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A STUDY ON ECOLOGICAL SUCCESSION OF MACROFOULING COMMUNITIES IN SEA CAGE FARM IN SOUTH-WEST COAST OF INDIA

SONALI S. MHADDOLKAR[1*], A.P. DINESHBABU[2], JAYASREE LOKA[1], SUJITHA THOMUS[2]

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

ABSTRACT

Development of aquaculture facilities like cages has led to rise in submerged structures which provide ample substratum to biofoulers which could greatly interfere with culture operations. An attempt was made to study the biofouling communities and succession of macro foulers on the cage culture net installed in the open sea. The main objective of the present study is to reveal the succession pattern of the biofouling communities on the panels of cage culture sites to find out seasonal settlement pattern, Dominant species and Climax community. A long-term study on the succession pattern of the cage farm experimental-net-panels revealed results as Hydroids-Gastropods-Hydroids-Barnacles-Modiolus-Green mussels. Hydroids were initial communities on the net panels and green mussels (*Perna viridis*) formed the climax community, also dominating on the cage culture nets. Different succession patterns were observed in two sites as well as in culture nets studied. The net panels of the cage are loaded with hydroids in the initial months and the peak fouling will be during May. So frequent net cleaning is required during summer and during the spat settlement period of green mussels (September, October, and November). Modiolus settlement during February month on the culture nets can be avoided by net exchange immediately after spat fall in this month. This attempt was made to study the ecological succession on the panels, in cages installed in Karwar, which is the first attempt since the open sea cage culture was initiated in India. And looking at vast opportunities for further development in biofouling research, the aim of this research work is to obtain the baseline information about the ecological succession pattern of biofouling in cage sites. More research on biofouling in mariculture is essential to ensure the profitability of the aquaculture operations with environmental safety measures as a prime criterion.

Keywords: macrofouling communities, succession, climax community, panels, sea cage farm.

INTRODUCTION

Development of aquaculture facilities like cages has led a sore in submerged cage-structures like nets, floats, ropes which provide ample substratum to the biofoulers, greatly interfering culture operations.[1] The assemblage and development of biofouling communities is a typical exemplar for succession process.[2] Succession is a process where in community moves from a simple to complex form.[3] Railking[4] carried out detailed studies on marine biofouling process. Many studies are undertaken to understand the spatial temporal succession patterns of the biofoulers and to ascertain the period in which interventions are required to reduce the loss of aquaculture materials due to biofouling.[5,6] Panels are used widely to study the biofouling and several researchers have worked on the succession involving size, duration, location, season, months for studying the biofouling on different structures mainly ships hulls, water exchange pipes, jetties, buoys, mariculture structures and other submerged surfaces.[7,8] Research is carried out in biofouling on mariculture structures worldwide.[9,10,7,11] The ecological succession of biofoulers is very complex process and development pattern found on the suspended cage structure may vary from the natural sea bed and hard substratum.[3] Formation of biofouling community is site specific[12] and their development with respect to time is prerequisite for the marine structures and for developing cleaning practices[13]. Ecological process of biofouling community-development may take a day or week [6]and biofouling community varies with time and space but the major variations will be the seasonal variations. [3,14,15] Duration of substrate immersion is an important aspect to be considered for studying the assemblage of biofouling in succession experiments.[1] Along with the other factor's predation is a major factor affecting the succession of the fouling communiies[3]. Severity of settlement varies on different substrata based on the choice of settlement of planktonic larval-forms.[16] Succession studies at different depth were by Dziubińska and Szaniawska[2].The attaching foulers forms the bigger components but the free-living forms are also found in the community of biofoulers[17].

Pioneering study in biofouling along the Indian coast were conducted on different structures such as experimental panels, ship halls, jetties etc.[17,18,19]. Many research works are carried on the fouling community structure [7,12,20,21,22]. Literature review about succession and climax communities of biofouling in general (other than mariculture facilities) is available along the Indian coast,[12] but very less literature is available on the ecological succession of biofouling on the panels in marine culture sites, along the coasts of India. This attempt was made to study the biofouling and ecological succession on the panels, in cages installed in Karwar, which is the first attempt since the open sea cage culture was initiated in India. The main objective of the present study is to reveal the succession pattern of the biofouling communities on the panels of cage culture sites to find out seasonal settlement patterns, Dominant species and Climax community. And looking at vast opportunities for the further development in biofouling research, the aim of this research work is to obtain the baseline information about the ecological succession pattern of biofouling in cage sites. More research on biofouling in mariculture is essential to ensure the profitability of the aquaculture operations with environmental safety measures as a prime criterion.

MATERIAL AND METHOD

In marine cages installed in the Arabian Sea at Karwar, Karnataka (N 14°48.406', E 074°06.664'), so far seven varieties of finfishes (*Lates calcarifer*, *Rachycentron* *canadum, Lutjanus argentimaculatus, L.johnii, Trachinotus blochii, Acanthopagrus latus)* and shellfishes (*Perna viridis)* are successfully farmed. For experimental studies two sites were chosen so as to compare between the cage and the reference.

The experimental panels were installed in marine farm and the reference site during the period 2015 to 2016. Annual Panel setups were made with 12, HDPE net panels (100mm^2) of mesh size 22 mm fixed to 19mm diameter half inch PVC pipe frame. They are tied by using 4mm nylon rope in the water column adjacent to the cages in the culture site. These panels were anchored with 5 kg weight to stay in vertical position in the water column. Reference site is 500m away from the cage site where the panels were placed using the barrel and the anchor. Every month three panels (from 1m, 3m, 6m depth) from each site were brought to the laboratory for analysis. Monthly, seasonal (exchange) data of culture net are collected for further analysis.

Laboratory studies

The net panels were brought to the laboratory separately in the plastic trough with sea water. The fouling organisms are washed with sterile sea water and sieved in 200-micron sieve.[23]The fouling samples were preserved in 5% formaldehyde for further identification. Smaller fouling organisms were observed under AXIO, Zeiss (Scope-A1) microscope (5x magnifications). Taxonomic Identifications were done using identification keys.[24,25,26] Density (number/10cm^2), total length, percentage of major macro fouling organisms were studied using digital vernier caliper and photographic images. The identified foulers were reclassified to different groups (community).

Statistical Analysis

The collected data was analyzed statistically using software like PAST, PRIMER 0.5 and XL-STAT version 2018. Average data of the panels from three depths of each site was taken for the analysis and comparison between the sites.

RESULTS

Succession of biofouling on long term panels:

Hydroids were the initial settlers dominating from December to May on the experimental panels of cage and reference sites. June month 2016, they totally vanished in both the sites. The density of hydroids ranged from85 no/10cm^2 in January-16 to1433no/10cm^{2}in July-16 in the cage site whereas, 180no/10cm^2 in January to 1733no/10cm^2 August in the reference site. In June gastropods dominated both in cage sites with 16no/10cm2 and reference sites with33 no/10 cm^2.July and August hydroids dominated. Oysters dominated in August (57no/10cm^2) in reference site where as in September barnacles dominated with 41no/10cm^{2}in cage site and Green mussels dominated (29no/10cm^2) in reference site. October Modiolus dominated in both the sites with 547no/10cm^2 and during November Green mussel was most dominating (188no/10cm2) abundant group in cage site and Amphipods were the dominant communities (43 no/10cm^2) in reference site. Fig. 1 & 2 represents dominant fouling organisms on long term panels of cage and reference site.

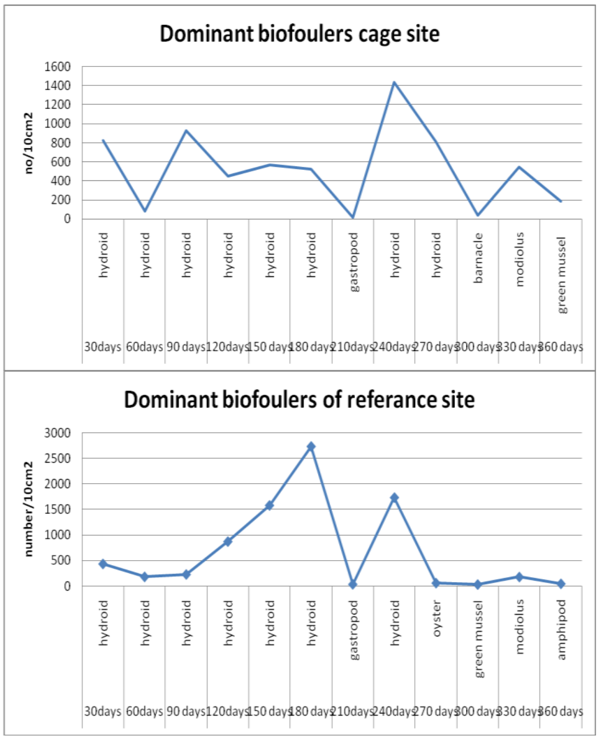


Figure 1. &2. Dominant biofouling communities of cage site and reference site

The pioneering biofouling communities on the panels was composed of hydroids, barnacles, green mussels in December-15(30 days) panel in cage site where as in reference site along with hydroids, polychaete worms, amphipods, barnacles, crabs, shrimps, Isopods, green mussels, modiolus, oysters, are the fouling communities got settled. In January-16 (60 days) panel bryozoans, crabs, shrimps and modiolus started appearing on the cage panels where as in the reference site Bryozoans started appearing on the panel and Polychaete worms, amphipods, shrimps, Isopods started disappearing from the panel. In February-16 (90days) amphipods, isopods, gastropods, oysters got introduced on the panel. Good density of isopods and slight increase in the bryozoan number was observed but Crabs and shrimps disappeared and decrease in the barnacle number was also observed in cage sites, whereas in reference site Barnacle density decreased. Crabs, green mussels, modiolus, oyster density started decreasing and vanished towards the end of this period. Sponges, flatworms, scallops, nudibranchs appeared for the first time on the panel. Polychaete worms, amphipods, Isopods, reappeared during this period. March-16 (120 days) panel, Sponges, Polychaete worms, Echinoids which were not present in previous months was observed during this month in cage site but in reference site Sponge, hydroids, sea anemones, bryozoans, flatworms, polychaete worms, amphipods, Isopods showed an increase in trend. Sea anemones, gastropods, ascidians appeared for the first time on the panel. Scallops and nudibranch disappeared. During April-16 (150 days) there was a slight increase in the sponge density. Crabs disappeared in the cage site but in the reference site the green mussels, sponges, amphipods, hydroids, sea anemones, barnacles, crabs' number has also increased then the previous period. Nudibranch which disappeared in the previous period has appeared during this period whereas gastropods and oysters disappeared in this period. In May-16 (180 days) Sea anemones and ophiuroids settled for the first time. The communities of crabs, green mussels, oyster, reappeared which were absent in the previous month in cage site but in reference site Sponge, bryozoans, polychaete worms, Amphipods, crabs, Isopod, green mussel showed a decreasing trend, Flatworms, nudibranch and ascidians disappeared during this period. Shrimp and ophiuroids reappeared during this period. June-16 (210 days) most of the communities like Hydroids, sea anemones, bryozoans, barnacles, isopods, oysters, ophiuroids disappeared and Ascidians got introduced for the first time and Echinoids reappeared on the cage panel. In reference, most of the fouling communities disappeared during this period. Polychaete worms, amphipods, barnacles, crabs, gastropods, green mussels modiolus were present among the fouling community. Hydroids showed a complete decline. Sponges, hydroids, sea anemones, Bryozoans, shrimps, Isopods, oysters, echinoids, ophiuroids which were present in the previous period completely disappeared. Modiolus appeared during this period. In

July-16 (240 days), Hydroids again reappeared along with Bryozoans and barnacles. Amphipods, gastropods, Ascidians which were present in the previous month disappeared from the panels. In the reference site Sponges, hydroids, sea anemones, Bryozoans, barnacles, crabs, green mussels, modiolus, echinoids and ascidians were the fouling communities on the panel. The polychaete, amphipods, gastropods which were present in the previous period, disappeared. Most of the communities which disappeared during the previous duration have started appearing again like sponges, hydroids, Sea anemones, Bryozoans, echinoid, ascidians. August-16 (270 days), Flat worms got introduced for the first time in this month. Amphipods modiolus, Ascidians, reappeared in the panel, whereas in the reference panel Sponges polychaete worms, amphipods, barnacles, crabs, green mussels, oyster limpets were present on the panel. The communities which were present during the previous period like Hydroids, sea anemones, bryozoans, modiolus disappeared. Polychaete worms, amphipods, oyster and limpets, reappeared on the panel. Oysters are the dominating community ($57 no/10cm^2$). Barnacles were the next dominating community. September-16 (310days) Oysters reappeared on the panel. Flatworms, modiolus, Ascidians which were lesser in number during the previous month completely vanished whereas in reference Polychaete worms, barnacles, crabs, Isopods, Green mussels, modiolus, oysters were the communities which appeared on the panel. Oysters which were dominant during the previous period started decreasing. Sponge, amphipod, limpets were completely declined. Isopod and modiolus reappeared on the panel. October-16 (340 days) highest density was of Modiolus (77.47%). Polychaete worms, Shrimps, Gastropods, Modiolus, Ophiuroids reappeared. Bryozoans and oysters disappeared in this month where as in reference Polychaete worms, Barnacle, crabs, Isopods, green mussels, modiolus were present on the panel. Density of barnacle, isopod, modiolus showed an increase in trend. Oyster density declined. Modiolus density increased. November-16 (360 days) panels were fully covered by green mussels (100%) and the community reached its climax stage. Whereas Hydroids, sea anemones, polychaete worms, amphipods, crabs, gastropods, modiolus were the communities observed in the reference panel and Amphipods were the dominant communities ($43 no/10cm^2$).

Seasonal succession of the long-term panels:

In the present case the long-term cumulative panels were studied up to 360 day(1year). The settlement pattern revealed Hydroids as prominent communities in all the seasons both in culture site and reference site (fig.1&2). Cage sites the high settlement of hydroid, barnacles, modiolus and green mussels was observed, along with the gastropods. Where as in the reference where there is no culture activities hydroids, oysters, anemones, modiolus have settled on the panels along with gastropods and amphipods on the panel. Other than these major fouling organisms' sponges, sea anemones, bryozoans, flatworms, polychaete worms, pycnogonida, crabs, shrimps, Isopods, Scallops, Nudibranchs, limpets, Echinoids, Ophiuroids and ascidians were also formed succession sequences as a minor biofouling species. Seasonal succession patterns on the long-term studies of cage and reference were presented in the fig.9.

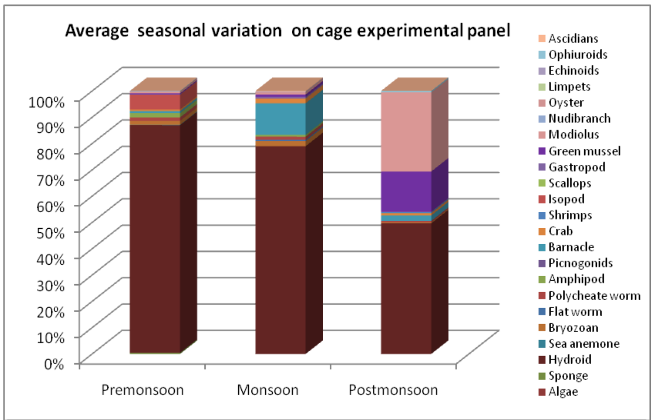
Peak settlement period for the major fouling organisms on long term panels:

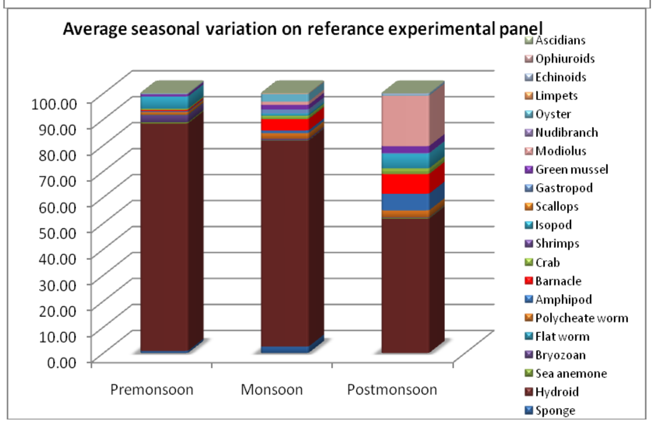
Hydroids: peak settlement month is July for the culture site and for reference site May Modiolus: peak month is October both for cage and reference site Barnacles: peak month is August both for cage and reference

Green mussels: peak month is November in cage and April in reference Isopods: peak month is February in cage and March in reference Polychaete worms: peak month is May in cage site and June in reference Bryozoans: peak months are September and March for cage and reference.

Seasonal fouling on the culture net:

Seasonal settlement pattern (fig.5) and succession pattern biofouling on the culture net (fig.10) revealed the Hydroid and algal dominance in short term fouling studies. Total 22 fouling communities were present on the net viz. algae, sponge, hydroids, sea anemones, bryozoans, flatworms, polychaete worms, amphipods, pycnogonida, barnacles, crabs, shrimps, Isopods, gastropods, green mussels, modiolus, nudibranch, oysters, limpets, echinoids, ophiuroids, and ascidians. during Pre-monsoon season algae were the dominating community with 40.85% followed by hydroids 34.98% and modiolus by 10.89%.The fouling communities like algae, hydroids, sea anemones, bryozoans, flatworms, polychaete worms, amphipods, pycnogonida, barnacles, crabs, shrimps, Isopods, gastropods, green mussels, modiolus, nudibranch, oysters,echinoids and ascidians appeared in this season on the culture net.During Monsoon season hydroids dominated on the net 50.69% followed by algae 16.50% ,Modiolus 9.31%. Sea anemones, pycnogonida, shrimps, gastropods, nudibranch and ascidians which were present in the pre monsoon disappeared in this season. Sponges and limpets appeared in this season. Hydroids showed an increasing trend whereas algae showed a decreasing trend. Modiolus showed a decline during monsoon.Algae dominated during Post-monsoon season, with 37.70% followed by modiolus 29.18% and hydroids 16.87%. Algae showed an increasing trend and hydroids showed a decreasing trend. Modiolus also showed an increasing trend during post monsoon. Flat worms and ascidians which were present in the monsoon are absent in this season.





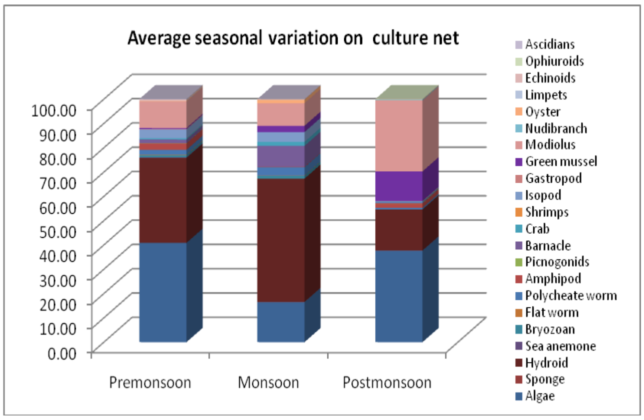


Figure 3,4,5. Seasonal settlement pattern of Cage panel, reference panel, culture net

Monthly succession pattern:

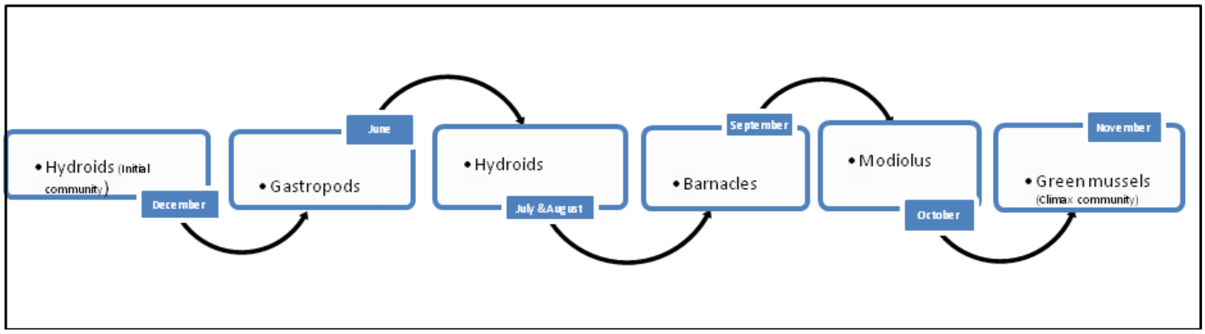


Figure 6. Succession pattern on the long-term panels of cage site

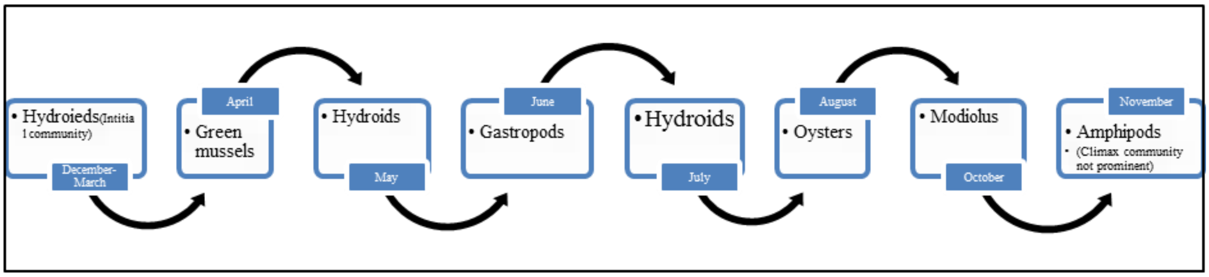


Figure 7. Succession pattern on the long-term panels of Reference site

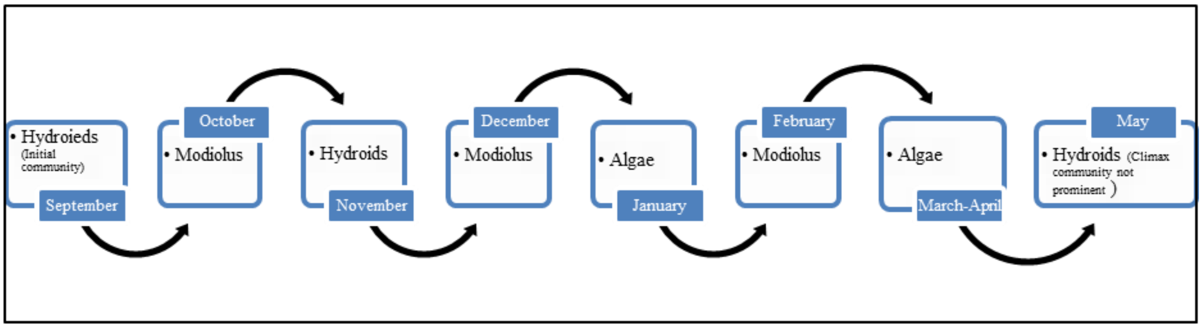


Figure 8. Succession pattern on the Short term panels of culture net

Seasonal succession pattern:

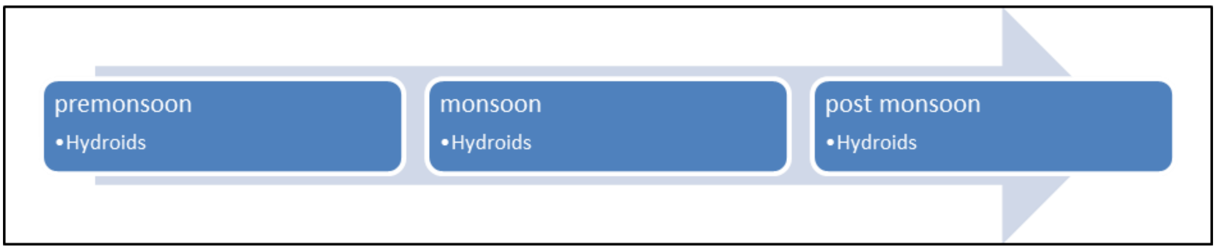


***Figure* 9 Seasonal Succession pattern on the long-term panels (cage site and reference)**

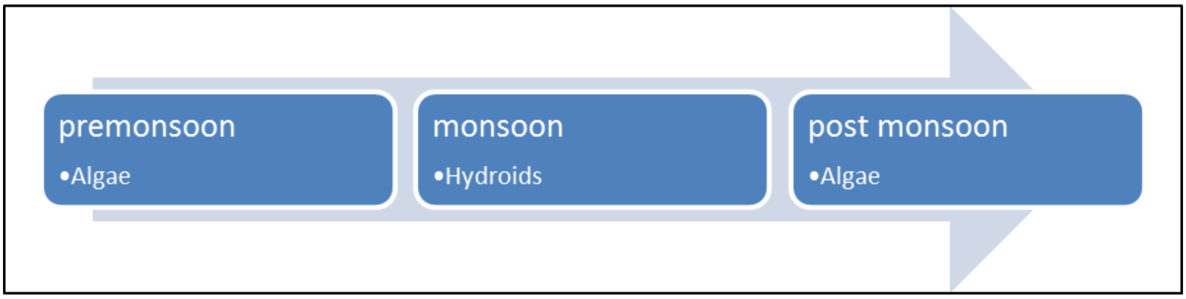


***Figure* 10. Seasonal Succession pattern on the short term cage culture net**

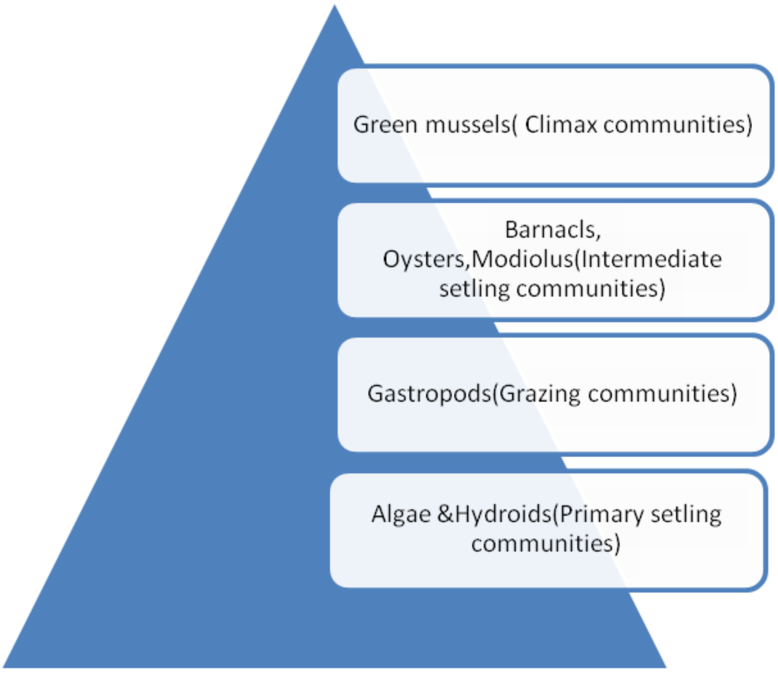


Figure 11.A model of overall Macro fouling of cage farm of Karwar, India

Climax community:

Green mussels (*Perna viridis*) were the dominant fouling community forming the climax in the cage site on the net panels after 12 months of immersion. But in the reference site panels and the other structures the climax community is not so prominent. Overall macrofouling in the cage culture site is presented (fig.11).

DISCUSSION

This present study can be compared with the biofouling studies in bivalve aquaculture (oyster culture) wherein initial colonies included hydroids, bryozoans, sponges, ascidians, polychaetes, bivalves, barnacles and algae.[27,28,29] In bivalve aquaculture practices the primary colonies enables the attachment of groups like crustaceans, polychaete worms or echinoderms and secondary colonization occurs after a month or few month.[27,30]In the present study Hydroids and barnacles appeared in the initial month in the cage panel whereas Hydroids, polychaete worms, amphipods, barnacles, crabs, shrimps, Isopods, green mussels, modiolus, oysters appeared in the reference panel. The recruitment, settlement complexities could be the reason for these differences in marine invertebrates.[27,31] The similar reasons could be given in the case of fin fish aquaculture cage panel and the reference panel. The biofouling succession as well as colonization patterns differs with climatic zone, as in tropical zones constant settlements around all the months whereas at fixed intervals in temperate zone.[6,27]The local surveys are necessary as the colony patterns of biofuels differ along the farming area.[27]

Literature on succession studies of biofoulers is available on marine cages of

Gulf of Maine, United States of America.[3]The basic information on fouler diversity, composition and succession is very much required to control the foulers and estimate the fouling potency of that locality.[7,32]Sahu et al. [12]suggested low salinity and high turbidity favorable for barnacle which settle year around.

Seasonal succession pattern

In the seasonal succession pattern of biofoulers settlement of short-term studies are different from long term studies, similar observations were made by Sahu et al.[12] During monsoon low fouling diversity and density due to low salinity and low temperature. [12]Long term panels peak settlement is during May in reference with Hydroids highest total density in November (green mussels) in a cage with experimental panels. Overall, in the May month fouling abundance was more on the cage nets.

Cage panel succession was represented in fig6. Hydroids were the first to settle on the long-term panels during the initial month (December) along with barnacles, followed by the gastropods in June. During this succession period Barnacles, bryozoans and other fouler were found to colonies on the panel. But the hydroids population was not much affected by secondary fouling communities' settlements. But during June month hydroids totally vanished and gastropods were the dominant fouling group along with polychaete worms, Ascidians and other species. Again, in July hydroids reappeared and dominated the panels till august. In August barnacles dominated over the hydroids. October Modiolus started dominating, along them green mussel settlement was also started increasing, green mussels which started their appearance in May month started increasing steadily from August onwards and during November it reached highest. Total panel was covered by green mussels forming the climax community in the cage site (fig.12).

Reference panel succession was represented in fig7. Reference site the hydroids were the first settlers followed by the gastropods, Oysters in August and green mussels in June, September and Modiolus in October and amphipods in November. The climax community was not so prominent, since it is open waters the grazing and predation may be the factor which is affecting the dominancy and the climax communities of biofoulers.[13]

Table .1. ANOVA results for site and Biofoulers

ANOVA Table							
			Sum of Squares		F		
Sponge * site	Between Groups	(Combined)	314.618	1	314.618	2.739	0.113
	Within Groups		2412.155	21	114.865		
	Total		2726.773	22			
Hydroid * site	Between Groups	(Combined)	116168.775	1	116168.775	0.218	0.645
	Within Groups		11170000	21	531766.432		
	Total		11280000	22			
Sea Anemones * site	Between Groups	(Combined)	35.077	1	35.077	1.927	0.18
	Within Groups		382.324	21	18.206		
	Total		417.401	22			

Bryozoans * site	Between Groups	(Combined)	235.929	1	235.929	0.614	0.442
	Within Groups		8067.617	21	384.172		
	Total		8303.546	22			
Flatworm * site	Between Groups	(Combined)	1.886	1	1.886	0.196	0.662
	Within Groups		201.718	21	9.606		
	Total		203.604	22			
Polychaete worms * site	Between Groups	(Combined)	132.536	1	132.536	2.124	0.16
	Within Groups		1310.324	21	62.396		
	Total		1442.86	22			
Amphipod * site	Between Groups	(Combined)	118.841	1	118.841	0.856	0.365
	Within Groups		2916.367	21	138.875		
	Total		3035.208	22			
Barnacles * site	Between Groups	(Combined)	1731.834	1	1731.834	0.448	0.51
	Within Groups		81148.533	21	3864.216		
	Total		82880.367	22			
Crab * site	Between Groups	(Combined)	1.235	1	1.235	0.029	0.867
	Within Groups		896.672	21	42.699		
	Total		897.907	22			
Shrimps * site	Between Groups	(Combined)	0.443	1	0.443	0.75	0.396
	Within Groups		12.407	21	0.591		
	Total		12.85	22			
Isopod * site	Between Groups	(Combined)	1649.751	1	1649.751	1.043	0.319
	Within Groups		33231.061	21	1582.431		
	Total		34880.812	22			
Scallops * site	Between Groups	(Combined)	0.018	1	0.018	0.913	0.35
	Within Groups		0.407	21	0.019		
	Total		0.425	22			
Gastropod * site	Between Groups	(Combined)	8.432	1	8.432	0.142	0.71
	Within Groups		1250.505	21	59.548		
	Total		1258.937	22			
Green mussels * site	Between Groups	(Combined)	2142.918	1	2142.918	1.197	0.286
	Within Groups		37589.468	21	1789.975		
	Total		39732.386	22			
Modiolus * site	Between Groups	(Combined)	5436.515	1	5436.515	0.386	0.541
	Within Groups		295390.963	21	14066.236		
	Total		300827.478	22			
Nudibranchs * site	Between Groups	(Combined)	4.822	1	4.822	1.906	0.182

	Within Groups		53.139	21	2.53		
	Total		57.961	22			
Oyster * site	Between Groups	(Combined)	140.451	1	140.451	1.009	0.327
	Within Groups		2922.351	21	139.16		
	Total		3062.802	22			
Limpets * site	Between Groups	(Combined)	0.443	1	0.443	0.913	0.35
	Within Groups		10.185	21	0.485		
	Total		10.628	22			
Echinoids * site	Between Groups	(Combined)	1.321	1	1.321	0.274	0.606
	Within Groups		101.094	21	4.814		
	Total		102.415	22			
Ophiuroids * site	Between Groups	(Combined)	7.677	1	7.677	1.691	0.208
	Within Groups		95.357	21	4.541		
	Total		103.034	22			
Ascidians * site	Between Groups	(Combined)	1.583	1	1.583	1.807	0.193
	Within Groups		18.397	21	0.876		
	Total		19.981	22			

Table .2. ANOVA results for season and Biofoulers

ANOVA Table							
			Sum of Squares		F		
Sponge * season	Between Groups	(Combined)	257.717	2	128.859	1.044	0.371
	Within Groups		2469.056	20	123.453		
	Total		2726.773	22			
Hydroid * season	Between Groups	(Combined)	2305338.653	2	1152669.326	2.568	0.102
	Within Groups		8977925.192	20	448896.26		
	Total		11280000	22			
Sea anemones * season	Between Groups	(Combined)	59.933	2	29.966	1.677	0.212
	Within Groups		357.468	20	17.873		
	Total		417.401	22			
Bryozoans * season	Between Groups	(Combined)	2692.3	2	1346.15	4.798	0.02
	Within Groups		5611.246	20	280.562		
	Total		8303.546	22			
Flatworm * season	Between Groups	(Combined)	10.396	2	5.198	0.538	0.592

	Within Groups		193.208	20	9.66		
	Total		203.604	22			
Polychaete worms * season	Between Groups	(Combined)	165.239	2	82.619	1.293	0.296
	Within Groups		1277.621	20	63.881		
	Total		1442.86	22			
Amphipod * season	Between Groups	(Combined)	136.882	2	68.441	0.472	0.63
	Within Groups		2898.325	20	144.916		
	Total		3035.208	22			
Barnacles * season	Between Groups	(Combined)	10618.889	2	5309.444	1.47	0.254
	Within Groups		72261.478	20	3613.074		
	Total		82880.367	22			
Crab * season	Between Groups	(Combined)	87.148	2	43.574	1.075	0.36
	Within Groups		810.759	20	40.538		
	Total		897.907	22			
Shrimps * season	Between Groups	(Combined)	1.483	2	0.742	1.305	0.293
	Within Groups		11.367	20	0.568		
	Total		12.85	22			
Isopod * season	Between Groups	(Combined)	13253.478	2	6626.739	6.128	0.008
	Within Groups		21627.333	20	1081.367		
	Total		34880.812	22			
Scallops * season	Between Groups	(Combined)	0.036	2	0.018	0.932	0.41
	Within Groups		0.389	20	0.019		
	Total		0.425	22			
Gastropod * season	Between Groups	(Combined)	150.009	2	75.004	1.353	0.281
	Within Groups		1108.929	20	55.446		
	Total		1258.937	22			
Green mussels * season	Between Groups	(Combined)	6911.609	2	3455.804	2.106	0.148
	Within Groups		32820.778	20	1641.039		
	Total		39732.386	22			
Modiolus * season	Between Groups	(Combined)	59763.716	2	29881.858	2.479	0.109
	Within		241063.762	20	12053.188		

	Groups						
	Total		300827.478	22			
Nudibranchs * season	Between Groups	(Combined)	9.864	2	4.932	2.051	0.155
	Within Groups		48.097	20	2.405		
	Total		57.961	22			
Oyster * season	Between Groups	(Combined)	274.109	2	137.055	0.983	0.392
	Within Groups		2788.692	20	139.435		
	Total		3062.802	22			
Limpets * season	Between Groups	(Combined)	0.906	2	0.453	0.932	0.41
	Within Groups		9.722	20	0.486		
	Total		10.628	22			
Echinoids * season	Between Groups	(Combined)	0.431	2	0.216	0.042	0.959
	Within Groups		101.984	20	5.099		
	Total		102.415	22			
Ophiuroids * season	Between Groups	(Combined)	7.764	2	3.882	0.815	0.457
	Within Groups		95.27	20	4.763		
	Total		103.034	22			
Ascidians * season	Between Groups	(Combined)	3.828	2	1.914	2.37	0.119
	Within Groups		16.153	20	0.808		
	Total		19.981	22			

The ANOVA results obtained from SPSS (table.1), for site and biofouling communities have shown no significance, but the season and the biofouling communities(table.2) have shown significance ($P<0.05$). Some Biofoulers showed significance between the seasons, influencing the biofouling community as a whole.

Short term seasonal succession studies (cage culture net):

In the cage net Hydroids, Algae, Modiolus were the important foulers observed in the seasonal succession series. In the pre-monsoon season algae appeared in the panel followed by hydroids and modiolus in less density along with other fouling organisms like sea anemones, barnacles, crabs, shrimps, Isopods, gastropods, green mussels, nudibranchs, oysters, echinoids, Ascidians. In the monsoon hydroids dominated, reducing the algae. Modiolus also appeared in the monsoon panel. But the important foulers like sea anemones, shrimps, gastropods, nudibranchs and ascidians disappeared. Sponges and limpets appeared. In post monsoon algae dominated and modiolus density also increased. Flat worms and ascidians disappeared. On the short-term panels in the premonsoon Ascidians appeared and were absent in the monsoon and post monsoon. Flatworms absent in the monsoon.

It is observed that in the short-term studies on the culture nets hydroids settlement is during the month of September. Modiolus settlement in May, October, November, December and February month and algae settlement during March and April.

Climax community:

In literature of ecological succession, Clements theory is an idealistic theory proposing climax as the final stage of succession process.[33]Most of the Indian studies climax species is *Pernaviridis*, few studies barnacles and ascidians were climax communities.[12]Scanty of literature is available on the Climax communities concerned to the aquaculture net panels. Sahu et al.[12] has reported Green mussels as the climax community on wooden panels.In the present study which was carried out in a culture farm, the green mussels formed the climax community. But in the reference site which is away from the culture activities no climax as such was observed. This may be due to the grazing and predation effect of wild fishes and other animals in the reference site.

Green mussels are the dominant foulers forming the climax, due to their higher efficiency to hold the net fibers, fast growth and higher ability to filter the photo-planktons which are available in large quantities due to the higher nutrients' availability. The other foulers get fewer places to survive, so not able to establish on the net. [12] The dominant organisms are successful due to their size, growth, longer life span, longer larval stage.[34] In most of the aqua culture related biofouling studies carried out in Mediterranean where sea bass is culture fish, the mussels, hydroids, algae were the dominating communities.[35] The present results also move in this direction.

CONCLUSION

Hydroids were the initial community on the long-term panels and green mussels formed the climax community in the cage site panel. Highest fouling in July month (mainly by hydroids) in cage long term panels, reference highest fouling in May (hydroids), net highest settlement in May (due to hydroids and algae). When the biofoulers and seasonal dominance of biofouling communities of experimental panels were compared with that of net fouling, completely different fouling structure was observed and the different foulers dominated in the months studied. The hydroids were frequently occurring biofoulers on the long-term panels. Algae, hydroids were dominant on the cage net. And the net panels of the cage are loaded with hydroids in the initial months and the peak fouling will be during May. So frequent net cleaning is required during summer and during the spat settlement period of green mussels (September, October, and November). Modiolus settlement during February month on the culture nets can be avoided by net exchange immediately after spat fall in this month. In the initial months the grazing organisms and fishes can be introduced in the cages along with the culture fishes so as to reduce the fouling by biological method.

It is suggested to use eco friendly organic artificial agents which will not harm the ecosystem and the water quality to overcome these fouling. Net service stations are available for cleaning and treating the fouled nets in many countries. And environmental regulations have been put forth for cage culture activities in the marine waters which restrict the use of anti-fouling chemicals for net maintenance. Since India is still in developing stage in cage culture, when compared to many maritime countries, there is remarkable opportunity for the further development of cage farming in India and much more opportunities to biofouling research in Mariculture. This ecological study will initiate further research in this aspect.

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Authors Contribution statement

Mrs.Sonali S.Mhadolkar, contributed to writing of the manuscript, and gathered the data with regard to this research. Co Authors contributed to the analysis of the results and necessary inputs are given for the designing of manuscript.

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