

## Variations in the Intensity of Fouling Organism Settlement on Different Types of Submerged Materials in Bivalve Farms of Thangaserry Bay (Kerala) during Post-Monsoon Period

R. K. JALAJ, A. R. GUPTA AND L. P. VERMA<sup>1</sup>

*R. A. Krishi Vigyan Kendra, Rajendra Agricultural University  
 Pusa, Samastipur, India*

<sup>1</sup>*Directorate of Extension ND University of Agriculture & Technology, Faizabad, India*

### Abstract

The present study deals with the intensity of fouling organism's settlement, their interaction and pattern on different suspended materials in bivalve farms. *Pseudomonas* among the bacteria was found to be dominant foulers. Barnacles were most dominant fouling organism contributing more than 60%. Polychaete was abundant in 30 days biofouling sample, but reduced drastically in 60 days sample. Among the submerged material de-twisted rope showed least fouling while roofing tiles were seen with maximum fouling settlement. These settlement patterns of different foulers on different materials will prove beneficial for mariculture.

**Key words :** Biofouling, Sedentary organism, Settlement, Microfoulers, Macrofoulers.

The study on biofouling associated with bivalve farms in Thangaserry bay was conducted during December 2004 to February 2005 and the results are presented. Marine biofouling communities are composed of plants and animals, which are basically drawn from the organisms present on natural substrate in the sea. The process of fouling starts with the settlement of microfoulers and succeeded by macrofoulers. Mostly bacteria and micro-algae especially diatoms are the microfoulers which provide foothold to the macrofoulers constituting mainly barnacles, polychaetes, anemone, hydrozoans, bryzoans, algae, tunicates, amphipods, isopods and sponges. Under normal condition, the bivalves reared in the farm are subjected to fouling and boring by different organisms. Most of these foulers are sedentary filter feeders, and are therefore a potential competitor with bivalves cultured in the coastal areas. This could lead to a reduction in meat yield and survival of cultured bivalves. Fouling of bivalve culture unit has several drawbacks including reduced water flow through culture units causing decreases in food availability (1); increased competition for available food from filter-feeding fouling organisms (2); and reduced oxygen availability which may affect growth (3); and Increased strain on culture equipment due to excess weight from fouling organisms. Fouling has been shown to affect growth

and survival of pearl oysters. The most visible and well-known forms of such fouling are the barnacles, limpets and seaweeds that adorn ships' hulls, sea-side piers and coast defences. Fouling is a menace to bivalve culture system as reported by Velayudhan (4, 5) and Appukuttan (6).

### Methods

Thangaserry bay (8°87'N latitude and 76°56'E longitude) located at Kollam in Kerala on the south west coast of India was selected as study area as many as bivalve farms are located here. Studies on bio-fouling organisms were carried out mainly on five different types of materials submerged for a period of 3 months to assess their seasonal settlement pattern.

The macrofoulers settled on the sampled materials were studied and identified following the procedures of Hynd (7) and Rao and Rao (8). Bacteriological studies were carried out following the method given by APHA et al. (9) and estimation of total bacterial count was done following the serial dilution technique.

A total of six sets of each material were fixed during initial month (November 2004). In December 2004, the two suspended sets of each material (30-day sampled material sets) were taken out for the

**Table 1.** Environmental parameters varies with month in Thangaserry bay and Ashtamudi lake.

Months	Salinity	Temp	pH	Environmental Parameters									
				DO (mg/l)	GP (mg C/l/day)	Chl.a (mg/m <sup>3</sup> )	Chl.b (mg/m <sup>3</sup> )	Chl.c (mg/m <sup>3</sup> )	NH <sub>3</sub> (μmol/l)	PO <sub>4</sub> (μmol/l)	NO <sub>2</sub> (μmol/l)	NO <sub>3</sub> (μmol/l)	TSS (mg/l)
Dec	30.000	29.000	8.500	4.040	1.801	0.4	0.2	0.3	0.000	0.707	0.050	0.037	24.95
Jan	32.000	29.000	7.800	3.330	0.394	0.4	0.5	0.6	0.043	0.653	0.050	0.048	21.30
Feb	36.000	31.000	7.600	7.434	4.435	0.9	0.7	0.9	0.214	0.598	0.122	1.541	25.20
Mean	32.667	29.667	7.967	4.935	2.210	0.57	0.47	0.60	0.086	0.653	0.074	0.542	23.82

biofouling study from experimental areas and another two new sets of each material were introduced again. In January 2005, four sets of each material (two 30-day sampled material sets and two 60-day sampled material sets) were taken out from the experimental areas for biofouling studies and another two new sets of each material were introduced. In the last month of experiment period (February 2005), all the remaining four sets of samples (two 30-day sampled material sets and two 90-day sampled material sets) were taken out for biofouling study purpose. A total of 10 sets of each sampled material were suspended during the experimental post-monsoon period from November 2004 to February 2005.

One-way analysis of variance (ANOVA) using

**Table 2.** Biofouling organisms observed during experimental period.

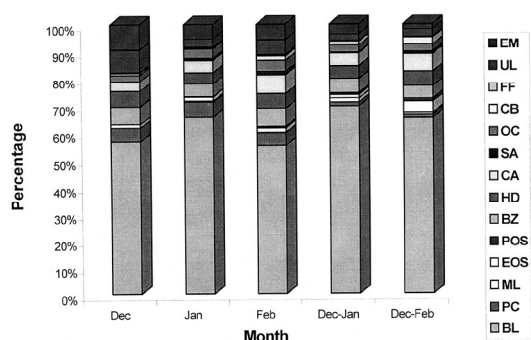
Fouling groups	Thangaserry bay
Barnacles	<i>Balanus amphitrite communis</i> , <i>B. amphitrite variegates</i> , <i>B. eburneus</i>
Polychaetes	<i>Hydriodes norvegica</i> , <i>H. lunulifera</i> , <i>Serpula vermicularis</i> , <i>Mercierella enigmatica</i>
Bivalves	<i>Modiolus striatulus</i> , <i>Crassostrea madrasensis</i> , <i>Pinctada fucata</i> , <i>Pteria macroptera</i> , <i>Saccostrea cucullata</i>
Bryozoans	<i>Electra bengalensis</i> , <i>E. crustulenta</i> , <i>Membranipora</i> sp., <i>Thalamoporella</i> sp., <i>Lagenipora</i> sp.,
Hydroids	<i>Laomedea spinulosa</i> , <i>Obelia</i> , <i>Campanularia</i> sp., <i>Sertularia</i> , <i>Bugula</i>
Compound ascidians	<i>Diplosoma</i> sp., <i>Botrylloides</i> sp., <i>Herdmania</i> sp., <i>Diandrocarpa</i> sp.
Simple ascidians	<i>Ascidia depressiuscula</i> , <i>Dicarpa</i> sp.
Crabs	<i>Thalamitta</i> sp., <i>Charybdis</i> sp., <i>Uca</i> sp.
Other crustaceans	<i>Elasmopus</i> sp., <i>Limnoria</i> sp., <i>Protogeton</i> sp., <i>Sphaeoma</i> sp.
Fish fry	<i>Tetrosomus gibbosus</i> , <i>Blennius steindacneri</i>
Sea weeds	<i>Ulva reticulata</i> , <i>Enteromorpha</i> sp.

SPSS software was done for finding out whether there is any significant difference ( $P < 0.05$ ) in attachment of fouling organisms in relation with different sampled materials suspended in Thangaserry bay.

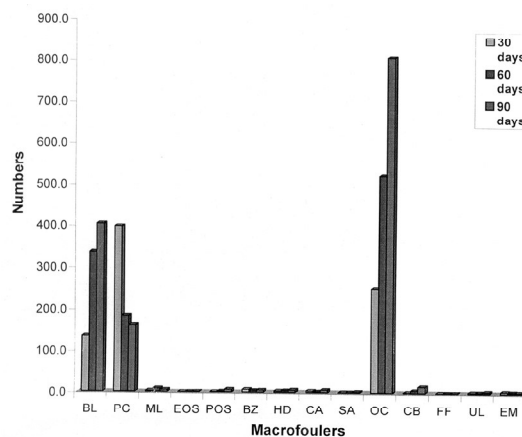
## Results and Discussion

The environmental data collected during the period December 2004 to February 2005 showed that the monthly mean water temperature during the period was 29.67°C, which indicated a marine sub-tropical climate of Thangaserry farm (Table 1). The mean salinity was 32.67‰ and pH varied between 7.60 to 8.50 during the experimental period. The average chlorophyll value for the surface water was 0.57, 0.47 and 0.60 mg/m<sup>3</sup> respectively for chl *a*, chl *b* and chl *c*. The average gross productivity of the surface water was 2.210 mg C/l/day during study period (Table 1). The average phosphate content throughout the study period was 0.653 μmol at PO<sub>4</sub>/liter. The average ammonia, nitrite and nitrate contents at the farm site throughout the study period were 0.086, 0.074 and 0.542 μmol at N/l, respectively. The average of total suspended solids was found to be 23.82 mg/liter.

The major fouling communities observed in Thangaserry bay can be classified under two major groups: Microfoulers and macrofoulers. Bacteria were observed as the main constituent of primary biofilm, which was influencing the settlement of macrofoulers. Majority of the isolates were gram negative. Altogether 12 genera (3 gram positive and 9 gram negative) were identified from the spat samples using four selective media. The most frequently isolated ones among the gram positive were *Micrococci*, *Streptococci* and *Coreneform* while *Vibrio*, *Pseudomonas*, *Alcaligenes*, *Aeromonas*, *Flavobacterium*, *Serratia marinorubra*, *Chromobacterium violacium* (SWA),



**Figure 1.** Percentage average fouling in different month. BL–Barnacle ; PC–Polychaete, ML–Modiolus ; EOS–Edible oyster spat ; POS–Pearl oyster spat ; BZ–Bryozoan ; HD–Hydriods ; CA–Compound ascidians ; SA–Simple ascidians ; OC–Other crustaceans ; CB–Crabs ; FF–Fish fry ; UL–Ulva ; EM–Enteromorpha.



**Figure 2.** Average macrofouler numbers varies with days. BL–Barnacle ; PC–Polychaete ; ML–Modiolus ; EOS–Edible oyster spat ; POS–Pearl oyster spat ; BZ–Bryozoan ; HD–Hydriods ; CA–Compound ascidians ; SA–Simple ascidians ; OC–Other crustaceans. CB–Crabs ; FF–Fish fry ; UL–Ulva ; EM–Enteromorpha.

fecal coliforms (*Escherichia coli*) were predominant gram negative bacteria. The important heterotrophic genera such as *Corenebacterium*, *Bacillus*, *Micrococcus*, *Vibrio*, *Pseudomonas*, *Alcalligenes*, *Aeromonas*, *Serratia marcescens* and *chromobacterium violacium* were isolated.

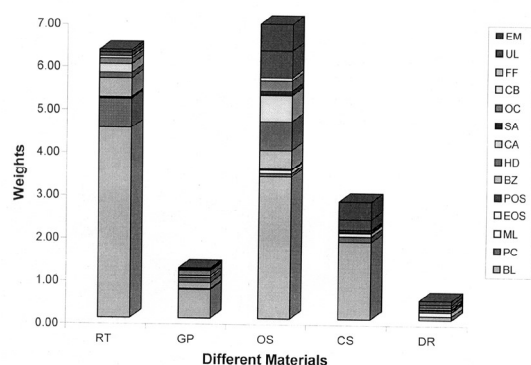
Total counts of bacteria were recorded as  $64 \times 10^2/\text{cm}^2$  during December 2004,  $72 \times 10^3/\text{cm}^2$  during

January 2005, and  $67 \times 10^3/\text{cm}^2$  during February 2005.

Microalgae mainly included diatoms and algal spores, which were contributing equally to biofilm formation. Diatoms observed in the given arear were *Biddulphia*, *Rhizosolenia*, *Chaetoceros*, *Thalasiaiothrix*, *Bacteriastrum*, *Coscinodiscus*, *Asterionella* and *Nitzschia*. Spore of algae such as

**Table 3.** ANOVA results between different materials and fouling organisms. Significance at 0.05 (\*) and 0.01 (\*\*). Materials with similar superscripts do not differ significantly across the rows. RP–Roofing tiles ; GP–Glass panel ; OS–Oyster shell ; CS–Coconut shell ; DS–De-twisted rope.

Fouling organism	Significance of F	Materials used as substratum					DR
		RT	GP	OS	CS	DR	
1. Barnacle	**	4.1092 <sup>c</sup>	0.7308 <sup>b</sup>	3.3000 <sup>d</sup>	1.6580 <sup>c</sup>	0.0900 <sup>a</sup>	
2. Polychaete	**	0.5942 <sup>c</sup>	0.0183 <sup>b</sup>	0.0620 <sup>ab</sup>	0.1190 <sup>b</sup>	0.0000 <sup>a</sup>	
3. Modiolus	*	0.0000 <sup>a</sup>	0.0000 <sup>b</sup>	0.0180 <sup>a</sup>	0.0080 <sup>a</sup>	0.0610 <sup>b</sup>	
4. Edible oyster Spat	**	0.0275 <sup>ab</sup>	0.0000 <sup>a</sup>	0.0960 <sup>b</sup>	0.0920 <sup>b</sup>	0.0000 <sup>a</sup>	
5. Pearl oyster Spat	**	0.0108 <sup>a</sup>	0.0000 <sup>a</sup>	0.3200 <sup>b</sup>	0.0000 <sup>a</sup>	0.0000 <sup>a</sup>	
6. Bryozoan	**	0.3208 <sup>c</sup>	0.1425 <sup>b</sup>	0.4550 <sup>d</sup>	0.0000 <sup>a</sup>	0.0100 <sup>a</sup>	
7. Hydroids	**	0.1092 <sup>b</sup>	0.1325 <sup>b</sup>	0.6220 <sup>c</sup>	0.0000 <sup>a</sup>	0.0000 <sup>a</sup>	
8. Compound ascidians	**	0.1483 <sup>b</sup>	0.0600 <sup>ab</sup>	0.6210 <sup>c</sup>	0.0340 <sup>ab</sup>	0.0000 <sup>a</sup>	
9. Simple ascidians	**	0.0033 <sup>a</sup>	0.0067 <sup>a</sup>	0.1180 <sup>b</sup>	0.0000 <sup>a</sup>	0.0000 <sup>a</sup>	
10. Other crustaceans	**	0.1108 <sup>b</sup>	0.1108 <sup>b</sup>	0.2660 <sup>c</sup>	0.0420 <sup>a</sup>	0.0480 <sup>a</sup>	
11. Crabs	**	0.0575 <sup>b</sup>	0.0150 <sup>a</sup>	0.670 <sup>b</sup>	0.0040 <sup>a</sup>	0.0220 <sup>a</sup>	
12. Fish fry	**	0.0067 <sup>a</sup>	0.0000 <sup>a</sup>	0.0000 <sup>a</sup>	0.0000 <sup>a</sup>	0.0400	
13. Ulva	**	0.0692 <sup>a</sup>	0.0492 <sup>a</sup>	0.5100 <sup>c</sup>	0.2190 <sup>b</sup>	0.0690 <sup>a</sup>	
14. Enteromorpha	**	0.0608 <sup>a</sup>	0.0108 <sup>a</sup>	0.6210 <sup>c</sup>	0.3450 <sup>b</sup>	0.0660 <sup>a</sup>	



**Figure 3.** Average fouling weight on different materials (per 100 cm<sup>2</sup>). BL–Barnacle ; PC–Polychaete ; ML–Modiolus ; EOS–Edible oyster spat ; POS–Pearl oyster spat ; BZ–Bryozoan ; HD–Hydriods ; CA–Compound ascidians ; SA–Simple ascidians ; OC–Other crustacean ; CB–Crabs ; FF–Fish fry ; UL–Ulva ; EM–Entomorphia ; RT–Roofing tiles ; GP–Glass panel ; OS–Oyster shell ; CS–Coconut shell ; DR–De-twisted rope.

*Ulothrix*, *Champia*, *Centrocreos*, *Oscillatoria*, *Prizeps* contributed to the formation of the algal film.

#### *Macrofoulers and Their Pattern of Settlement*

Macrofoulers were composed of a mixture of animals and plants drawn from different groups having common characteristics. Macrofoulers observed throughout the experimental period from Thangaserry bay was categorized broadly into 14 major groups (Tables 2 and 3). Among these groups, barnacle was the most dominant fouling group, contributing more than 60% of total fouling by weight, observed during experimental period (Fig. 1). Polychaete was dominating in number for 30-day sample, but reduced drastically in 60-day and 90-day samples where other crustaceans dominated (Fig. 2). Bryozoans, hydroids, compound ascidians, ulva and enteromorpha were the other major fouling organisms settled followed by barnacles. Among all different types of material used in Thangaserry bay, the oyster shell and roofing tile showed high fouling (per 100 cm<sup>2</sup> area) while glass panel showed least (Fig. 3). There was not much variation in fouling weight with the variation of water depth, but the composition of biofoulers varied. Seaweeds (ulva and enteromorpha) dominated in samples from 1 m depth (lighted part) while hydrozoans were at-

tached more on the shaded part (opposite side). The fouling weight did not vary much upto 3 m depth in roofing tiles and glass panel. De-twisted rope showed the least fouling settlement among all test materials and coconut shell had moderate fouling settlement (Fig. 3). The settlement of all fouling organisms in respect with different materials used was highly significant ( $P < 0.01$ ) except modiolus (Table 3). Macrofoulers were significantly increasing with days (Fig. 2). The succession of fouling organisms was clearly visible as the 60-day and 90-day samples contained compound ascidians, bryozoans and hydroids over the initial settled barnacles and polychaetes. Barnacle was the dominant fouling organism over all fouling materials (roofing tiles, glass panels, oyster shell and coconut shell) except de-twisted rope (Fig. 3). Settlement of barnacle with all materials showed a high significance ( $P < 0.01$ ) and roofing tiles showed maximum affinity for barnacles and minimum affinity was shown to de-twisted rope (Table 3).

Polychaete was an important constituent among the fouling communities, in Thangaserry farms. Settlement of polychaete showed a high significance with all materials ( $P < 0.01$ ). Glass panel, oyster shell and de-twisted rope did not differ significantly for polychaete settlement, similarly oyster spat and coconut shell did not show significant difference. The settlement of polychaete in roofing tile was significantly different from all other test materials and it favored maximum settlement of polychaete than other materials (Table 3). Roofing tiles, glass panel, oyster shell and coconut shell were did not differ significantly for modiolus settlement. The settlement of modiolus in de-twisted rope was significantly different from all other material and it favored maximum settlement of modiolus than other materials (Table 3). Pearl oyster and edible oyster spat settlement was present in Thangaserry farms. Settlement of pearl oyster spat and edible oyster spats showed a high significance with all materials ( $P < 0.01$ ). Bivalve spats dominated in farms were *Crassostrea madrasensis*, *Pinctada fucata*, *Pteria macroptera* and *Saccostrea cucullata*.

Hydroid dominated in settlement at Thangaserry bay. Settlement of hydroids showed a highly significant difference with all materials ( $P < 0.01$ ). Coconut shell and de-twisted rope did not contribute to hydroids settlement. Similarly roofing tiles and glass panel showed no significant difference for the settle-

ment of hydroids whereas oyster shell contributed maximum for hydroids settlement (Table 3). Coconut shell and de-twisted rope did not differ significantly in the settlement of bryozoans whereas other three materials showed significant difference in which oyster shell attracted maximum settlement (Table 3). Compound Ascidian group was well-represented settled animals in the Thangaserry bay. Settlement of compound ascidians showed a highly significant difference with all materials ( $P < 0.01$ ) in which de-twisted rope, coconut shell and glass panel did not differ significantly among themselves.

In the group of seaweeds, Chlorophyceae was the main flora settled in which ulva and enteromorpha were highly dominant within one meter depth. Settlement of ulva and enteromorpha gave a highly significant result with all materials ( $P < 0.01$ ). The species of seaweeds presented were *Ulva reticulata* and *Enteromorpha* sp.

#### *Organisms Associated with Foulers*

**Crustaceans.** Crabs and other crustaceans (amphipods, isopods, copepods) were two main groups, which were associated with suspended material in the Thangaserry farms. Settlement of crabs and other crustaceans showed a high significant difference with all materials ( $P < 0.01$ ). For other crustaceans aggregation, coconut shell and de-twisted rope showed similarity and differed significantly from roofing tiles and glass panel. Oyster shell showed significant difference than other materials and contributed maximum in settlement of other crustaceans (Table 3). Dominant crabs found in farms were *Thalamitta* sp., *Uca* sp. and *Charybdis* sp. Other crustaceans found over the different materials suspended during experimental period were *Elasmopus* sp., *Protogeton* sp., *Limnoria* sp. and *Sphaeroma* sp.

**Fish Fry.** Fish fry was rare, but sometimes were found during the collection of suspended materials. Settlement of these small fish fry showed a high significance with all test materials ( $P < 0.01$ ). Except de-twisted rope, others did not differ significantly for aggregation of these small fishes. De-twisted rope was ideal test material for fish fry aggregation compared with other materials (Table 3). Common fish fry found were fry of parrotfish (*Colliodon dussumieri*), *Tetrosomus gibbosus* (box fish), *Balistes* sp.,

*Thalassoma lunare* (wrasse) and *Blennius steindacneri*.

Different fouling communities in Thangaserry farms were observed monthly in the post-monsoon season. Observation of water temperature confirms about a marine sub-tropical climate of the study area. Temperature was the main factor, which triggered the biofouling process.

Among the bacterial foulers *Pseudomonas* was dominant. Among different fouling group observed in the present study, the most dominant fouling organism was barnacles contributing more than 60% of total fouling by weight and was causing serious damage to the bivalve farms.

Stachowitsch et al. (10) found that sessile filter feeders dominated the biomass, whereas small mobile forms had the largest number of individuals. Barnacles dominated over bivalves and sponges exceeded bryozoans, and biomass values here ranged from 84 g/0.1 m<sup>2</sup> at 10 m to 153 g/0.1 m<sup>2</sup> at 0 m; the corresponding individual numbers were 695 (10 m) and 3,125 individual/0.1 m<sup>2</sup> (0 m).

Polychaete was dominating in number for 30 days biofouling sample, but reduced drastically in 60-day biofouling samples and 90-day biofouling samples where other crustaceans were dominating in numbers. This might be due to inter-specific competition and succession of other organisms.

The settlement of all fouling organisms in respect with different test materials used was highly significant ( $P < 0.01$ ) except modiolus, which was significant at the level of  $P < 0.05$ . The roofing tile showed maximum fouling settlement while and de-twisted rope showed the least fouling settlement among all test materials. Glass panel also showed less fouling as compared to roofing tiles. Roofing tiles showed maximum affinity for barnacle settlement whereas minimum affinity was shown by de-twisted rope. Oyster shell showed more affinity for pearl oyster spat and edible oyster spat when compared to other test materials. All differences might be due to the various texture, color and chemical nature of substratum.

An understanding of ecology of fouling is necessary for the success in the practical problem of preventing the attachment of sedentary organisms to the submerged animals as several ecological factors namely texture and color of the substratum, temperature, salinity, phosphate, nitrate and chlorophyll con-

tent of the water, depth and interaction of flora and fauna present in that environment, influence the settlement and growth of these sedentary organisms. At the same time the interaction between bivalve spats and fouling organisms should be studied deeply with depth, substratum, biofilm organisms so that bivalve spat settlement can be enhanced in natural spat collection. To develop efficient and environment friendly controls for marine biofouling, we need to know more about the dynamic processes that are involved. Mathematical modelling can focus the experimental research and explain the development of ecological niches.

#### References

1. Taylor J. J., P. C. Southgate and R. A. Rose. 1997. Fouling animals and their effect on the growth of silverlip pearl oysters, *Pinctada maxima* (Jameson) in suspended culture. *Aquaculture* 153 : 31—40.
2. Claereboudt M. R., D. Bureau, J. Cote and J. H. Himmelman. 1994. Fouling development and its effect on the growth of juvenile giant scallop (*Placecten magellanicus*) in suspended culture. *Aquaculture* 121 : 327—342.
3. Wallace J. C. and T. G. Reisnes. 1985. The significance of various environmental parameters for growth of the Iceland scallop, *Chlamys islandica* (Pectinidae) in hanging culture. *Aquaculture* 44 : 229—242.
4. Velayudhan T. S. 1983. On the occurrence of shell boring polychaetes and sponges on pearl oyster *Pinctada fucata* and control of boring organisms. *Proc. Symp. Coastal Aquac., Mar. Biol. Ass. India* 2 : 614—618.
5. Velayudhan T. S. 1988. Studies on the settlement of barnacles at different depths in the pearl oyster farm at Tuticorin. *CMFRI Bull.* 42 : 301—305.
6. Appukuttan K. K. 1987. Pearl culture in Vizhinjam Bay. *CMFRI, Bull.* 39 : 54—61.
7. Hynd J. S. 1955. A revision of the Australian pearl shells, genus *Pinctada* (Lamellibranchia). *Aust. J. Mar. Freshw. Res.* 6 : 98—137.
8. Rao K. V. and K. Satyanarayana Rao. 1974. Pearl oysters. *CMFRI Bull.* 25 : 84—105.
9. APHA, AWWA and WPCF. 1985. Standard methods for water and wastewater, 16th edition. American Public Health Association, Washington DC, USA.
10. Stachowitsch M., K. Reinhard, H. Jurgens, Z. Pamela and G. Ernst. 2002. Offshore oil platforms and fouling communities in the southern Arabian Gulf (Abu Dhabi). *Marine Poll. Bull.* 44 : 853—860.