only during 1st year at Marine Foreman Jetty explains probable effect of pollution on this species.

Recruitment of *Hydroides elegans*

Recruitment of *Hydroides elegans* varied temporally. High recruitment was found during 1st year. Though there have been no definite spatial trends between the years, an occasional very low recruitment at Marine Foreman Jetty indicates pollution at this Jetty affect recruitment of this species, which is further supported by the fact that recruitment of this species was continuous during both the years at Slipway Complex only. Balaji (1988) reported a year round recruitment of this species with peak from February to May in Visakhapatnam harbour, but Daniel (1954) noted November and December as peak periods for this serpulid at Madras. Alam *et al.* (1988) encountered *H. elegans* throughout the year at Ratnagiri coast.

Recruitment of *Amphibalanus amphitrite amphitrite*

The recruitment of *A. a. amphitrite* at Slipway Complex during both the years can be said to have varied not much significantly. But at Ore Berth and Marine Foreman Jetty, this species showed high recruitment during the 1st year. Like that of *Polydora* sp., this species also did not show any distinct trends in temporal and spatial variations, which indicate pollution may not be a limiting factor for their settlement. Rajagopal *et al*. (1997) found that though barnacles settled on concrete panels continuously throughout the year at Kalpakkam, peak recruitment was recorded during March, April, July, September and November. Satheesh and Godwin Wesley (2008b) also observed high recruitment of a few species of barnacles during July to December at Kudankulam waters.

Recruitment of *Mytilopsis sallei*

Quite contradictory to the trends depicted by the above four species, recruitment of *M. sallei* was not only dominant but also very significant at Marine Foreman Jetty whereas its recruitment at the other two stations was discontinuous and sporadic, yet alarming. Marine Foreman Jetty is a highly polluted station with limited action of tides and waves as compared to other two stations. This species being a pollutant loving species in stagnant waters (Pati and Rao 2012) settled profusely on test panels in the inner harbour. Recruitment of this species was high during the 1st year at all the stations. The species showed two peaks, the major being in May followed by the minor in July during 1st year, but a single peak in October during 2nd year at Marine Foreman Jetty. In an earlier study, Balaji (1988) also observed closely overlapping peaks of recruitment of this species at the same harbour.

Recruitment patterns of these above foulers showed either temporal variation or spatial variation or both at Vishakhapatnam harbour. Such variations may be due to influence of environmental parameters on period of settlement and abundance of fouling organisms (Sahu *et al.* 2011) since these parameters showed some spatial and temporal variations during the same study period (February 2007 to January 2009) and at the same three stations (Slipway Complex, Ore Berth and Marine Foreman Jetty) in Visakhapatnam harbour (Pati 2011). Further, competition among the species for space could have played a significant role in recruitment pattern of foulers (Rajagopal *et al.* 1990). For example, at Slipway Complex while the dominancy was shared by number of foulers during different months, *A. a. amphitrite* at Ore Berth and *M. sallei* at Marine Foreman Jetty were the most abundant species during most of the study periods. As discussed earlier, some of the fouling species such as *D. cingulata*, *H. elegans* could not tolerate pollution either at Ore Berth or Marine Foeman Jetty, hence appeared abundantly at Slipway Complex. In contrast, *M. sallei*, due to its capacity to tolerate pollution and preference of stagnant waters, became more abundant and reduced the available space for recruitment of other fouling species at Marine Foreman Jetty. The balanid *A. a. amphitrite*, though present at all the stations, showed high recruitment at Ore Berth only due to low recruitment of other important foulers. Hence, specificity noticed in the recruitment patterns of the fouling organisms considered is the strategy of individual species to exploit the resources that an ecosystem offers, avoiding competition from other species either by resorting to colonization mostly during non-overlapping periods (Eguia and Trueba 2007) or by settling in a favourable environment. On the other hand, overlapping recruitment seasons observed as in the present instance arise as a result of a particular dynamic equilibrium established between two or among more fouling organisms during colonization (Khalaman 2005).

Thus, the recruitment dynamics of the five fouling species monitored exhibits either overlapping or independent periods of recruitment (with variable peaks) during different months and years. This kind of variations in the recruitment of five fouling organisms appear to be not uncommon as Hoagland and Crocket (1978) pointed that time of settlement, growth and species composition of fouling organisms vary from year to year. These observations suggest the necessity of long-term studies on the subject in tune with work on the breeding behaviour of the corresponding benthic species in adjacent environment to thoroughly establish the recruitment cycles of the fouling organisms.

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