



Comparative assessment of fish assemblages around open sea cages *vis-a-vis* common fishing ground

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Sea farm cages attract a range of wild fish species by providing shelter and food. The fish aggregation study was carried out around the open sea cages deployed at (9°20'03.95"N; 79°19'53.05"E) Olaikuda, Rameshwaram. A total of 2515 fish representing 51 species from 26 families and 9 orders were recorded by Underwater Visual Census (UVC) method from both sea-cage farm and control site. The genus *Siganus* was very common in both the cage and the control site and recorded in each sampling. The fish abundance distribution depicted a similar pattern to that of the cluster analysis when subjected to 2D NMDS ordinations and showed a distinct cluster pattern for the cage site. The Shannon Wiener diversity indices illustrated high abundance (224) and richness (7.33) at the cage site compared to the control site (common fishing ground). There was a significant temporal variation ($F = 8.9$, $p < 0.05$) in the abundance of fish between the cage and the control site. In general, the congregation, density, and diversity of aggregated fish were much higher around sea cages than control site. This study reports the number of fish species in the vicinity of the cage system and the reasons for the congregation of fishes below the cage system was discussed in detail.

Keywords. Open sea cages; fish aggregation; underwater visual census; fish diversity.

1. Introduction

The association of fish in different developmental stages, with floating objects, has been widely documented (Freon and Dagorn 2000). Interestingly, floating structures attract comparatively more fishes than natural underwater structures (Sanchez-Jerez and Ramos-Espla 2000). Traditionally fishermen use floating palm leaves and other similar floating objects to attract fishes to enhance their catches globally. Based on the traditional

concept, high-performing Fish Aggregating Devices (FAD) are developed to enhance the capture fisheries (Massuti *et al.* 1999). Floating and anchoring structures of open sea cage fish farms congregate large numbers of fish species of economic importance. Fishes aggregate for food in the form of unconsumed feed fall from the cages, fish excreta, and edible bio-foulant around cages which provide more feeding opportunities for the wild fishes in the surrounding vicinity. Though open sea cage culture practices increase production, its

impact on various aspects of marine ecology are extensively studied (Naylor *et al.* 2000). Further, fish aggregation studies around open sea fish farms also drawn high attention as this influences diversity, density, diet, feeding behaviour, and change of habitat of wild fishes inhabited around fish farms (Carss 1990). Fish aggregation around sea cages is well documented in various locations in European countries (Boyra *et al.* 2002; Dempster *et al.* 2002; Thetmeyer *et al.* 2003; Tuya *et al.* 2005). Though there is an increasing trend in open sea cage culture practices in tropical countries (Jha *et al.* 2017), fish aggregation studies are very sparse than temperate conditions (Bjorn *et al.* 2001). It is well documented that pelagic fishes aggregate around floating bodies and offshore positioned fish farms (Castro *et al.* 2002). The present study aimed to describe the aggregation of bottom-dwelling fishes below open sea fish farms, and compare the assemblage pattern of the wild fish population at culture and control site (i.e., common fishing ground) through a multivariate statistical approach.

2. Materials and methods

The fish aggregation study was carried out around the open fish farms (4 numbers of 9-m diameter cage) deployed at depth of 7 m ($9^{\circ}20'03.95''\text{N}$; $79^{\circ}19'53.05''\text{E}$) about 1 km off Olaikuda, Rameshwaram, Tamil Nadu, India (figure 1). The cages were positioned in the site with a multipoint mooring system (Santhanakumar *et al.* 2017). The

cage site dimension is $40 \times 40 \times 7$ m ($l \times b \times h$) including the subsurface cage mooring grid. The study was conducted during the culture of cobia (*Rachycentron canadum*) stocked at a production density of 12 kg/m^3 . The fishes cultured in a cage were fed with a fish meal based formulated slow sinking feed (40% protein) with the feeding rate of 10 to 3% of total biomass inside the cage from nursery to harvest stage, respectively.

During the underwater study, it was observed that majority of the fishes assembled vertically (surface to bottom) around the cage. Hence, it was planned to study the fish assemblage by placing stripe transects vertically on the surface of the fish cage nets. Vertical line strip transect placed on the outside of the four cage system covering a total transect length of 135 m. The same length of strip transect was placed horizontally on the common fishing ground (control) which is located 2 km away from the cage site. To study the pattern of the fish abundance, the underwater visual census (UVC) method was followed (Dempster *et al.* 2002). UVC was carried out and the various species of fishes around the cage site and control site were identified visually by SCUBA diving and underwater video graphs. Monthly sampling of fish assemblage and abundance was carried out from June to October (2017). The study period could not be extended beyond October due to the onset of northeast monsoon which would lead to high turbidity and poor visibility in the study area. At each sampling occasion, three replicates of 135 m length transects were laid by SCUBA diving and recorded 1 m on either side of the transect.

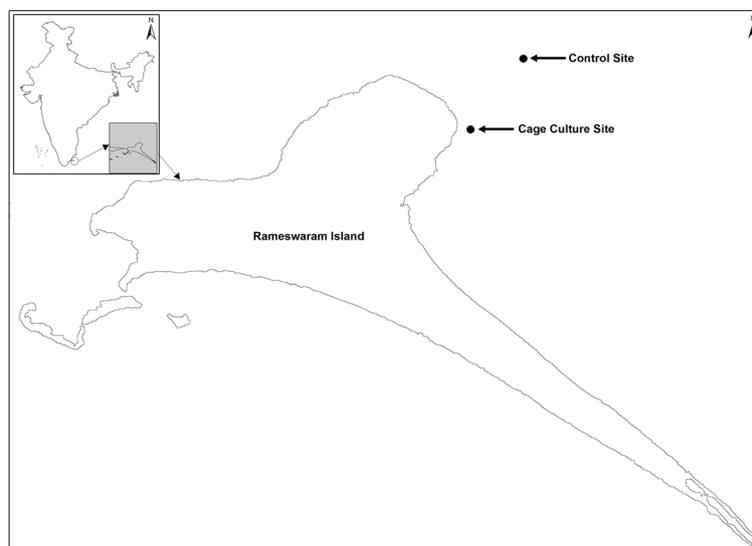


Figure 1. Map showing the cage and control sites at Olaikuda, Rameshwaram, India.

To study the aggregation of bottom-dwelling fishes, we used traditional traps (dimension: $90 \times 60 \times 40$ cm ($l \times b \times h$)) by using formulated pellet fish feed as an attractant. Fish traps were placed in triplicates: (1) below cage system, (2) 40 m away, (3) 60 m away and (4) usual fishing ground (control) (2 km away from the farm site where no farm site influence observed). Traps were placed for 24 h (figure 2). Trapped fishes were quantitatively and qualitatively analyzed in live conditions and released immediately in the sea at the same locations. The mean values were used for statistical analysis and data interpretation. Identification of fishes and taxonomical classification was carried out by following the protocol of Smith and Heemstra (1986) and Nelson (2006). During qualitative analysis, fish species belonging to genera *Liza*, *Strongylura*, *Hippocampus*, *Pterois*, *Beryx*, *Epinephelus*, *Lethrinus*, *Upeneus*, *Mulloidies*, *Apogon*, *Caranx*, *Dipterygnotus*, *Scolopsis*, *Chaetodon*, *Heniochus*, *Abudefduf*, *Coris*, and *Balistoides* were identified following Smith and Heemstra (1986).

2.1 Multivariate and univariate analysis

Fish aggregation data collected through the UVC method from open sea cage culture and control sites were processed and analyzed using non-metric multidimensional scaling (nMDS) (Clarke 1993) to assess differences in community structure among the farms and reference locations. Fish abundance indices were processed following the standard protocol (Clarke and Warwick 1994). Cluster analysis was also applied to understand the similarity matrix between the different fish assemblage data in different months during the study period. All multivariate analyses were carried out using the PRIMER software (Clarke and Warwick 1994).

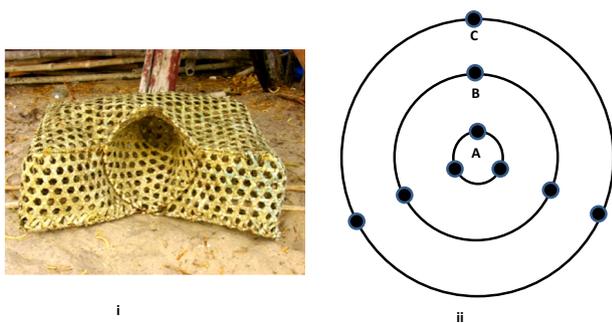


Figure 2. (i) shows the structure of the traditional fish trap used, and (ii) shows the distance of traps placed (A) below the cages (B) 40 m away, and (C) 60 m away from cage.

To examine the significant difference between the farm and control site, a one-way analysis of variance (one-way ANOVA) was applied on the fish abundance data in Microsoft Excel 2007. The mean fish abundance and standard deviation (SD) was also calculated at both sea-cage farms and control site.

3. Results and discussion

In the present study, a total of 2515 fishes, belonging to 51 species and 26 families under nine orders were recorded at sea-cage and control site (fishing ground). Minimum (52 ± 7 individuals) and maximum (224 ± 8 individuals) abundance from the sea-cage site has been recorded. A total of 19 species were recorded in June, whereas 38 species in October (table 1). An increasing trend of the abundance of wild fish was observed in consecutive months of July, August, and September as 90 ± 12.1 , 116 ± 8.3 , and 158 ± 9 individuals, respectively. An increase in species diversity could be directly correlated with an increasing number of individuals in the sea cage site. Further, variation was significant ($F = 35.6$, $p < 0.05$) between the cage site and control (usual fishing ground) in terms of fish abundance in the different months during the study, though negative ecological impacts between aquaculture and wild fish stocks are widely documented (Naylor *et al.* 2000). However, aggregation of wild fishes at fish farms site could be beneficial by increasing the production of local fisheries through spillover of adults (McClanahan and Mangi 2000) and better spawning-stock biomass, which may subsequently magnify larval recruitment in the region (Chiappone and Sullivan 2000). Consumption of the persistent supply of food at farm sites by wild fish may enhance growth, and reduce the eutrophication possibility. Feeding by the wild fish around sea cages may also diminish the amount of food that reaches the sea floor and reduce effects upon the benthos (Katz *et al.* 2002). In contrast, at farms where fishing is permitted, uncontrolled fishing efforts would affect the maximum sustainable yield from farm aggregated wild stock. Though the sea cage site is rich in diversity, the species such as *Echidna* sp., *Hemiramphus* sp., *Hippocampus kuda*, *Epinephelus* sp., *Lutjanus decussates*, *Parupeneus macronema*, *Chaetodon semeion*, *Heniochus singulararius*, *H. pleurotaenia*, and *H. singularius* were not observed at the sea cage site.

Table 1. Abundance (mean \pm SD) of wild fish species at the cage and control sites.

Fish	Cage site Abundance (%)	Control site Abundance (%)
Muraenidae		
<i>Echidna</i> sp.	–	2.86
Mugilidae		
<i>Mugil cephalus</i>	1.93	–
<i>Liza parsia</i>	1.25	–
<i>Liza</i> sp.	0.73	–
Belonidae		
<i>Strongylura</i> sp.	1.41	2.19
<i>Hemiramphus</i> sp.	–	4.38
Holocentridae		
<i>Neoniphon samara</i>	0.52	2.86
Berycidae		
<i>Beryx</i> sp.	2.08	
Syngnathidae		
<i>Hippocampus kuda</i>	–	2.02
Scorpaenidae		
<i>Pterois</i> sp.	0.83	–
Centropmidae		
<i>Psammoperca vigeinsis</i>	0.83	–
Serrandiae		
<i>Epinephelus</i> sp.	–	4.71
Rachycentridae		
<i>Rachycentron canadum</i>	1.30	
Apogonidae		
<i>Apogon</i> sp.	6.51	–
Carangidae		
<i>Caranx ignobilis</i>	1.87	–
<i>Caranx</i> sp.	2.13	–
Lutjanidae		
<i>Lutjanus bohar</i>	5.05	–
<i>Lutjanus biguttatus</i>	2.45	3.87
<i>Lutjanus erhenbergii</i>	3.44	5.56
<i>Lutjanus johnii</i>	2.45	4.55
<i>Lutjanus argentimaculatus</i>	0.68	–
<i>Lutjanus decussatus</i>	–	2.53
<i>Lutjanus bengalensis</i>	–	3.20
Caesionidae		
<i>Caesio</i> sp.	4.42	–
<i>Dipterygonotus</i> sp.	0.78	–
Nemipteridae		
<i>Scolopsis xenochroa</i>	0.88	5.56
<i>Scolopsis</i> sp.	2.39	–
Lethrinidae		
<i>Lethrinus mahsena</i>	1.04	
<i>Lethrinus</i> sp.	0.68	2.69
Mullidae		
<i>Parupeneus macronema</i>	–	3.70
Monodactylidae		
<i>Monodactylus argenteus</i>	6.40	–

Table 1. (Continued.)

Fish	Cage site Abundance (%)	Control site Abundance (%)
Chaetodontidae		
<i>Chaetodon gardineri</i>	1.67	6.23
<i>Chaetodon interruptus</i>	1.04	–
<i>Chaetodon semeion</i>	–	8.08
<i>Chaetodon</i> sp.	3.59	–
<i>Heniochus singularius</i>	–	4.21
<i>Heniochus pleurotaenia</i>	–	4.38
<i>Heniochus</i> sp.	1.20	–
Pomacentridae		
<i>Abudefduf bengalensis</i>	3.54	–
<i>Abudefduf notatus</i>	2.39	–
<i>Abudefduf</i> sp.	5.52	–
<i>Chromis dimidiata</i>	1.46	2.86
Labridae		
<i>Coris</i> sp.	0.52	–
Scaridae		
<i>Scarus ghobban</i>	3.07	5.72
Scatophagidae		
<i>Scatophagus argus</i>	10.57	–
Siganidae		
<i>Siganus argenteus</i>	2.65	3.03
<i>Siganus javus</i>	2.03	6.90
<i>Siganus canaliculatus</i>	2.34	–
<i>Siganus lineatus</i>	3.23	3.70
Acanthuridae		
<i>Paracanthurus hepatus</i>	2.39	4.21
Balistidae		
<i>Balistoides</i> sp.	0.73	–

Note. –: not present.

During the initial phase of culture, a formulated floating nursery feed of 1.5–2.5 mm diameter was provided. During which, bottom detritus feeder such as *Mugil cephalus* and other *Liza* sp. switched over to surface feeding on escaping floating pellet feed from the cage. But its occurrence was insignificant ($p > 0.05$). These studies revealed that the fish diversity associated with the cage culture site is more similar to coral-reef fish communities than to local pelagic communities, despite the considerable distance (2 km) between farms and reefs area. Coral-reef fishes generally have small home ranges and do not migrate more than 100 m from their habitat (Özgül and Angel 2013), however, brackishwater catadromous migrating species such as *M. cephalus* and *L. argentimaculatus* get attracted towards farm sites. There was a significant temporal variation ($F = 8.9, p < 0.05$) in the abundance of fish between the cage and the control site (figure 3). The abundance showed that it was higher in October at the cage site (224 ± 7)

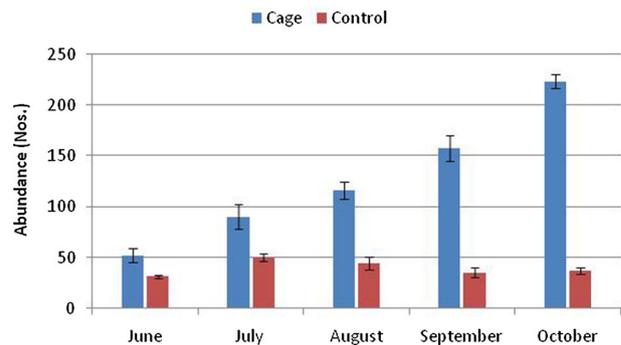


Figure 3. Abundance (mean ± SD) of fish at the cage and control sites.

compared to the control (37 ± 3) site. Monthly fish abundance data were subjected to Bray–Curtis similarity cluster analysis and 2D NMDS ordinations to identify the relationship between cage and control site. A dendrogram using a Bray–Curtis similarity analysis of fish abundance shows that the cage site (48%), is significantly different from the control sites (figure 4a). The fish abundance

distribution depicted a similar pattern to that of the cluster analysis when subjected to 2D NMDS ordinations (figure 4b).

The community characteristics of fishes at cage and control sites as well as their variation at temporal scale are presented in table 2. The number of species at the cage site quadrupled from June to October, whereas at the control site the species number remained the same. Abundance continuously increased from 52 in June to 224 individuals in October at the cage site whereas the control site did not show any trend in the abundance and a maximum (50 individuals) was recorded in July. Species richness was recorded higher at the cage site (except June) compared to the control site. Evenness, however, was higher at the control site due to the low abundance of the fishes.

Shannon–Wiener diversity index was maximum at the cage site during September (4.911), whereas the control site also recorded good diversity showing H' value >4 . Simpson's index of diversity ($1-\lambda$) was maximum at the cage site during September (0.959) and minimum during June (0.923). Overall, except June, the fish community at the cage site showed a higher number of species, abundance, and diversity with time whereas the control site did not show any significant variation over time and remained almost the same.

There was a significant ($F = 35.6, p < 0.05$) variation between the trap placed at the cage site and the usual fishing ground in terms of fish observed in the different months during the study. During the trap study, increment in the abundance has been observed from 54 individuals at the

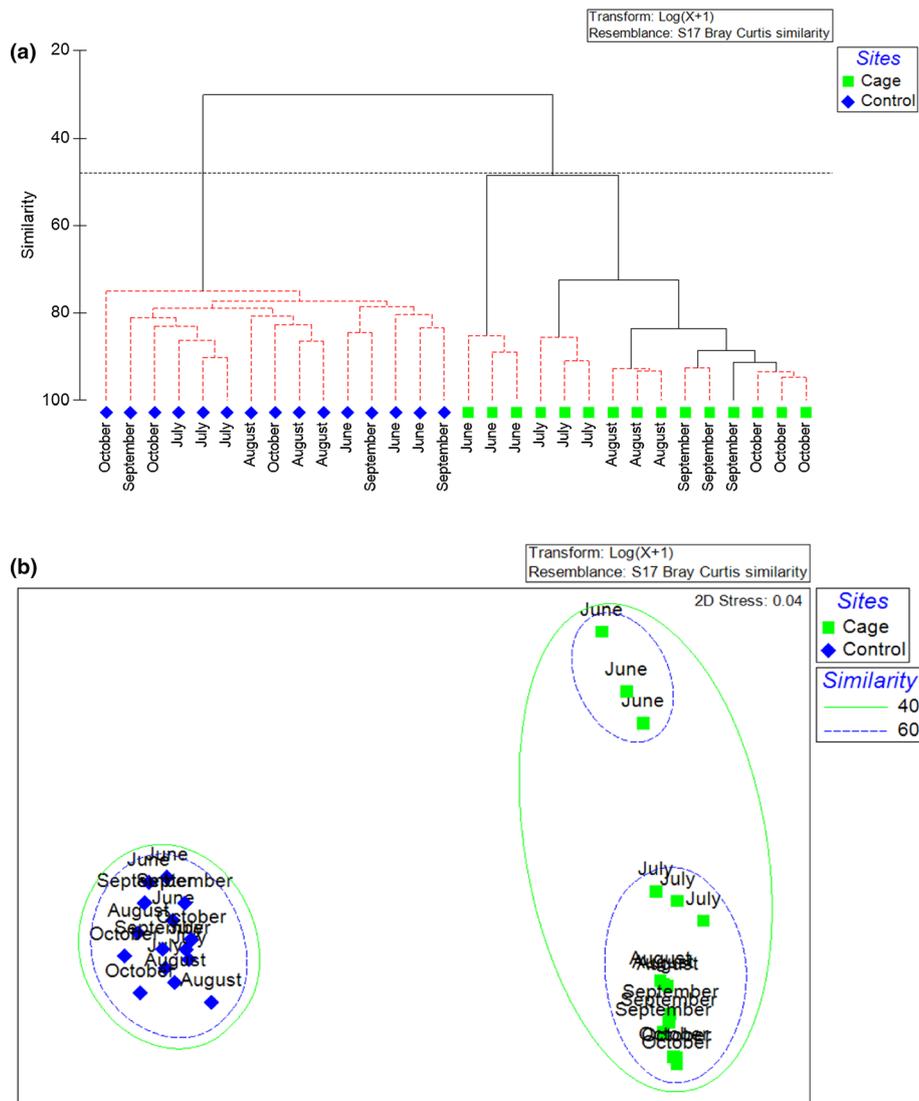


Figure 4. (a) Bray–Curtis cluster analysis for cage and control site. (b) Non-metric multidimensional scaling (nMDS) ordination plot representing for cage and control site.

Table 2. Comparative data on the relative abundance, Shannon–Wiener diversity, evenness and number of species at the cage site and control site.

	Cage site					Control site				
	June	July	Aug.	Sep.	Oct.	June	July	Aug.	Sep.	Oct
No. of species	19	34	35	38	38	24	23	22	24	24
Abundance (ind/transect)	52	90	116	158	224	31	50	44	35	37
Species richness	4.55	7.33	7.15	7.31	6.84	6.68	5.62	5.54	6.47	6.35
Evenness index	0.93	0.94	0.94	0.94	0.92	0.98	0.98	0.96	0.97	0.96
Shannon–Wiener diversity	3.96	4.77	4.81	4.91	4.84	4.51	4.44	4.30	4.46	4.38
Simpson index	0.94	0.97	0.96	0.97	0.96	0.99	0.97	0.97	0.98	0.97

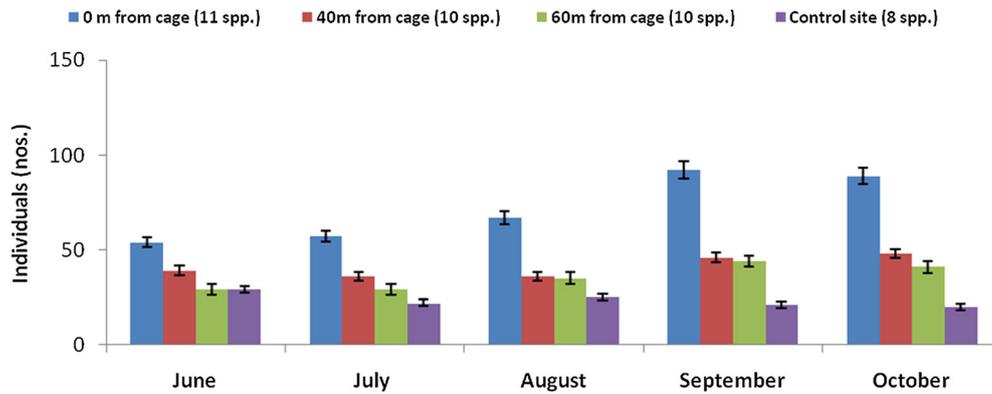


Figure 5. Abundance (mean ± SD) in the trap around cage and control sites.

beginning (June) to 89 individuals in October (figure 5). However, number of species remains constant from beginning to the end. Similarly, abundant data from the trap places at 40 and 60 m from the cage showed an increasing trend which could be attributed to the increasing availability of feed resources in the vicinity of the open sea cage fish farm site due to escaped feeds and fish excreta that fall from the cage system.

In the trap study, increasing abundance has been observed from 54 ± 4.6 individuals comprising 11 species in the initial month of June to 89 ± 4.8 individuals comprising 11 species in the end month of October. The second and third higher abundance and slightly increasing trend were recorded in traps placed 40 and 60 m away from the cage. This shows the increasing availability of feed resources in the vicinity of the open sea cage fish farm site due to escaped feeds and excreted matters from the culture system. In the case of control site (common fishing ground), a decreasing trend of abundance was observed from 29 ± 1.81 individuals comprising eight species (June) to 20 ± 1.27 individuals comprising eight species (October) due to the influence of natural predation and fishing efforts. In

traps, the species come under the genus *Siganus* (Rabbit fish) showing the highest level of contribution in all the sites. Further, species such as *Platicephalus* sp. and *Mullus* sp. were recorded only in traps placed below cages.

During UVC observation, fishes were distributed from the bottom of the cage net to HDPE floating frames. However, during observation at the control site (usual fishing ground), the majority of the fishes were associated with reef crevices and boulders at the bottom. It shows that the vertical arrangement of farm components providing more space for accommodation and feeding ground for wild fishes. The cages provide structure in the pelagic environment, although the unused portion of feed that falls through the cages probably enhances the attractive effect (Bjordal and Skar 1992). Although research into the environmental effects of marine fish farms is well documented (e.g., impact on seagrasses, transfer of antibiotics, etc.), little is known of the ecological impacts of coastal fish farms on wild fish assemblages. Several authors (Carss 1990; Bjordal and Skar 1992; Dempster *et al.* 2002) have pointed out that fish farms affect the presence and abundance of wild

fish assemblages in a given area. Open sea cage farms attract a variety of fishes since it provides free food and shelter to wild fish stock to some extent for periods of weeks to months, and the restrictions on fishing that apply within farm leasehold areas, we suggest that these fish farms may act as small marine protected areas.

4. Conclusion

It was also observed that traditional near-shore fishermen of nearby fishing villages used to operate fishing gears such as traps, hook and lines, and gillnets to capture the aggregated wild fishes around the sea cage farm site. Conservation and exploitation are generally viewed as contrasting approaches to the marine environment and it is creating a new area of research on maximum sustainable yield from aggregated wild fish stock. Obtaining proper knowledge of managing the fisheries from wild stock in a sustainable way would help both local fisheries and conservation. UVC and fish trap method combined with a multivariate statistical approach illustrates that the presence of wild fish near the cage site compared to the control site (usual fishing ground) could be used as an efficient tool to monitor the fish stock with proper significance level and efficacy for a better fisheries management in the open sea environment. Further, it is pertinent to mention that future studies will focus on the size of the fishes that are attracted towards the cage sites and also its positive/negative impact on the wild stock.

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Author statement

JS: Work plan, scuba diving studies, analysis and writing original draft; CS: Collection of fish data through traps; DKJ: Reviewing the data, statistical analysis, and suggestions; GR: Field investigation; PV: Field investigation and scuba diving; RSK: Taxonomical identification of fishes; GD:

Scuba diving studies, suggestions and reviewing the manuscript; RK: Manuscript correction and guidance; and MAA: Project administration and suggestions.

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