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***Research Article** (Open Access)*

STUDIES ON THE MACROFOULING COMMUNITY ON CONCRETE TEST PANELS AT CHENNAI PORT, SOUTH EAST COAST OF INDIA

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ABSTRACT
The macrofouling community structure on the concrete panels at Dr. Ambedkar dock, Chennai port, southeast coast of India was surveyed over a 12-month period from March 2018 to February 2019. The settlement and recruitment of encrusting communities has been recorded and photographed each month. The results showed that the biofouling community occurred with different densities throughout the year. In the current study, macrofoulants belonging to 10 Phyla represented by 18 families and 21 species were observed. Barnacles, polychaetes, mussels and sea squirts were the dominant groups observed in the test panels. In February 2019 a maximum biomass of 2.87 kg and in May 2018 a minimum of 1.37 kg was observed. The maximum number of fouling groups were observed in December 2018 and the maximum density in April 2018. The Green mussel *Perna viridis* was the dominant fouling organism in the climax community, followed by tube dwelling polychaetes. In this study, the relationship between the physicochemical parameters and the diversity indices was analyzed using the Karl-Pearson correlation coefficient.

Keywords: *Biofouling, Fouling communities, Biomass, Polychaetes, Bivalves*

INTRODUCTION
Biofouling is characterized by a broad spectrum of organisms adhering to submerged surfaces in the ocean and affecting the surface or substrate of any object. Biofouling is a complex process that often begins with the formation of biofilm and concludes with the undesirable accumulation of microorganisms, algae, plants and animals on damp structures. Biofouling has been a universal phenomenon in the marine environment, especially along coasts (Holmstrom *et al*., 1996; Callow, 2002). The establishment of the fouling community consists of four phases, and some of these phases may overlap or occur in parallel (Abarzua and Jakubowski, 1995). In the biofouling process, microfouling is the first phase which mainly consists of bacterial colonies, diatoms, fungi and protozoans (Hadfield, 2011). Microbial biofilms generate chemical signals that acts as triggers for certain invertebrates and algae to settle nearby, increasing the degree of biofouling (Hadfield, 2011; Dobretsov and Rittschof, 2020). A macrofouling community consists of soft or hard scales which develop and grow over the microfouling. Soft crusts include algae and invertebrates such as sponges, anemones, tunicates and hydroids. Hard crusts include invertebrates such as barnacles, mussels, tubeworms, and bryozoans.

Fouling pattern is influenced by various phenomenon such as environmental, seasonal, competitive, and depth variables (Vedaprakash *et al*., 2013). So, it is important to carefully evaluate the time frame over which such studies are conducted while seeking to investigate these qualities, especially in respect to the life spans of the component organisms (Richmond and Seed, 1991). The potential for colonizing organisms as well as the biotic and abiotic parameters of the water body can be well understood through fouling studies (Sandrock, 1991). The importance of fouling communities can be characterised as opportunistic, rapidly growing and metabolically highly active (Costlow and Tipper, 1984)

Macroalgae such as green, brown and red algae create a leaf canopy on the hard surface, which acts as an additional substrate and serves as a place of refuge for the migratory organisms living above and below. Among the sessile organisms, crustaceans, worms, molluscans and echinoderms find their habitat. Sessile form communities usually dominate in abundance and biomass, and act as edificators which include macro-forms such as sponges, hydroids, corals, sessile polychaetes, barnacles, mussels, bryozoans, sea anemone, ascidians.

The sessile macro-organisms inhabiting hard surfaces, in turn serve as a new substrate for colonization by other organisms, including sessile ones. As a result, new sessile organisms of the second, third, and higher orders are involved in the process of successive colonization (Partaly, 2003).

Knowledge of taxonomic diversity at the species level is also a prerequisite for understanding how community functions, as each species is characterized by an independent ecological role (Maggiore and Keppel, 2007). Biofouling studies on artificial substrates are useful to understand the succession process of the corresponding sedentary organisms on natural substrates (Perkol-Finkel & Benayahu, 2007). Fouling studies on hard substrates are considered an important tool in environmental impact assessment (Balaji and Rao, 2004). The morphological identification of the studied organisms proved challenging even for specialized experts, since many species are difficult to identify taxonomically (cryptic species) or are in juvenile stages and therefore lack the required morphological features required for accurate identification (Danovaro *et al*., 2016). Therefore, the present study was conducted with the aim of understanding the diversity and frequency of biofouling in the Chennai port. Biofouling community structure was assessed in long-term panels using Biodiversity indices.

MATERIALS AND METHODS

Study area

The port of Chennai is located in southeastern India, at 13.0815°N and 80.2921°E. It covers 420 acres of water and 586.96 acres of land. The port has three docks known as Bharathi, Jawahar and Dr. Ambedkar Docks. Dr. Ambedkar dock was selected as the sampling site for this study.

Figure 1 - Location of the Ambedkar Dock at Chennai Port

Hydrological parameters

Surface water sample was collected in a sterile bottle and brought to the laboratory for the analysis of hydrological parameters every month during the study period. Temperature, pH and Salinity were recorded at the time of sample collection. Water temperature measured by mercury thermometer. pH was measured by Portable pH Meter (HANNA HI98107). Salinity was estimated with the help of a hand refractometer (ERMA, Japan). Dissolved oxygen was estimated by Winkler's method (Montgomery *et al.*, 1964).

Submersion of Concrete panels

Twelve cement panels with an area 21cm x 21cm x 1cm were used as test panels for this fouling study. Before immersion, the cement panels were sterilized with 10% HCl solution, rinsed with distilled water and dried in a hot air oven at 40°C for 24 hours and stored in a dry place. The test panels were securely tied down with a nylon rope submerged at depth of 1m. The cement panels were placed at a distance of 3 to 5 meters around the Dr. Ambedkar dock in Chennai port.

Quantitative analysis of macrofouling organisms

One panel was retrieved every month from the water and gently washed with seawater to remove adherent mud and slime. Care was taken to ensure that no species were lost during the retrieval process and they were brought to the laboratory in an individual container filled with seawater. Each panel was examined to determine the total biomass, group composition, and numerical abundance of the encrusting communities. The average density of encrusting organisms observed in the panels in each month was expressed as number of individuals/m^2, except in the case of colonial forms such as sea squirts and bryozoans. The retrieved panels were preserved in 5% formalin for further investigation. Quantitative estimation of fouling organisms on the plates was made by counting both sides and edges of the plate.

The accumulated fouling community in each plate was carefully removed, separated into individual species, and preserved in 5% formaldehyde solution and then in 70% ethyl alcohol for qualitative and quantitative analysis. Fouling species have been identified according to the standard literature (Fernando, 2006; Cinar, 2006; Dev and Bhadra, 2005; Dey *et al*., 2007; Fauvel, 1953; Kott, 1985; Pillai, 1961; Rao, 1969; Mammen, 1963; Menon and Menon, 2006; Rao, 1975; Rao, 2003).

Statistical Analysis

Community structure of the fouling organisms was analyzed using species richness (S), Shannon's diversity index (H), Simpson's dominance index (D), Pielou's evenness index (E) and Index of Relative abundance as per Magurran (1988) using MS Excel 2019. The SHE Analysis was also calculated to study the relationship between the species richness (S), Shannon Wiener Diversity index (H) and Shannon Wiener Evenness index (E) according to Balaji and Rao, 2017. The relationship between the physico-chemical parameters and fouling community as well as with the fouling load characteristics were analyzed with Karl Pearson's correlation coefficient using MS Excel 2019.

RESULTS AND DISCUSSION

During the period of observation in the study site, macrofoulants belonging to 10 Phyla were recorded which included Chlorophyta, Porifera, Cnidaria, Platyhelminthes, Annelida, Bryozoans, Arthropoda, Mollusca, Echinodermata, and Tunicates. The macrofoulants were categorised into different groups and the organisms were listed in the studies. The phylum Annelida was the dominant macrofouler group in terms of species represented by 5 families. The table 1 illustrates the list of macrofouler groups of Chennai port and Figure 2 shows the common macrofoulers of the study region. A total of 27 species belonging to 10 biofouling groups have been recorded in Tuticorin port, 13 species belonging to 7 groups been recorded in Chennai port, 5 species belonging to 3 groups have been recorded in Paradeep port, 5 species belonging to 4 groups have been recorded in Haldia port by (Balaji and Rao, 2017). A total of 100 species belonging to 22 biofouling groups were found in Vishakapatnam harbour by Pati *et al*., in 2015. In Kalpakkam coastal waters, 57 fouling taxa were observed by Sahu *et al*., 2015.

The Figure 3 represents the important physico-chemical parameters recorded during the study period. The physico-chemical parameters varied according to the various seasons due to the prevailing climatic conditions and interaction between the wide range of biotic and abiotic factors. Environmental parameters particularly salinity and pollution are known to affect the structure and composition of biofouling community (Ramadan *et al*., 2006; Sahu *et al*., 2011; Swami and Udhayakumar, 2008). Physico-chemical parameters such as water temperature and salinity have high influence on the development and recruitment of marine foulers (Anil and Kurien, 1996).

Table 1: List of Biofouling groups observed in the Chennai port during the study period

Phylum	Family	Species of foulers
Chlorophyta	Chlorodendraceae	*Prasinocladus marinus*
Porifera	Leucosolenidiiae	*Leucosolenia variabilis*
Cnidaria	Bouganvilliidae	*Bimeria vestita*
	Actiniidae	*Anemonia manjano*
Platyhelminthes	Leptoplanidae	*Leptoplana mediterranea*
	Prosthiostomidae	*Prosthiostomum siphunculus*
Annelida	Eunicidae	*Eunice indica*
	Nereididae	*Perinereis cultrifera*
	Syllidae	*Syllis amica*
		Syllis gracilis
		Syllis prolifera
		Scoletoma fragilis
	Serpulidae	*Hydroides elegans*
	Glyceridae	*Glycera alba*
Bryozoa	Bugulidae	*Bugula neritina*
Arthropoda	Balanidae	*Amphibalanus amphitrite*
	Cirolanidae(Isopoda)	*Cirolana willeyi*
Mollusca	Mytilidae	*Perna viridis*
	Acanthochitanidae(Polyplacophora)	*Acanthochitona mahensis*
Echinodermata	Ophiotrichidae	*Ophiocnemis marmorata*
Chordata	Polyclinidae(Tunicata)	*Aplidium solidum*

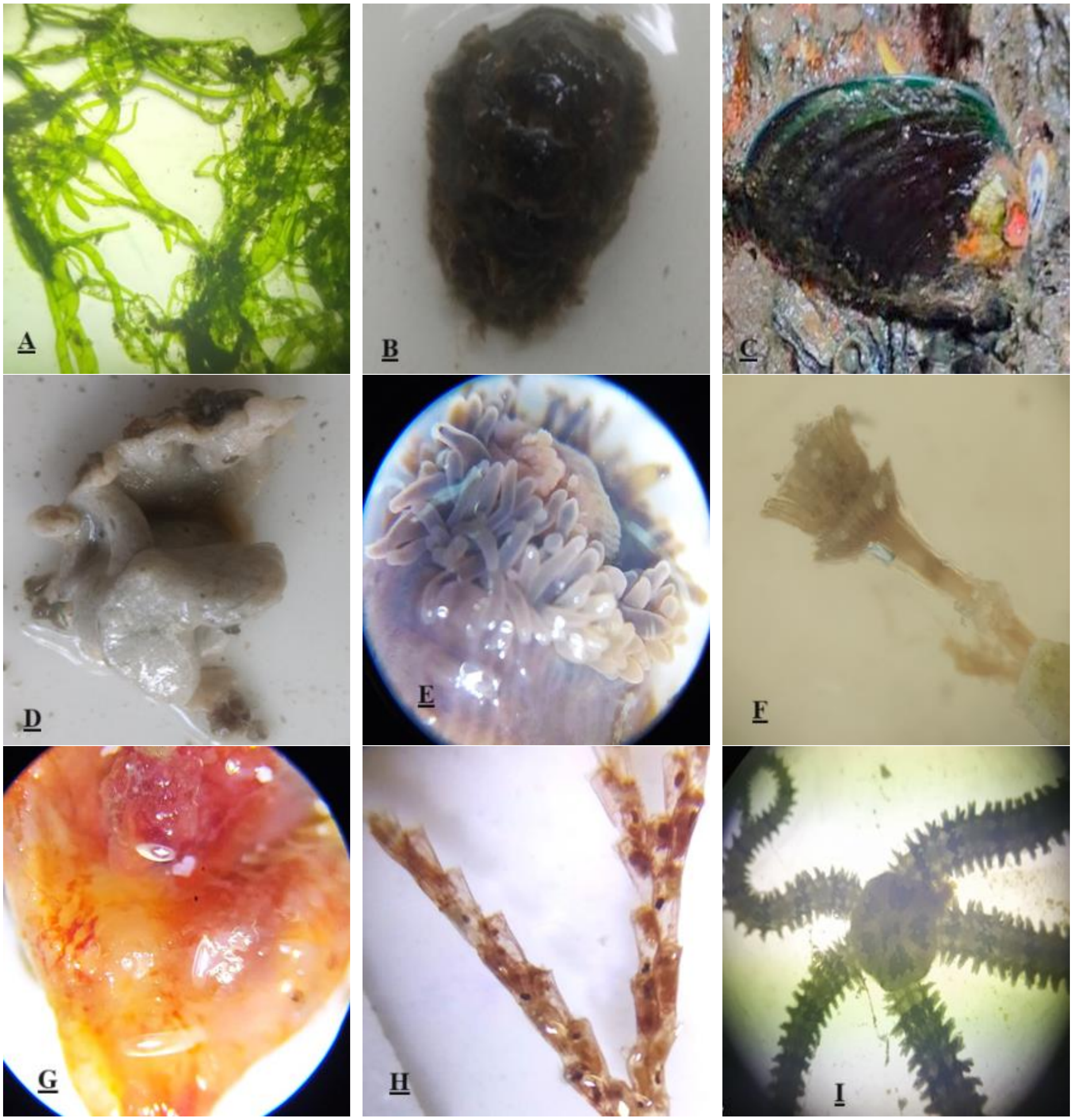

Figure 2: Common Macrofouling organisms A. *Prasinocladus marinus* B. *Acanthochitona mahensis* C. *Perna viridis* D. *Leucosolenia variabilis* E. *Anemonia manjano* F. *Hydroides elegans* G. *Aplidium Solidum* H. *Bugula neritina* I. *Ophiocnemis marmorata*

The list of macrofoulants observed at the study site portrays the gradual increase in the inhabitation of the foulants corresponding to the study period. The end of study period marked a significant rise of the macrofoulants amounting to ten groups. The climax community was dominated by green mussel *Perna viridis* followed by polychaetes.

In the macrofouling studies of Mangalore port by Venkat *et al*., (1997), polychaetes and cirripedes were dominant followed by a weak representation of bivalves and a very rare representation of Ascidian and Bryozoan larvae. The wet biomass of the biofoulants gradually increased during the study period. The number of foulants also increased consistently. The total number of individual foulants showed a decreasing trend from the beginning and increased towards the end of the study period. The analysis of the fouling load characteristics

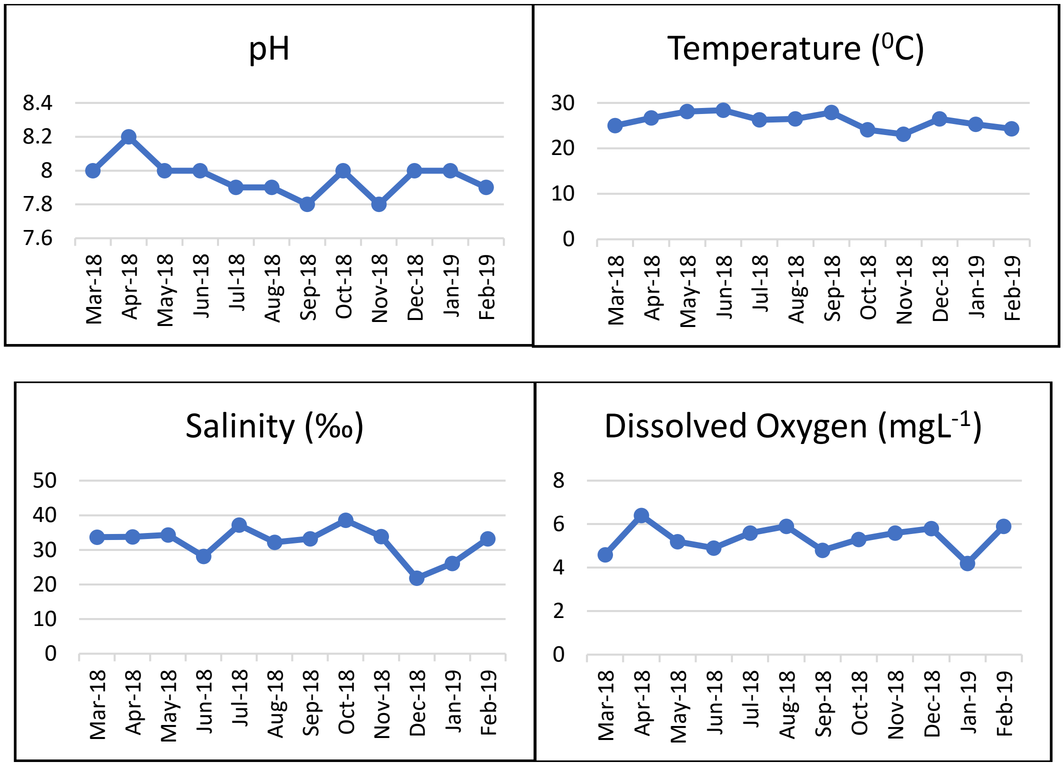

Figure 3: Physico-chemical parameters observed at Chennai port during Mar 2018- Feb 2019

shows that the succession of the macrofoulants over the concrete panels were rapid. As the succession of foulants proceeded towards the climax, the total number of individual organisms which could be inhabited began to reduce and at the end of the period there were only individuals of the climax community occupying the substrate for exploration. Hence the total number of individuals foulants showed a remarkable downfall towards the end of the study period.

Various biodiversity indices were calculated for the study period and the results are shown in the Figure 4. The Index of species richness (S) reached its crest during October 2018 and February 2019. Index of relative abundance was contributed largely by the cirripedes which was at the peak during December 2018. The figure 4 shows the maximum and minimum species diversity, species evenness and which states that dominance decreases with increasing diversity and evenness (Magurran,1988). The earlier part of the succession was marked by the competition between various species of foulants which hindered their distribution. But with the progression of time, resource partitioning between the foulant species enabled them to get accustomed to their respective niches causing an even distribution over the habitat. This can well be understood by the calculation of Pielou's species evenness Index. The strength of the climax community, the green mussel is well portrayed by the maximum values of the Relative abundance index at the end of the succession which progressed slowly from lower to higher values during the study period. The Figure 5 shows the SHE analysis of foulers at Chennai port.

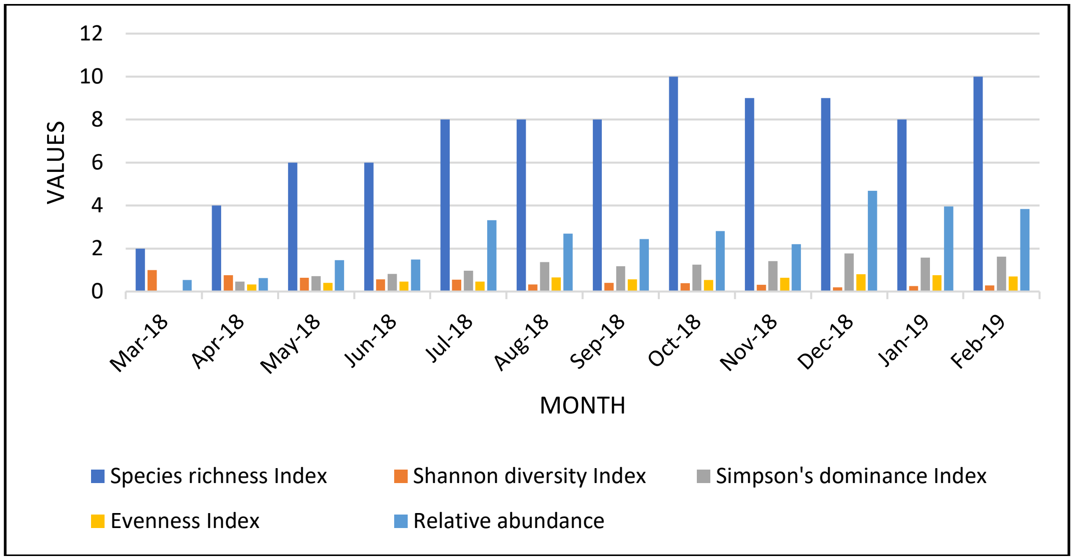

Figure 4: Ecological Indices of macrofoulants at the study site for the study period

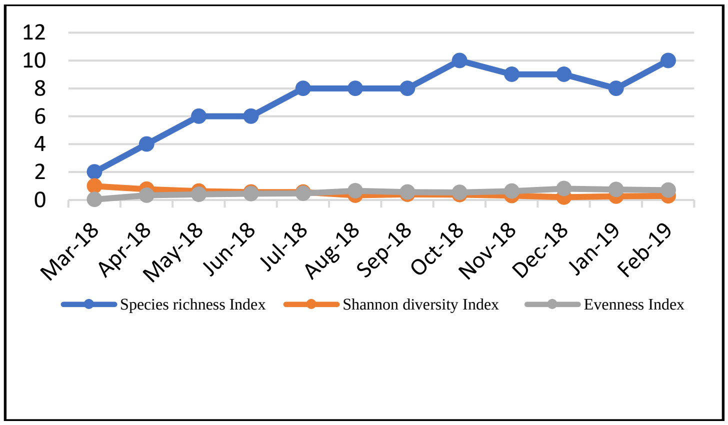

Figure 5: SHE analysis of foulers at Chennai port

Table 2: Fouling load on the concrete panel for a period of one year March 2018 – February 2019

Study period	Wet Biomass (kg)	No of Fouling species	Mean density (kg/m^3)
Mar-18	1.45	3	564
Apr-18	1.5	11	647
May-18	1.37	15	412
Jun-18	1.75	13	400
Jul-18	1.42	14	233
Aug-18	1.75	14	284
Sep-18	1.55	15	321
Oct-18	2	12	350
Nov-18	1.75	13	388
Dec-08	2.1	17	178
Jan-19	2.45	15	254
Feb-19	2.87	16	252

The table 2 portrays the fouling load at the study site during the study period. The wet biomass was calculated highest during February 2019 and lowest during July and September 2018. Comparatively a greater number of fouling organisms were found during December 2018 and a smaller number of organisms during March 2018. The total number of organisms were recorded greatest during April 2018 and lowest during December 2018.
The analysis of species richness index proves that number of species ascended gradually to maximum during the study period. Thus, the concrete panel served as an excellent habitat for thriving by a wide variety of foulants throughout the study.

Table 3: Relationship between physico-chemical parameters and biodiversity indices

	S	H	D	E	Relative Abundance
r value	-0.7225	0.8071	-0.8158	-0.756	-0.7557
p value	0.0079	0.0015	0.0012	0.0044	0.0044

Species richness – S, Shannon -Weiner diversity Index – H, Simpson's Dominance Index – D,
Pielou's species evenness Index **-** *E*

The relationship between physico-chemical parameters and biodiversity indices was calculated using Karl-Pearson's correlation coefficient. Shannon -Weiner diversity Index correlated positively with the physico-chemical parameters while the other parameters correlated negatively. The wet biomass varied positively with physicochemical parameters while the number of foulants and the total number of individuals varied negatively.

Table 4: Relationship between physico-chemical parameters and fouling load

Fouling characteristics	**r value**	**p value**
Wet biomass	0.0629	0.846
No. of foulants	-0.1105	-0.733
Total of individual organisms	-0.0039	-0.99

CONCLUSION

The present study observed the species composition of the macrofouling community in the Chennai port during March 2018 to February 2019. In the current study, 10 macrofouling groups represented by 21 species belonging to 18 families were observed. The Green mussel *Perna viridis* was the dominant fouling organism, followed by tube dwelling polychaetes. The macrofouling observed at the study site was consistently rapid with its diversity largely contributed by the various physico-chemical parameters and other biotic interactions.

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