Fishery Technology 57 (2020) : 250 - 257

Studies on the Diversity and impact of Macro Biofouling Organisms in Brackish Water Finfish Cage

K. Sunithakumari[1,2]*, Shoji Joseph[1], P. B. Ajithkumar[1,2], M. S. Smina[1,2], and N. P. Priya[1,2]

[1]*ICAR Central Marine Fisheries Research Institute, Post Box No. 1603, Ernakulam North P. O., Kochi - 682 018, Kerala, India*

[2]*Cochin University of Science and Technology, Cochin, Kerala, India*

Abstract

Biofouling refers to accumulation of organisms on submerged surfaces. In case of open water cage culture, fouling organisms attached to cage nets block water flow and reduces waste removal resulting in increased stress levels on stocked fishes and reduces the rate of intake of feed and growth. It also increases weight of the nets leading to its damage. The quantity and diversity of biofouling organisms and their effects on the growth and survival of stocked fishes were studied. The study was conducted at *Moothakunnam*, Ernakulam, Kerala. In the present investigation the data is of one culture period (10 months February - November 2017). The water quality parameters observed are: temperature (24.1°C to 31.7°C), Ph (6.81-7.87), salinity (0-29), light penetration (31.8 cm to 162.475 cm), DO (4.94-10.528 mg L^{-1}), nitrate (0.016-4.521 mg L^{-1}), nitrite (0 to 0.954 mg L^{-1}), orthophosphate (0.011-0.771 mg L^{-1}) and ammonia (0 to 0.031 mg L^{-1}). Biofouling was found initiated with filamentous algae followed by molluscs dominated by modiolus and other invertebrate organisms. Majority of the fouling organisms observed were molluscs and filamentous algae. Biofouling was highest in areas near the water surface and found reduced with depth. Almost 44.44% of the total net area was affected by biofouling. The total weight of the attachment with net was 3354.88 kg. Macrobiofoulers itself shared a total weight of 658.56 kg and modiolus (90.53%) alone contributed 588.8 kg. Apart from these associated animals like Arthropods, Annelids etc. were also found. Infestation was found increased with salinity and peaked during April-May (29 psu).

Received 30 August 2019; Revised 31 October 2020; Accepted 02 November 2020

*E-mail: sunithasreevilasam@gmail.com

Keywords: Biofouling, macrobiofoulers, cage farming, modiolus

Introduction

Biofouling is the accumulation of living organisms on submerged surfaces by adhesion and its further growth and reproduction. Biofouling is a problem in finfish cage aquaculture world wide. In cage farming, biofoulers can cause degradation of cage accessories such as cage frame, nets, barrels, ballast and ropes. The growth of fouling organisms on the nets restricts water exchange by net occlusion. The open waters where net cages located are highly favourable for rapid fouling development. The reasons for this rapid fouling are increased nutrients and organic loads inside the cages from feed wastes and fish excretion. These make the system conducive for the growth of filamentous algae (Ruokolahti, 1988; Madin et al., 2010). The growth of the filamentous algae along with the suspended mud on it atracts other biofoulers and finally forms thick beds on the net. These communities compete with the cultured fishes for food, space and oxygen. The accumulation of excess feed and waste is another problem which leads to poor water quality and fish growth and sometimes it may cause mortality of the farmed stock. Apart from these, the fouling communities act as reservoirs for pathogenic microorganisms and increase the risk of diseases in farmed fishes (Alagarswami & Chellam, 1976; Pit & Southgate, 2003; Kripa et al., 2012).

Braithwaite & McEvoy (2005); de Nys & Guenther (2009); Durr & Watson (2010) and Fitridge et al. (2012) reported in their studies that the development of biofouling communities may be influenced by factors such as seasonality, succession, depth, physical and chemical water properties, hydrodynamic conditions and substrate orientation and material. Stress level of fishes increases due to the

reduction in dissolved oxygen levels if there is excess fouling. As a result of this, immunity of caged fish get lowered and it increases the vulnerability to diseases (Fitridge et al., 2012). The occlusion and increased weight of the net imposed by fouling cause cage deformation and structural fatigue and it negatively influences cage structure and stability. The aims of this study are to assess (1) the seasonal diversity and quantification of macrobiofoulers and (2) assessment of biofouling and associated problems.

Materials and Methods

The site selected for this study is the cages moored in the estuarine delta formed by the *Periyar* River at *Moothakunnam* ($N10^{0}11.478'E076^{0}11.901'$+4m), a coastal village in *Vadakkekkara* panchayat, Ernakulam, Kerala. In cage fish farming biofouling on nets and other structures of cage is the major problem in this area during summer season (high saline phases). The present study was conducted in where 3 GI cages stocked with Asian Seabass (*Lates calcarifer*) and Pearl spots in a fish farm. Samples were collected every month (from February 2017 to December 2017) for water quality analysis and assessment of biofouling on net.

The study was conducted since February 2017 at *Moothakunnam* where Sea bass culture is progressing in three cages (8 x 4 m). The study started immediately after the stocking of fishes in the cages. The depth of site varied from 4-5 m depending on tides and cages were moored approximately 4 m depth at low tide. Water samples were collected from both cage site (inside the net) and reference site (5 m away from the cage site).

Water quality parameters such as temperature, salinity and pH of the culture site were tested *in situ* using digital thermometer, hand refractometer and pH meter, respectively, from the culture site monthly. Water transparency (light penetration) was measured using standard secchi disc. Orthophosphate, nitrite, nitrate and ammonia were estimated by standard spectrophotometric methods by following APHA, 2005. Dissolved Oxygen content was determined using Winkler's titrimetric method.

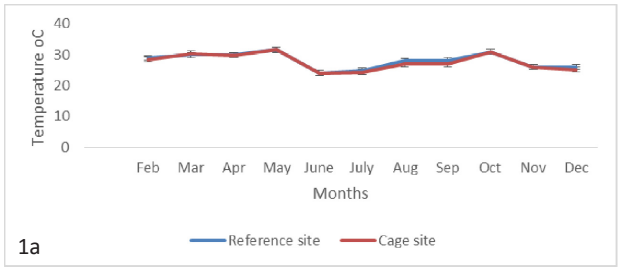
In order to study the biofouling intensity, monthly samples were collected from four randomly selected areas (50 cm^2 area) of all the four panels of the net. Samples were collected every month from 10% area of the net. For collecting biofoulers from different depths (1 m each) the net was marked with ropes. The total collected samples were brought to the laboratory and weighed. The fouling organisms were sorted and washed with sterile water. Total and individual weights of sorted biofoulers were taken separately. The fouling organisms were preserved in 5% formaldehyde solution for further identification and studies.

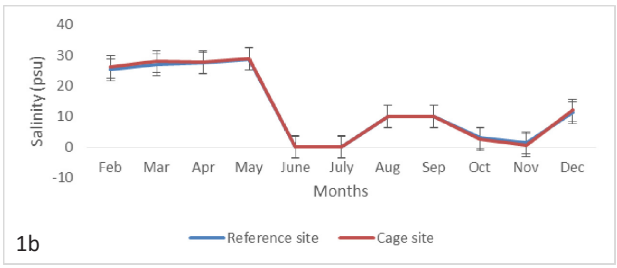
$$\text{Percentage of affected net area} = \frac{\text{Area of net affected by biofouling x 100}}{\text{Total area of the net}}$$

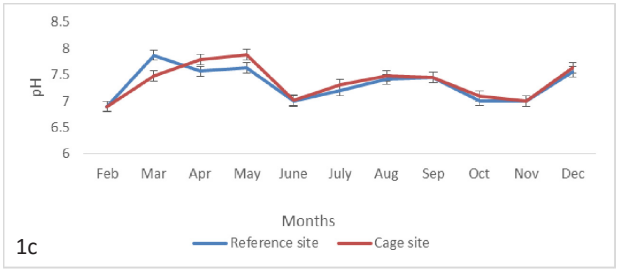
Results and Discussion

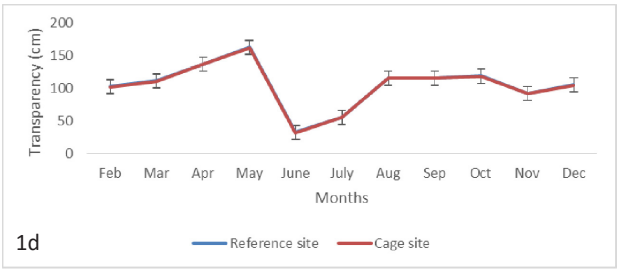
The observations revealed that the physico-chemical parameters of water inside the cages were higher than those at the outside control site except temperature, salinity, pH, transparency and nitrate. Statistical analysis of the results indicated that there were significant differences in parameters ($p<0.05$) like ammonia, orthophosphate and nitrite between reference site and cage site. Beveridge (1984); Philips et al. (1985); Wisniewski & Planter (1987); Stirling & Dey (1990); Pitta et al. (1999) reported that during cage farming nutrient levels, turbidity and organic matter in water inside the cages as well as in the bottom sediments increased whereas light penetration, dissolved oxygen levels and pH levels decreased. The observations from the present study revealed that there were only seasonal fluctuations in the case of water temperature, salinity and pH; and the parameters were found similar in the reference site as well as cage site. Water temperatures in both sites were same as the cage was in the open water systems where there was continuous water flow (Fig. 1a). Salinity was the highest during summer and became zero in monsoon due to influx of rain water in both the sites (Fig. 1b). In monsoon the pH was close to neutral due to the addition of large quantity of rain water and it was slightly alkaline during the summer months (Fig. 1c). Cornel & Whoriskey (1993) also made a similar observation. On the contrary Beveridge (1984); Pitta et al. (1999) reported drop in pH in fish cage culture because of waste deposits. However, in the present study no such pH drop was observed which may be due to the sufficient water flow. Transparency of the water at the reference site and cage site was high during summer season and low during rainy season (Fig. 1d). The main reason for the reduction of the transparency was the presence of dissolved and

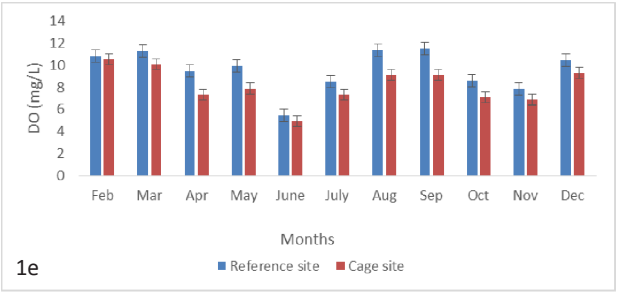
suspended organic and inorganic matters during monsoon. Triyuang et al. (2009) also reported similar observations.

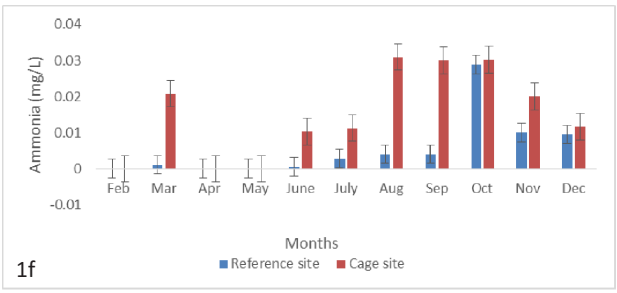


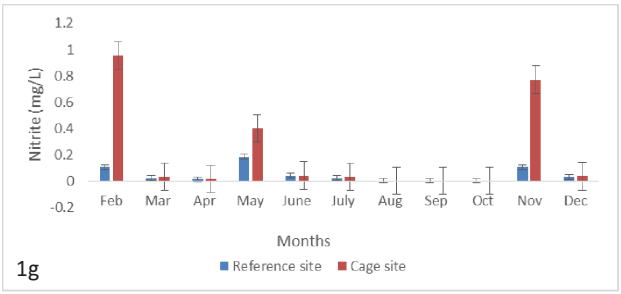


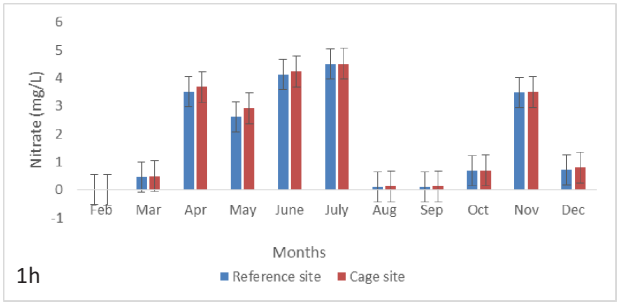












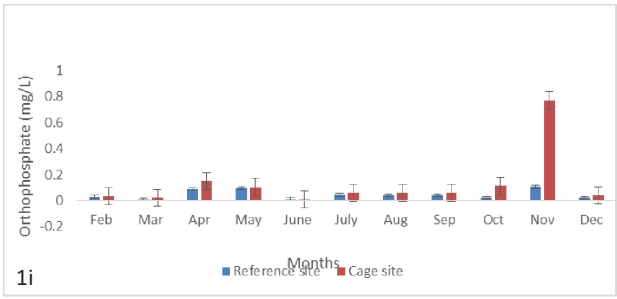


Fig. 1. Graphs showing the physico- chemical parameters of water in Reference site and Cage site during February to December; a. Temperature, b. Salinity, c. pH, d. Transparency, e. Dissolved Oxygen, f. Ammonia, g. Nitrite, h. Nitrate, i. Orthophosphate.

Mrcelic & Sliskovic (2010); Cornel & Whoriskey (1993) observed that there was low oxygen content in water inside the cages due to the oxygen consumption by fish. They emphasized that the

depletion of oxygen was associated with higher summer temperature and reduced water exchange. Low DO level in aquaculture systems is the major water quality parameter that affects the growth negatively. Similary in the present study the dissolved oxygen (DO) levels varied at cage and control sites (Fig. 1e). The DO levels in both sites were found to be high during summer which may be due to the high productivity due to increased phytoplankton (Krishnamurthy, 1990 and Patil et al., 2012). Aarsnes et al. (1990); Madin et al. (2009 & 2010) reported that biofouling reduced the water exchange resulting in reduction of supply of dissolved oxygen to the caged fishes. In the present study high rate of biofouling was observed from the month of March to May. DO level in cage site during this time was slightly lower than the reference site but not statistically significant. It is observed that good mixing, water exchange and flushing by proper currents, tides and wind are required to maintain DO. Even though the fouling intensity was high, there was no drastic depletion in the DO levels. This may be due to the availability of proper currents and water flow at the site.

Values of ammonia, nitrite, nitrate and orthophosphate varied in both sites and with months. Ammonia levels in cage and control site differed statistically ($p<0.05$) with a range of 0 to 0.031 mg L^{-1} and 0 to 0.029 mg L^{-1} respectively (Fig. 1f). It might be from the excess feed as well as faecal waste of the fishes in the cages. Nitrite level ranged between 0 to 0.954 mg L^{-1} in cage site and in reference site it was 0 mg L^{-1} to 0.183 mg L^{-1} which was statistically significant ($p<0.05$) (Fig. 1g). The nitrate levels in cage and reference site were found almost similar throughout the culture period (Fig. 1h). Orthophosphate concentration in the cage site (0.011-0.771 mg L^{-1}) was higher than in the reference site (0.01-0.11 mg L^{-1}), and the p-value indicated that the difference was significant ($p<0.05$) (Fig. 1i). Phillips et al. (1985); Stirling & Dey (1990); Pitta et al. (1999); Demir et al. (2001) have made similar observations and reported that nutrient levels might be increased by fish cage culture depending on the site and size of farms, water exchange rates and other characteristics of the water body. Whereas, similar levels of ammonia, nitrate and orthophosphate in both cage and control sites were reported by Cornel & Whoriskey (1993).

Madin et al. (2009 & 2010) conducted a study on macrofouling assemblages and found that it can reduce water flow through the net and affect oxygen supply as well as waste removal. Aarsnes et al. (1990) and Loland (1993) in their studies found that biofouling occludes the openings of pen or cage nets causes' serious oxygen and water quality problems which lead to the death of fishes. Apart from them Beveridge (2001); Cornel & Whoriskey (1993); Clottery et al. (2016) have reported that fish cage culture systems chiefly make use the artificial feed and the wastes comprise uneaten food, fish wastes (urine and faeces) as well as chemicals, microorganisms, parasites and feral animals associated with it become important sources of organic matter and nutrient enrichment in the water and sediments.

Biofouling on cages is a serious problem in cage farms of *Moothakunnam* area as it is very nearer to the sea and the long high saline phase prevailing in that area. In the present study biofouling started exactly after one month of culture and it became noticeable after 45-50 days. Succession of communities initiated with filamentous algae followed by molluscs, mainly modiolus and other invertebrate organisms. Heavy attachment of these organisms lead to settlement of large quantity of mud in between and finally formed a thick bed-like structure on the nets preventing the water flow through the nets resulting in poor water quality and increased net weight (Fig. 2). Braithwaite & McEvoy (2005) reported that the development of biofouling communities may be influenced by the factors such as seasonality, succession, depth, physical and chemical water properties, hydrodynamic conditions and substrate orientation and material. Shan et al. (2011) observed that within minutes of immersion, a surface becomes 'conditioned' through the adsorption of macromolecules such as proteins present in the water. Bacteria colonize within hours followed by unicellular algae, protozoa and fungi. These early colonizers form a biofilm, which is an assemblage of attached organisms that is often referred to as micro-fouling or slime. Finally, a layer of macro-fouling organisms colonises on the surface consisting of larger algae such as brown and green algae or seaweed, and invertebrates such as barnacles, mussels, ascidians and hydroids. de Nys & Guenther (2009); Durr & Watson (2010) and Fitridge et al. (2012) also reported that biofouling seriously affects the cage culture by reducing water flow through the nets.

The present study showed that biofouling increased with salinity and peaked at 29 psu which was the

Fig. 2. Biofouling on cage net after 3 months of fish culturing

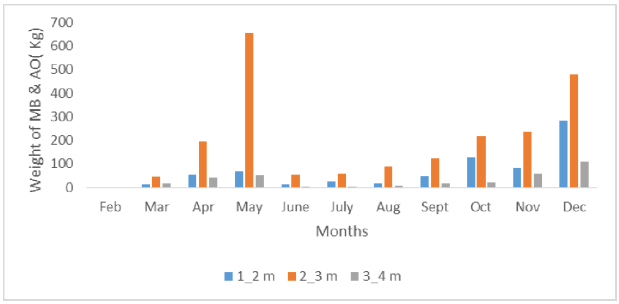


Fig. 3. Quantity (Kg) of Macrobiofoulers and associated organisms (including Modiolus) at different depths from February to December. (MB & AO: Macrobiofoulers and associated organisms)

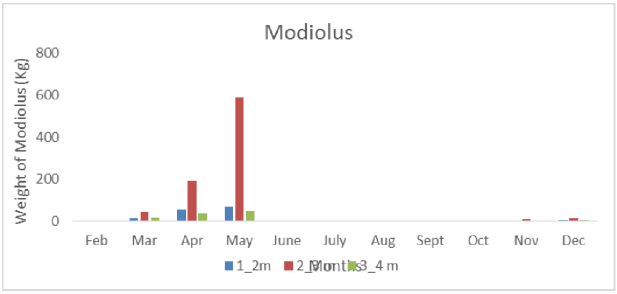


Fig. 4. Quantity (Kg) of Modiolus at different depths from February to December

maximum salinity observed. During summer season decreased water movement, along with increased salinity accelerated the biofouling. 44.5% of the total net area was found affected by biofouling increasing the total weight of net from 33.56 kg to 3354.88 Kg (100 times increase) at the peak fouling time. Macrobiofoulers altogether contributed a total weight of 658.56 Kg (19.63%) (Fig. 3). A total of 6 groups of macro-fouling organisms (mainly from 3 phyla) and filamentous algae were identified on the cage nets. Dominant fouling organisms included filamentous algae, Molluscs (Gastropods, Oysters and Bivalves, mainly Modiolus), Annelids (polychaetes) and associated Arthropods (Crabs, Amphipods, Isopods, Barnacles and Shrimp larvae). Among the molluscs modiolus alone contributed the lion share of 588.8 Kg (90.53%). Dominance of modiolus was observed maximum during summer season, which became a serious problem in the study site (Fig. 4). Biofouling problems were not observed during monsoon and post-monsoon periods. A few number of small annelids and arthropods were observed on the cage nets during monsoon season; however, the numbers observed were very negligible. Whereas, during post monsoon arthropods dominated; within the associated animals on cages and nets.

The study revealed that the occurrence of biofouling communities on cage nets varied significantly in accordance with the change of depths and months. Another important observation made in the present study was the maximum density of biofoulers occurred at the middle portion of net (1-2 m depth from the water surface). Intensity of fouling was found increasing up to 2m from the water surface and then found less up to 4m (Fig. 5a, 5b & 5c). Maximum biofouling (by weight of the samples) occurred at 2 m depth and then it gradually decreased according to the change of depth ($p<0.05$). This was mainly due to the occurrence of filamentous algae depending on the light availability. Mathieson et al. (1991) explained the role of light in the development of filamentous algae as biofouler. Reports of Nellis et al. (1996); Svane et al. (2006); Mhaddolkar et al. (2017) also showed a significant variation in the assemblage of fouling organisms on the net panels with the depth. Similarly, Moring & Moring (1975); Heath et al. (1992); Cronin et al. (1999); Chinnadurai et al. (2018) observed difference in the settlement of fouling organisms at different depths. This variation may be due to a series of factors such as temperature, salinity, light intensity, nutrient availability, dissolved oxygen and water

current. Cronin et al. (1999); Howes et al. (2007); Guenther et al. (2010) reported, variation in biofouling is predominantly driven by the availability of light and water flow and is often related to the depth and orientation of infrastructure.

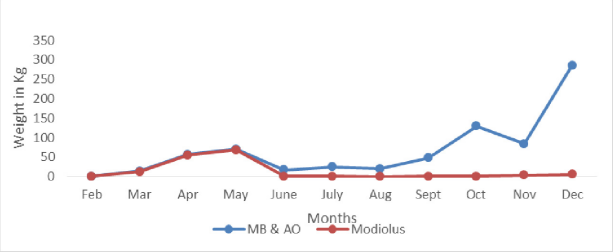


Fig. 5a. Quantity of Macrobiofoulers and associated organisms (including Modiolus) and Modiolus alone at a depth of 1m- 2m from February to December. (MB & AO: Macrobiofoulers and associated organisms)

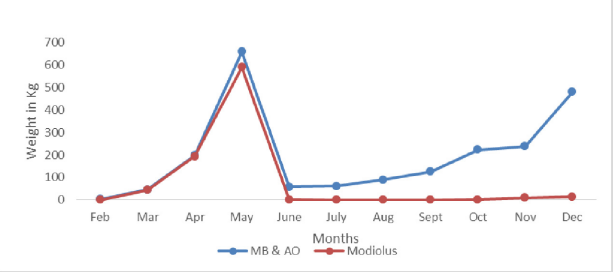


Fig. 5b. Quantity of Macrobiofoulers and associated organisms (including Modiolus) and Modiolus alone at a depth of 2m- 3m from February to December. (MB & AO: Macrobiofoulers and associated organisms)

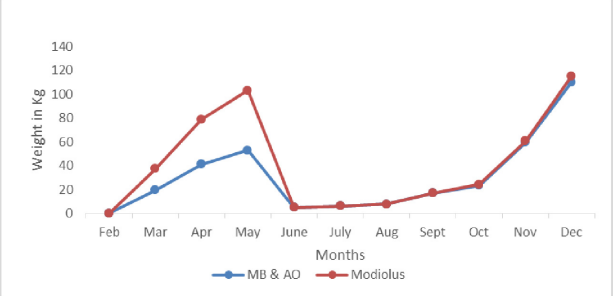


Fig. 5c. Quantity of Macrobiofoulers and associated organisms (including Modiolus) and Modiolus alone at a depth of 3m- 4m from February to December. (MB & AO: Macrobiofoulers and associated organisms)

The main reasons for this rapid fouling development are nutrient and organic load from feed wastage, fish excretion and faecal production (Ruokolahti, 1988). It increases the growth of algae and is eventually colonized by a variety of micro and macro organisms. Fish stocking density and feed input also contribute to the development of biofouling (Madin et al., 2010). Retarded water flow and inorganic and organic enrichment (via fish feeds and faecal matter) as a result of fish culture enhance the macro-fouling assemblage on fish nettings. Alagarswami & Chellam (1976); Pit & Southgate (2003); Kripa et al. (2012) concluded in their studies that biofouling reduces growth rate or causes mortality of the farmed stock. As these fouling communities chiefly act as reservoirs for pathogenic microorganisms, they increase the risk of disease in farmed fish. Stress levels of caged fishes get increased due to the reduction in DO levels and this lowers the immunity of caged fish and increases vulnerability to diseases (Fitridge et al., 2012).

The most important impact of bio-fouling was the severe economic loss to the farmer due to heavy management charges and decreased growth of fishes. In the present study it was observed that biofouling seriously affected the total infrastructure of the cage especially due to heavy weight. The nets used in the cages got damaged seriously and the farmer discarded it. Braithwaite & McEvoy (2005); de Nys & Guenther (2009); Durr & Watson (2010); Fitridge et al. (2012); Bloecher et al. (2013) reported the negative impacts of increased weight of nets by biofouling on cage structure and stability. Biofouling can rapidly occlude mesh and necessitate frequent and costly cleaning of nets (Hodson et al., 1995&1997). Net cleaning and changing incur heavy financial burden to the farmer. Frequent net changing may cause damage and loss of the stocks. Strength of the cage structures found reduced due to biofouling and recurrent maintenance adversely affected the profit. However, as monsoon started it was observed that a reduction in salinity led to sudden death and gradual detachment of the biofoulers initiated by modiolus and followed by the total detachment of the bed that became another problem as it fell inside the cage. This again led to poor water quality, increased stress conditions and sometimes wound to the farmed fishes inside.

The effect of biofouling is highly detrimental to aquaculture as it increases the burden of the farmer in terms of labour and money during the culture management. The issue should be treated carefully; otherwise it may lead to unprecedented damage to the cage culture and subsequent economic loss. So

interference on this matter is an urgent need of the hour as it is a very useful, farmer friendly and highly adopted technology forming a major livelihood for many coastal people in Kerala. Therefore, it is suggested that frequent and/or regular inspection of cage and nets are inevitable during culture period especially in the summer months. Proper management is the first and foremost thing needed in which net cleaning is the first step to control the fouling and associated damage to the farmer. Awareness of farmers about biofouling, its nature and the organisms cause it, is needed to decide the management practices. Care should be taken to give only adequate amount of feed to limit the release of excess nutrients to the surroundings. Algal fouling can be controlled by using grazing fishes in the cages like pearl spots, rabbit fishes etc. If the fouling is with molluscs the best method of management is the net exchange as soon as the spat settlement. Antifouling nets can be tried in these areas during the summer months.

Acknowledgements

The authors are grateful to Dr. A. Gopalakrishnan, Director CMFRI, for providing all the facilities for the carrying out this study. We would like to thank the HOD and staff and scholars in Mariculture Division for help and support. We express our sincere thanks to Dr. Mini K. G, for her help and support in the statistical studies and other friends for their timely support. We also express our sincere thanks to CSIR for their financial support.

References

Aarsnes, J.V. (1990) Current forces on cages, net deflection. In: Institute of Civil Engineers (Great Britain) (Rudi, H and Loland, G., Eds), pp 137-152, Engineering for Offshore Fish Farming, Thomas Telford House, London

Alagarswami, K. and Chellam, A. (1976) On fouling and boring organisms and mortality of pearl oysters in the farm at Veppalodai, Gulf of Mannar. Indian J Fish. 23: 10-22

APHA (2005) Standard methods for the examination of water and waste water (21st edn). Washington, DC:American Public Health Association. American Water Works Association. Water Environment Federation

Beveridge M.C.M. (1984) Cage and Pen Fish Farming. Carrying Capacity Models and Environmental Impact. 131 p, FAO Fish. Tech. Pap., Rome

Beveridge M.C.M. (2001) Aquaculture and wildlife interactions. In: (Uriarte, A. and Basurco, B., Eds), pp 57-66, Environmental impact assessment of Mediterranean aquaculture farms. Zaragoza: International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM), Chania

Bloecher, N., Olsen, Y. and Guenther, J. (2013) Variability of biofouling communities on fish cage nets: A 1-year field study at a Norwegian salmon farm. Aquaculture. 416: 302-309

Braithwaite, R.A and McEvoy, L.A. (2005) Marine biofouling on fish farms and its remediation. Adv. Mar. Biol. 47: 215-252

Chinnadurai, S., Jagadis, I., Meenakshi, V. K. and Mohamed, K. S. (2018) Effect of Acetic acid treatment on the control of non-indigenous ascidians in farmed Indian pearl oyster *Pinctada fucata*. Journal of the Marine Biological Association of India. 60: 67-74

Clottey, M.N.K., Asmah, R., Ofori-Danson, P.K., Ameworwor, M.Y., and Karikari, A.Y. (2016) Impacts of cage culture on physico-chemical and bacteriological water quality in Lake Volta, Ghana. African Journal of Aquatic Science. 41: 473-480

Cornel, G.E. and Whoriskey, F.G. (1993) The effects of rainbow trout (*Onchorynchus mykiss*) cage culture on the water quality, zooplankton, benthos and sediments of Lac du Passage. Quebec. Aquaculture. 109: 101-117

Cronin, E.R., Cheshire, A.C., S.M, Clarke and Melville, A.J. (1999) An investigation into the composition, biomass and oxygen budget of the fouling community on tuna aquaculture farm. Biofouling. 13: 279-299

Demir, N., Kirkagac, M.U., Serap, P and Süleyman, B. (2001) Influence of trout cage Culture on water quality, plankton and benthos in an Anatolian dam lake. The Israeli Journal of Aquaculture. 53: 115-127

de Nys R and Guenther, J. (2009) The impact and control of biofouling in marine finfish aquaculture: In Advances in marine antifouling coatings and technologies (Hellio, Claire and Yebra, Diego Eds.), pp 177-221, Woodhead Publishing Ltd, Cambridge (UK)

Durr, S., Thomason, J.C. and Watson, D.I. (2010) Biofouling and antifouling in aquaculture. In: Biofouling. (Durr, S.,Thompson, J.C., Eds), pp 267-287 Wiley-Blackwell. Oxford (UK)

Fitridge, I., Dempster, T., Guenther, J and de Nys.R. (2012) The impact and control of biofouling in marine aquaculture: a review. The Journal of Bioadhesion and Biofilm Research. 28: 649-669

Guenther, J., Misimi, E. and Leif, M.S. (2010) The development of biofouling, particularly the hydroid *Ectopleura larynx*, on commercial salmon cage nets in Mid-Norway. Aquaculture. 300: 120-127

Heath, C. R., Leadbeater, B. S. C. and Callow, M. E. (1993) Formation and calcification of biofilms on anti-fouling paints in hard waters. Biofouling. 7: 29-57

Hodson, S. L., Lewis, T. E. and Burke, C.M. (1995) *In situ* quantification of fish-cage fouling by underwater photography and image analysis. Biofouling 9: 145-151

Hodson, S. L., Lewis, T. E. and Burke, C.M. (1997) Biofouling of fish-cage netting: efficacy and problems of *in situ* cleaning. Aquaculture. 152: 77-90

Howes, S., Herbinger, C M., Darnell, P and Vercaemer, B. (2007) Spatial and temporal patterns of recruitment of the tunicate *Ciona intestinalis* on a mussel farm in Nova Scotia, Canada. J Exp. Mar. Biol. Ecol. 342: 85-92

Kripa, V., Mohamed, K.S and Velayudhan, T.S. (2012) Seasonal Fouling Stress on the Farmed Pearl Oyster, *Pinctada fucata*, from South-eastern Arabian Sea. J. World Aquac. Soc. 43: 514-525

Krishnamurthy,R (1990) Hydro-biological studies of Wohar reservoir Aurangabad (Maharashtra State) India. Journal of Environmental Biology. 11: 335-343

Loland, G. (1993) Current forces on and water flow through and around, floating fish farms. Aquaculture International. 1: 72-89

Madin, J., Chong, V.C. and Basri, B. (2009) Development and short-term dynamics of macrofouling assemblages on fish-cage nettings in a tropical estuary, Estuarine Coastal and Shelf Science. 83: 19-29

Madin, J., Chong, V.C., Hartstein, N.D. (2010) Effects of water flow velocity and fish culture on net biofouling in fish cages. Aquac. Res. 41: 602-617

Mathieson, A.C., Penniman, C.A., Nienhuis, P.H. and Harris, L.G. (1991) Northwest Atlantic rocky shore ecology. In: (Mathieson, AC., Nienhuis, P.H., Eds.), pp109–191, Intertidal and Littoral Ecosystems, Ecosystems of the World. Elsevier, Amsterdam

Mhaddolkar, S.S., Loka, J., Philipose, K.K and Dineshbabu, A.P. (2017) Experimental studies on Macro fouling communities on net panels at marine cage farm of Karwar, India. Int. J. Fish. Aquat. Stud. 5: 184-187

Moring, J. R. and Moring, K. A. (1975) Succession of Net Biofouling Material and its Role in the Diet of Pen-Cultured Chinook Salmon. Progress. Fish-Culturist. 37: 27-30

Mrcelic, G. J. and Sliskovic, M. (2010) The impact of fish cages on water quality in one fish farm in Croatia. World Acad. Sci. Eng. Technol. Int. J. Nutr. Food Eng. 4: 547-550

Nellis, P. and Bourget, E. (1996) Influence of physical and chemical factors on settlement and recruitment of the hydroid *Tabularia larynx*. Marine Ecology Progress Series. 140: 123-139

Patil, P. N., Sawant, D. V. and Deshmukh, R. N. (2012) Physico-chemical parameters for testing of water – A review. Int. J. Environ. Sci. 3: 1194-1207

Phillips, M.C., Beveridge, M.C.M. and Ross, L.G. (1985) The environmental impact of salmonid cage culture on inland fisheries: present status and future trends. J. Fish Biol. 27: 123-137

Pit, J.H and Southgate, P.C. (2003) Fouling and predation: how do they affect growth and survival of the blacklip pearl oyster, *Pinctada margaritifera*, during nursery culture?. Aquacult. Int. 11: 545-555

Pitta, P., Karakassis, I., Tsapakis, M. and Zivanovic,S. (1999) Natural vs. mariculture induce variability in nutrients and plankton in the eastern Mediterranean. Hydrobiologia. 391: 181-194

Ruokolahti, C. (1988) Effects of fish farming on growth and chlorophyll *a* content of *Cladophora.* Mar. Pollut. Bull. 19: 166-169

Shan, C.A.O., Jia Dao, W.A.N.G., HaoSheng, C.H.E.N. and DaRong, C.H.E.N.G. (2011) Progress of Marine biofouling and antifouling technologies. Chinese Science Bulletin. 56: 598-612

Stirling H.P. and Dey, T. (1990) Impact of intensive cage fish farming on the phytoplankton and periphyton of a Scottish freshwater loch. Hydrobiologia. 190: 193-214

Svane, I., Cheshire, A and Barnett, J. (2006) Test of an antifouling treatment on tuna fish-cages in Boston Bay, Port Lincoln, South Australia. Biofouling. 22: 209-219

Triyuang, P., Piyatiratitivorakul, S and Sriburi, T. (2009) Effect of fish cage culture on water Quality: A case study of Chi river and Yang river, Roi et province. J. Environ. Res. 31: 55-65

Wisniewski, R.J. and Planter, M. (1987) Phosphate exchange between sediments and the near bottom water in relationships to oxygen concentrations in a lake used for intensive trout cage culture. Ekol. Pol. 35: 219-236