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Growth studies of foulers in a polluted Indian harbour

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Original Article

Abstract

Growth of five important/dominant foulers *viz. Polydora sp., Dasychone cingulata* Grube, 1878, *Hydroides elegans* (Haswell, 1883), *Balanus amphitrite amphitrite* Darwin, 1854 and *Mytilopsis sallei* (Recluz, 1849) was monitored on monthly and cumulative panels at three stations (Slipway Complex, Ore Berth and Marine Foreman Jetty) in the polluted Visakhapatnam harbour from February 2007 to January 2009. Growth of *Polydora* sp. and *B.amphitrite amphitrite* was highest at Marine Foreman Jetty, thereby, indicating that growth of these two species is affected by competition for space rather than pollution. But, growth of *D. cingulata* and *H. elegans* showed a reduction from Slipway Complex to Ore Berth to Marine Foreman Jetty, which reflects the probable indirect effect of pollution stress on their physiology. *Mytilopsis sallei* being a pollution loving species had grown to maximum size at Marine Foreman Jetty. This dreissenid bivalve gradually adjusted to newer localities (Slipway Complex and Ore Berth) in the harbour giving a very alarming signal of its capacity to cause potential biodiversity losses and ecosystem damages. Currently, this invasive species reached the third and most dangerous stage of biological invasion *i.e*. 'diffusion'.

Keywords: *Biofouling, growth, pollution, invasion, diffusion, Visakhapatnam harbour.*

Introduction

Biofouling, which affect various maritime activities including shipping, oil and gas industries, fishing and aquaculture equipments, cooling systems of power plants, etc. (Callow and Callow, 2002); is a serious problem particularly in tropical waters (Nagabhushanam and Alam, 1988). Studies on different aspects of fouling such as, biology, physiology, succession, recruitment, etc. (Oshurkov, 1992; Koçak, 2007; Litulo, 2007 and Tremblay et al., 2007) have been carried out. Growth of foulers is an important aspect in fouling studies as size of a fouler often determines magnitude of fouling. Some of the important contributors to study of growth of various foulers are Mawatari *et al.* (1954a,b), Cheung (1993), Geraci *et al*. (2008) and Nelson (2009). In India, studies on this aspect were that of Rao (1990), Karande *et al*. (1986), Meenakumari and Nair (1988) and Rajagopal *et al*. (1998). Since observation on growth of foulers is a necessary part of biofouling studies, growth of some important/dominant foulers was observed in Visakhapatnam harbour.

Material and methods

Investigations on marine fouling were carried out at three test stations, namely, Slipway Complex, Ore Berth and Marine Foreman Jetty of Visakhapatnam harbour in Andhra Pradesh state (17°N 40′ Lat; 83° 16′E Long) (Fig.1) for a period of two

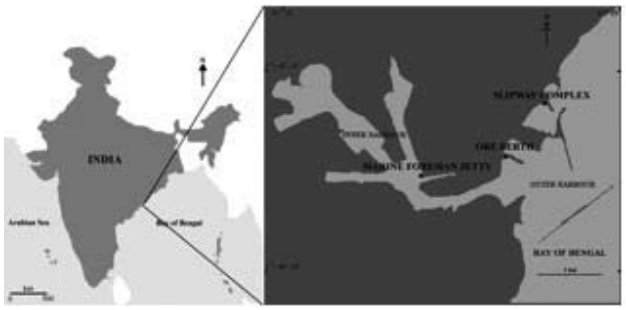

Fig.1. Map of Visakhapatnam harbour

years from February 2007 to January 2009. Visakhapatnam harbour waters are facing pollution particularly eutrophication but with a decreasing gradient from Marine Foreman Jetty to Ore Berth to Slipway Complex (Tripathy *et al*., 2005). During each study year, wooden test panels (150×80×20 mm) of *Bombax ceiba* for monthly observations and *Pinus roxburghii* for cumulative observations were immersed at each of the test sites in the form of vertical ladders containing 6 panels each (topmost panel kept in the intertidal zone and others well below lowest water mark). In order to study growth, the size of one important/dominant primary fouling species, namely, *Polydora* sp., *Dasychone cingulata* Grube, 1878, *Hydroides elegans* (Haswell, 1883), *Balanus amphitrite amphitrite* Darwin, 1854 and *Mytilopsis sallei* (Recluz, 1849) in five of

Table 1. Size of *Polydora* sp. (tube length in mm)

Month and year	Slipway Complex						Ore Berth						Marine Foreman Jetty					
	Monthly panels			Cumulative panels			Monthly panels			Cumulative panels			Monthly panels			Cumulative panels		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Feb-07	7.0	7.0	7.0															
Mar-07	4.0	7.0	5.6	3.0	9.0	7.4							-	-	-			
Apr-07	5.0	5.0	5.0	9.0	12.0	10.3	6.0	8.0	6.7				8.0	28.0	18.0	18.0	31.0	23.2
May-07	8.0	8.0	8.0	6.0	12.0	10.5	7.0	10.0	8.8	8.0	11.0	10.2	9.0	18.0	13.4	12.0	34.0	20.9
Jun-07	6.0	6.0	6.0	6.0	12.0	9.7				8.0	12.0	11.1	4.0	14.0	11.5	12.0	34.0	14.3
Jul-07	6.0	9.0	7.8	6.0	11.0	9.1	10.0	11.0	10.6	8.0	11.0	10.5	9.0	19.0	14.0	10.0	28.0	14.2
Aug-07	6.0	8.0	7.5	12.0	13.0	12.6	5.0	6.0	5.6	11.0	12.0	11.4	9.0	22.0	13.1	17.0	32.0	23.1
Sep-07	4.0	8.0	6.2	11.0	13.0	12.5							7.0	9.0	8.1	12.0	24.0	17.6
Oct-07	3.0	8.0	5.8	7.0	12.0	10.0							5.0	16.0	9.0	8.0	24.0	17.1
Nov-07	3.0	7.0	4.6	5.0	12.0	8.7							6.0	14.0	10.6	7.0	17.0	11.6
Dec-07	5.0	9.0	7.7										3.0	8.0	5.7	5.0	10.0	8.1
Jan-08	4.0	10.0	7.2	8.0	13.0	10.5												
Feb-08																		
Mar-08	6.0	14.0	9.6															
Apr-08	2.0	8.0	4.9	8.0	15.0	12.1												
May-08	4.0	8.0	4.9	10.0	13.0	11.5												
Jun-08	5.0	14.0	9.6	4.0	14.0	7.7	-	-	-				4.0	18.0	8.8			
Jul-08	8.0	15.0	12.4	1.0	16.0	10.7	-	-	-	-	-	-	-	-	-	-	-	-
Aug-08	4.0	8.0	6.4	-	-	-	3.0	4.0	3.7	4.0	6.0	4.8	4.0	13.0	9.8	6.0	21.0	13.2
Sep-08	3.0	11.0	6.5	-	-	-	-	-	-	-	-	-	6.0	11.0	9.0	2.0	10.0	7.2
Oct-08	5.0	9.0	7.2	-	-	-	4.0	8.0	5.6	-	-	-	5.0	16.0	10.0	7.0	14.0	9.9
Nov-08	3.0	7.0	6.3	-	-	-	-	-	-	-	-	-	3.0	10.0	4.8	1.0	15.0	8.7
Dec-08	3.0	8.0	5.6				-	-	-				2.0	6.0	4.5	5.0	16.0	10.6
Jan-09	-	-	-				-	-	-				8.0	12.0	10.0	8.0	17.0	13.1

the major groups, viz., spionids, sabellids, serpulids, balanids and dreissenids, respectively was measured using a sliding caliper. To estimate the size of a fouling species, a maximum of 10 individuals per panel whenever present from each of the 6 replications were measured up to nearest 0.1 mm.

Results and discussion

Temporally, foulers (*Polydora sp., D. cingulata, H. elegans, B. a. amphitrite* and *M. sallei*) monitored for growth attained different sizes during each month as well as each augmented period in a year.

Polydora sp. recorded a size of 5 mm (April '07) to 10 mm (January '08) in one month at Slipway Complex followed by 6 mm (August '07) to 11 mm (July '07) at Ore Berth and 8 mm (December '07) to 28 mm (April '07) at Marine Foreman Jetty during 1st year (Table 1). While at the same time, this species had grown to a size of 13 mm on 7month old panel (mop) at Slipway Complex, 12 mm on 3mop at Ore Berth and 34 mm on 3mop at Marine Foreman Jetty on cumulative panels. During 2nd year, this spionid attained a maximum size of 7 mm (November '08) to 15 mm (July '08) in one month at Slipway Complex followed by 4 mm (August '08) to 8 mm (October '08) at Ore Berth and 6 mm (December '08) to 18 mm (June '08) at Marine Foreman Jetty (Table 1). This species had registered a size of 16 mm on 5mop at Slipway Complex, 6 mm on 3mop at Ore Berth and 21 mm on 3mop at Marine

Table 2. Size of *Dasychone cingulata* (tube length in mm)

Month and year	Slipway Complex						Ore Berth						Marine Foreman Jetty					
	Monthly panels			Cumulative panels			Monthly panels			Cumulative panels			Monthly panels			Cumulative panels		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Feb-07	25.0	25.0	25.0															
Mar-07	1.0	7.0	2.5	2.0	52.0	21.5							-	-	-			
Apr-07	5.0	7.0	5.8	9.0	52.0	24.5	4.0	23.0	8.6				-	-	-	-	-	-
May-07	8.0	14.0	10.9	6.0	26.0	15.2	6.0	18.0	13.4	8.0	26.0	16.4	11.0	12.0	11.5	12.0	22.0	16.9
Jun-07	6.0	6.0	6.0	4.0	32.0	18.7				5.0	28.0	14.3	10.0	15.0	12.3	14.0	28.0	20.4
Jul-07	6.0	23.0	9.0	6.0	58.0	27.5	10.0	17.0	12.9	8.0	27.0	18.4	-	-	-	-	-	-
Aug-07	6.0	14.0	9.9	12.0	62.0	37.3	3.0	6.0	4.0	12.0	18.0	14.6	-	-	-	-	-	-
Sep-07	4.0	11.0	6.9	11.0	29.0	19.0							-	-	-	-	-	-
Oct-07	3.0	8.0	5.9	7.0	25.0	16.5							-	-	-	-	-	-
Nov-07	3.0	7.0	4.5	5.0	14.0	9.5							-	-	-	-	-	-
Dec-07	5.0	18.0	9.4										-	-	-	13.0	24.0	18.7
Jan-08	2.0	12.0	7.1	8.0	44.0	20.6												
Feb-08																		
Mar-08	11.0	19.0	15.8															
Apr-08	4.0	15.0	8.1	18.0	38.0	25.6												
May-08	5.0	21.0	10.6	6.0	28.0	17.5												
Jun-08	2.0	11.0	7.5	12.0	51.0	25.5	-	-	-				-	-	-			
Jul-08	4.0	14.0	9.3	12.0	38.0	22.9	6.0	6.0	6.0	-	-	-	-	-	-	-	-	-
Aug-08	6.0	24.0	13.6	2.0	36.0	22.7	6.0	7.0	6.5	-	-	-	-	-	-	-	-	-
Sep-08	4.0	13.0	7.3	20.0	62.0	34.8	-	-	-	-	-	-	-	-	-	-	-	-
Oct-08	3.0	12.0	5.8	21.0	38.0	30.4	8.0	13.0	10.5	-	-	-	-	-	-	-	-	-
Nov-08	6.0	9.0	6.5	11.0	34.0	18.9	2.0	10.0	6.0	5.0	21.0	13.3	-	-	-	-	-	-
Dec-08	4.0	12.0	7.0				4.0	7.0	6.0				-	-	-	-	-	-
Jan-09	4.0	4.0	4.0				7.0	12.0	10.0				-	-	-	-	-	-

Table 3. Size of *Hydroides elegans* (tube length in mm)

Month and year	Slipway Complex						Ore Berth						Marine Foreman Jetty					
	Monthly panels			Cumulative panels			Monthly panels			Cumulative panels			Monthly panels			Cumulative panels		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Feb-07	1.0	25.0	5.6															
Mar-07	1.0	13.0	3.5	1.0	22.0	9.6							-	-	-			
Apr-07	1.0	14.0	5.9	3.0	24.0	11.4	1.0	19.0	9.6				-	-	-	-	-	-
May-07	4.0	15.0	8.9	6.0	19.0	10.9	4.0	15.0	8.6	4.0	27.0	8.5	-	-	-	-	-	-
Jun-07	-	-	-	3.0	19.0	9.4				2.0	14.0	6.5	-	-	-	-	-	-
Jul-07	3.0	12.0	7.4	4.0	16.0	11.0	6.0	9.0	7.8	4.0	14.0	9.8	-	-	-	-	-	-
Aug-07	5.0	11.0	7.5	6.0	8.0	11.8	5.0	12.0	7.9	-	-	-	-	-	-	-	-	-
Sep-07	-	-	-	7.0	18.0	11.6							-	-	-	-	-	-
Oct-07	5.0	11.0	6.8	7.0	26.0	16.1							-	-	-	-	-	-
Nov-07	3.0	9.0	6.2	5.0	14.0	8.1							-	-	-	-	-	-
Dec-07	4.0	15.0	9.1										9.0	9.0	9.0	-	-	-
Jan-08	4.0	14.0	8.5	4.0	16.0	9.6												
Feb-08																		
Mar-08	5.0	14.0	9.0															
Apr-08	7.0	13.0	9.2	1.0	13.0	8.8												
May-08	2.0	8.0	3.8	5.0	14.0	9.4												
Jun-08	2.0	10.0	3.7	4.0	16.0	10.0	-	-	-				-	-	-			
Jul-08	-	-	-	6.0	15.0	10.1	4.0	9.0	6.3	-	-	-	-	-	-	-	-	-
Aug-08	3.0	16.0	8.0	5.0	14.0	7.9	-	-	-	14.0	14.0	14.0	-	-	-	-	-	-
Sep-08	2.0	32.0	6.3	4.0	21.0	11.3	4.0	7.0	4.7	1.0	7.0	4.0	-	-	-	-	-	-
Oct-08	3.0	15.0	7.1	2.0	35.0	13.1	-	-	-	3.0	3.0	3.0	-	-	-	-	-	-
Nov-08	3.0	15.0	6.5	10.0	24.0	15.7	8.0	20.0	12.9	6.0	8.0	6.8	-	-	-	-	-	-
Dec-08	1.0	13.0	6.4				11.0	16.0	12.8				-	-	-	-	-	-
Jan-09	2.0	7.0	4.1				4.0	16.0	9.8				-	-	-	-	-	-

Foreman Jetty during the same year on cumulative panels.

The sabellid *D. cingulata* recorded a growth of 6 mm (June '07) to 25 mm (February '07) in one month at Slipway Complex followed by 6 mm (August '07) to 23 mm (April '07) at Ore Berth and 12 mm (May '07) to 15 mm (June '07) at Marine Foreman Jetty during 1st year (Table 2). While at the same time, this species had grown to a size of 62 mm on 7mop at Slipway Complex, 28 mm on 3mop at Ore Berth and 28 mm on 4mop at Marine Foreman Jetty on cumulative panels. During 2nd year, this sabellid had assumed a length of 4 mm (January '09) to 24 mm (August '08) in one month at Slipway Complex followed by 6 mm (July '08) to 13 mm (October '08) at Ore Berth (Table 2). This species registered a size of 62 mm on 7mop at Slipway Complex and 21 mm on 6mop at Ore Berth during the same year on cumulative panels.

The serpulid *H. elegans* recorded a growth of 9 mm (November '07) to 25 mm (February '07) in one month at Slipway Complex followed by 9 mm (July '07) to 19 mm (April '07) at Ore Berth and 9 mm (December '07) at Marine Foreman Jetty during 1st year (Table 3). While at the same time, this species had grown to a size of 26 mm on 9mop at Slipway Complex and 27 mm on 2mop at Ore Berth on cumulative panels. During 2nd year, this annelid registered a size of 7 mm (January '09) to 32 mm (September '08) in one month at Slipway Complex followed by 7 mm (September '08) to 20 mm (November '08) at Ore Berth (Table 3). This species had grown to a size of 35

Table 4. Size of *Balanus amphitrite amphitrite* (rostro-carinal diameter in mm)

Month and year	Slipway Complex						Ore Berth						Marine Foreman Jetty					
	Monthly panels			Cumulative panels			Monthly panels			Cumulative panels			Monthly panels			Cumulative panels		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Feb-07	1.0	4.0	2.2															
Mar-07	1.0	5.0	1.4	1.0	15.0	8.8							1.0	7.0	2.2			
Apr-07	1.0	6.0	3.3	1.0	15.0	7.6	1.0	11.0	5.4				3.0	7.0	5.0	4.0	8.0	5.8
May-07	1.0	4.0	2.7	2.0	15.0	9.0	2.0	9.0	4.8	2.0	9.0	6.0	3.0	13.0	6.5	3.0	16.0	6.7
Jun-07	2.0	2.0	2.0	1.0	16.0	6.9				2.0	13.0	8.0	2.0	12.0	6.9	3.0	16.0	5.7
Jul-07	1.0	6.0	2.6	3.0	16.0	8.4	2.0	9.0	6.0	2.0	16.0	6.9	-	-	-	4.0	16.0	6.0
Aug-07	1.0	4.0	2.8	4.0	15.0	10.1	3.0	4.0	4.9	4.0	12.0	8.3	3.0	6.0	3.9	2.0	9.0	4.8
Sep-07	2.0	3.0	2.3	4.0	15.0	10.8							-	-	-	4.0	5.0	4.5
Oct-07	1.0	11.0	4.9	4.0	15.0	12.5							1.0	4.0	2.8	-	-	-
Nov-07	2.0	8.0	4.5	3.0	12.0	7.7							2.0	16.0	7.8	2.0	8.0	6.3
Dec-07	1.0	4.0	2.8										1.0	5.0	2.9	4.0	16.0	12.7
Jan-08	1.0	8.0	4.3	4.0	15.0	12.0												
Feb-08																		
Mar-08	3.0	9.0	6.3															
Apr-08	3.0	7.0	4.7	5.0	15.0	10.6												
May-08	3.0	4.0	3.2	4.0	15.0	10.1												
Jun-08	4.0	4.0	4.0	4.0	15.0	11.1	-	-	-				1.0	2.0	1.5			
Jul-08	2.0	4.0	2.9	3.0	15.0	10.0	1.0	9.0	4.3	2.0	2.0	2.0	-	-	-	-	-	-
Aug-08	2.0	8.0	4.9	5.0	16.0	10.1	1.0	5.0	2.7	1.0	9.0	3.9	3.0	7.0	4.7	-	-	-
Sep-08	1.0	7.0	2.7	4.0	16.0	13.3	1.0	7.0	3.1	1.0	10.0	4.3	2.0	4.0	3.1	5.0	9.0	7.1
Oct-08	2.0	8.0	5.2	4.0	15.0	11.2	1.0	4.0	2.6	2.0	12.0	5.9	2.0	9.0	4.7	1.0	10.0	4.9
Nov-08	2.0	5.0	2.7	4.0	16.0	12.9	1.0	3.0	1.7	2.0	14.0	6.2	2.0	7.0	3.4	3.0	16.0	10.5
Dec-08	1.0	6.0	3.2				1.0	7.0	4.0				1.0	7.0	3.6	1.0	15.0	11.0
Jan-09	1.0	7.0	3.1				2.0	13.0	4.2				2.0	10.0	4.6	4.0	15.0	11.7

mm on 8mop at Slipway Complex and 14 mm on 3mop at Ore Berth during the same year on cumulative panels.

The balanid, *B. a. amphitrite* recorded a growth of 2 mm (June '07) to 11 mm (October '07) in one month at Slipway Complex followed by 4 mm (August '07) to 11 mm (April '07) at Ore Berth and 4 mm (October '07) to 16 mm (November '07) at Marine Foreman Jetty during 1st year (Table 4). While at the same time, this species had grown to a size of 16 mm at all the three stations in different periods during 1st year on cumulative panels. During 2nd year, this balanid attained a maximum size of 4 mm (May '08) to 9 mm (March '08) in one month at Slipway Complex followed by 3 mm (November '08) to 13 mm (January '09) at Ore Berth and 2 mm (June '08) to 10 mm (January '09) at Marine Foreman Jetty (Table 4). This species had registered a size of 16 mm on 6mop at Slipway Complex and Marine Foreman Jetty, but only 14 mm on 6mop at Ore Berth during the same year on cumulative panels.

The dreissenid *Mytilopsis sallei* attained a maximum size of 2 mm (February/December '07) to 5 mm (October '07) in one month at Slipway Complex followed by 4 mm (August '07) to 8 mm (July '07) at Ore Berth and 5 mm (March '07) to 18 mm (May/September '07) at Marine Foreman Jetty during 1st year (Table 5). While at the same time, this species had grown to a size of 17 mm on 4mop at Slipway Complex, 6 mm on 4mop at Ore Berth and 24 mm on 5mop at Marine Foreman Jetty on cumulative panels. During 2nd year, this

bivalve attained a maximum size of 2 mm (May/June '08) to 8 mm (March '08) in one month at Slipway Complex followed by 3 mm (September/November '08) to 5 mm (October '08) at Ore Berth and 4 mm (December '08) to 19 mm (October '08) at Marine Foreman Jetty (Table 5). This species registered a size of 21 mm on 7mop at Slipway Complex, 6 mm on 6mop at Ore Berth and 24 mm on 6mop at Marine Foreman Jetty during the same year on cumulative panels.

The growth of *Polydora* sp. seems to have been affected in all probability by competition for space from other species rather than anthropogenic load as it attained a maximum size of 28 mm in one month and 34 mm in 3 months at Marine Foreman Jetty during 1st year.

The growth of *D. cingulata* showed a reduction from Slipway Complex to Ore Berth to Marine Foreman Jetty both on monthly and cumulative panels, the largest size recorded being ~25 mm on monthly panels and 62 mm on 7mop from Slipway Complex during both the years.

The growth of *H. elegans* on monthly and cumulative panels also followed more or less similar pattern (as that of *D. cingulata*), the maximum size attained being 32 mm on monthly panels and 35 mm on 8 mop at Slipway Complex during the 2nd year. The growth of these above two species reflects the probable indirect effect of pollution stress on their physiology. Rao (1990) while observing macrofouling on east coast of India mentioned that within a month this serpulid

Table 5. Size of *Mytilopsis sallei* (shell length in mm)

Month and year	Slipway Complex						Ore Berth						Marine Foreman Jetty					
	Monthly panels			Cumulative panels			Monthly panels			Cumulative panels			Monthly panels			Cumulative panels		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Feb-07	1.0	2.0	1.5															
Mar-07	3.0	3.0	3.0	9.0	10.0	9.8							1.0	5.0	1.9			
Apr-07	-	-	-	4.0	10.0	6.0	1.0	5.0	3.4				1.0	11.0	5.9	2.0	15.0	8.3
May-07	-	-	-	17.0	17.0	17.0	2.0	6.0	3.6	3.0	3.0	3.0	2.0	18.0	8.4	2.0	22.0	11.4
Jun-07	-	-	-	2.0	8.0	3.0				-	-	-	-	-	-	2.0	22.0	12.5
Jul-07	2.0	3.0	2.5	3.0	11.0	7.0	3.0	8.0	4.5	3.0	6.0	2.9	1.0	12.0	7.2	1.0	24.0	13.5
Aug-07	-	-	-	7.0	11.0	9.4	1.0	4.0	2.2	5.0	5.0	5.0	1.0	13.0	6.9	2.0	18.0	10.9
Sep-07	-	-	-	8.0	9.0	8.7							1.0	18.0	9.1	4.0	18.0	11.3
Oct-07	1.0	5.0	1.3	3.0	5.0	4.3							1.0	8.0	4.2	8.0	18.0	13.0
Nov-07	1.0	3.0	2.4	2.0	3.0	2.8							2.0	11.0	5.3	2.0	24.0	13.9
Dec-07	2.0	2.0	2.0										-	-	-	7.0	22.0	15.8
Jan-08	2.0	3.0	2.3	-	-	-												
Feb-08																		
Mar-08	3.0	8.0	5.3															
Apr-08	-	-	-	-	-	-												
May-08	2.0	2.0	2.0	-	-	-												
Jun-08	2.0	2.0	2.0	12.0	12.0	12.0	-	-	-				1.0	18.0	3.9			
Jul-08	2.0	6.0	3.5	5.0	5.0	5.0	-	-	-	-	-	-	-	-	-	-	-	-
Aug-08	1.0	3.0	2.4	5.0	16.0	7.7	-	-	-	-	-	-	1.0	7.0	2.6	1.0	18.0	10.7
Sep-08	3.0	3.0	3.0	11.0	21.0	16.2	3.0	3.0	3.0	-	-	-	1.0	7.0	2.7	1.0	8.0	2.5
Oct-08	-	-	-	-	-	-	1.0	5.0	2.3	5.0	5.0	5.0	1.0	19.0	5.1	1.0	21.0	5.7
Nov-08	-	-	-	10.0	10.0	10.0	1.0	3.0	2.1	6.0	6.0	6.0	1.0	10.0	3.6	1.0	24.0	9.6
Dec-08	6.0	6.0	6.0				-	-	-				1.0	4.0	1.8	2.0	19.0	11.6
Jan-09	-	-	-				4.0	4.0	4.0				1.0	8.0	3.2	4.0	20.0	10.4

had grown to a size of 25 mm and 53 mm at Visakhapatnam and Madras harbour, respectively.

The growth of *B. a. amphitrite* also appears to have been affected by the same factor as that of the growth of *Polydora* sp. This barnacle had reached a maximum size of 16 mm in one month at Marine Foreman Jetty during 1st year and an equal size on all cumulative panels during both the years except at Marine Foreman Jetty during 2nd year. A maximum growth of 13 mm was attained by this species during 2nd year on one month panels from Ore Berth. Thus, the growth of this species appears to have been affected more by competition for space from other species and/or even predation by free living forms within the community (Secondary Fouling Assemblage) or outside than pollution at Slipway Complex and Ore Berth during both the years. In accordance with the ability of nitrogen and phosphorous sequestration, the growth of *B. a. amphitrite* is high at Marine Foreman Jetty (Geraci *et al.*, 2008). Mawatari *et al.* (1954a,b) while studying the growth of *B. a. amphitrite* (=*B. a. communis*) recorded a size of 18 mm to 20 mm in 6 months at Ago Bay of Japan whereas a growth of 12 mm in 6 months at port of Mar Del Plata, Argentina. In India, Meenakumari and Nair (1988) observed a 22 mm growth of the same species in 5½ months at Cochin harbour. The growth rate of *B. amphitrite* at different harbours on the east coast as noticed by Rao (1990) reveals that it had grown to 11 mm in 1 month and 12.4 mm in 6 months at Visakhapatnam, 9.1 mm in 1 month and 11.3 mm in 6 months at Kakinada and 8 mm in 1 month and 15 mm in 6 months at Krishnapatnam harbour.

Mytilopsis sallei being a pollution loving rather than tolerant species had grown to a maximum size of ~19 mm in one month and 24 mm in 5/6 months at Marine Foreman Jetty during both the years. The growth of this species at Ore Berth and Slipway Complex suggests that it is able to grow faster at the former than the latter initially, but once acclimated could grow better at the relatively less polluted second site (Slipway Complex) than the first. This is a very alarming signal of its capability to gradually adjust to environmental conditions at newer localities which leads to potential biodiversity losses and ecosystem damages. Among the three stages (arrival, establishment and diffusion) identified in biological invasions (Carlton, 1987), this non-indigenous species (NIS) seems to have reached the most dangerous third phase of diffusion after its arrival during 1970's and thorough establishment during the last four decades in Visakhapatnam harbour and this issue needs to be addressed quickly with due commitment and sincerity before the naturalization of this species, especially because "….little is known about the diffusion over small-scale spread of marine NIS after they have invaded a region (Grosholz and Ruiz, 1996) despite this being a critical component of marine invasions (Glasby *et al.*, 2007). Slow growth of *M. sallei* at Ore Berth might be due to comparatively high turbulence at this station than the other two as this physical force is a generally known impediment to the growth of marine animals (Rajagopal *et al.*, 2006). During earlier studies, this dreissenid was reported to have grown to a size of 5 mm at Visakhapatnam harbour and to an almost equal size (5.1 mm) at Kakinada port in a single month (Rao, 1990). But, this animal had attained a size of 25 mm in 9 months at Visakhapatnam harbour and 27 mm at Kakinada port. Karande *et al.* (1986) recorded 10 mm size in this bivalve in 1 month and 25 mm in 12 months.

From the study, it was observed that growth of *Polydora* sp. and *B. a. amphitrite* was affected mainly due to competition for space, whereas *D. cingulata* and *H. elegans* had grown well in the region where pollution stress was minimum. *Mytilopsis sallei* grown to maximum size at the polluted Marine Foreman Jetty. Growth of this species at Ore Berth and Slipway Complex suggests that it is able to grow faster at the former than the latter initially, but once acclimated could grow better at the relatively less polluted Slipway Complex than the Ore Berth. This invasive bivalve has reached the third and most dangerous stage 'diffusion' of bioinvasion.

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