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Impact of water quality parameters on diversity and intensity of biofouling at sea cage farm, Karwar, Karnataka, India

Mhaddolkar Sonali S[1], Dineshbabu AP[2], Thomas Sujitha[2] and Loka Jayasree[1]

[1]Karwar Research Centre of Central Marine Fisheries Research Institute , P.O. Karwar, Uttarkannada, Karnataka, India 581 301
[2]Mangalore Research Centre of Central Marine Fisheries Research Institute, PB No.244,Hoige Bazar, Mangalore
Email: sonamdkar@gmail.com

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ABSTRACT

Marine cage farming is becoming a viable method for marine food production and the economical viability of the production is very much influenced by infestation of biofoulers. The distribution and abundance of biofoulers depends on the environmental and hydrographical parameters of the water body. Present study was carried out to understand the impact of different parameters on the composition of the biofouling communities at sea cage farm at Karwar, India. Physico-chemical parameters were studied by taking samples from reference & cage site, at 1m, 3m and 6m depths. Even though there was no significant variation in the water quality parameters of two locations, community compositions of the biofoulers are reported to have significant correlation with the various environmental parameters. For example, Nitrite has showed a significant positive correlation with Hydroids and Sea-anemones. Many of the biofoulers showed significant positive correlation with other foulers. Present study was also attempted to understand the interdependency of the fouling species along with their dependency on the environmental parameters. Information on the correlation of environmental parameters and biofouling characteristics will help to ensure feasibility of the fish farming operations by taking appropriate decisions on site selection, duration and period of cage farming etc.

Keywords: biofoulers, correlation, community composition, environmental parameters.

INTRODUCTION

Study of hydrological parameters has gained importance because these hydrological parameters affect greatly on the abundance, occurrence and survival of the biofouling organisms. As favorable water quality parameters are prerequisite for plankton production which indirectly effects on the growth of biofoulers in the sea. The literature study on the Karwar hydrological parameters gives an insight on contribution of researchers (Ramamurthy, 1963; Noble, 1968; Annigeri, 1968, 1972; Radhakrishnan *et al*., 1978; Philipose *et al*., 2014) on hydrology study.

Salinity, Temperature, pH, Dissolved oxygen and Ammonia are considered as very important parameters in aquaculture practices (Pitta *et al*., 1999; Wu *et al*., 1999; Karakassis *et al*., 2001). Fouling rate on submerged marine substratum varies with the environmental parameters such as Temperature, Salinity, nutrients and current velocity etc. The influence of physico-chemical parameters on *Tubularia larynx* (hydroid) was studied by Nellis (1996). The community compositions of the biofoulers are reported to have significant correlation with the various environmental parameters (Fitridge *et al*., 2012).

Water quality studies of Indian cage culture sites were carried out by many authors (Imelda *et al*., 2010; Anil *et al*., 2010; Prema *et al*., 2010; Philippose *et al*., 2010, 2012). Earlier studies on variations of environmental parameters of sea cage farm of Karwar in west coast were conducted by Philipose *et al*.(2010). But the seasonal correlation studies between the Cage environmental parameters and biofouling is the first of its kind in Indian mariculture studies. Here more emphasis is given on the correlation between the cage environmental parameters and the biofouling community structure. So this study is very important in cage culture research in Indian waters. The main objective to study the hydro biological parameters of the study sites is to understand the trend of different parameters which are influencing on the composition of the biofouling communities. Along with the biological factors like grazing, competition for space and various other factors ,these hydrological parameters are controlling the biofouling intensity.

MATERIALS AND METHODS

This study was conducted at the fish cage farm, located at N 14°48.406' & E 074°06.664' in Karwar, Karnataka, west-coast of India, in the Arabian Sea (Fig.1.a &b). Area of marine cage farm is about 1.5 Km^2 and depth 8-10m. It holds floating circular cages ranging from 3m - 12m diameter size. Finfishes like Mangrove redsnapper- *Lutjanus argentimaculatus [Forsskal],* Johns snapper- *L. johnii [Bloch],* Pompano- *Trachinotus blochii [Lacepede],* Cobia-*Rachycentron canadum [Linnaeus]* and Seabass- *Lates calcarifer [Bloch]* were being cultured so far.

Physico-chemical parameters like Temperature, Salinity, Dissolved oxygen, pH, Ammonia, Nitrite, Phosphate (Gouri *et al*., 2011) were estimated by standard methods (APHA, 2007). Temperature was measured by mercury thermometer (±0.01^{0}C accuracy) and Salinity is measured by Knudsen's method. Dissolved Oxygen is estimated by Winkler's Method and pH, is measured by using the pH probe (Multi parameter-Test-35-series). The nutrients Ammonia, Nitrite, and Phosphate were estimated by using colorimetric (Strickland and Parsons, 1975) and Spectrophotometeric method. Monthly and Seasonal variation in Salinity, Temperature, Dissolved oxygen, pH, Ammonia, Nitrite and Phosphate were studied in all the three depth where the experimental panels were deployed at cage and reference site.

Biofouling density and diversity was analyzed by taking monthly and seasonal data from the cumulative experimental panels of cage and reference site for the year 2015-2016. Rectangular experimental panel set-ups with total 72 HDPE net pieces of 10cm^2 (mesh =22mm) size were fixed to three PVC frames, deployed at 3 depths viz. 1mt,3mt,6mt(top, middle, bottom) each in cage and reference site. The panels were submerged vertically in the water column by using float and anchors. Reference selected was 500 meters away from cage farm.

The data collected was analyzed statistically using software like SPSS, PAST, compared using two way ANOVA. The correlation with the seasonal variation of hydrography, fouling diversity and fluctuations in the growth of fouling organisms were studied. The biofouling community structure and seasonal variations were analysed using the PAST software. The biofoulers seasonal correlation between the water quality parameters and the diversity indices were analyzed with CCA (canonical-correspondence-analysis). The detailed study about the correlation between each community and the water quality parameter is further studied using the Two tailed Pearson correlation analysis, using SPSS software.

Fig.1. A : Cage farm of Karwar where the panel experiment was conducted**, B:** Experimental panels designed for biofouling studies

RESULTS AND DISCUSSION

The water quality parameters like variations in Salinity, Temperature, Dissolved oxygen, pH, Ammonia, Nitrite and Phosphate were collected to understand the relationship between these parameters and fouling. The correlation with the seasonal variation of hydrography, fouling number and diversity will be useful in understanding the influence of environmental parameters on the large scale fluctuations in the growth of fouling organisms.

Water quality parameters:

Seasonal variations in water quality parameters are analyzed between the two sites (fig.2). ANOVA study has shown that there is no significant variation in the water quality parameters and depth of two sites. Water quality studies of Indian cage culture sites were carried out by Imelda *et al*., (2010); Anil *et al*., (2010) and Prema *et al*., (2010) including studies of the same sea cage farm (Philipose *et al*.2012).

Seasonal variations in Temperature ranges have shown similar trend in cage and reference sites i.e. Temperature was low in monsoon near bottom panel and higher at top panel during pre monsoon. One way ANOVA results showed there is no significant difference between the sites but there is significance between monsoon and pre monsoon seasons ($p \leq 0.05$). The general studies on Monthly variations of water quality parameters of Karwar waters (Noble, 1968) observed higher Temperature ranges at deeper water, during the month of March and May. But overall the Temperature values were found slightly lower towards the depth at Karwar waters (Annigeri, 1966). In present study the deeper water during March and May month has showed higher ranges of Temperature, supporting the earlier observations of Noble (1968). and the studies by Philipose *et al*. (2012) in the cage farm covered under present study. In the present observations the highest Temperature was found to fluctuate from May to March. But in reference site similar observations were made as the previous studies of the same sites and the peak Temperature was observed during May. At the cage site two peaks have been observed during March and May 2015 with significant variation in Temperature among the sites. Comparatively higher Temperature ranges were observed in the cage site compared to the reference site this may be due to the influence of the rocky stretch of break water near the cage site.

Seasonal Salinity was low at top panel during monsoon high near bottom panel during post monsoon at both the sites. Comparatively Salinity is less in the cage site, this may be due to the effect of the estuarine fresh water influx from Kali estuary. One way ANOVA results showed there is significance between seasons ($p \leq 0.05$). The earlier works state that significant variations have not observed between the stations. Our present results also support the same. Seasonal Salinity ranged from 19.97 ‰ near top panel during monsoon to 33.11‰ near bottom panel during post-monsoon in the cage site. In the reference site the Salinity varied from 25.28 ‰ during monsoon near top panel to 32.86 ‰ in post-monsoon near bottom panel.

Dissolved oxygen in water was maximum during post monsoon near top panel of both cage and reference site. DO was low during monsoon near bottom panel at the cage site, but in the reference site it is low during pre-monsoon near bottom panel. DO levels were lower in the cage site when compared to the reference site. Trends in Dissolved oxygen accord with the results of previous workers (Annigeri, 1966). During July the values were the lowest & May it was highest at the cage site (Philipose *et al*., 2012). In the reference site the peak values were recorded in the month of August 2016 in the toper layers of water column. Significant difference was not found between the stations in the earlier studies. The lowest value in monsoon in all the panels of cage site, may be due to the increased zooplankton density in water. The higher levels of DO in reference may be due to the current pattern and wave action.

In both the sites pH was low near bottom panel during monsoon and high during post monsoon near bottom panel at the cage site, and top panel of the reference. pH levels were higher in the reference site compared to the cage site, in top and middle panels but in bottom panels it is reverse in all the seasons. pH values were in the similar range (Philipose *et al*.2012) as that of earlier workers except during January and September in cage and reference site respectively.

Ammonia was maximum during monsoon near bottom panel in both the sites, the highest was 0.28 mg/l, in bottom waters near the cage panels. This may be due to low Salinity, the disintegration of most of the marine fouling species has taken place in monsoon. The minimum Ammonia values were observed in pre-monsoon season near middle panel in the reference site and top, middle panels at the cage site. The present values of ammonia were higher compared to the earlier works of 2009-10 (Philipose *et al*., 2012) in the same site.

Overall the higher ranges of nitrite were observed in cage site. Nitrite ranges were low during pre-monsoon season near bottom panel and maximum near middle panel at the cage site, In the reference site the nitrite was low during Monsoon near middle panel, higher in post monsoon near bottom panel. In the monsoon season highest nitrite values were observed in cage site. During 2009 and 2010 (Philipose *et al*., 2013) values ranged between 0.1 -0.6mg^{-1}, but in present period the values ranged between 0.00 to 1.09mg^{-1}. In reference site during September depletion of nitrite was observed in the three depths and the values of nitrite were comparatively higher in the cage site when compared with the reference site. This may be due to the higher nutrients in the cage due to artificial and live fish feed given to the cultured fishes in the cages. The reference site is free of added nutrients as feed, the values of nitrite are lower in the present case.

Phosphate ranges are higher during pre monsoon near top panels at the cage and reference sites. Phosphate ranges were low near middle panel, during post monsoon in cage site and pre-monsoon in reference site. Phosphate values were high in the cage site in all the seasons when compared to the reference site. Ammonia, nitrite and phosphate levels were higher in the cagesite when compard to the referance site.

Correlation between the water quality parameters and the fouling organisms:

The results of two tailed Pearson correlation analyzed in SPSS software were presented in table 1. The cnidarians like hydroids and sea anemones have showed significant negative correlation ($p \leq 0.01$) with pH and positive correlation with Nitrite. Ascidians showed a significant negative correlation with Salinity, Dissolved oxygen ($p<0.01$) and Nitrite ($p<0.05$). Echinoderms showed significant negative correlation with Nitrite ($p<0.05$). *Gouri et al*. (2015) analyzed that Salinity effects the biofoulers settlement in the Kalpakkam waters. Swami and Udaykumar (2008) observed effect of pollution on reducing the biodiversity in two different localities, and suggested influence of Salinity and pollution on structure and composition of boifoulers. Also there are reports of faster development of foulers (FAO, 1989) with higher Salinity, Temperature and nutrients. The blockages of meshes of cage net due to fouling leads to the low Dissolved oxygen level inside the cage and the influence of these parameters on hydroid *was* studied by Nellis (1996).

Environmental parameters like Temperature and Salinity have impact on development and recruitment of biofoulers (Anil *et al*., 1996). Nasar (2017) while investigating biofoulers assemblage on experimental panel in two locations observed nutrients play important role in development of communities and described the biofouling pattern by combined effect of water quality parameters (Temperature, Ammonia, Nitrite and Phosphate). The flatworms and barnacles showed positive correlation (r=0.841, at 0.01 significance level) the similar observations were made in case of Gouri *et al*.(2015) in the Kalpakkam waters ,on the teak wood panels in bay of Bengal.

Assemblage of fouling organisms varies in different depth of the water column. It is due to the variation in light penetration, Salinity, Temperature, DO, pH, water current and physico chemical characteristics. The physical and biological characteristic along the water column brings out some systematic responses among the fouling organisms. A special temporal variations result into the deferral assemblage composition which differs over time and space.

Biofouling is mainly contributed by Cnidarians (hydroids) and hydroid showed a significant negative correlation ($p < 0.01$) with pH and showed a significant positive correlation with Nitrite (0.598). Ascidians showed a significant negative correlation with Salinity i.e. the number of ascidians decreased with the increase in Salinity.

The hydroids, sea anemones, echinoids and ascidians showed significant negative correlation with pH i.e. when the pH is low the theses communities were more in number. Nitrite level influences the number of Hydroids and sea anemone i.e. they have showed significant positive correlation with nitrite. It is also concluded from the results that when the Nitrite level is high and pH and DO are less hydroids were abundant.

Salinity, DO, pH exhibited significant negative correlation with Ascidians, Hydroids, Sea anemones, Echinoids, So as to influencing the biofouling community structure. Similarly Nitrite has showed a significant positive correlation with Hydroids and sea anemones, influencing the biofouling community structure in the Karwar waters. The similar results have been obtained by Pati and Balaji (2015) where they concluded that BOD, Salinity, Nitrite, Silicate and Phosphate were influencing water quality parameters determining the community structure of biofoulers in Vishakhapatnam Harbor.

Most of the biofoulers are having significant positive correlation with other foulers. Sponges showed significant positive correlation with Hydroids and echinoderms it was seen that sponges have grown on the hydroids and whenever the hydroids population is more on the panels echinoderms were found grazing on them. Sea anemones showed significant positive correlation with echinoderms, like hydroids sea anemones were also grazed by echinoderms (they attracted the echinoderms). Bryozoans have significant positive correlation with Isopods, because the isopods have been seen near the bryozoans in clusters. Flat worms have showed significant positive correlation with barnacles, It is seen that the flat worms were more abundant near the barnacle shells and ascidians may be they are taking the food particles or getting shelter. On the other hand Barnacles have significant positive correlation with Ascidians. Ascidians were found near the barnacle shell, there may be some kind of association with these two (association unknown). Shrimps and modiolus have significant positive correlation may be shrimps are feeding on the modiolus. So their number is showing positively significant correlations. Scallops have significant positive correlation with Nudibrachs. Nudibranch will feed on the bivalves like scallops. Oysters have significant positive correlation with Limpets. Limpets and oysters are seen more on the surfaces of barnacles and both will prefer same type of substratum and similar kind of water quality parameters and depth.

The ANOVA results obtained (SPSS) for both site (cage and reference) and biofouling communities has showed no significance, but between the season and the biofouling communities has shown significance ($P<0.05$). Dehmordi *et al*. (2011) worked on the parameters influencing the diversity the biofoulers of port of Deilam, Iran, found that it varied with Temperature and other parameters like Salinity, pH, conductivity had no significance on diversity. The Bryozoans and the isopods were showed significance between the seasons, influencing the structure of the biofouling community. The community compositions of the biofoulers are reported to have significant correlation with the various environmental parameters (Fitridge *et al*. 2012). Pati *et al.* (2015) concluded that biofouling community structure is mainly influenced by BOD, Salinity, Nitrite and Phosphate. And the similar results were obtained with the present study.

Table 1. Correlation between hydrological parameters and Biofoulers:

	Temp	salinity	DO	pH	Ammonia	Nitrite	Phosphate	Sponge	Hydroid	Seaanemon	Bryz	Flworm	Poly	Amphipod	Bar	Crab	Shrimps	Isopod	Scallops	Gastropod	Gmussl	Modiolus	Nudi	Oyster	Limpets	Echinoids	Ophiuroids	Ascidians
Temp	1	0.335	-0.058	0.308	-0.374	.517*	0.238	-0.178	-0.077	-0.033	0.095	-0.298	0.195	0.323	-0.348	-0.145	-0.12	0.183	-0.141	0.24	-0.081	-0.12	0.024	-0.329	-0.332	-0.086	0.008	-0.205
Salinity		1	.599**	.655**	-0.291	-0.083	0.008	-0.183	-0.195	-0.101	0.006	-0.122	-0.054	0.29	-0.166	-0.175	0.048	0.123	0.076	-0.241	0.266	0.096	0.103	-0.207	-0.192	-0.232	0.008	-.651**
DO			1	.758**	-0.31	-0.306	-0.234	0.201	-0.194	-0.15	0.085	-0.368	-0.102	0.098	-0.377	-0.127	0.109	0.339	0.084	-0.285	0.114	0.154	0.068	0.138	0.135	-0.312	0.068	-.630**
pH				1	-.430*	-0.319	-0.184	-0.041	-.544**	-.513*	-0.024	-0.244	-0.072	0.21	-0.323	-0.218	-0.156	0.291	0.109	-0.112	0.152	-0.036	0.125	0.021	0.062	-.453*	-0.132	-.433*
Ammonia					1	-0.314	.500*	0.043	0.111	-0.231	-0.083	0.176	-0.126	-0.336	0.304	0.265	0.224	-0.356	-0.169	-0.2	-0.006	0.176	-0.224	0.068	0.086	-0.031	0.152	0.079
Nitrite						1	-0.024	0.209	.598**	.686**	0.303	-0.181	0.065	0.08	-0.217	-0.059	-0.053	-0.025	-0.119	-0.041	-0.066	-0.193	0.197	-0.216	-0.267	0.325	0.002	0.022
Phosphate							1	-0.131	-0.11	-0.212	0.051	0.232	-0.201	-0.067	0.307	0.108	0.364	-0.093	-0.132	-0.094	-0.005	0.338	-0.191	-0.158	-0.14	-0.113	0.348	0.186
Sponge								1	.556**	0.319	0.335	-0.03	-0.096	-0.181	-0.102	-0.165	-0.097	0.037	0.098	-0.158	-0.112	-0.132	0.258	-0.061	-0.033	0.222	-0.115	-0.056
Hydroid									1	.752**	0.393	0.029	0.019	-0.104	0.042	-0.09	-0.118	0.048	-0.108	-0.257	-0.226	-0.241	0.077	-0.144	-0.177	.441*	-0.131	-0.031
Seaanem										1	0.171	-0.101	0.102	0.042	-0.075	0.036	-0.005	-0.072	-0.081	-0.125	-0.105	-0.111	0.071	0.014	-0.081	.597**	0.008	-0.109
Bryz											1	0.193	0.334	-0.063	0.068	0.288	-0.151	.601**	0.085	-0.152	-0.097	-0.196	0.395	-0.152	-0.139	-0.142	-0.16	0.14
Flworm												1	0.147	0.097	.841**	-0.019	-0.077	0.085	0.412	-0.112	-0.069	-0.066	0.343	-0.103	-0.065	-0.169	-0.088	.584**
Poly													1	0.406	0.024	0.302	0.005	0.344	0.094	0.409	-0.196	-0.029	0.183	-0.074	-0.085	-0.012	0.092	0.043
Amphipod														1	0.153	0.087	-0.116	-0.028	-0.095	0.147	-0.248	-0.168	-0.065	-0.046	-0.033	0.222	-0.087	0.017
Bar															1	0.131	-0.043	-0.192	-0.091	-0.113	-0.076	-0.02	-0.123	0.066	0.079	-0.165	-0.065	.624**
Crab																1	0.18	-0.059	-0.253	-0.118	-0.044	0.189	-0.041	0.167	0.088	0.014	0.267	0.102
Shrimps																	1	-0.144	-0.054	0.002	0.375	.938**	-0.076	-0.073	-0.054	-0.077	.941**	-0.098
Isopod																		1	0.401	-0.108	-0.139	-0.079	0.374	-0.124	-0.128	-0.263	-0.076	-0.1
Scallops																			1	-0.079	-0.098	-0.069	.831**	-0.072	-0.045	-0.117	-0.061	-0.083
Gastropod																				1	-0.098	-0.016	-0.112	-0.122	-0.079	0.012	-0.014	0.22
Gmussl																					1	0.395	-0.023	-0.116	-0.081	-0.221	0.34	-0.094
Modiolus																						1	-0.098	-0.103	-0.069	-0.129	.888**	-0.098
Nudi																							1	-0.101	-0.064	-0.166	-0.087	-0.075
Oyster																								1	.975**	-0.106	-0.039	-0.122
Limpets																									1	-0.117	-0.061	-0.083
Echinoids																										1	-0.115	0.057
Ophiuroids																											1	-0.112
Ascidians																												1

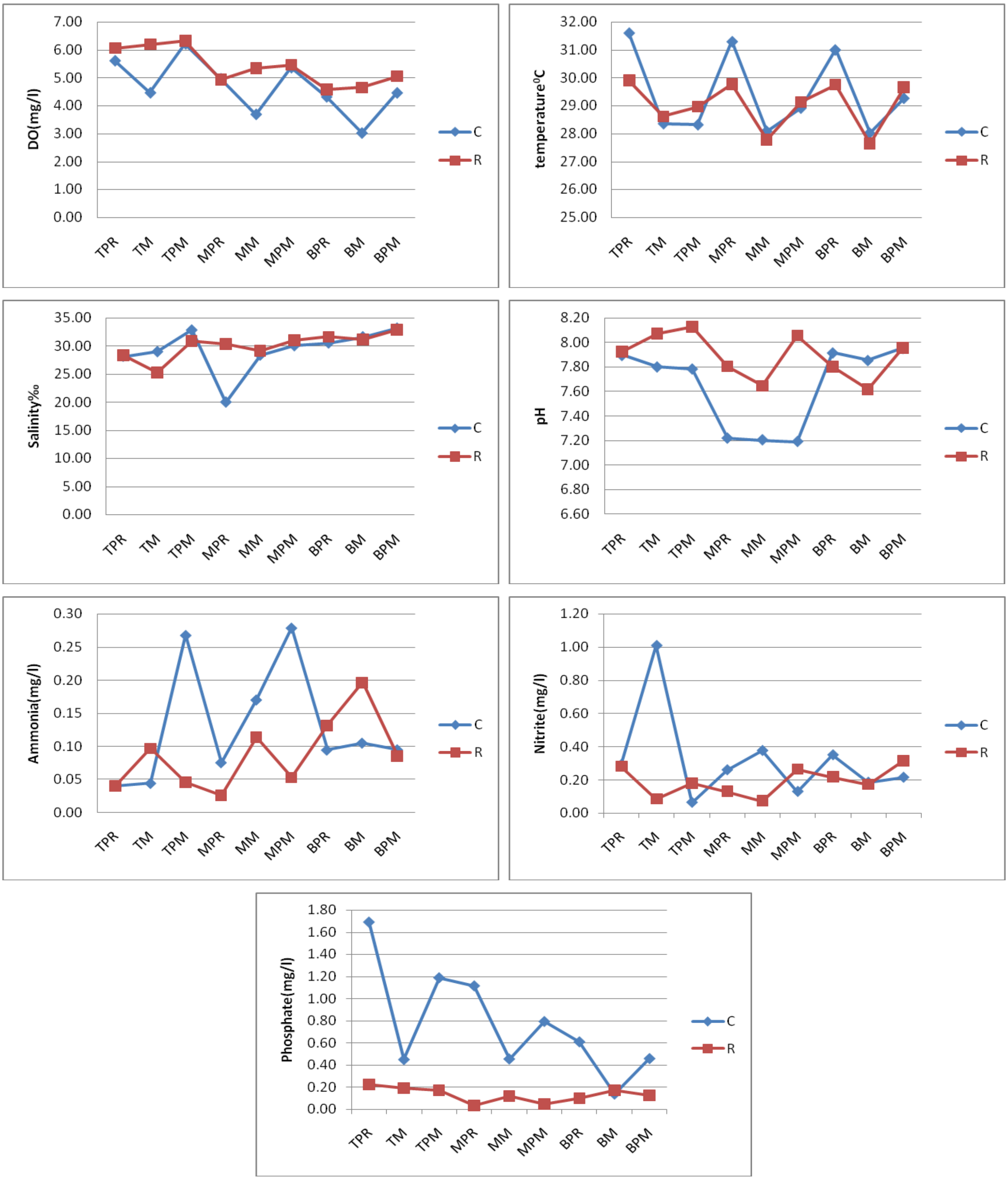

Fig.2. Seasonal variation of hydrological parameters at cage and reference experimental panel [TPR-top premonson, TM-top monsoon, TPM-top post monsoon, MPR-middle premonsoon, MM-Middle monsoon, MPM-middle post monsoon, BPR-Bottom premonsoon, BM-bottom monsoon, BPM-Bottom post monsoon].

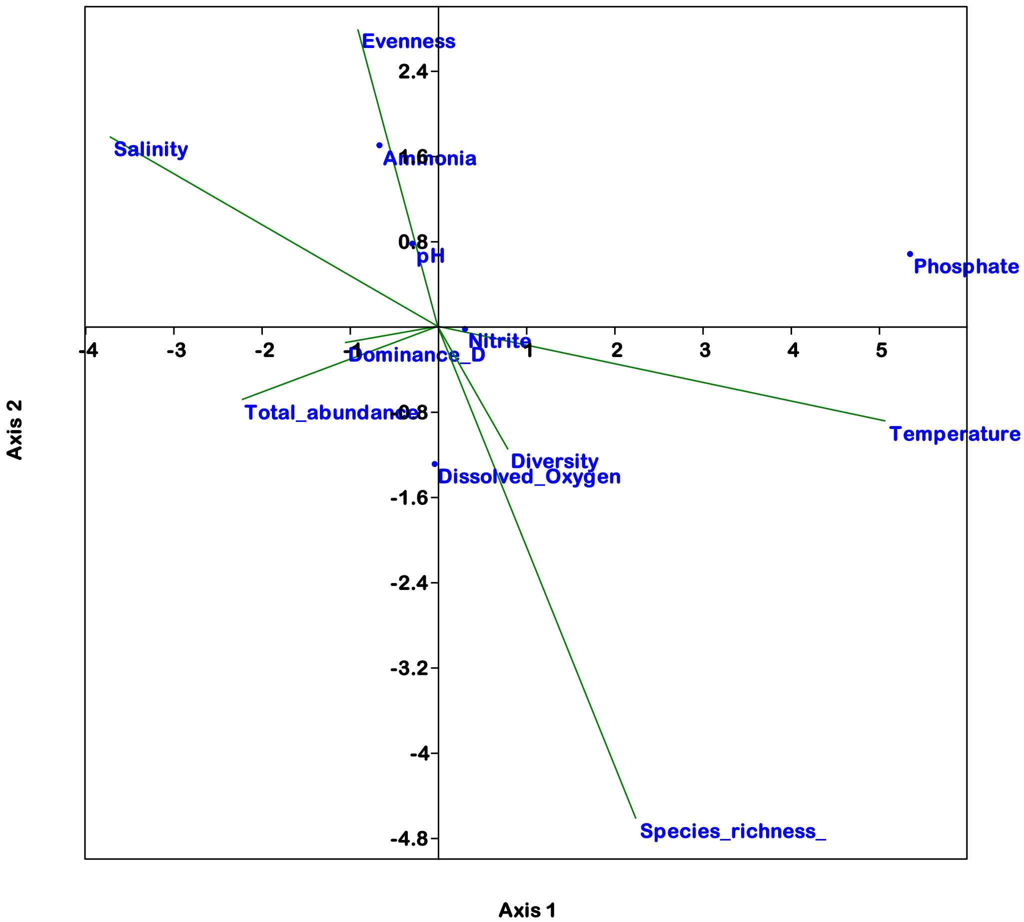

Fig. 3. CCA showing relation between water quality and biofouling community indices.

Relationship between environmental parameters and Diversity indices of fouling communities

Seasonal biodiversity Indices of both the sites were studied by taking the density of biofoulers. Low abundance (97no10cm^{-2}) in middle panels in cage during monsoon and high (1685no10cm^{-2}) in reference pre-monsoon panel. Diversity in Experimental panels of cage site during premonsoon was low in Bottom (BPR) and higher in Middle (MPR) panel. Dominance in cage site during pre-monsoon was low in middle (MPR) panel and high in the bottom (BPR) panel. Evenness was low in bottom reference pre-monsoon (BPR) and high in bottom cage monsoon (BM) panel. Species richness was low in Bottom cage post-monsoon, (BPM) and high in Middle cage pre-monsoon (MPR) panel.

The CCA Graph is generated from PAST using canonical correspondence showing relationship between environmental parameters and seasonal abundance of biofoulers in different sites and depths. The results obtained using CCA of relationship between the water quality parameters (Salinity, Temperature, Dissolved oxygen, pH, Ammonia, Nitrite, Phosphate) and biofouling community indices (dominance, diversity, evenness and total abundance) are presented in Fig.3.

When the Temperature, phosphate levels were high the species richness was relatively high, when the Salinity and the ammonia levels was more, the evenness was relatively more. The species richness is low when the Salinity is lower. Diversity was more when DO, nitrite, levels were relatively high. Fouling rate varies with the environmental parameters such as Temperature, Salinity, nutrients and current velocity etc. Salinity, Temperature, pH, Dissolved oxygen and Ammonia are considered as very important parameters in aquaculture practices (Pitta *et al*., 1999; Wu *et al*., 1999; Karakassis *et al*., 2001).

According to well known principal of Maguran (1988), biofoulers diversity and evenness decreased with intensification of dominance. In present investigations the dominance of biofoulers was contrary to the evenness and diversity. Similar results were obtained in wooden panel studies of biofoulers in Vishakhapatnam Jetty (Pati *et al*., 2015).

CONCLUSION

When DO, Temperature is high the diversity is more and when the Salinity and Ammonia levels are high evenness is more. The water quality parameters influence the diversity, fouling community structure and composition of biofoulers. Seasonal studies showed that Ammonia levels were low during pre-monsoon and high during monsoon. Highest diversity and density was recorded in pre-monsoon. Because of the Salinity changes, the disintegration of most of the fouling species, high ranges of Ammonia were towards the bottom during the monsoon in both the sites. In the cage site because of the external feed and fecal matters of culture fishes the Ammonia levels are higher than the reference site.

Biofouling is mainly contributed by cnidarians (hydroids) and showed a significant negative correlation with pH and significant positive correlation with nitrite. Ascidians showed a significant negative correlation with Salinity i.e. the number of ascidians decreased with the increase in Salinity and also most of the biofouling communities are having significant positive correlation other foulers. The analysis of relationship between the water quality parameters and biofouling diversity studies revealed that Temperature, Salinity, DO, pH and Nitrite can be considered as major water quality parameters influencing the community structure and diversity of biofoulers in Karwar cage farm.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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