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Observations on selected characteristics of water and sediment at the open sea cage culture site of Asian seabass *Lates calcarifer* (Bloch) off Cochin, south-west coast of India

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ABSTRACT

Study was undertaken to assess the impact of open sea cage culture of Asian seabass *Lates calcarifer* on selected parameters of water as well as sediment at Munambam off Cochin, Kerala coast from November 2008 to March 2009. Periodic observations were made on temperature, pH, dissolved oxygen, salinity, nutrients (NO_3, PO_4, SiO_3), nitrite, ammonia, BOD, total suspended solids, chlorophyll *a*, gross and net primary productivity as well as bacterial load of the surface and near bottom water from the cage site (N 10º 08' 162"; E 76º 08' 901") and also from a reference site (N 10º 07' 189"; E 76º 09' 210") during pre- as well as post-stocking periods. Sediment samples were collected simultaneously from both the sites and analysed for texture, pH, organic carbon and bacterial load. A significant reduction ($p<0.05$) in silicate and chlorophyll *a* was perceived in surface water at the cage site, during the culture period as compared to pre-stocking period. No significant variations were noticed in any of the other parameters studied. The sand, silt, clay and organic carbon content in sediment at cage site differed significantly ($p<0.05$) from that of the reference site. There was no significant difference in the mean values of total heterotrophic bacterial count as well as presumptive *Vibrio* count of the water and sediment, either between the cage site and reference site or between the pre- and post-stocking samplings. No adverse effect as influenced by cage culture of fish was observed on any of the environmental parameters studied during the period of investigation.

Keywords: Asian seabass, Cage culture, Kerala coast, Sediment and water characteristics, Total bacterial load

Introduction

The practice of rearing fish in floating cages can be applied in existing bodies of water that cannot be drained and would otherwise not be suitable for aquaculture. These include lakes, large reservoirs, farm ponds, rivers and coastal waters. Environmental monitoring is an essential pre-requisite in site selection for cage culture in order to understand the suitability of the site with regard to its water and sediment quality. Water quality parameters such as temperature, pH, dissolved oxygen, nutrients, ammonia, nitrite and turbidity are crucial parameters to identify suitability of the cage sites (Masser, 1997; O'Hanlon *et al*., 2001). Environmental monitoring needs to be continued during culture period to observe the pattern of variation in water and sediment quality.

The present investigation was carried out from November 2008 to March 2009, in connection with the open sea cage culture of *Lates calcarifer* off Cochin, undertaken by the Central Marine Fisheries Research Institute (CMFRI), Cochin, after the successful demonstration of the technology at Visakhapatnam along the east coast of India. The environmental monitoring done in sea cage farms in comparison with reference sites done elsewhere showed no significant difference in water quality parameters due to the influence of cage culture (Maldonado *et al*., 2005; D'Agaro and Domenico, 2006; Castillo-Vargasmachuca *et al.,* 2007). However, the present investigation is a pioneering attempt of its kind, carried out along the south-west coast of India to evaluate the effect of open sea cage culture on water as well as sediment quality in and around the culture site.

Materials and methods

Study site and collection of samples

The cage (6 m dia) was installed at Munambam, off Cochin (N 10º 08' 162"; E 76º 08' 901"), south-west coast of India by CMFRI for culture of Asian seabass in December, 2008. The cage site was about 4.5 km south of Munambam Fisheries Harbour at a distance of about 2 km, from the shore having a depth of 10 m. A reference site was fixed at 2 km away from the cage site towards south (N 10º 07' 189"; E 76º 09' 210"), having same depth (Fig. 1).

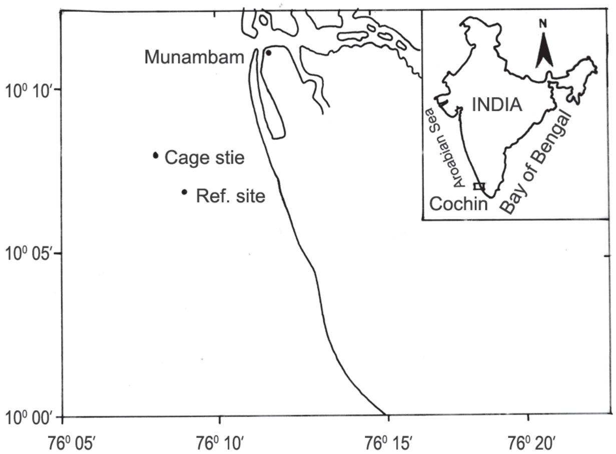

Fig. 1. Map showing location of the cage and reference sites

Prior to installation of the cage, the suitability of the site for culture of fish was assessed by analysing the water and sediment parameters in the monthly samples collected in November and December, 2008. Seabass fingerlings with an average size of 7 cm was stocked at a rate of 35 nos. m^{-3}. Fishes were fed *ad libitum* with chopped trash fishes. Periodic monitoring of water quality and sediment parameters were carried out throughout the culture period during January - March 2009, by fortnightly samplings. Water samples were taken from the surface and from the near bottom (10 m) using a Nansen water sampler. The sediment samples were collected using a Van Veen Grab.

Analysis of environmental parameters

Water samples were analysed for the standard water quality parameters *viz*., temperature, pH, dissolved oxygen, salinity, nutrients (NO_3, PO_4, SiO_3), nitrite, ammonia, BOD, total suspended solids (TSS), chlorophyll *a*, gross and net primary productivity by following APHA (1981). Sediment analyses for texture (percentage sand, silt and clay), pH and organic carbon were done as per Jackson (1958).

Bacterial load of water and sediment

The total culturable heterotrophic bacterial counts (THB) and presumptive *Vibrio* counts (PV) of the surface water, near bottom water (10 m) and the sediment from the cage site as well as from the reference site were monitored as per FDA (1995). Water as well as sediment samples for bacteriological analysis were collected in sterile polypropylene tubes/bottles and were transported to the laboratory in an ice cooler. Sediment samples (1 g) were diluted in 9 ml of filtered and sterilised seawater, vortexed and 10 fold serial dilutions were prepared in sterile seawater. Similarly, for water samples, decimal dilutions were prepared in filtered sterile seawater. Subsequently, the THB counts were estimated in triplicate by spread plate method using Marine Agar. The inoculated plates were incubated at 28 $\pm$ 2 °C and the colonies were enumerated after 48 h. The plate counts of aerobic heterotrophic bacteria are expressed as colony forming units per ml (cfu ml^{-1}). Presumptive halophilic *Vibrio* counts of the water as well as sediment samples were estimated using TCBS (thiosulphate citrate bile salt sucrose) agar plates supplemented with 3% NaCl.

Statistical analysis

The data obtained for various parameters were analysed statistically using one way analysis of variance (ANOVA) and Pearson Correlation using SPSS10 software.

Results and discussion

Water quality

Temperature, pH, salinity and dissolved oxygen

The variations in temperature, pH, salinity and dissolved oxygen (DO) at the cage and reference sites at different samplings are depicted in Fig. 2. No significant difference was noticed between temperature recorded at the

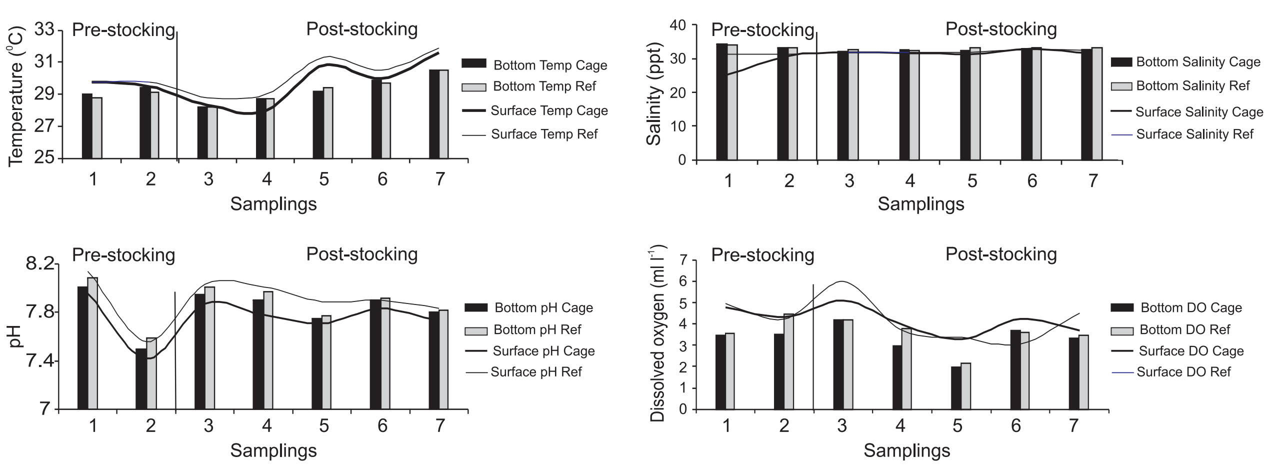

Fig. 2. Variations in temperature, pH, salinity and dissolved oxygen of surface and bottom water in the cage and reference sites, during pre- and post-stocking periods

cage site and reference site during pre- and post-stocking periods, in the surface or bottom water. The pH of surface water at the cage site was significantly low ($p<0.05$) compared to that of the reference site, during post-stocking period. The pH at the cage site was comparatively lower during the pre-stocking period also. This may be due to spatial effect, being the outcome of river flow towards the cage site, which is nearer to the barmouth than the reference site. A significant ($p<0.05$) reduction in salinity of bottom water was noticed during post-stocking compared to the pre-stocking period. This could be due to the significant negative correlation ($r = -0.539$) observed between bottom salinity and sand content as well as significant positive correlation ($r = 0.604$) between bottom salinity and clay content of the sediment. The cage site being nearer to the barmouth than the reference site, accumulated sand during cage culture, probably through river flow, would have caused a corresponding reduction in the clay content. This might have resulted in the lowering of bottom water salinity, as it leads to reduction in adsorbed ions coming into solution. Negative correlation ($r= -0.565$) was observed between the surface and bottom water salinity, showing vertical stratification. The DO concentrations in the cage site at surface during the cage culture activity showed fluctuations, but it did not reach below 4.7 mg l^{-1}. The observations recorded in the present investigation with regard to temperature, pH, salinity and DO were in concordance with the variations of these parameters reported by DOD (2002) from the inshore waters off Cochin during pre- and post-monsoon seasons.

Positive correlations were observed between the samples collected from surface and bottom temperature ($r=0.847$), pH ($r = 0.942$) and dissolved oxygen ($r = 0.602$) signifying the mixing of water mass in the study area.

Nutrients

No significant alterations in the level of nitrate, phosphate and silicate as influenced by cage culture were detected (Fig. 3). The recorded variations in the case of nitrate were of seasonal nature which were similar to the observations of DOD (2002) during pre- and post-monsoon periods in the inshore waters off Cochin. Concentrations of phosphate and silicate at cage as well as reference sites were lower than that of the corresponding values reported by DOD (2002) during pre- and post-monsoon seasons. Phosphate values showed fluctuations both at cage and reference sites. Significant reduction ($p<0.05$) in silicate content of the surface waters was observed during culture period, which may be attributed to seasonal changes as indicated by similar trend at the reference site also. Surface and bottom water nutrients were found to be positively correlated in the case of nitrate (0.547), silicate ($r=0.649$) and phosphate ($r = 0.650$).

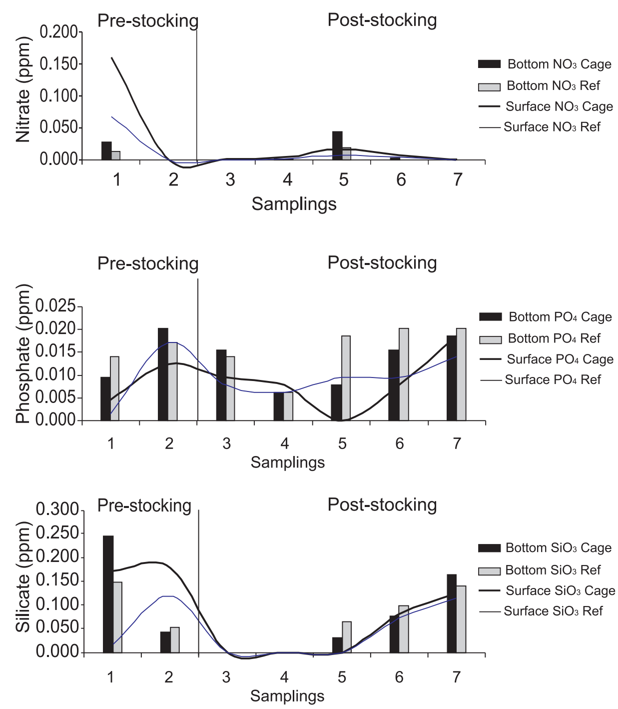

Fig. 3. Variations in nutrients (nitrate, phosphate and silicate) of surface and bottom water in the cage and reference sites, during pre- and post-stocking periods

Nitrite - N, ammonia – N, BOD and TSS

The changes in concentration of nitrite-N, ammonia-N, BOD, and TSS are shown in Fig. 4. Cage culture did not appear to have any significant influence on the variations in these parameters. Nitrite concentrations recorded were similar to that reported by DOD (2002) in the inshore waters off Cochin. Ammonia -N levels were well below the maximum permissible limit (<0.1 ppm) for fish culture. The ammonia -N in the bottom water during post-stocking period was significantly lower ($p<0.05$) than that of the pre-stocking period which is due to seasonal difference.

In general, the BOD values of surface water were comparatively higher during the culture period in cage site, in contrast to the reference site, though the difference was not statistically significant. However, the higher values recorded were all well within the permissible limits (<4 mg l^{-1}) for aquaculture. Fluctuations observed in the levels of TSS at cage site in comparison with reference site during pre- and post-stocking periods were not statistically significant. It is also worthy to note that short term changes induced by tidal currents in inshore waters off Cochin are quite large during pre- and post-monsoon months. The total material transported from sea into backwater amounts to approximately 900 t day^{-1} (Gopinathan and Quasim, 1971).

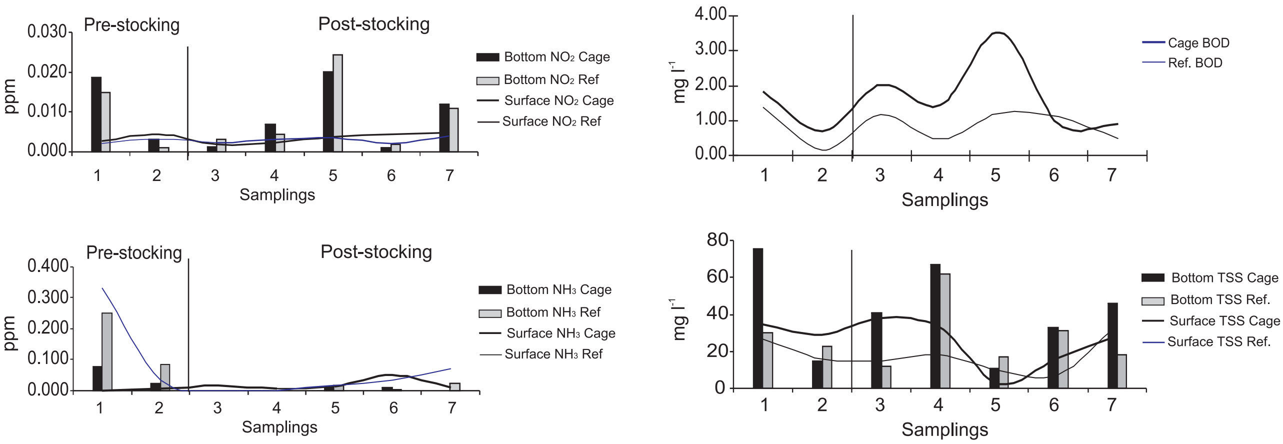

Fig. 4. Variations in nitrite-N, ammonia-N, BOD and total suspended solids of surface and bottom water in the cage and reference sites, during pre- and post-stocking periods

Sterling and Dey (1990) observed significant increase in TSS near the cages in surface and bottom water, in intensive cage farming in a Scottish freshwater lake, but the increased levels of TSS did not limit nutrients or phytoplankton growth.

Chlorophyll a and primary productivity

A significant reduction ($p<0.05$) was noticed in the content of chlorophyll *a* in the surface water during cage culture compared to the pre-stocking period (Fig. 5).

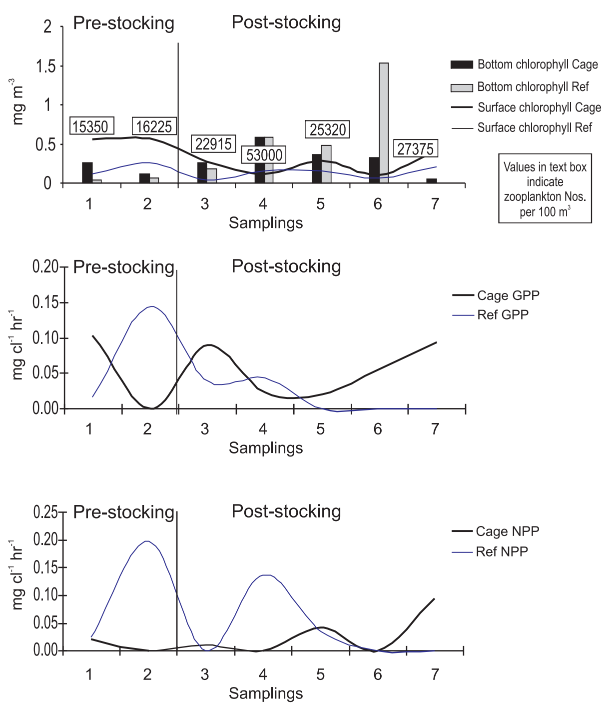

Fig. 5. Variations in chlorophyll *a*, gross and net primary productivity of surface and bottom water in the cage and reference sites, during pre- and post-stocking periods

Zooplankton data collected simultaneously (Molly-Varghese, personal communication) from the same site showed presence of comparatively higher biomass (nos. per 100 m^3 of surface water) during cage culture period (Fig. 5). The reduction in chlorophyll *a* may be attributed to the consumption by zooplankton at secondary level. The reference station did not show any significant difference between pre- and post-stocking periods. It may be noted that the nutrient content of surface water were also comparatively lower during cage culture period. However, the content of chlorophyll *a* of bottom water was higher during cage culture. The increased levels of chlorophyll *a*, though not statistically significant could be attributed to reduced consumption by zooplankton.

The gross and net primary productivity indicated a reverse trend at cage and reference sites during pre- and post-stocking periods, even though variations were not statistically significant. Towards the later part of the culture period, both the productivity parameters exhibited an increasing trend at cage site, in contrast to the reference site. This might be an indication that the cage culture activity helped in increasing the primary production at the site. Cornel and Whorisky (1993) have reported consistently low levels of chlorophyll *a* and nutrients at the cage site in an oligotrophic lake in Quebec, Canada.

Bacterial load

The mean values of THB recorded at the reference site and cage site during the pre- and post-stocking periods did not show significant variation (Fig. 6). However, there was a substantial increase in THB counts in the surface as well as bottom waters during the 4th post-stocking sampling, which came down to normal values within a fortnight. A substantial increase in THB counts was also noticed in the reference site during the 2nd post-stocking sampling which came down to normal values during subsequent

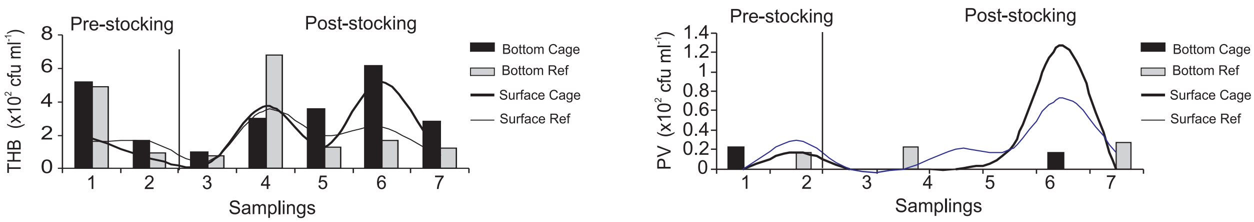

Fig. 6. Variations in total heterotrophic bacterial counts (THB) and presumptive *Vibrio* counts (PV) of surface and bottom water in cage and reference sites, during pre- and post-stocking periods

samplings. There was no significant difference in the presumptive *Vibrio* counts (PV) either between the cage site and reference site or between the pre- and post-stocking samplings.

Sediment quality

Texture

The sand content in cage site was higher in contrast to the reference site before and during the cage culture, the difference being significantly ($p<0.05$) high during the culture period (Fig. 7). This is not due to cage culture activity because sand content was higher at the cage site prior to stocking of fish also. The accumulation of sand might be due to the influence of river discharge as the cage site was closer to the barmouth than the reference site.

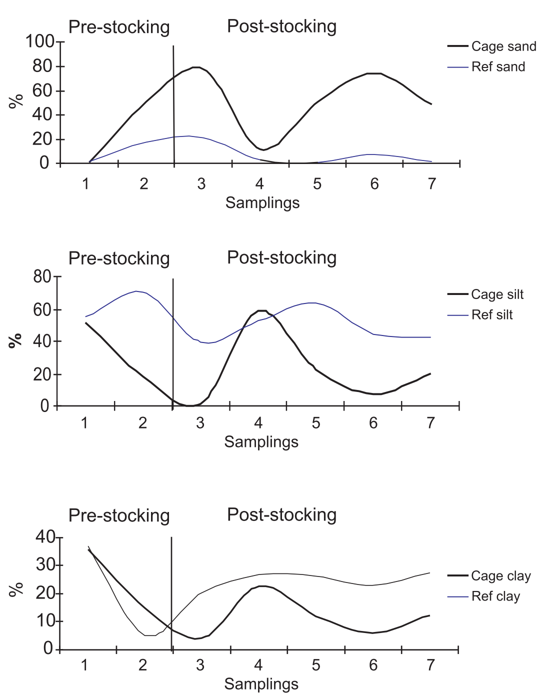

Fig. 7. Variations in texture (percentage sand, silt and clay) of sediment in the cage and reference sites, during pre- and post-stocking periods

The content of silt in sediment was lower in the cage site compared to the reference site before and almost during the culture period. A significant ($p<0.05$) reduction in silt content was recorded during cage culture due to the increase of sand content in the sediment at cage site. Significant negative correlation ($r = -0.906$) detected between sand and silt further confirms this observation.

The clay content in sediment was more at cage site than in reference site before cage culture, but their difference was not statistically significant. During cage culture, the clay levels recorded at the cage site were significantly lower ($p<0.05$) than the values recorded at the reference site. This can be attributed to the decreased silt and increased sand contents in sediment at cage site. This is further supported by the significant positive correlation between silt and clay ($r = 0.589$) as well as highly significant negative correlation between sand and clay ($r = - 0.829$).

pH and organic carbon

There was no significant differene between the sediment pH of the cage site and the reference sites. The organic carbon content in sediment of the cage site was lower ($p<0.05$) than that of the reference site throughout the culture period (Fig. 8). This may be attributed to the increased sand and decreased silt as well as clay content in sediment at cage site compared to the reference site. This was further evidenced by the significant negative correlation obtained between the organic carbon and sand ($r = - 0.942$) as well as positive correlation with silt ($r = 0.918$) and clay ($r = 0.699$).

Bacterial load

The THB counts of the sediment recorded at the cage site during the pre- and post-stocking periods did not vary significantly (Fig. 9). A substantial increase in THB load was recorded during the 2nd and 4th post-stocking samplings at the reference site and cage site respectively, which dropped to normal values during the subsequent samplings. The increase in THB counts recorded at the reference site was corresponding to the increased organic carbon levels recorded during the same period (Fig. 8 and 9). Increased THB levels were noticed at the cage site only about one month following the increased levels of organic carbon recorded in the sediment. However, there was no significant

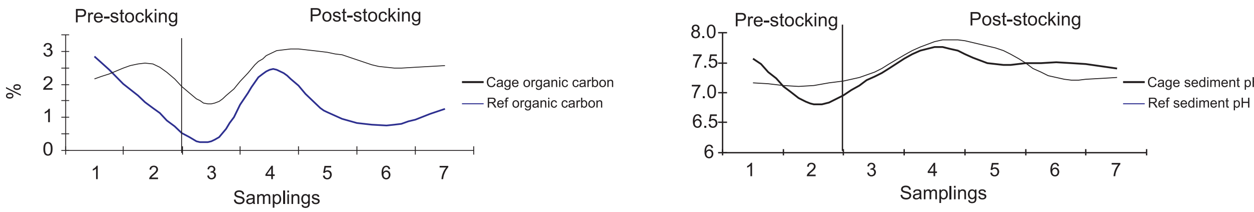

Fig. 8. Variations in organic carbon and pH of sediment in the cage and reference sites, during pre- and post-stocking periods

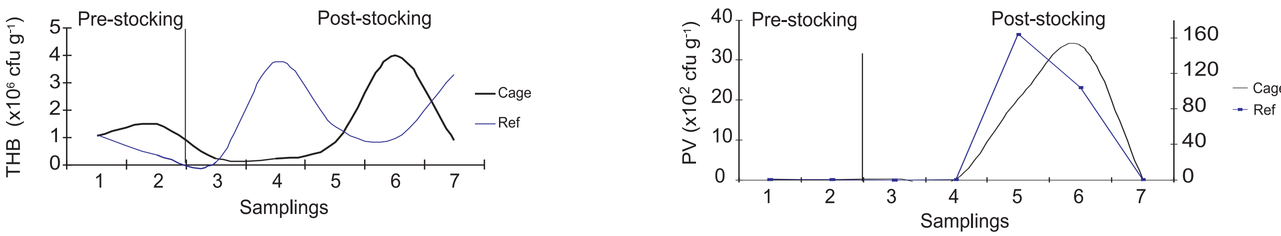

Fig. 9. Variations in total heterotrophic bacterial counts (THB) and presumptive *Vibrio* counts (PV) of sediment in the cage and reference sites, during pre- and post-stocking periods

correlation between the THB counts and organic carbon levels of sediment either at the cage site or at the reference site. The average THB values of the sediment recorded in the cage and reference sites also did not differ significantly.

The PV counts recorded in the sediment samples showed a significant increase in the cage site as well as in the reference site during the 3rd and 4th post-stocking samplings, which dropped to normal values in the 5th sampling after stocking. However, there was no significant difference in the mean PV values either between the cage site and reference site or between the pre- and post-stocking samplings.

La Rosa *et al*. (2002) reported that cage farming activity has comparatively lower impact on water environment than on the sediment. The influence of aquaculture on the benthic environment is due to the deposition of organic loads such as uneaten feed and dead fish (Wu *et al*., 1994; Wu, 1995). However in the present study, no significant difference was noticed in the bacterial load either between the cage and reference sites or between the pre- and post-stocking samplings. The density of microbial communities beneath the fish farm increased only during the 4th post-stocking sampling (Fig. 9). Deviations in the values between the cage and the reference sites did not indicate any significant impact of fish farming on bacterioplankton or sediment bacteria and the difference in bacterial load between cage site and reference site was not consistent. Therefore, it appears that during the present investigation, open sea cage culture of fish did not play any significant role in modifying the natural load of bacteria in the seawater and sediment surrounding the cage site. This may be attributed to the open sea location of the cage facilitating high rate of flushing and exchange of water. Maldonado *et al*. (2005) also have reported that medium sized cage fish farms located along western Mediterranean coasts exposed to semi-offshore conditions have fewer environmental impacts than traditional cage farms located in shallow sheltered sites. However, the findings of the present investigation are based on a pioneering attempt for cage culture of seabass along the south-west coast of India for a short duration and further investigations are needed in this direction to assess the impact in the long run.

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