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A Study on Ecological Succession of Macrofouling Communities in Sea Cage Farm in South-West Coast of India

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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 were loaded with hydroids in the initial months and the peak fouling was during May. So frequent net cleaning was required during summer and during the spat settlement period of green mussel (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. Looking at vast opportunities for further development in biofouling research, the aim of this investigations was to obtain the baseline information about the ecological succession pattern of biofouling organisms in fish 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 criteria.

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

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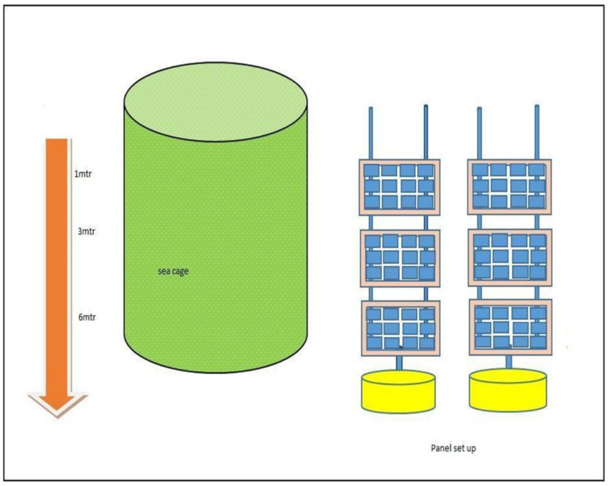
1. INTRODUCTION

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] Many studies were undertaken to understand the spatio 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.[3,4] Panels were 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.[5,6] Research are being carried out in biofouling on mariculture structures worldwide.[7,8,5,9] The ecological succession of biofoulers is a very complex process and development pattern found on the suspended cage structure may vary from the natural sea bed and hard substratum.[10] Formation of biofouling community is site specific[11] and their development with respect to time is prerequisite for the marine structures and for developing cleaning practices.[12] Ecological process of biofouling community-development may take a day or weeks[4] and biofouling communities varies with time and space but the major variations were the seasonal variations.[10,13,14] 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 factors predation was a major factor affecting the succession of the fouling communities.[10] Severity of settlement varied on different substrata based on the choice of settlement of planktonic larval-forms. [15]Succession studies at different depth were by Dziubińska and Szaniawska.[2] The attaching foulers forms formed the bigger components but the free-living forms were also found in the community of biofoulers.[16] Succession is a composite process in which simple organization level changing to compound community form.[10] Comprehensive studies on marine biofouling process were carried out by Railkin.[17] Pioneering study in biofouling along the Indian coast were conducted on different structures such as experimental panels, ship halls, jetties etc.[16,18,19] Many research works were carried on the fouling community structure.[5,11,20-22] Literature review about succession and climax communities of biofouling in general (other than mariculture facilities) is available along the Indian coast[11] ,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 on open sea cages in India.

2. MATERIAL AND METHODS

In marine cages installed in the Arabian Sea at Karwar, Karnataka (N 14°48.406', E 074°06.664'), so far six species of finfishes (*Lates calcarifer, Rachycentron canadum, Lutjanus argentimaculatus, L.johnii, Trachinotus blochii, Acanthopagrus latus)* and one shellfish species (*Perna viridis)* are being 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 dia half inch PVC pipe frame. They were tied by using 4mm nylon rope in the water column adjacent to the cages in the culture site. (fig.1)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.



The orange arrow indicates the 3depths, sea cage (represented by Green cylinder), panel set up (orange colour rectangles)with net panels (blue colour)and weight (yellow colour)

Fig 1. Diagrammatic representation of field setup at cage site

2.1 Laboratory studies

The net panels were brought to the laboratory separately in the plastic trough with sea water. The fouling organisms were 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.[24-26] 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).

3. STATISTICAL ANALYSIS

The data collected was analyzed statistically using SPSS16.0, PRIMER 0.5 and XLSTAT2016 softwares. Average data of the panels from three depths of each site was taken for the analysis and comparison between the sites.

4. RESULTS

4.1 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 16, they totally vanished from both the sites. The density of hydroids ranged from85 no/10cm^2 in January-16 to1433 no/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/10cm^2 and reference sites with33 no/10 cm^2. During 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. In October *Modiolus* dominated in both the sites with 547no/10cm^2 and during November green mussel was most dominating (188no/10cm^2) group in cage site and Amphipods were the dominant communities (43 no/10cm^2) in reference site. Fig. 2 & 3 represents dominant fouling organisms on long term panels of cage and reference site.

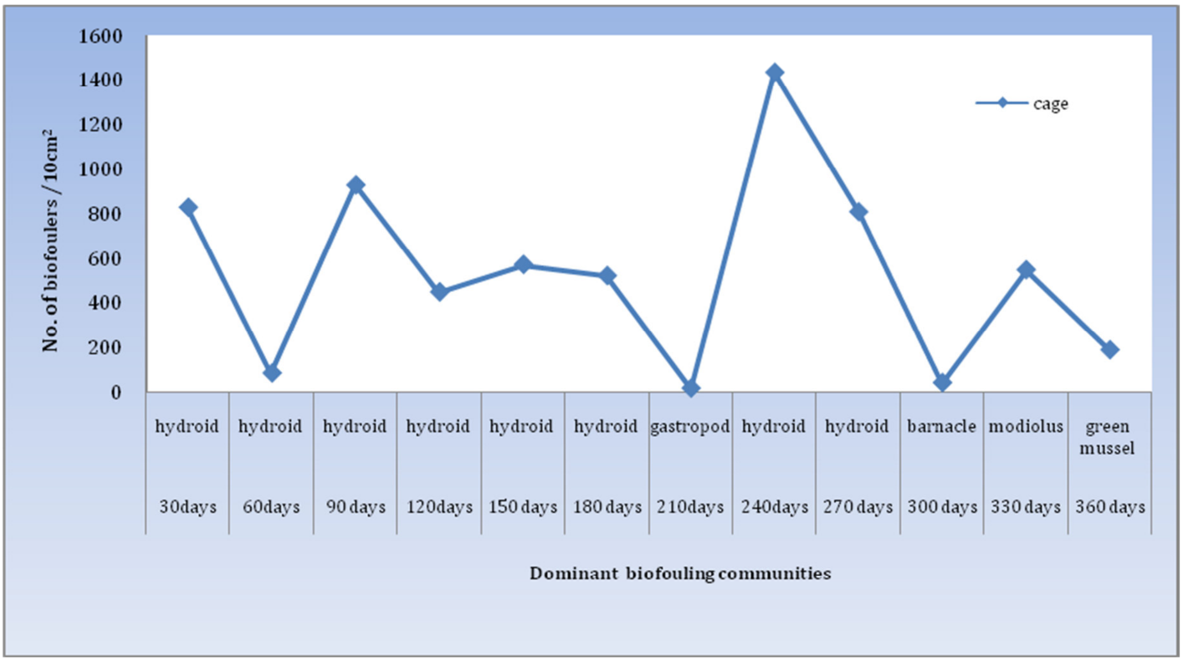


Fig 2. Dominant biofouling communities of cage site during the immersion period (30 to 360 days)

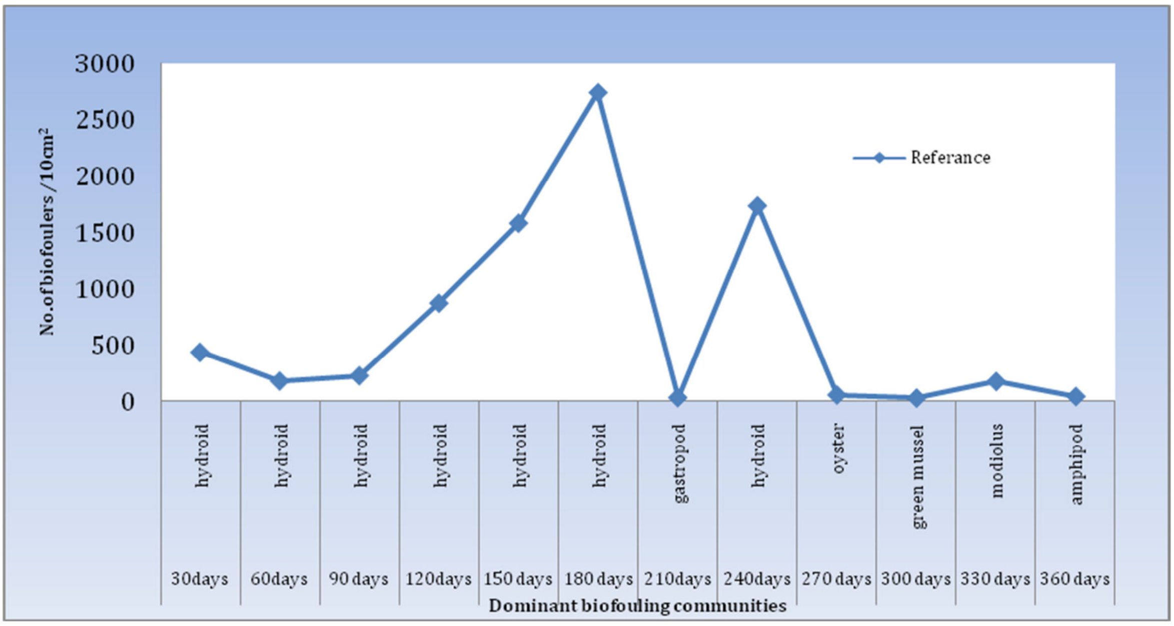


Fig 3. Dominant biofouling communities of reference site during the immersion period (30to360 days)

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, were 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. Considerable density of isopods and slight increase in the bryozoan number were observed during this period but Crabs and shrimps disappeared and decrease in the barnacle number also were observed in cage sites, whereas in reference site barnacle density decreased. Crabs, green mussels, *Modiolus*, oyster density started decreasing and they 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 were 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, sponge, amphipod, hydroid, sea anemone, barnacle, crab number has increased than the previous period. Nudibranch which disappeared in the previous period has appeared, 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. Hydroids showed a complete decline. Sponges, hydroids, sea anemones, bryozoans, shrimps, Isopods, oysters, echinoids, ophiuroids which were present in the previous period were 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. By August-16 (270 days), flat worms got introduced for the first time. 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, oysters and limpets, reappeared on the panel. Oysters were the dominating community (57no/10cm^2). Barnacles were the next dominating community. By September-16 (310days), oysters reappeared on the panel. Flatworms, *Modiolus*, ascidians which were lesser in number during the previous month were completely vanished whereas in the reference site, polychaete worms, barnacles, crabs, Isopods, green mussels, *Modiolus* and 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*. 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 increasing trend. Oyster density declined. By November-16 (360 days), the panels were fully covered by green mussels (100%) and the community reached its climax stage. Whereas hydroids, sea anemones, polychaete worms, amphipods, crabs, gastropods, and *Modiolus* were the communities observed in the reference panel and Amphipods were the dominant communities (43 no/10cm^2).

4.2 *Seasonal succession of the long-term panels*

In the present case the long term cumulative panels were studied up to360 day (1year). The settlement pattern revealed Hydroids as prominent communities in all the seasons both in culture site and reference site (fig.2&3). 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 was 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.10.

4.3 *Peak settlement period for the major fouling communities 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.

4.4 *Seasonal fouling on the culture net*

Seasonal settlement pattern (fig.6) and succession pattern biofouling on the culture net (Fig.11) 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.

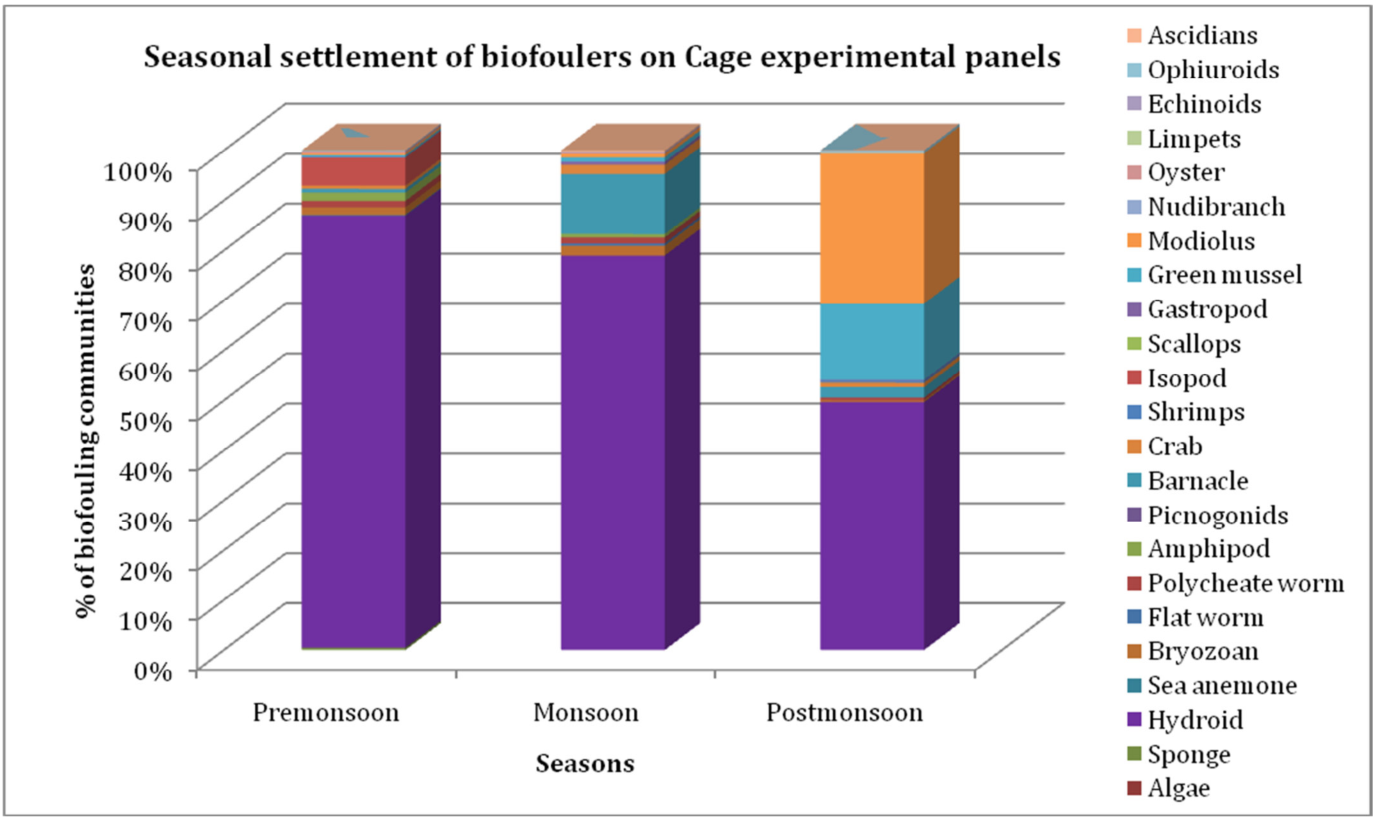


Fig 4. Seasonal settlement pattern of Cage panel

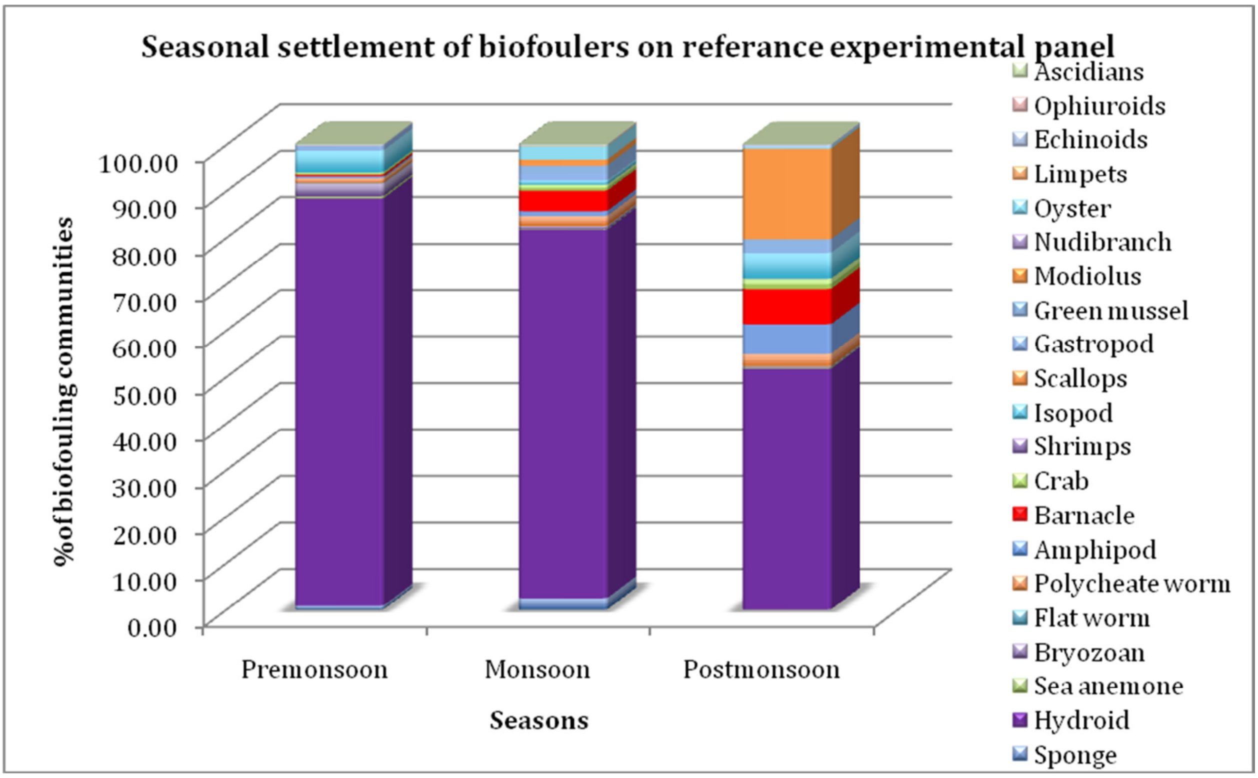


Fig 5. Seasonal settlement pattern of reference panel

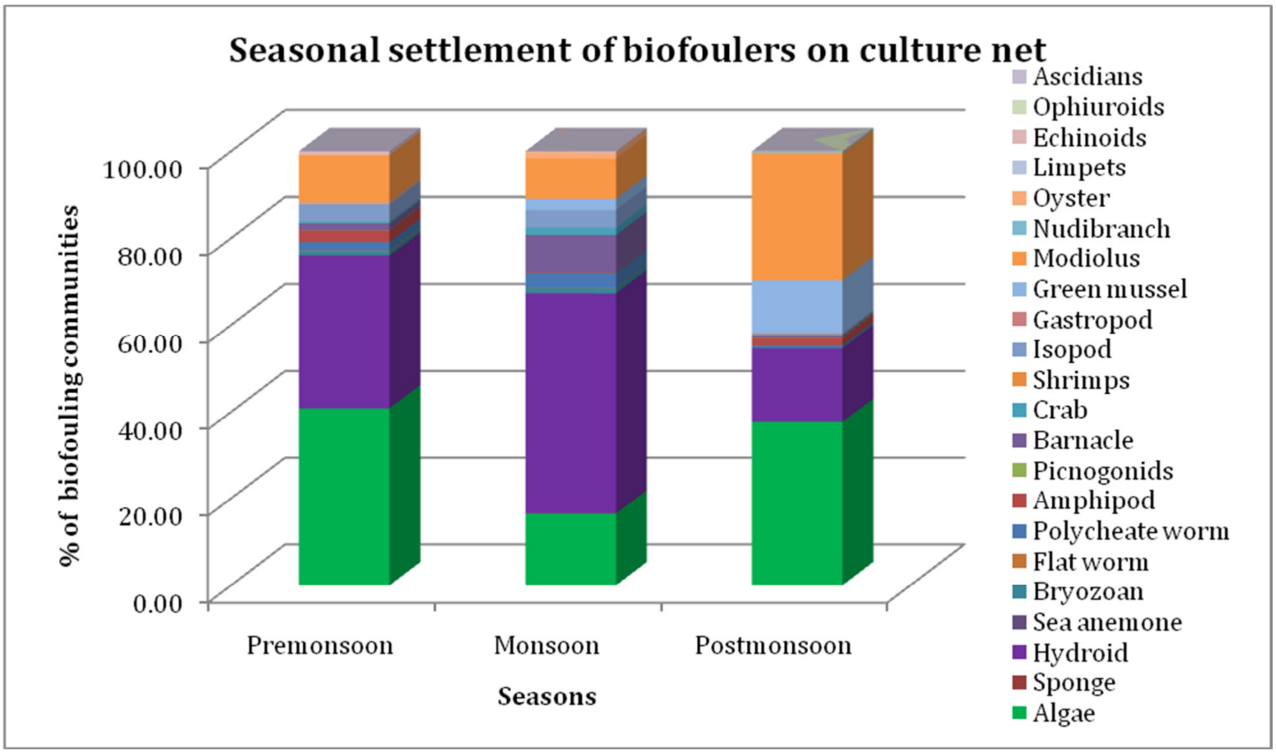


Fig 6. Seasonal settlement pattern of culture net

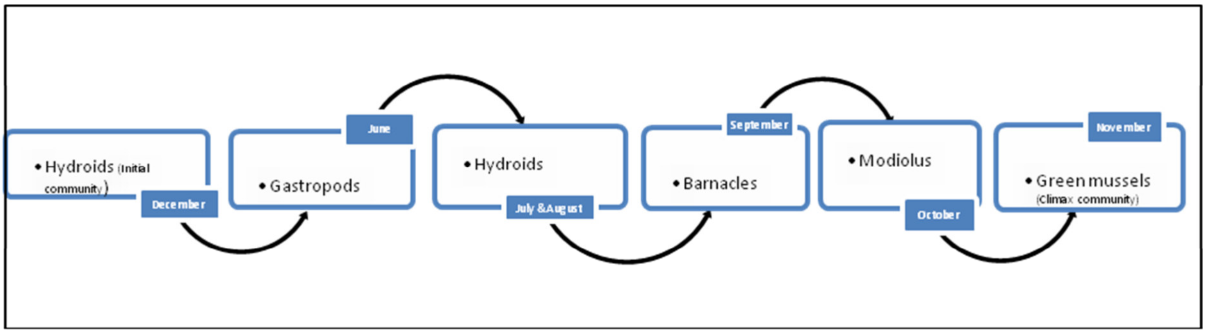


Fig 7. Month wise succession pattern on the long term panels of cage site

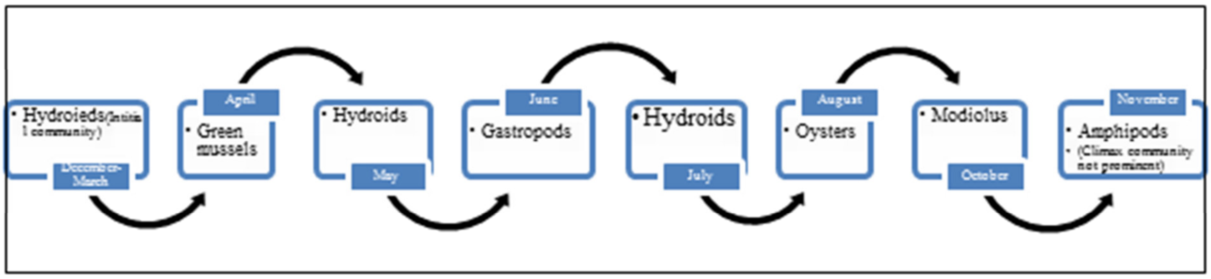


Fig 8. Month wise succession pattern on the long term panels of Reference site

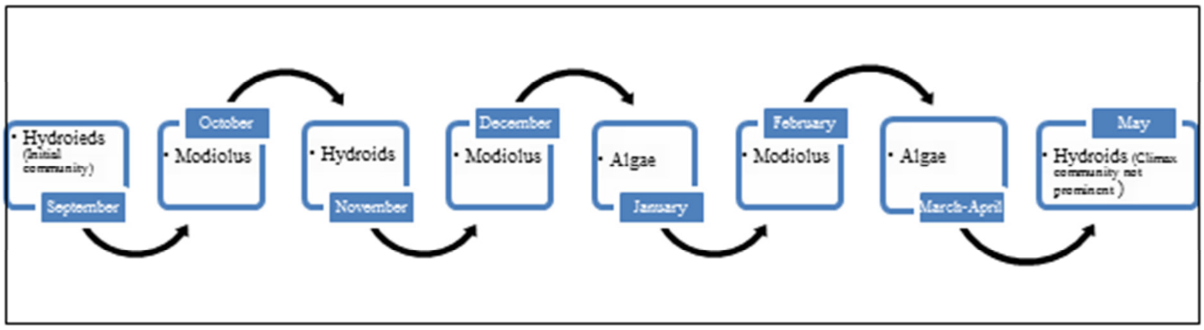


Fig 9. Month wise succession pattern on the Short term cage culture net

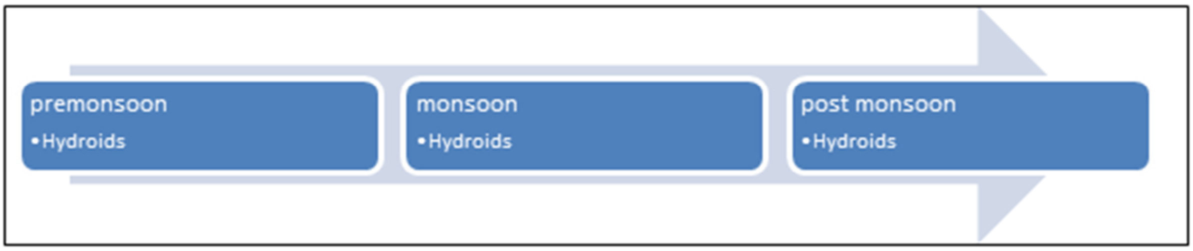


Fig 10 . Seasonal succession pattern on the long term panels (cage site and reference)

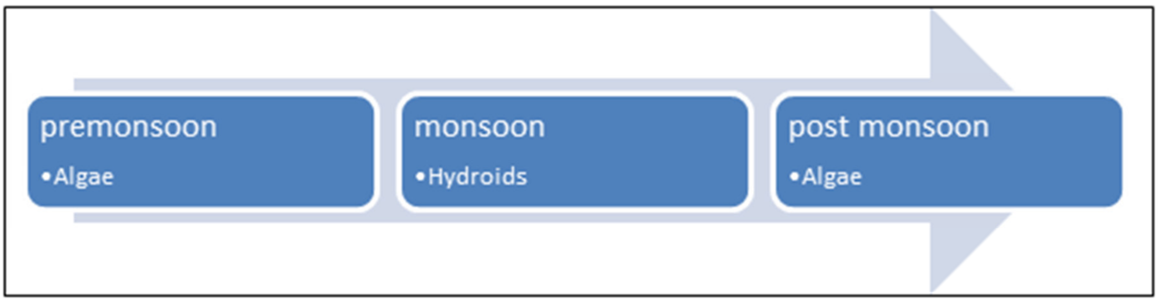


Fig 11 . Seasonal succession pattern on the short term cage culture net

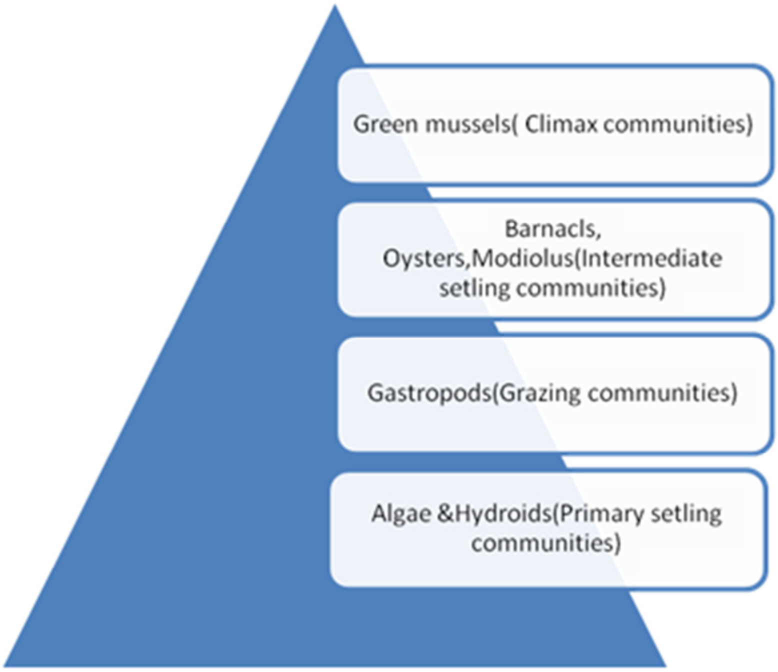


Fig 12. A model of overall macro fouling of cage farm of Karwar, India

4.5 *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.12).

5. DISCUSSION

This present study can be compared with the biofouling studies in bivalve aquaculture (oyster culture) where in 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 occurred after a month or few month.[27,30] In the present study, hydroids and barnacles were appeared in the initial month in the cage panel whereas hydroids, polychaete worms, amphipods, barnacles, crabs, shrimps, isopods, green mussels, *Modiolus* and oysters appeared in the reference panel. The recruitment, settlement complexities could be the reason for these differences in marine invertebrates.[27,31] Similar reasons could be attributed in the case of fin fish aquaculture cage panel and the reference panel. The biofouling succession as well as colonization patterns differs with climatic zones, as in tropical zones constant settlements around all the months, whereas at fixed intervals in temperate zone.[4,27] The local surveys are necessary as the colony patterns of biofoulers 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.[10] The basic information on fouler diversity, composition and succession are required to control the foulers and estimate the fouling potency of that locality. [5,32] Sahu et al.[11] suggested low salinity and high turbidity favorable for barnacles which settled year around.

5.1 *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] On long term panels, peak settlement was during Mayand in hydroids highest total density was in November (green mussels) in a cage with experimental panels. As far as overall period is concerned, in the May , fouling abundance was more on the cage nets. Cage panel succession was represented in fig. 7. 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 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. In October *Modiolus* started dominating, along with them green mussel settlement was also started increasing. Green mussels which started their appearance in May started increasing steadily from August onwards and during November it reached the highest. Total panel was covered by green mussels forming the climax community in the cage site (fig.13). Reference panel succession was represented in fig. 8. In reference site, the hydroids were the first settlers followed by the gastropods, oysters were settled in August, green mussels in June and September, *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.[12] Some Biofoulers showed significance between the seasons, influencing the biofouling community as a whole (table1&2).

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 Groups		241063.762	20	12053.188		
	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 the site and biofouling communities have shown no significance, but the season and the biofouling communities(table.2) have shown significance (P<0.05).

5.2 Short term seasonal succession studies (cage culture net)

In the cage net, hydroids, algae and *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 i*n 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 the settlement, with reduction in algal settlement. *Modiolus* also appeared on the panel during monsoon. But the important foulers like sea anemones, shrimps, gastropods, nudibranchs and ascidians disappeared during monsoon, where as sponges and limpets appeared during the sesaon. In post monsoon, algae dominated and the *Modiolus* density also was increased. Whereas flat worms and ascidians disappeared. On the short-term panels in the premonsoon, ascidians appearedon the panel which were absent in the monsoon and post monsoon. Flatworms were also absent in the monsoon. It is observed that in the short-term studies on the culture nets, hydroids settlement was during the month of September. *Modiolus* settlement was in May, October, November, December and February month and algal settlement was during March and April.

5.3 Climax community

In literature of ecological succession, Clements theory is an idealistic theory proposing climax as the final stage of succession process.[33] In most of the Indian studies, climax species was *Perna viridis*, and in few studies barnacles and ascidians were climax communities[12]. Scanty literature is available on the Climax communities concerned to the aquaculture net panels. Sahu et al.[11] 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 was 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 were 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. These dominant biofoulers were successful in competing with other biofouling communities due to their larger size, growth, longer life span, longer larval stage.[11,34] 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] and the present study also endorse those results.

Fig 13. Green mussels forming the climax on the panel in sea cage farm

6. CONCLUSION

Hydroids were the initial and frequently occurring community, and green mussels formed the climax community on the long term panels of cage site. In cage net, highest settlement was in May dominated by hydroids and algae. Frequent net exchange was need to be carried out during summer months and immediately after spat settlement of green mussels (September-November), *Modiolus* (February). During 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 also suggested to use eco friendly organic artificial agents to overcome these fouling. Environmental friendly net service stations are available for cleaning and treating the fouled nets in many countries and it is suggested that similar facilities need to be developed in India also, to promote open sea mariculture.

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9. AUTHORS CONTRIBUTION STATEMENT

Mrs.Sonali S.Mhadolkar, conducted the research work and contributed to writing of the manuscript. Co Authors contributed to the analysis of the results and necessary inputs are given for the designing of manuscript.

10. CONFLICT OF INTEREST

Conflict of interest declared none.

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