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TEMPORAL VARIATIONS IN CATCH COMPOSITION OF STATIONARY BAGNETS ALONG MAHARASHTRA COAST IN RELATION TO ENVIRONMENTAL FACTORS

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ABSTRACT : Stationary bagnets are one of the most extensively operated traditional fishing gears along Maharashtra Coast. Despite being the most important traditional gear of the State, no systematic studies on the temporal variations in catch composition and the influence of environmental factors on the bagnet fishery of Maharashtra Coast have been conducted till date. Thus, the present study aimed at evaluating temporal variations in catch composition and the influence of environmental variables on the same. To this end, fishing experiments and environmental assessments were conducted every month at four stations for two years, and analysed to achieve the objectives.A total of 156 species belonging to 63 families were recorded in the catch. The most dominant species in the catch were *Harpadon nehereus* (19.16%), *Acetes* spp. (14.24%), *Nematopalaemon tenuipes* (8.97%), *Coilia dussumieri* (5.27%), *Chrysaora* sp. (3.98%) and *Lepturacanthus savala* (2.31%). No significant spatial variations were observed for the different resources, whereas temporal variations were significant. Major environmental variables (temperature, salinity, pH, DO, BOD, current speed, turbidity, TSS, ammonia, phosphate, nitrate, nitrite, silicate, chlorophyll-a, phytoplankton and zooplankton) were analysed and compared among the seasons.Significant temporal variations were observed for all the environmental variables. Catch composition and environmental data were subjected to different multivariate analyses. The results of cluster analysis, ANOSIM and SIMPER established a significant difference in catch composition among the seasons. The diagnostic species for each season were identified through CCA and SIMPER. The results of CCA, Pearson's correlation analysis revealed that current speed, temperature, salinity, pH, DO, turbidity, chlorophyll-a and plankton density play significant roles in structuring the catch composition acrossthe different seasons and current speed exerts maximum influence on catchrate. The information from the study could be used as baseline data for framing management measures for a sustainable bagnet fishery along Maharashtra Coast.

Key words : Catch composition, environmental factors, diversity indices, temporal variations, sustainable management.

INTRODUCTION

Fisheries and aquaculture remain as a primary production sector, which increasingly contributes to the nutritional security and livelihoods of millions of people around the world. Maharashtra is one of the dominant marine fish producing coastal states of India, with a coastline of 720 km extended along six maritime districts, namely Sindhudurg, Ratnagiri, Raigad, Greater Mumbai, Thane and Palghar from south to north. Due to the multi-species nature of the fishery, the resources of Maharashtra are mostly distinguished based on the type of gear used rather than the kind of species caught (Deshmukh, 2013). Stationary bag nets fishery of Maharashtra contribute about 24% of the total catch of the state and thus, became the second-highest revenue generating fishing gear after trawl (Kumawat *et al*, 2015). Stationary bagnets are conical passive non-selective traditional gear with rectangular mouth and tapering cod endoperated in areas of strong tidal currents. These kinds of nets are lowered and hauled based on the tidal directions and force (Bapat, 1970). Maharashtra stateis having the maximum number of stationary bag nets in operation, the majority of which are operated along Thane, Greater Mumbai and Raigad districts (CMFRI, 2012). The tidal currents are strong in the northern coastal waters of Maharashtra owing to which, the traditional bagnet fishery is established along the northern coastal districts of Maharashtra (Deshmukh,

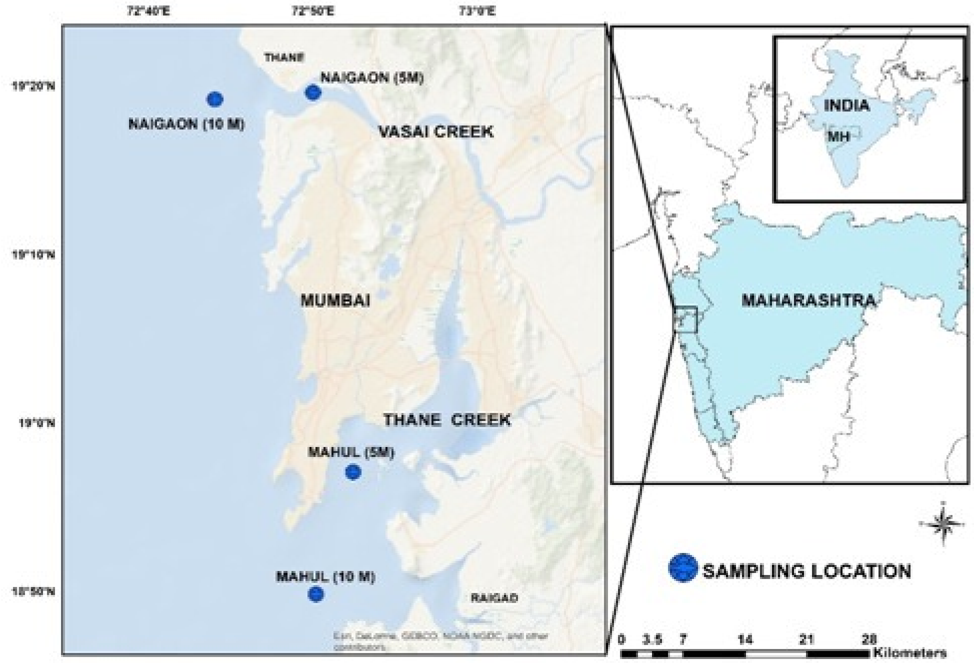

Fig. 1 : GIS map showing sampling sites along Maharashtra coast.

2013). The areas for stationary bag net operation with strong tidal currents in the coastal waters and creeks are identified by the fishers through their indigenous knowledge.

In spite of being the most common traditional gear,contributes significantly to the fishery of Maharashtra, no systematic studies have been conducted on the temporal variations in catch composition and the influence of environmental factors on the bagnet fishery of Maharashtra coast. Further, there is hardly any clear policy framework to regulate, develop and ensure the sustainability of the stationary bagnet fishery till date. Analysing the temporal patterns of community and variations across ecosystems with contrasting environmental conditions provides new insights on factors that interact and influence the structure and functioning of coastal ecosystems (Royer *et al*, 2008; Link *et al*, 2010). Exploring these seasonal variations in catch composition and abundance would also help to understand the effect of environmental factors on coastal fisherywhich will help to work out an ecosystem-based fishery management framework along the region and to suggest measures to make thebagnet fishery a suatainable one. Considering the above facts a study was undertaken to understand the species divesity and variations in catch composition of bagnets with reference to environmental variables.

MATERIALS AND METHODS

Study area

Four locations were selected along Maharashtra coast based on the intensity of bagnet operation (CMFRI, 2012), technical feasibility to carry out the experiment and geographical proximity to minimise the cost involved. These stations represent the major stationary bagnet fishing grounds of Maharashtra and were selected after conducting a baseline survey on the intensity of net operations (*Bokshi nets*). As per the 2010 Marine Census conducted by CMFRI, the majority of stationary bagnets were found operating along the coasts of Greater Mumbai and Thane districts. Sites selected for the study were: (1) The lower stretch of Vasai Creek at an average depth of 5m, (2) Off Vasai at an average depth of 10m, (3) The lower stretch of Thane Creek at an average depth of 5m (4) Off Thane Creek at an average depth of 10m.The stations 1 and two borders Thane and Greater Mumbai districts and the stations 3 and four borders Greater Mumbai and Raigad districts (Fig. 1). The depths mentioned here represent the depth at which the spikes were fixed for setting the nets and the locations of net operation were set using GPS.

Experimental fishing

Experimental bagnet operation and catch assessment was done on a monthly basis from December, 2015 to November, 2017. Fishing experiments were set to run for 3 h since most commercial bagnets operate between 2-4 hours. Length of the experimental gear operated was 30 m with four segments of webbing with large meshes at the mouth and smaller meshes towards the codend.At the mouth opening, the length and width of the net used were 10 m and 4 m, respectively and codend mesh size was 10 mm (Fig. 2). Gear design used for the experimental fishing,

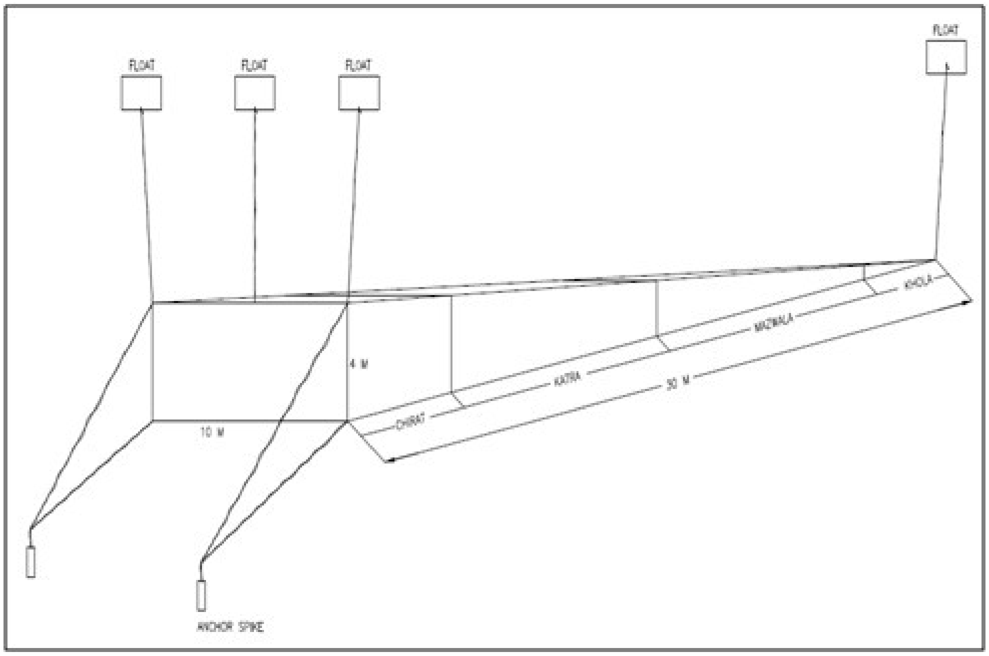

Fig. 2 : Sketch of experimental gear used for the study.

depth of operation and mooring material were also kept fixed for the identified stations, throughout the study period. The net was set against flood tide in the identified locations during morning hours.

Catch analysis

Onboard information was collected for total catch/ haul, quantity of jelly fish, plastic and discards. Catch was brought to CMFRI, Mumbai laboratory, sorted and identified using conventional taxonomic methods such as morphology, colour, texture patterns, morphometric measurements and meristic counts following standard taxonomic literature (Fischer and Whitehead, 1974; Fischer and Bianchi, 1984; Talwar and Kacker, 1984), and internet websites such as WORMS (Eschmeyer and Fong, 2013), FishBase (Froese and Pauly, 2010) and Sealifebase (Palomares and Pauly, 2010).

Estimation of environmental variables

The physico-chemical parameters such as temperature (°C), salinity (‰), pH and turbidity (NTU) of water were recorded onsite using a mercury-in-glass thermometer, a refractometer (ERMA, Tokyo), digital pH meter (Hanna Instruments, India) and nephelometer (Eutech Instruments, Singapore), respectively. For the estimations of dissolved oxygen (DO in mg L^{-1}), biochemical oxygen demand (BOD5 in mg L^{-1}), ammonia-N (µM L^{-1}), nitrate-N (µM L^{-1}), nitrite-N (µM L^{-1}), reactive phosphorus (µM L^{-1}), silicate (µM L^{-1}) total suspended solids (TSS in mg L^{-1}), Chlorophyll-a (mg m^{-3}.) and for phytoplankton and zooplankton densities, the standard methodologies described in APHA (2005) guidelines were used. The current speed on sampling days for the sites were downloaded from the OSCAR (Ocean Surface Current Analysis Real Time).

Data analysis

To understand the temporal variations, data collected from the four stations were pooled into 4 pre-determined seasons; winter monsoon- WM (December to February), spring inter-monsoon-SI (March to May) summer monsoon- SM (June to September) and fall inter-monsoon-FI (October -November) (Chatterjee *et al*, 2012). These summarized data were used for further analysis. Two-way ANOVA and post-hoc comparison using Tukey's HSD were carried out to determine whether they are significantly different between the seasons using PROC GLM procedure for the above parameters.

Cluster analysis (Bray-Curtis similarity matrix) using the abundance data obtained for the different seasons and from different sampling stations were used to generate a dendrogram for investigating the similarities among different stations and seasons using PAST software (Hammer *et al*, 2001). To test the changes in fish assemblages between the different seasons and stations, a non-parametric analysis, permutation based one-way analysis of similarity (ANOSIM) was carried out following Clarke (1993). ANOSIM was used to test the null hypothesis that no changes in community structure were observed between seasons and stations. Using the species abundance data, the similarity in fish assemblages between seasons and stations were compared employing similarity percentage (SIMPER) analysis (Clarke, 1993).

Applying this method, species that contribute significantly to fish assemblages were measured and ranked. To visualize the temporal variations in fish assemblages, and their relationship with the environmental variables, the data were subjected to canonical correspondence analysis (CCA) using PAST software (Hammer *et al*, 2001).

RESULTS AND DISCUSSION

Overall faunal diversity catch rate and catch composition

During the study period, a total of 156 species belonging to 63 families were recorded from the experimental gears operated at four stations across four seasons. The fishery was constituted by 114 teleosts belonging to 42 families, 29 crustaceans belonging to 9 families, five molluscan species belonging to 3 families, four elasmobranchs from 3 families. In addition, 2 species of sea snakes and 2 species of jelly fishes were also recorded. Sciaenidae was the richest family observed in terms of number of species (14 species) followed by Engraulidea (9 Species), Carangidae (9 species), Penaeidae (8 species) and Clupeidae (8 species) (Table 1). Kumawat (2014) reported the contribution of 66 species in the single-day bagnet catch of Bassein Koliwada. Another study conducted by Iburahim *et al* (2017) on bagnets operated in Karanja Estuary of Maharashtra coast reported 92 species. The increase in the number of species recorded in the present study compared to the earlier reports from Maharashtra could be due to the species abundance and the increased accessibility and vulnerability of species to the fishing gear (Hovgard and Lassen, 2000).

The most dominant species in the catch as per relative abundance in terms of weight were *Harpadon nehereus* (19.16%), *Acetes* spp. (14.24%), *Nematopalaemon tenuipes* (8.97%), *Coilia dussumieri* (5.27%), *Chrysaora* sp (3.98%), *Lepturacanthus savala* (2.31), *Parapenaeopsis sculptilis* (1.74%), *Parapenaeopsis stylifera* (1.44%), *Chiropsoides buitendijki* (1.31), *Charybdis callianassa* (1.23%), *Escualosa thoracata* (1.16%), *Pampus argenteus* (1.15%), *Thryssa hamiltoni* (1.07%), *Eupleurogrammus muticus* (1.04%) and *Johnieops vogleri* (1.02%). Out of 156 species recorded, above mentioned 15 species contributed to about 66% percentage of the total bag net catch. These observations are supported by the fact that even though the tropical ecosystems have a high diversity of fishery resources, a few numbers of species dominate the fishery (Blaber *et al*, 1995; Sreekanth *et al*, 2015).

It can be inferred from the present study that there is a rich diversity of fish and shellfish species in the study area. However, an abundance of most of the individual species in the total catch was low with a few species dominating the percentage composition. In the tropical ecosystems, high diversity and low abundance of individual species are regular phenomena (Ansari *et al*, 1995; Whitfield, 1999; Rojo-Vazquez *et al*, 2008). It was observed that *Harpadon nehereus*, *Acetes* spp., *Nematopalaemon tenuipes* and *Coilia* sp. *dussumieri* dominate the species composition in all the seasons except WM at all the stations. Previous studies also reported the above mentioned species as the mainstay of bagnet fishery along the coasts of Maharashtra and Gujarat (Pillai, 1983; Khan, 1986; Manojkumar and Dineshbabu, 1999; Iburahim *et al*, 2017).

The species recorded during the study were classified into 27 resource groups (Table 2). Overall percentage composition of major groups in stationary bag nets observed during the study period is depicted in Fig. 3. Overall catch rate of stationary bag nets studied was 45.75 kg/haul. Kumawat (2014) reported a mean catch rate of 14.44 kg/haul for single day bagnet operation and 41.57 kg/haul for multi-day fishing operations at Bassein Koliwada (Thane). Manoj Kumar and Dineshbabu (1999) observed an overall catch of 66.34 kg/haul by dolnetters of Rajpara, Gujarat. The differences in catch rates compared to previous reports could be due to the difference in area and depth of operation, the design of gear used and environmental conditions. During the present study, high catch rate was observed during SM with a mean value of 61.02 kg/haul, and low catch rate was recorded during WM with a mean value of 32.75 kg/haul (Fig. 4). These results are consistent with the reports of Pillai *et al* (1983), who reported an increase in dolnet catch during SM and decrease during winter along the Maharashtra Coast. Similarly, Deshmukh (2013) opined that the catch of bagnets declined during the winter season due to the weakening of coastal current along the northwest coast. On the other hand, researchers (Khan, 1986; Khan, 1987) reported the abundance of catch during FI. This difference could be due to the fact that earlier studies were based on commercial bagnet operations, which are restricted during the monsoon fishing ban which leads to the realisation of low catch during the season. Moreover, the success of bagnet fishery is hugely dependent upon the coastal currents (Manojkumar and Dineshbabu, 1999). Oceanographic studies along the northwest coast have shown that during the winter season, the tidal currents reversed the flow and become weak (Banse, 1968), which adversely affects the dolnet fishery. Thus, the low catch rate during WM could be interrelated to the low current speed during WM.

Table 1 : Faunal diversity of bagnet catch.

Sl No	Resource group	Family	*Species name*	Local name	% Abundance
			Molluscs		
1	Cephalopods	Loliginidae	*Loliolus hardwickei*	Maakul	0.30
2	Cephalopods	Loliginidae	*Uroteuthis duvaucelii*	Maakul	0.24
3	Cephalopods	Sepiidae	*Sepiella inermis*	Chota goti	0.38
4	Cephalopods	Octopodidae	*Amphioctopus aegina*	Jeevrae makul	0.07
5	Cephalopods	Octopodidae	*Cistopus indicus*	Kend makhul	0.07
			Crustaceans		
1	Alpheids	Alpheidae	*Alpheus* sp.	Jhinga	0.05
2	Acetes	Sergestidae	*Acetes* spp.	jawla	14.24
3	Other nonpenaeids	Lysmatidae	*Exhippolysmata ensirostris*	Ghobi	0.61
4	Other nonpenaeids	Lysmatidae	*Lysmata vittata*	kardi	0.03
5	Other nonpenaeids	Palaemonidae	*Exopalaemon styliferus*	kardi	0.31
6	Other nonpenaeids	Palaemonidae	*Nematopalaemon tenuipes*	Kardi	8.97
7	Other nonpenaeids	Palaemonidae	*Macrobrachium rosenbergii*	Pocha	0.00
8	Penaeid prawns	Penaeidae	*Penaeus indicus*	Safed zinga	0.11
9	Penaeid prawns	Penaeidae	*P. merguiensis*	Safed zinga	0.35
10	Penaeid prawns	Penaeidae	*P. sculptilis*	Kolbi	1.74
11	Penaeid prawns	Penaeidae	*P. stylifera*	Tiny	1.44
12	Penaeid prawns	Penaeidae	*Metapenaeus brevicornis*	Polan	0.77
13	Penaeid prawns	Penaeidae	*M. monoceros*	Kapshi	0.64
14	Penaeid prawns	Penaeidae	*M. affinis*	Chaiti	0.46
15	Penaeid prawns	Penaeidae	*M. dobsoni*	Polan	0.19
16	Penaeid prawns	Solenoceridae	*Solenocera crassicornis*	Goyanar	0.32
17	Crabs	Portunidae	*Scylla serrata*	Khekda	0.48
18	Crabs	Portunidae	*Portunus pelagicus*	Khekda	0.35
19	Crabs	Portunidae	*P. sanguinolentus*	Khekda	0.21
20	Crabs	Portunidae	*Charybdis callianassa*	Khekda	1.23
21	Crabs	Portunidae	*C. lucifera*	Khekda	0.23
22	Crabs	Portunidae	*C. annulata*	Khekda	0.00
23	Crabs	Portunidae	*C. feriata*	Khekda	0.26
24	Crabs	Portunidae	*Thalamita crenata*	Khekda	0.04
25	Crabs	Matutidae	*Ashtoret lunaris*		0.04
26	Stomatopods	Squillidae	*Harpiosquilla harpax*	Hijada	0.39
27	Stomatopods	Squillidae	*Miyakella nepa*	Hijada	0.18
28	Stomatopods	Squillidae	*O. interrupta*	Hijada	0.26
29	Stomatopods	Squillidae	*O. perpensa*	Hijada	0.20
			Chondrichthyes		
1	Elasmobranchs	Carcharhinidae	*Scoliodon laticaudus*	Sonmishi	0.52
2	Elasmobranchs	Dasyatidae	*Brevitrygon imbricata*	Pakat	0.21
3	Elasmobranchs	Hemiscylliidae	*Chiloscyllium punctatum*	Mushi	0.04
4	Elasmobranchs	Hemiscylliidae	*C. griseum*	Mushi	0.06
			Teleostei		
1	Sea breams	Sparidae	*Acanthopagrus arabicus*	Kalikishi	0.06
2	Carangids	Carangidae	*Alepes djedaba*	Kakari bangada	0.37
3	Carangids	Carangidae	*A. kleinii*	Kala bangada	0.24
4	Carangids	Carangidae	*Megalaspis cordyla*	kati bangada	0.16
5	Carangids	Carangidae	*Scomberoides lysan*	Dagol	0.13
6	Carangids	Carangidae	*S. commersonnianus*	Dagol	0.13
7	Carangids	Carangidae	*S. tala*	Dagol	0.14
8	Carangids	Carangidae	*Atropus atropos*	Kat Bangada	0.13
9	Carangids	Carangidae	*Atule mate*		0.14
10	Carangids	Carangidae	*Parastromateus niger*	Halwa	0.19
11	Clupeids	Clupeidae	*Anodontostoma chacunda*		0.24
12	Clupeids	Clupeidae	*Escualosa thoracata*	Bhiljee	1.16
13	Clupeids	Clupeidae	*Sardinella longiceps*	Tarli	0.26
14	Clupeids	Clupeidae	*S. albella*	Tarli	0.02
15	Clupeids	Clupeidae	*S. fimbriata*	Pedwa	0.07
16	Clupeids	Clupeidae	*S. gibbosa*	Tarli	0.09

Table 1 continued...

Table 1 continued...

17	Clupeids	Clupeidae	*Tenualosa toli*	Tarli	0.28
18	Clupeids	Clupeidae	*Nematolosa nasus*	Kati	0.03
19	Clupeids	Pristigasteridae	*Pellona ditchela*	Kati	0.69
20	Clupeids	Pristigasteridae	*Opisthopterus tardoore*	Kati	0.31
21	Clupeids	Pristigasteridae	*Ilisha filigera*	Kati	0.43
22	Clupeids	Dussumieriidae	*Dussumieria acuta*	Kati	0.02
23	Wolf herrings	Chirocentridae	*Chirocentrus dorab*	Karli	0.20
24	Coilia	Engraulidae	*Coilia dussumieri*	Mandeli	5.27
25	Other anchovies	Engraulidae	*Stolephorus commersonnii*	Dindus	0.26
26	Other anchovies	Engraulidae	*S. indicus*	Dindus	0.37
27	Other anchovies	Engraulidae	*Thryssa dayi*	Kati	0.19
28	Other anchovies	Engraulidae	*T. dussumieri*	Kati	0.11
29	Other anchovies	Engraulidae	*T. mystax*	Kati	0.82
30	Other anchovies	Engraulidae	*T. setirostris*	Kati	0.11
31	Other anchovies	Engraulidae	*T. hamiltonii*	Kati	1.07
32	Other anchovies	Engraulidae	*T. malabarica*	Kati	0.12
33	Pomfrets	Stromatidae	*Pampus argenteus*	Saranga	1.15
34	Pomfrets	Stromatidae	*P. chinensis*	Kalwad	0.38
35	Bombay duck	Synodontidae	*Harpadon nehereus*	Bombil	19.16
36	Goatfishes	Mullidae	*Upeneus supravittatus*	Chiri	0.01
37	Catfishs	Ariidae	*Arius maculatus*	Shingala	0.69
38	Catfishs	Ariidae	*Arius jella*	Shingala	0.15
39	Catfishs	Ariidae	*Nemapteryx caelata*	Shingala	0.32
40	Catfishs	Ariidae	*Plicofollis tenuispinis*	Shingala	0.48
41	Catfishs	Ariidae	*P. dussumieri*	Shingala	0.40
42	Catfishs	Ariidae	*Osteogeneiosus militaris*	Shingala	0.04
43	Catfishs	Plotosidae	*Plotosus lineatus*	Shingala	0.06
44	Catfish	Bagridae	*Mystus* sp.	Shingada	0.06
45	Gobies	Gobiidae	*Boleophthalmus boddarti*	Newti	0.10
46	Gobies	Gobiidae	*B. dussumieri*	Newti	0.11
47	Gobies	Gobiidae	*Glossogobius giuris*	Newti	0.12
48	Gobies	Gobiidae	*Trypauchen vagina*	Newti	0.60
49	Gobies	Gobiidae	*Odontamblyopus roseus*	Newti	0.16
50	Gobies	Gobiidae	*Parachaeturichthys polynema*	Newti	0.04
51	Gobies	Gobiidae	*Periopthalamus sp*	Newti	0.08
52	Eels	Muraenidae	*Congresox talabonoides*	Wam	0.37
53	Eels	Muraenidae	*Muraenesox cinereus*	Wam	0.27
54	Eels	Ophichthidae	*Pisodonophis boro*	Wam	0.06
55	Polynemids	Polynemidae	*Eleutheronema tetradactylum*	Rawas	0.48
56	Polynemids	Polynemidae	*Leptomelanosoma indicum*	Dara	0.15
57	Polynemids	Polynemidae	*Polydactylus mullani*	Rawas	0.41
58	Groupers	Serranidae	*Epinephelus diacanthus*	Hekru	0.14
59	Ribbonfishes	Trichiuridae	*Eupleurogrammus muticus*	Piti	1.04
60	Ribbonfishes	Trichiuridae	*E. glossodon*	Wagti	0.01
61	Ribbonfishes	Trichiuridae	*Lepturacanthus savala*	Wagti	2.31
62	Ribbonfishes	Trichiuridae	*Trichiurus lepturus*	Wagti	0.61
63	Silver biddies	Gerreidae	*Gerres filamentosus*	Shetak	0.06
64	Ponyfishes	Leiognathidae	*Leiognathus daura*	Kap	0.37
65	Ponyfishes	Leiognathidae	*Nuchequula blochii*	Kap	0.40
66	Ponyfishes	Leiognathidae	*Secutor insidiator*	Kap	0.31
67	Ponyfishes	Leiognathidae	*S. interruptus*	Kap	0.28
68	Ponyfishes	Leiognathidae	*Gazza minuta*	Kap	0.48
69	Barracudas	Sphyraenidae	*Sphyraena* spp.	Badvi	0.12
70	Croakers	Sciaenidae	*Johnius belangerii*	Dhoma	0.63
71	Croakers	Sciaenidae	*J. amblycephalus*	Dhoma	0.02
72	Croakers	Sciaenidae	*J. glaucus*	Dhoma	0.61
73	Croakers	Sciaenidae	*J. macrorhynus*	Dhoma	0.07
74	Croakers	Sciaenidae	*J. dussumieri*	Dhoma	0.06

Table 1 continued...

Table 1 continued...

75	Croakers	Sciaenidae	*J. borneensis*	Dhoma	1.02
76	Croakers	Sciaenidae	*J. macropterus*	Dhoma	0.03
77	Croakers	Sciaenidae	*Otolithes ruber*	Dhoma	0.10
78	Croakers	Sciaenidae	*Protonibea diacanthus*	Ghol	0.24
79	Croakers	Sciaenidae	*Otolithoides biauritus*	Koth	0.50
80	Croakers	Sciaenidae	*Pseudotolithus elongatus*	Dhoma	0.04
81	Croakers	Sciaenidae	*Dendrophysa russelii*	Teli bangada	0.07
82	Croakers	Sciaenidae	*Otolithes cuvieri*	Dhoma	0.26
83	Croakers	Sciaenidae	*Pennahia anea*	Dhoma	0.06
84	Pufferfishes	Tetraodontidae	*Lagocephalus guentheri*	Kend	0.07
85	Pufferfishes	Tetraodontidae	*L. inermis*	Kend	0.05
86	Pufferfishes	Tetraodontidae	*L. spadiceus*	Kend	0.86
87	Pufferfishes	Tetraodontidae	*L. lunaris*	Kend	0.10
88	Pufferfishes	Tetraodontidae	*Takifugu oblongus*	Kend	0.00
89	Snappers	Lutjanidae	*Lutjanus johnii*	Chavri Tamb	0.11
90	Thread fins	Nemipteridae	*Nemipterus japonicus*	Rani / Chiri	0.09
91	Mullets	Mugilidae	*Mugil cephalus*	Boita / Boi	0.20
92	Mullets	Mugilidae	*Planiliza subviridis*	Boi	0.17
93	Mullets	Mugilidae	*Valamugil* sp.	Boi	0.14
94	Flatfishes	Psettodidae	*Psettodes erumei*	Zhipali	0.05
95	Flatfishes	Soleidae	*Brachirus orientalis*	Lep	0.05
96	Flatfishes	Cynoglossidae	*Cynoglossus arel*	Lep	0.25
97	Flatfishes	Cynoglossidae	*Cynoglossus macrostomus*	Lep	0.19
98	Scats	Scatophagidae	*Scatophagus argus*	Keski	0.24
99	Sand whiting	Sillaginidae	*Sillago sihama*	Mudadi	0.05
100	Tiger perch	Terapontidae	*Terapon jarbua*	Naveri	0.08
101	Tiger perch	Terapontidae	*T. theraps*	Dada	0.00
102	Tiger perch	Terapontidae	*T. puta*	Naveri	0.03
103	Toadfish	Batrachoididae	*Colletteichthys dussumieri*		0.07
104	Unicorn cod	Bregmacerotidae	*Bregmaceros mcclellandi*	Tendli / Khada	0.51
105	Mackerel	Scombridae	*Rastrelliger kanagurta*	Bangada	0.19
106	Seer fish	Scombridae	*Scomberomorus guttatus*	Surmai	0.27
107	Seer fish	Scombridae	*S. commerson*	Surmai	0.28
108	Lactarius	Lactariidae	*Lactarius lactarius*	Saundala	0.01
109	Grunts	Haemulidae	*Pomadasys maculatus*	Karkara	0.02
110	Glassfish	Ambassidae	*Ambassis ambassis*	Kachak	0.18
111	Tripodfishes	Tricanthidae	*Triacanthus biaculeatus*		0.00
112	Cardinal fishes	Apogonidae	*Ostorhinchus fasciatus*	Kachak	0.00
113	Cardinal fishes	Apogonidae	*Apogon* sp.	Kachak	0.06
114	Flatheads	Platycephalidae	*Platycephalus* sp.		0.03
			Sea snake		
1	Sea snakes	Elapidae	*Enhydrina schistosa*	Samudri saap	0.35
2	Sea snakes	Acrochordidae	*Acrochordus granulatus*	Samudri saap	0.12
			Jellyfishes		
1	Jellyfishes	Chiropsalmidae	*Chiropsoides buitendijki*	Jelly	1.31
2	Jellyfishes	Pelagiidae	*Chrysaora* spp.	Jelly	3.98

Temporal variations in catch composition and environmental variables

The recorded species were classified into different resource groups to understand their spatio-temporal variations. F-test proved that significant temporal variations exist in the catch of major resources in bagnets. *H. nehereus, C. dussumieri*, clupeids, catfishes, pomfrets and mullets were abundant in the catch during SM, whereas *Acetes* spp., *N. tenuipes*, anchovies, unicorn cod and flatfishes were abundant during WM. The peak season for penaeids, cephalopods, eels, elasmobranchs and polynemids was FI, while ribbon fishes, sciaenids, crabs and carangids were found to be abundant during SI (Table 2).

Environmental variables are considered as the key factors to determine the composition, distribution,

Table 2 : Temporal variations in percentage composition of major resources.

	FI	SI	SM	WM	P value
Bombay duck	$21.44^{b}±1.54$	$18.99^{b}±2.27$	$33.77^{c}±1$	$1.65^{a}±0.66$	0.001
***Acetes* spp.**	$12.31^{a}±2.85$	$8.02^{a}±0.84$	$7.76^{a}±0.79$	$27.27^{b}±0.57$	0.001
***Coilia* sp.**	$4.83^{b}±0.16$	$3.76^{ab}±0.29$	$9.36^{c}±0.34$	$3.14^{a}±0.21$	0.001
Other non-penaeids	$4.12^{a}±0.68$	$6.38^{a}±1.13$	$2.83^{a}±0.39$	$21.58^{b}±1.67$	0.001
Penaeids	$10.91^{b}±0.38$	$5.51^{a}±0.41$	$3.90^{a}±1.52$	$4.14^{a}±1.11$	0.01
Ribbon fishes	$1.77^{a}±0.13$	$11.32^{b}±1.16$	$1.10^{a}±0.21$	$1.52^{a}±0.39$	0.001
Sciaenids	$1.75^{a}±0.47$	$8.67^{b}±0.64$	$1.84^{a}±0.30$	$2.03^{a}±0.35$	0.001
Clupeids	$2.42^{a}±0.19$	$3.23^{b}±0.29$	$6.10^{c}±0.09$	$2.36^{a}±0.10$	0.001
Anchovies	$1.14^{a}±0.14$	$2.72^{b}±0.11$	$3.05^{b}±0.46$	$5.95^{c}±0.36$	0.001
Crabs	$1.03^{a}±0.38$	$5.87^{b}±1.31$	$1.77^{a}±0.75$	$2.72^{ab}±0.51$	0.01
Catfishes	$0.99^{a}±0.07$	$1.43^{a}±0.28$	$4.58^{b}±0.51$	$1.39^{a}±0.29$	0.001
Unicorn cod	$0.30^{ab}±0.07$	$0.76^{b}±0.21$	$0.05^{a}±0.02$	$4.57^{c}±0.17$	0.001
Pomfrets	$1.46^{ab}±0.45$	$1.46^{ab}±0.20$	$2.56^{b}±0.67$	$0.62^{a}±0.40$	0.07
Carangids	$0.76^{a}±0.10$	$5.02^{b}±0.45$	$0.16^{a}±0.06$	$0.94^{a}±0.32$	0.001
Cephalopods	$2.30^{b}±0.32$	$0.72^{a}±0.26$	$0.11^{a}±0.07$	$1.16^{ab}±0.38$	0.001
Eels	$1.67^{b}±0.42$	$0.61^{ab}±0.19$	$0.21^{a}±0.12$	$0.35^{a}±0.22$	0.01
Elasmobranchs	1.76±0.98	0.81±0.49	0.35±0.31	0.38±0.16	0.32
Flatfishes	$0.04^{a}±0.02$	$0.31^{a}±0.14$	$0.27^{a}±0.15$	$2.20^{b}±0.26$	0.001
Mullets	$0.020^{a}±0.02$	$0.11^{a}±0.10$	$1.21^{b}±0.42$	$0.22^{a}±0.13$	0.01
Polynemids	$2.53^{b}±0.42$	$0.83^{a}±0.12$	$0.57^{a}±0.06$	$0.25^{a}±0.06$	0.001
Ponyfishes	$2.12^{ab}±0.13$	$1.50^{a}±0.45$	$3.13^{b}±0.51$	$1.03^{a}±0.32$	0.01
Seerfishes	0.93±0.43	0.27±0.12	0.46±0.16	0.53±0.20	0.37
Gobies	$1.20^{a}±0.32$	$2.30^{b}±0.34$	$0.65^{a}±0.09$	$0.72^{a}±0.11$	0.01
Pufferfishes	$0.48^{a}±0.37$	$2.35^{b}±0.50$	$0.55^{a}±0.32$	$0.63^{a}±0.20$	0.01
Sea snakes	$0.30^{a}±0.14$	$0.06^{a}±0.06$	$0.02^{a}±0.02$	$1.51^{b}±0.45$	0.06
Stomatopods	$1.37^{ab}±0.53$	$1.66^{b}±0.12$	$0.30^{a}±0.23$	$1.02^{ab}±0.25$	0.05
Jellyfishes	$14.73^{c}±0.64$	$0.78^{a}±0.39$	0	$5.17^{b}±0.30$	0.001
Total catch (kg/haul)	$50.94^{ab}±6.89$	$39.55^{ab}±6.47$	$61.02^{b}±4.87$	$32.75^{a}±4.57$	0.001

Data are expressed as Mean±SE. Mean values bearing different superscripts in the same row differ significantly (Post hoc grouping by Tukeys HSD, P<0.05)

Table 3 : Temporal variations in environmental parameters.

	FI	SI	SM	WM	P value
Temperature (°C)	$27.89^{b}±0.14$	$30.54^{c}±0.39$	$26.32^{a}±0.31$	$27.13^{ab}±0.11$	0.001
Salinity (‰)	$28.94^{b}±0.26$	$33.48^{c}±0.50$	$26.19^{a}±0.69$	$31.68^{c}±0.43$	0.001
pH	$7.720^{b}±0.04$	$8.21^{d}±0.04$	$7.47^{a}±0.05$	$7.92^{c}±0.03$	0.001
DO (mg L^{-1})	$5.06^{ab}±0.28$	$4.23^{a}±0.12$	$5.86^{b}±0.15$	$5.44^{b}±0.30$	0.002
BOD (mg L^{-1})	$2.29^{b}±0.06$	$2.94^{c}±0.15$	$1.79^{a}±0.11$	$2.65^{bc}±0.13$	0.001
Current speed (cm s^{-1})	$119.03^{b}±8.30$	$88.59^{a}±2.33$	$139.43^{b}±9.06$	$75.58^{a}±2.20$	0.001
Turbidity (mg L^{-1})	$56.81^{bc}±4.36$	$37.34^{a}±3.58$	$71.17^{c}±6.19$	$46.87^{ab}±3.71$	0.01
TSS (mg L^{-1})	$75.83^{a}±6.54$	$57.11^{a}±7.07$	$127.10^{b}±14.68$	$64.54^{a}±4.25$	0.001
Chlorophyll-a(mg m^{-3})	$4.23^{ab}±0.43$	$3.51^{ab}±0.54$	$2.90^{a}±0.21$	$5.21^{b}±0.47$	0.014
Ammonia-N (µM L^{-1})	$0.65^{ab}±0.10$	$1.86^{b}±0.56$	$0.21^{a}±0.06$	$0.61^{a}±0.12$	0.01
Silicate (µM L^{-1})	$13.13^{b}±1.76$	$4.74^{a}±0.93$	$7.80^{ab}±1.53$	$5.05^{a}±0.86$	0.03
Reactive Phosphorus(µM L^{-1})	$3.46^{b}±0.92$	$1.93^{a}±0.67$	$1.33^{a}±0.18$	$4.32^{b}±0.94$	0.05
Nitrate -N (µM L^{-1})	$13.95^{ab}±2.20$	$9.39^{ab}±2.47$	$6.65^{a}±1.54$	$19.39^{b}±3.25$	0.01
Nitrite-N (µM L^{-1})	$1.48^{b}±0.28$	$0.78^{ab}±0.15$	$0.43^{a}±0.06$	$2.19^{c}±0.10$	0.001
PD (*1000)	$165.26^{ab}±21.68$	$121.70^{a}±30.23$	$120.22^{a}±31.40$	$288.19^{b}±51.91$	0.004
ZD (*1000)	$2.78^{b}±0.30$	$1.38^{a}±0.13$	$1.05^{a}±0.12$	$2.05^{ab}±0.36$	0.02

PD- phytoplankton density, ZD- zooplankton density, Data are expressed as Mean±SE. Mean values bearing different superscripts in the same row differ significantly (Post hoc grouping by Tukey's HSD, P<0.05)

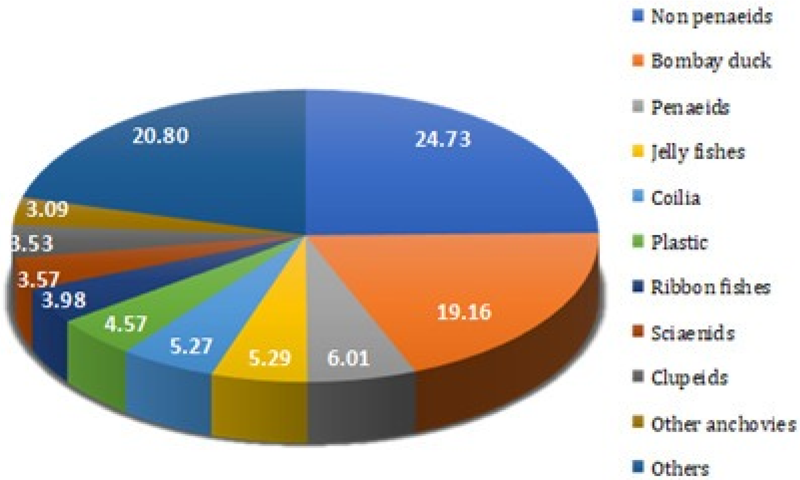

Fig. 3 : Overall annual composition of catch in stationary bagnets (%).

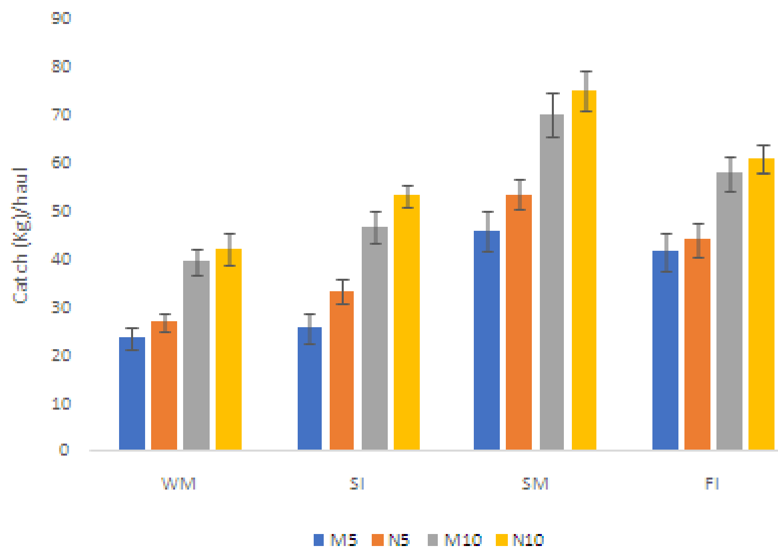

Fig. 4 : Spatiotemporal variations in the catch rate of bagnet.

assemblage and abundance of fish species in an aquatic environment (Whitfield and Elliot, 2002; Mansor *et al*, 2012). The variability in environmental factors has a profound impact on the spatial and seasonal variations in fish community structure (Kawasaki, 1991). Significant temporal variations were also observed for all the Environmental variables studied. Temperature, salinity, pH, BOD and ammonia were found to be high during SI whereas DO, current speed, turbidity and TSS were observed to be high during SM. Silicate content and zooplankton density were observed at higher levels during FI, while chlorophyll-a, phosphate, nitrate, nitrite and phytoplankton density were high during WM (Table 3). As mentioned by Shirodkar *et al* (2012), catch at different seasons are influenced by fluctuations in environmental parameters. The seasonal changes observed in the catch composition could also due to the seasonal migrations of species for breeding, larval development and feeding (Gaughan and Potter, 1994; Ansari *et al*, 1995).

Fish assemblages and interactions

The results of cluster analysis, ANOSIM and SIMPER established significant difference in catch composition among the seasons. Cluster analysis revealed the spatio-temporal patterns in fish assemblage and divided the fish assemblages into 2 major clusters (Fig. 5). The major clusters formed portrays high similarity of catch composition within the clusters and dissimilarity between the clusters. It can be inferred that the catch composition of WM varied substantially from other 3 seasons. Among the other 3 seasons the catch composition of SI varied considerably from SM and FI with almost similar catch composition during SM and FI. The pattern observed was same for all the stations. During SM and FI period, the environmental factor depicted almost similar values compared to other seasons. This may be the reason for the clustering of SM and FI in terms of catch composition. WM has formed into a distinctly separate cluster due to the variations in fish abundance. Current

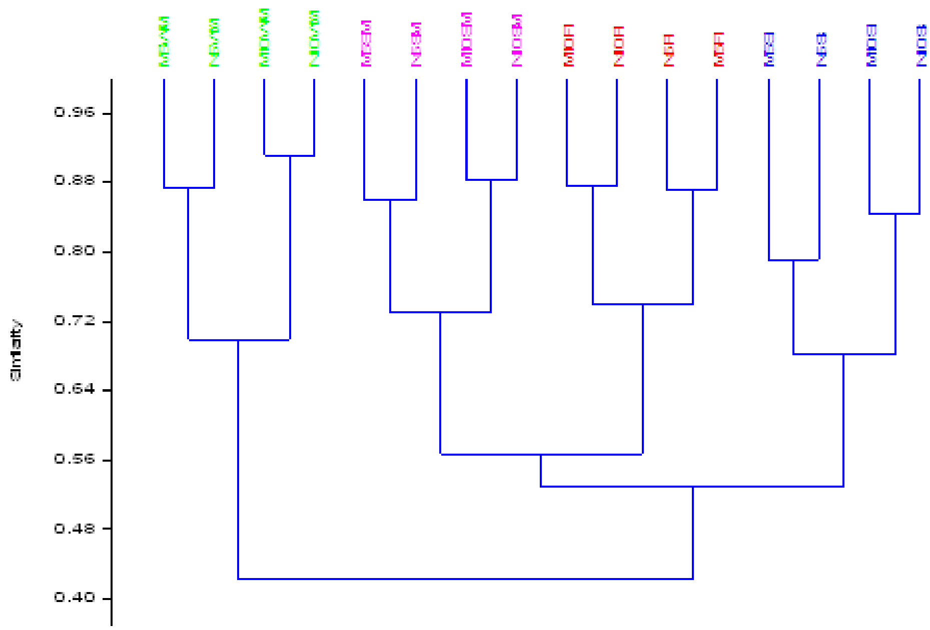

Fig. 5 : Spatial and temporal clustering of fish assemblage based on Bray–Curtis similarity matrix.

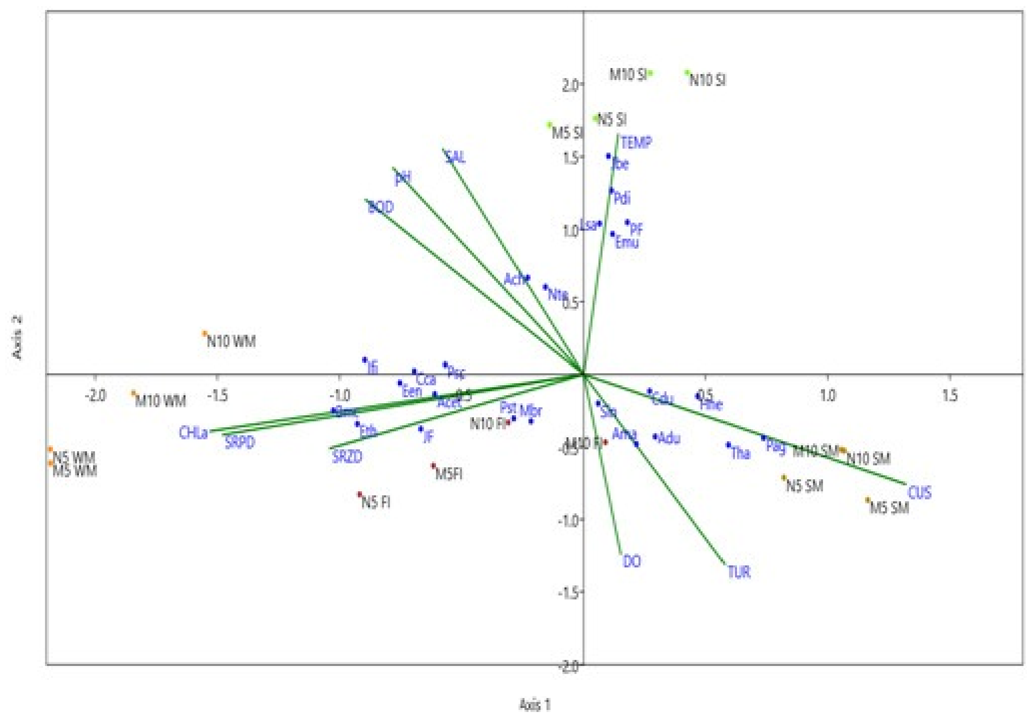

Fig. 6 : CCA biplot for major fish species and physico-chemical parameters (Abbreviations are given in Table 6).

speed might have exerted great influence on the separation of WM catch composition from the other seasons. ANOSIM analysis showed that the maximum difference in assemblage structure was observed between WM and SI as well as between WM and SM (Table 4).

SIMPER analysis disclosed that the major contributory species for temporal variations are *H. nehereus*, *Chrysaora* sp., *Acetes* spp., *N. tenuipes, C. dussumieri, L. savala, E. thoracata* and *T. hamiltoni.* Based on SIMPER analysis, about 62.12% and 44.5% overall average dissimilarity were found among the seasons and stations, respectively. The species contributing maximum with average percentage dissimilarity among the seasons and stations are shown in Table 5.

Canonical correspondence analysis (CCA) was carried out to determine the temporal variability of dominant species in bagnet and the major influencing environmental factor on it (Fig. 6). The canonical coefficients of environmental variables and fish groups

Table 4 : R values obtained for seasons using one-way ANOSIM.

Group/Group	FI	SI	SM	WM
FI				
SI	0.91			
SM	0.95	0.86		
WM	0.99	1	1	

The values indicate a significant difference between the clusters (R values >0.6)

Table 5 : Discriminating contribution of major groups (≥ 1%) through SIMPER analysis in stations and seasons.

Stations (43.5%)	Average dissimilarity	Seasons (62.12%)
Contributing %	Major contributing fishes	Contributing %
10.42	*Harpadon nehereus*	16.19
3.54	*Chrysaora* sp	5.45
3.86	*Acetes* spp.	4.41
3.32	*Nematopalaemon tenuipes*	3.93
2.35	*Coilia dussumieri*	2.83
1.98	*Lepturacanthus savala*	2.38
1.41	*Escualosa thoracata*	2.30
1.21	*Thryssa hamiltoni*	1.62
1.16	*Parapenaeopsis sculptures*	1.57
1.03	*Arius maculatus*	1.32
1.12	*Charybdis callianassa*	1.17
1.05	*Pampus argenteus*	1.16
0.99	*Johnieops vogleri*	1.02
0.97	*Lagocephalus spadiceus*	1.01

with the first two axes of CCA are given in Table 6. The results of CCA reveal that the seasonal variations in environmental factors are the major influencing factors for the distribution and abundance of phytoplankton. The diagnostic species group identified through CCA for WM and FI are *Bregmaceros maclellandi, Escuolosatho racata,* jelly fishes, *Acetes* spp., *Nematopaleomon tenuipes* (Nte), *Exhipholysmata ensirostris, Ilisha filigera, Parapenaeopsiss tylifera, Metapenaeus brevicornis* and *Parapenaopsiss culptilis*. The season of abundance of these species coincided with the season of plankton abundance (WM and FI). Most of this species are reported as planktivorous by researchers: *Bregmaceros maclellandi* (Kaviarasu *et al*, 2016; Bianchi, 1985), *Escuolosat horacata* (Raje *et al*, 1994; Gurjar *et al*, 2017), jelly fishes (Purcell *et al*, 1999), *Acetes* spp (Chiou *et al*, 2005), *Nematopaleomon tenuipes* (Deshmukh, 1988), *Ilishafiligera* (Blaber, 1998; Meenakshisundaram and Marathe, 1962). George (1974), Kulkani *et al* (1999) and Deshmukh *et al* (2006) reported that *Acetes* spp., zooplankton, phytoplankton and detritus forms the major food item of penaeid prawns. This could be the reason for positive correlation of species in the group with phytoplankton and zooplankton densities. From the synchronised abundance observed for this group of fishes with abundance of zooplankton and phytoplankton during WM and FI period, it can be inferred that food preference is a major factor influencing their distribution and abundance.

Table 6 : Canonical coefficients of environmental variables and major fish species with the first two axes of CCA.

CCA 1 (Major species)	Axis1 (39.91%)	Axis2 (27.78%)	CCA 1 (Major species)	Axis1	Axis2
Arius dussumieri (Adu)	0.29	-0.43	*Pampus argenteus* (Pag)	0.74	-0.44
Bregmaceros mcclellandi (Bmc)	-1.03	-0.25	*Charybdis callianasa* (Cca)	-0.69	0.02
Harpadon nehereus (Hne)	0.47	-0.15	*Exhippolysmata ensirostris* (Een)	-0.75	-0.06
Coilia dussumierii (Cdu)	0.27	-0.11	*Nematopalaemon tenuipes* (Nte)	-0.16	0.60
Arius maculatus (Ama)	0.22	-0.48	*Secutor insidiator* (Sin)	0.06	-0.20
Escualosa thoracata (Eth)	-0.93	-0.34	Jellyfish (JF)	-0.67	-0.37
Ilisha filifera (Ifi)	-0.90	0.10	Temperature (TEMP)	0.08	**0.92**
Johnius belangerii (Jbe)	0.10	1.51	pH	-0.43	**0.79**
Metapenaeus brevicornis (Mbr)	-0.22	-0.32	Salinity (SAL)	-0.32	**0.86**
Lepteuracanthus savala (Lsa)	0.07	1.04	DO	0.08	**-0.69**
Acetes sp.(Acet)	-0.61	-0.14	BOD	-0.50	0.67
Parapenaeopsis sculptilis (Psc)	-0.57	0.07	Current Speed (CUS)	**0.73**	-0.42
Parapenaeopsis stylifera (Pst)	-0.29	-0.30	Turbidity (TUR)	0.32	**-0.73**
Pellona ditchela (Pdi)	0.11	1.27	Chlorophyll a (CHLa)	**-0.85**	-0.22
Anodontostoma chacunda (Ach)	-0.23	0.67	Phytoplankton density (SRPD)	**-0.82**	-0.23
Thryssa hamiltonii (Tha)	0.59	-0.49	Zooplankton density (SRZD)	**-0.58**	-0.28

The coefficients of variables with bold values indicate significant loadings in canonical axes (values loaded in axes will be more than 0.45 (absolute value) in that and less than 0.4 (absolute value) in the other axes.

The diagnostic species for SI identified through CCA are *Lepturocanthus savala*, *Johniops vogleri*, *Johniops belangeri* and *Eupleurogramus muticus*. CCA indicated that this group of species are more influenced by temperature and salinity. It is reported that ribbonfishes and sciaenids prefer warm coastal waters (Shoba *et al*, 2014; Bhat *et al*, 2014). This could be the reason for positive correlation of ribbon fish and sciaenids with temperature. Ribbonfishes and sciaenids are marine migrants which does not prefer lower salinities (Elliott, 1998). This could be the reason for the positive correlation of ribbonfishes and sciaenids with salinity.

The diaganostic group identified for SM through CCA includes *Harpodon nehereus*, *Coilia dussumieri*, *Pampus argentius*, *Arius dussumieri*, *Arius maculatus* and *Secutor incidiator* and they correlated with current speed and turbidity. *Harpodon nehereus*, *Coilia dussumieri*, *Pampus argentius* (juveniles) and *Secutori ncidiator* are week swimmers and that attributed to the positive correlation with current speed. Schulz *et al* (2006) reported that catfishes are tactile hunters and turbidity is an important factor determining their abundance. Decreased light penetration and increase in turbidity might have altered the feeding environment to benefit non-visual predators over visual feeders (Schulz *et al*, 2006). It is speculated that abundance of catfishes in turbid waters may be due to well developed tactile senses, enabling them to feed in the turbid waters.

The results of CCA showed that the environmental variables current speed, temperature, salinity,turbidity, chlorophyll-a and plankton densities played a significant role in structuring the catch composition during the different seasons and the major parameter responsible for variations in catch rate was current speed. Even though the results from the present study of limited sampling stations and sampling period may not be sufficient to have comprehensive prediction of environmental influence on the fishery, indications received from the study will provide a guidance for the future research on these lines and will help policy makers to frame a policy for sustainable fisheries management in the region. The study also provides baseline data to work out an ecosystem-based fishery management framework along the region.

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