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Biodiversity of coral reef associated fishes along southeast coast of India

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HIGHLIGHTS

- Coral reef associated fish diversity along southeast coast of India was surveyed.
- Increased number of fishes in these areas indicates the presence of reef patches.
- The result indicates the seasonal variation in reef associated fish abundance.
- Maximum diversity indices were recorded in premonsoon compared to other seasons.
- The fish ban period increases spawning and hence increases fish production.

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ABSTRACT

A random sampling survey of coral reef associated fishes was conducted in Cuddalore (site 1), Parangipettai (site 2) and Nallavadu (site 3) along the southeast coast of India during January 2012 to December 2013. The aim of the present investigation was to reveal the biodiversity of coral reef associated fishes in these areas. Across the three study sites, a total of 162 species of coral reef associated fishes were recorded, belonging to 17 orders, 41 families and 94 genera. Among three regions, the values of Shannon diversity index (5.775), species richness (13.74) and phylogenetic diversity (4217) were found to be maximum in site 1 during premonsoon 2012, and the taxonomic diversity (55.86) was found to be maximum in site 2 during premonsoon 2012. But the evenness index (0.869) was maximum in site 1 during postmonsoon 2013. The Shannon diversity (4.326), evenness index (0.705) and taxonomic diversity (51.50) were found to be minimum in site 3 during summer 2012. But the species richness (8.479) and the phylogenetic diversity (2467) were minimum in site 3 during summer 2013. Hence the present study provided information regarding the biodiversity of coral reef associated fishes and analysis of data undertaken with conventional tools like univariate and multivariate methods clearly revealed the healthy nature of diversity of coral reef associated fishes along these areas.

1. Introduction

Coral reefs serve as a habitat for numerous commercially important species targeted for fishing. The diversity of fishes found on the coral reefs are overwhelming. Coral reefs provide approximately 25% of the total marine fish catches in India (Rajasuriya et al., 2002). Coral reefs, occupying less than 0.1% of the ocean surface and host approximately one-third of the estimated 15,000 marine fish species on the earth (Helfman et al., 1997). Coral reef fishes hold the most specious assemblages of vertebrates on the earth. The variety of colors, shapes, sizes, behavior and ecology exhibited by reef fishes is astounding. The shape, color, feeding habits of the reef fishes are specifically adapted to live in the coral reef environment. The body of these fishes are structured to operate in the complex underwater landscape and the confines spaces of the coral reefs. Reef-associated fish assemblages respond to changes in the environmental factors with fluctuations in abundance at various spatial and temporal scales (Anderson and Millar, 2004). The physical structure of the reef is a key characteristic that determine the organization of reef fish communities (Kingsford and Battershill, 1998). Studies related to the distribution and abundance of fishes in relation to the habitat structure is primarily common from tropical coral reefs (Kuffner et al., 2007).

Analyzing changes in the diversity components is a way of measuring these effects (Aguilar et al., 2004). In spite of complete periodical reviews, the selection of proper measures of diversity continues to be notorious (Lamb et al., 2009). Shannon's total diversity index and Pielou's evenness index ($J' = H'/H'$ max) extend to be the two most popular indexes (Gotelli and Graves,

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1996) and have normally been used for assemblages of reef fish studies (Walter and Haynes, 2006; Mallela et al., 2007).

Studies on coral reef associated fishes of Indian seas are mainly limited to the Lakshadweep groups of islands, Andaman and Nicobar islands and observation are lacking for other coral reef ecosystems, particularly, along the southeast coast except in the Gulf of Mannar. Only a few studies of coral reef associated fishes along the Coromandel Coast of Tamil Nadu are available. Hence the present study mainly focuses on diversity of coral reef associated fishes of the three areas, namely Cuddalore, Parangipettai and Nallavadu along southeast coast of India.

2. Materials and methods

The coral reef associated fishes were collected twice in a month from the landing centers in Cuddalore (site 1) (Lat. 11°43′N; Long. 79°49′E), Parangipettai (site 2) (Lat. 11°24′N; Long. 79°46′E) and Nallavadu (site 3) (Lat 11°46′03′N; Long 79°49′45′E), Southeast coast of India (Fig. 1) during January 2012 to December 2013. The fishes were identified by standard fish identification manuals (Day, 1878; Fischer and Bianchi, 1984; Ramaiyan et al., 1987; Talwar and Jhingran, 1991; Froese and Pauly, 2015). The habitat and IUCN status of the fishes were also identified by standard references (Froese and Pauly, 2015; IUCN, 2015). The diversity indices and multivariate analyses were performed by using PRIMER (Version 6.1.5) statistical software (Clarke and Gorley, 2006).

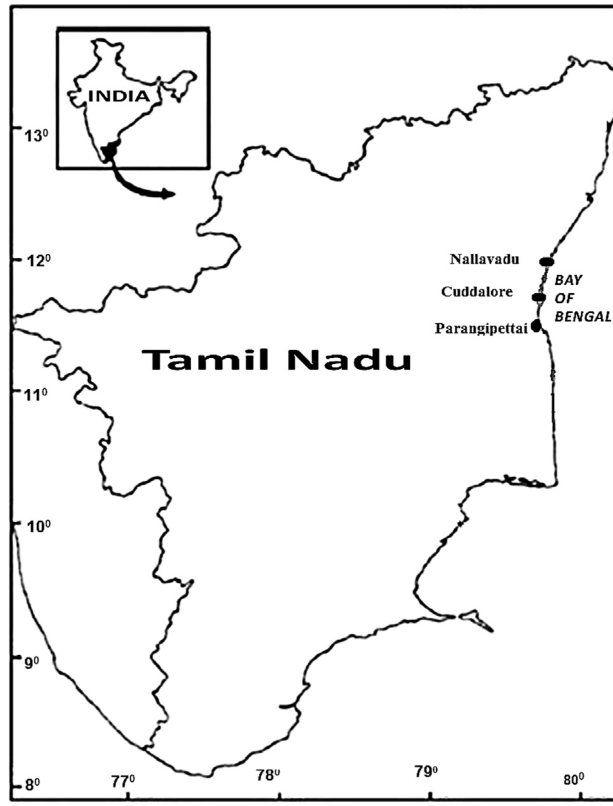

Fig. 1. Study area map showing the location where sampling was done.

2.1. Univariate methods

(a) Shannon–Wiener index

In the present study, the data were analyzed for diversity index (H') using the following Shannon–Wiener's formula (1949)

$$H' = -\sum^{S} Pi \log 2\, Pi \ldots\ldots \quad i = 1$$

This can be rewritten as,

$$H' = \frac{3.3219(N \log N - \sum ni - \log ni)}{N}$$

Where, H' = species diversity in bits of information per individual ni = proportion of the samples belonging to the ith species (Number of individuals of the ith species) N = total number of individuals in the collection and $\sum$ = sum.

(b) Margalef richness index (d)

Margalef richness index (d) was calculated using formula given by Margalef (1958)

$$d = (S - 1)/\log N$$

where, S = total number of species N = total number of individuals in the sample

(c) Pielou's evenness index

The equitability (J') was computed using the following formula of Pielou (1977):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\text{In} S}$$

Where, J' = evenness, H' = species diversity in bits of information per individual and S = total number of species.

(d) Taxonomic diversity index and Total phylogenetic diversity

The taxonomic diversity (Δ) and the total phylogenetic diversity indices were calculated by following Clarke and Warwick (2001).

2.2. Multivariate methods

Multivariate methods of classification and ordination were used to compare communities on the basis of the characteristics of the component species as well as their relative significance in terms of abundance or biomass. Multivariate analysis can be accommodated beneath two collective terms, namely classification and ordination. Classification analyses look for to assign entities to groups, whereas ordinations attempt to place these spatially, so that similar entities will be close and dissimilar ones will be faraway. The commonly used classification method is cluster analysis. In the present study, the data were approached to cluster analysis method.

2.3. Cluster analysis

Cluster analysis were used to find out the similarities between seasons. The most commonly used clustering technique is the hierarchical agglomerative method. The results of these are represented by a tree diagram or dendrogram with the x-axis representing the full set of samples and the y-axis defining the similarity level at which the samples or groups are fused. Bray–Curtis coefficient (Bray and Curtis, 1957) was used to produce the dendrogram. The coefficient was calculated by the following formula:

$$S_{jk} = 100 \left\{ 1 - \frac{\sum_{i=1}^{p} |y_{ij} - y_{ik}|}{\sum_{i=1}^{p} (y_{ij} + y_{ik})} \right\} = 100 \frac{\sum_{i=1}^{p} 2 \min(y_{ij}, y_{ik})}{\sum_{i=1}^{p} (y_{ij} + y_{ik})}$$

Where, y_{ij} represents the entry in the ith row and jth column of the data matrix i.e. The abundance or biomass for the ith species in the

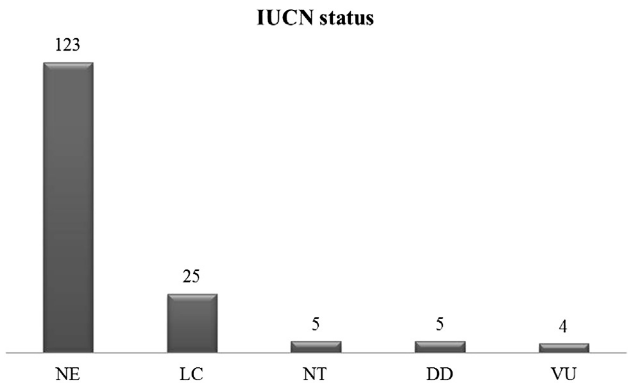

Fig. 2. IUCN status of coral reef associated fishes found in site 1, 2 and 3 during January 2012 to December 2013.

jth sample; y_{ik} is the count for the ith species in the kth sample; $|\ldots|$ represents the absolute value of the difference; 'min' stands for, the minimum of the two counts and $\sum$ represents the overall rows in the matrix.

2.4. SIMPER

By looking at the overall percentage contribution, each species makes to the average dissimilarity between two groups the species in decreasing order of samples can be listed. This was done using the SIMPER routine available in PRIMER.

3. Results and discussion

In the present study, on the whole a total of 162 species of coral reef associated fishes, belonging to 17 orders, 64 families and 94 genera were observed from site 1, 2 and 3 during January 2012 to December 2013 (Table 1). On site 1 alone 138 species of coral reef associated fishes were recorded. This is higher than the number of species recorded earlier along these area (Khan et al., 2008; Asta Lakshmi and Sundaramanickam, 2011; Purusothaman et al., 2016). These variations in the number of species may be due to changes in the period of study, duration of the study, frequency of sampling, seasonal changes and increasing of coral reef patchy areas.

As per the IUCN red list, among 162 species of coral reef associated fishes recorded, 123 species were listed in the status of Not Evaluated (NE). Twenty five species were in the status of Least Concern (LC), five species were in the status of Near Threatened (NE) and Data Deficient (DD) each and four species were in Vulnerable condition (VU) (Fig. 2). As per the IUCN red list most of the species listed are in the status of not evaluated. Most of the species recorded were commercially important species.

3.1. Diversity indices

The present study focussed on coral reef associated fish diversity in Site 1, 2 and 3 among various seasons (postmonsoon, summer, premonsoon and monsoon) for two years, and the results revealed that there was a significant changes in their diversity (Table 2). Among the three areas, the Shannon diversity (5.775), species richness (13.74) and phylogenetic diversity (4217) were found to be maximum in Site 1 during premonsoon 2012, taxonomic diversity (55.86) was found to be maximum in Site 2 during premonsoon 2012. But the evenness index (0.869) was maximum in Site 1 during postmonsoon 2013. The Shannon diversity (4.326), evenness index (0.705) and taxonomic diversity (51.50) were found to be minimum in Site 3 during summer 2012. But the species richness (8.479) and the phylogenetic diversity (2467) were minimum in Site 3 during summer 2013.

When considering the diversity indices calculated, there is a significant variation in the diversity of fishes between the areas as well as the year. In the present study the Shannon diversity was exceptionally high and was in the range of 4.326–5.775. The Shannon value of more than 3 is observed only in healthy and biodiversity rich areas (Clarke and Warwick, 2001). Hence this greater Shannon value indicate the diverse nature of coral reef associated fishes in these areas. The wide range of H' values reveals the large number of seasonal and occasional species can make use of these areas on a seasonal basis. These seasonality changes can be related to shelter, feeding and reproduction (Ansari et al., 1995). The species diversity in the reef slope of Kavaratti atoll was recorded as 3.32–4.45 range and in the seagrass bed of the same island ranges from 2.49 to 3.14 (Vijay Anand and Pillai, 2002, 2007). The availability of food resources was attributed to the high diversity in the reef slope.

The Margalef's richness index and the taxonomic diversity also showed higher values in all the regions. The maximum richness value was recorded on site 1 than in site 2 and 3 which might be due to greater fishing effort in site 1 when compared to site 2 and 3. The maximum taxonomic diversity was recorded in premonsoon 2012 in site 2. The higher values of Shannon index, Margalef index, taxonomic diversity and total phylogenetic diversity during premonsoon season and comparatively lower values during the monsoon and summer season could be attributed to the rainfall, the consequent sediment discharge and closed season for fishing. The inclement weather and cyclonic conditions prevented from venturing into the sea and thus the low values recorded during monsoon season may be attributed to less fishing activity and 45 days fish ban period during the summer resulting in collection of less number of coral reef associated fishes during these seasons. Khan et al. (2008) also reported that the diversity of coral reef fishes in Cuddalore waters showed seasonal contribution, fishes obtained maximum in premonsoon and minimum during monsoon. Low taxonomic values, namely reduced taxonomic/phylogenetic 'breadth' of assemblages for their number of species, can sometimes specify significant environmental stress caused by human impacts (Mouillot et al., 2005) or impacts of fishing (Mohamed et al., 2009), with higher values suggesting normal environmental conditions and no major human impacts.

3.2. Cluster analysis

Clustering methods are the extensively used methods in identifying and recognizing similarity/dissimilarity patterns among the sites (Eric, 1995; Ripley, 1996). Cluster analysis was supportive in finding natural groupings of samples, such that the sample within a group are more similar to each other than the samples in different groups. It also defined the species assemblages, i.e. groups of species that tend to co-occur in a parallel manner across months. In the present study, clusters were emerged, corresponding to the four seasons namely, postmonsoon (Jan–Mar), summer (Apr–Jun), monsoon (Jul–Sep) and premonsoon (Oct–Dec), thus showing seasonal differences in the coral reef associated fish assemblages. In site 1 the associations were around 77–90% similarity in 2012 (Fig. 3(a)) and 78–95% similarity in 2013 (Fig. 3(b)). Site 2 also revealed the seasonal variations in the reef fish assemblages. The associations were around 73–89% in similarity in 2012 (Fig. 4(a)) and 70–92% similarity in 2013 (Fig. 4(b)). In site 3 the associations were around 70–96% in similarity in 2012 (Fig. 5(a)) and 72–93% similarity in 2013 (Fig. 5(b)). This indicates, there was a clear separation between samples collected in different months from site 1, 2 and 3. The formation of cluster was owing to the

Table 1
List of coral reef associated fishes recorded from Cuddalore, Parangipettai and Nallavadu landing centers.

S.No.	Order	Family	Species	Common name	IUCN status
			Class: Elasmobranchii		
1.	Carcharhiniformes	Carcharhinidae	*Carcharhinus sorrah* (Müller & Henle, 1839)	Spot-tail shark	NT
2.	Myliobatiformes	Dasyatidae	*Himantura uarnak* (Gmelin, 1789)	Honeycomb stingray	VU
3.			*Pastinachus sephen* (Forsskål, 1775)	Cow tail stingray	DD
4.	Rajiformes	Rhinobatidae	*Rhynchobatus djiddensis* (Forsskål, 1775)	Giant guitarfish	VU
5.	Torpediniformes	Torpedinidae	*Torpedo sinuspersici* Olfers, 1831	Variable torpedo ray	DD
			Class: Actinopterigii		
6.	Anguilliformes	Congridae	*Ariosoma fasciatum* (Günther, 1872)	Barred sand conger	NE
7.			*Conger wilsoni* (Bloch & Schneider, 1801)	Cape conger	NE
8.		Muraenidae	*Gymnothorax monostigma* (Regan, 1909)	One-spot moray	NE
9.			*Gymnothorax pictus* (Ahl, 1789)	Paint spotted moray	NE
10.			*Gymnothorax randalli* Smith & Böhlke, 1997	Randall's moray	NE
11.	Aulopiformes	Synodontidae	*Saurida tumbil* (Bloch, 1795)	Greater lizardfish	NE
12.			*Saurida undosquamis* (Richardson, 1848)	Brushtooth lizardfish	NE
13.			*Synodus indicus* (Day, 1873)	Indian lizardfish	NE
14.			*Trachinocephalus myops* (Forster, 1801)	Snakefish	NE
15.	Beloniformes	Hemiramphidae	*Hemiramphus far* (Forsskål, 1775)	Black-barred halfbeak	NE
16.			*Hemiramphus lutkei* Valenciennes, 1847	Lutke's halfbeak	NE
17.	Beryciformes	Holocentridae	*Myripristis botche* Cuvier, 1829	Blacktip soldierfish	NE
18.			*Sargocentron rubrum* (Forsskål, 1775)	Redcoat	NE
19.	Clupeiformes	Chirocentridae	*Chirocentrus dorab* (Forsskål, 1775)	Dorab wolf-herring	NE
20.		Engraulidae	*Stolephorus insularis* Hardenberg, 1933	Hardenberg's anchovy	NE
21.		Clupeidae	*Sardinella albella* (Valenciennes, 1847)	White sardinella	LC
22.			*Sardinella gibbosa* (Bleeker, 1849)	Goldstripe sardinella	NE
23.			*Amblygaster sirm* (Walbaum, 1792)	Spotted sardinella	NE
24.	Dactylopteriformes	Dactylopteridae	*Dactyloptena orientalis* (Cuvier, 1829)	Oriental flying gurnard	NE
25.	Lophiiformes	Antennariidae	*Antennatus coccineus* (Lesson, 1831)	Scarlet frogfish	NE
26.			*Antennarius indicus* Schultz, 1964	Indian frogfish	NE
27.	Perciformes	Acanthuridae	*Acanthurus mata* (Cuvier, 1829)	Elongate surgeonfish	LC
28.			*Acanthurus tristis* Randall, 1993	Indian Ocean mimic surgeonfish	LC
29.			*Acanthurus nigrofuscus* (Forsskål, 1775)	Brown surgeonfish	LC
30.			*Naso tergus* Ho, Shen & Chang, 2011	Unicornfish	NE
31.			*Naso thynnoides* (Cuvier, 1829)	Oneknife unicornfish	LC
32.		Apogonidae	*Ostorhinchus aureus* (Lacepède, 1802)	Ring-tailed cardinalfish	LC
33.			*Ostorhinchus fasciatus* (White, 1790)	Broadbanded cardinalfish	NE
34.			*Pristiapogon fraenatus* (Valenciennes, 1832)	Bridled cardinalfish	NE
35.			*Holapogon maximus* (Boulenger, 1888)	Titan cardinalfish	NE
36.			*Zoramia gilberti* (Jordan & Seale, 1905)	Gilbert's cardinalfish	NE
37.		Caesionidae	*Pterocaesio chrysozona* (Cuvier, 1830)	Goldband fusilier	NE
38.		Carangidae	*Alectis ciliaris* (Bloch, 1787)	African pompano	LC
39.			*Alectis indica* (Rüppell, 1830)	Indian threadfish	NE
40.			*Alepes djedaba* (Forsskål, 1775)	Shrimp scad	NE
41.			*Alepes kleinii* (Bloch, 1793)	Razorbelly scad	NE
42.			*Atule mate* (Cuvier, 1833)	Yellowtail scad	NE
43.			*Carangoides caeruleopinnatus* (Rüppell, 1830)	Coastal trevally	NE
44.			*Carangoides chrysophrys* (Cuvier, 1833)	Longnose trevally	NE
45.			*Carangoides equula* (Temminck & Schlegel, 1844)	Whitefin trevally	NE
46.			*Carangoides malabaricus* (Bloch & Schneider, 1801)	Malabar trevally	NE
47.			*Carangoides oblongus* (Cuvier, 1833)	Coachwhip trevally	NE
48.			*Caranx heberi* (Bennett, 1830)	Blacktip trevally	NE
49.			*Caranx ignobilis* (Forsskål, 1775)	Giant trevally	NE
50.			*Caranx sexfasciatus* Quoy & Gaimard, 1825	Bigeye trevally	LC
51.			*Elagatis bipinnulata* (Quoy & Gaimard, 1825)	Rainbow runner	NE
52.			*Gnathanodon speciosus* (Forsskål, 1775)	Golden trevally	NE
53.			*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	NE
54.			*Parastromateus niger* (Bloch, 1795)	Black pomfret	NE
55.			*Scomberoides commersonnianus* Lacepède, 1801	Talang queenfish	NE
56.			*Scomberoides tol* (Cuvier, 1832)	Needlescaled queenfish	NE
57.			*Selar crumenophthalmus* (Bloch, 1793)	Bigeye scad	NE
58.			*Selaroides leptolepis* (Cuvier, 1833)	Yellowstripe scad	NE
59.			*Uraspis helvola* (Forster, 1801)	Whitetongue jack	NE
60.		Chaetodontidae	*Chaetodon decussatus* Cuvier, 1829	Indian vagabond butterflyfish	LC
61.			*Heniochus acuminatus* (Linnaeus, 1758)	Pennant coralfish	LC
62.		Drepanidae	*Drepane punctata* (Linnaeus, 1758)	Spotted sicklefish	NE
63.		Echeneidae	*Echeneis naucrates* Linnaeus, 1758	Live sharksucker	NE
64.		Ephippidae	*Ephippus orbis* (Bloch, 1787)	Orbfish	NE
65.			*Platax orbicularis* (Forsskål, 1775)	Orbicular batfish	NE
66.			*Platax teira* (Forsskål, 1775)	Longfin batfish	NE
67.		Gerreidae	*Gerres erythrourus* (Bloch, 1791)	Deep-bodied mojarra	LC
68.			*Gerres oblongus* Cuvier, 1830	Slender silver-biddy	NE
69.		Haemulidae	*Diagramma pictum* (Thunberg, 1792)	Painted sweetlips	NE

(*continued on next page*)

occurrence of species changes with the seasonal variations. The similar groupings due to seasonal variations were reported earlier by Khan et al. (2008) in Cuddalore coast and Purusothaman et al. (2015) in Cuddalore and Parangipettai coast.

Table 1 (*continued*)

S.No.	Order	Family	Species	Common name	IUCN status
70.			*Plectorhinchus lineatus* (Linnaeus, 1758)	Yellowbanded sweetlips	NE
71.			*Plectorhinchus vittatus* (Linnaeus, 1758)	Indian Ocean oriental sweetlips	NE
72.			*Plectorhinchus pictus* (Tortonese, 1936)	Trout sweetlips	NE
73.			*Pomadasys furcatus* (Bloch & Schneider, 1801)	Bandedgrunter	NE
74.			*Pomadasys maculatus* (Bloch, 1793)	Saddle grunt	LC
75.		Kyphosidae	*Kyphosus vaigiensis* (Quoy & Gaimard, 1825)	Brassy chub	NE
76.		Labridae	*Thalassoma lunare* (Linnaeus, 1758)	Moon wrasse	LC
77.		Leiognathidae	*Gazza achlamys* Jordan & Starks, 1917	Smalltoothed ponyfish	LC
78.		Lethrinidae	*Lethrinus harak* (Forsskål, 1775)	Thumbprint emperor	NE
79.			*Lethrinus lentjan* (Lacepède, 1802)	Pink ear emperor	NE
80.			*Lethrinus nebulosus* (Forsskål, 1775)	Spangled emperor	NE
81.		Lutjanidae	*Aphareus rutilans* Cuvier, 1830	Rusty jobfish	NE
82.			*Lutjanus argentimaculatus* (Forsskål, 1775)	Mangrove red snapper	NE
83.			*Lutjanus bohar* (Forsskål, 1775)	Two-spot red snapper	NE
84.			*Lutjanus fulviflamma* (Forsskål, 1775)	Dory snapper	NE
85.			*Lutjanus fulvus* (Forster, 1801)	Blacktail snapper	NE
86.			*Lutjanus johnii* (Bloch, 1792)	John's snapper	NE
87.			*Lutjanus kasmira* (Forsskål, 1775)	Common bluestripe snapper	NE
88.			*Lutjanus malabaricus* (Bloch & Schneider, 1801)	Malabar blood snapper	NE
89.			*Lutjanus quinquelineatus* (Bloch, 1790)	Five-lined snapper	NE
90.			*Lutjanus rivulatus* (Cuvier, 1828)	Blubberlip snapper	NE
91.			*Lutjanus russellii* (Bleeker, 1849)	Russell's snapper	NE
92.			*Lutjanus stellatus* Akazaki, 1983	Star snapper	NE
93.			*Lutjanus vitta* (Quoy & Gaimard, 1824)	Brownstripe red snapper	NE
94.		Menidae	*Mene maculata* (Bloch & Schneider, 1801)	Moonfish	NE
95.		Mullidae	*Mulloidichthys vanicolensis* (Valenciennes, 1831)	Yellowfingoatfish	NE
96.			*Parupeneus indicus* (Shaw, 1803)	Indian goatfish	NE
97.			*Parupeneus macronemus* (Lacepède, 1801)	Long-barbel goatfish	NE
98.			*Upeneus japonicus* (Houttuyn, 1782)	Bensasi goatfish	NE
99.			*Upeneus moluccensis* (Bleeker, 1855)	Goldband goatfish	NE
100.			*Upeneus tragula* Richardson, 1846	Freckled goatfish	NE
101.			*Upeneus vittatus* (Forsskål, 1775)	Yellowstriped goatfish	NE
102.		Nemipteridae	*Nemipterus furcosus* (Valenciennes, 1830)	Fork-tailed threadfin bream	NE
103.			*Scolopsis bimaculata* Rüppell, 1828	Thumbprint monocle bream	NE
104.			*Scolopsis vosmeri* (Bloch, 1792)	Whitecheek monocle bream	NE
105.			*Scolopsis xenochroa* Günther, 1872	Oblique-barred monocle bream	NE
106.		Opistognathidae	*Opistognathus rosenbergii* Bleeker, 1856	Rosenberg's jawfish	NE
107.		Pempheridae	*Pempheris mangula* Cuvier, 1829	Black-edged sweeper	NE
108.		Pinguipedidae	*Parapercis maculata* (Bloch & Schneider, 1801)	Harlequin sandperch	NE
109.		Pomacentridae	*Abudefduf bengalensis* (Bloch, 1787)	Bengal sergeant	NE
110.			*Abudefduf septemfasciatus* (Cuvier, 1830)	Banded sergeant	NE
111.			*Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	Indo-Pacific sergeant	NE
112.		Priacanthidae	*Priacanthus hamrur* (Forsskål, 1775)	Moontail bullseye	NE
113.			*Priacanthus tayenus* Richardson, 1846	Purple-spotted bigeye	NE
114.		Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	Cobia	NE
115.		Scaridae	*Scarus russelii* Valenciennes, 1840	Eclipse parrotfish	LC
116.		Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat	LC
117.		Serranidae	*Cephalopholis formosa* (Shaw, 1812)	Bluelined hind	LC
118.			*Cephalopholis sonnerati* (Valenciennes, 1828)	Tomato hind	LC
119.			*Cephalopholis urodeta* (Forster, 1801)	Darkfin hind	LC
120.			*Epinephelus areolatus* (Forsskål, 1775)	Areolate grouper	LC
121.			*Epinephelus chlorostigma* (Valenciennes, 1828)	Brownspotted grouper	LC
122.			*Epinephelus coioides* (Hamilton, 1822)	Orange-spotted grouper	NT
123.			*Epinephelus faveatus* (Valenciennes, 1828)	Barred-chest grouper	DD
124.			*Epinephelus fuscoguttatus* (Forsskål, 1775)	Brown-marbled grouper	NT
125.			*Epinephelus lanceolatus* (Bloch, 1790)	Giant grouper	VU
126.			*Epinephelus longispinis* (Kner, 1864)	Longspine grouper	LC
127.			*Epinephelus malabaricus* (Bloch & Schneider, 1801)	Malabar grouper	NT
128.			*Epinephelus poecilonotus* (Temminck & Schlegel, 1842)	Dot–dash grouper	LC
129.			*Epinephelus polyphekadion* (Bleeker, 1849)	Camouflage grouper	NT
130.			*Epinephelus undulosus* (Quoy & Gaimard, 1824)	Wavy-lined grouper	DD
131.			*Pseudanthias squamipinnis* (Peters, 1855)	Sea goldie	NE
132.		Siganidae	*Siganus canaliculatus* (Park, 1797)	White-spotted spinefoot	NE
133.			*Siganus javus* (Linnaeus, 1766)	Streaked spinefoot	NE
134.			*Siganus lineatus* (Valenciennes, 1835)	Golden-lined spinefoot	NE
135.			*Siganus vermiculatus* (Valenciennes, 1835)	Vermiculated spinefoot	LC
136.		Sillaginidae	*Sillago sihama* (Forsskål, 1775)	Silver sillago	NE
137.		Sparidae	*Rhabdosargus sarba* (Forsskål, 1775)	Goldlined seabream	NE
138.		Sphyraenidae	*Sphyraena barracuda* (Edwards, 1771)	Great barracuda	NE
139.			*Sphyraena jello* Cuvier, 1829	Pickhandle barracuda	NE
140.			*Sphyraena obtusata* Cuvier, 1829	Obtuse barracuda	NE
141.		Terapontidae	*Pelates quadrilineatus* (Bloch, 1790)	Fourlined terapon	NE
142.	Pleuronectiformes	Bothidae	*Bothus pantherinus* (Rüppell, 1830)	Leopard flounder	NE
143.		Soleidae	*Aesopia cornuta* Kaup, 1858	Unicorn sole	NE
144.	Scorpaeniformes	Platycephalidae	*Platycephalus indicus* (Linnaeus, 1758)	Bartail flathead	DD

(*continued on next page*)

Table 1 (*continued*)

S.No.	Order	Family	Species	Common name	IUCN status
145.			*Thysanophrys chiltonae* Schultz, 1966	Longsnout flathead	NE
146.		Scorpaenidae	*Pterois russelii* Bennett, 1831	Plaintail turkeyfish	NE
147.			*Pterois volitans* (Linnaeus, 1758)	Red lionfish	NE
148.	Siluriformes	Plotosidae	*Plotosus lineatus* (Thunberg, 1787)	Striped eel catfish	NE
149.	Syngnathiformes	Fistularidae	*Fistularia commersonii* Rüppell, 1838	Bluespotted cornetfish	NE
150.			*Fistularia petimba* Lacepède, 1803	Red cornetfish	NE
151.		Syngnathidae	*Hippocampus kuda* Bleeker, 1852	Spotted seahorse	VU
152.	Tetraodontiformes	Balistidae	*Abalistes stellatus* (Anonymous, 1798)	Starry triggerfish	NE
153.			*Odonus niger* (Rüppell, 1836)	Red-toothed triggerfish	NE
154.			*Sufflamen fraenatum* (Latreille, 1804)	Masked triggerfish	LC
155.		Diodontidae	*Cyclichthysorbicularis* (Bloch, 1785)	Birdbeak burrfish	NE
156.			*Diodon hystrix* Linnaeus, 1758	Spot-fin porcupinefish	NE
157.		Monacanthidae	*Monacanthus chinensis* (Osbeck, 1765)	Fan-bellied leatherjacket	NE
158.			*Paramonacanthus nipponensis* (Kamohara, 1939)	Japanese leatherjacket	NE
159.			*Aluterus monoceros* (Linnaeus, 1758)	Unicorn leatherjacket filefish	NE
160.		Ostraciidae	*Lactoria cornuta* (Linnaeus, 1758)	Longhorn cowfish	NE
161.			*Tetrosomus gibbosus* (Linnaeus, 1758)	Humpback turretfish	LC
162.		Tetraodontidae	*Arothron stellatus* (Anonymous, 1798)	Stellate puffer	NE

Note: NE—Not Evaluated, LC—Least Concern, DD—Data Deficient, NT—Near Threatened, VU—Vulnerable.

Table 2
Seasonal variation of diversity indices calculated for the coral reef associated fishes recorded in Cuddalore, Parangipettai and Nallavadu landing centers during January (2012)–December (2013)

Season	Cuddalore - 2012					Parangipettai - 2012					Nallavadu - 2012				
	H'(log 2)	d	J'	Delta	sPhi+	H'(log 2)	d	J'	Delta	sPhi+	H'(log 2)	d	J'	Delta	sPhi+
Postmonsoon	5.62	12.64	0.8388	54.77	3733	5.34	11.64	0.8165	54.71	3383	4.735	10.94	0.7349	53.58	3450
Summer	5.514	11.33	0.8493	53.57	3300	5.019	9.891	0.8033	54.76	2867	4.326	9.383	0.7058	51.59	2800
Premonsoon	5.725	13.74	0.8483	54.37	4217	5.407	13.37	0.8005	55.86	3867	4.82	12.31	0.7271	52.51	3783
Monsoon	5.464	9.891	0.8668	53.78	3083	5.001	9.438	0.8106	54.84	2600	4.553	8.768	0.7533	51.55	2650
	Cuddalore - 2013					Parangipettai - 2013					Nallavadu - 2013				
Postmonsoon	5.717	11.61	0.8697	54.79	3450	5.061	11.01	0.7876	55.2	3133	4.739	10.45	0.7454	53.7	3217
Summer	5.537	10.69	0.8594	54.19	3050	4.895	9.592	0.7909	54.45	2650	4.651	8.479	0.7811	51.87	2467
Premonsoon	5.775	12.51	0.8509	54.33	3883	5.211	12.28	0.7826	54.98	3550	4.948	11.29	0.7603	54.24	2487
Monsoon	5.475	9.726	0.8763	53.05	2833	5.073	9.542	0.8249	52.17	2717	4.685	7.975	0.7964	52.96	2567

H'(log 2)—Shannon–Wiener index; d— Margalef's richness; J'—evenness; Delta— Taxonomic diversity; sPhi+—Total phylogenetic diversity.

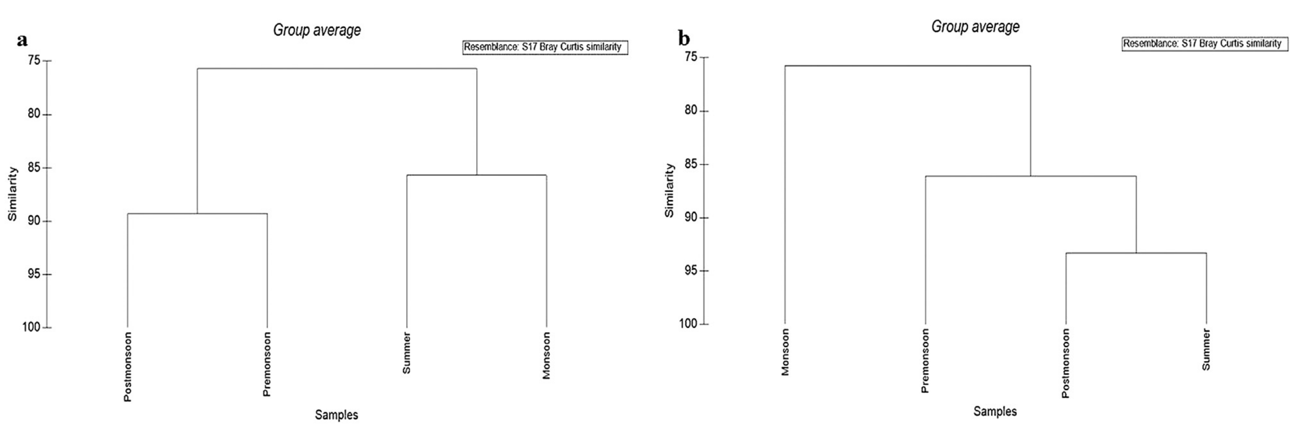

Fig. 3. Dendrogram showing similarity in species composition of coral reef associated fishes recorded in the various seasons in site 1 (a) 2012 (b) 2013.

3.3. k-dominance curve

In the dominance plot the curves for the pre-monsoon were found to lie at the bottom for all the three areas for both the year representing the higher diversity in that season followed by post-monsoon and summer. The curves for monsoon season were found at the top because of its lower diversity during monsoon season (Figs. 6–8).

3.4. Simper

Simper analysis indicated that the species mainly responsible for the dissimilarity in abundance between the sampling sites. Fishing has major effects both directly and indirectly on the environment, diversity and productivity of communities. The average similarity levels of groups 1–6 (group 1 (Cuddalore 2012), group 2 (Parangipettai 2012), group 3 (Nallavadu 2012), group 4 (Cuddalore 2013), group 5 (Parangipettai 2013) and group 6 (Nallavadu 2013) for the samples collected during various seasons of both the years were 61.49%, 52.60%, 43.59%, 57.91, 50.46, 60.64%. The average dissimilarity between groups 1 and 2 was 63.51% between groups 1 and 3 was 70.11%; between groups 1 and 4 was 54.55%; between groups 1 and 5 was 64.12%; between groups 1 and 6 was 68.93%; between groups 2 and 3 was 72.06%; between groups 2 and 4 was 65.51%; between groups 2 and 5 was 66.03%; between groups 2 and 6 was 66.85%; between groups 3 and 4 was 67.91%; between groups 3 and 5 was 69.59%; between groups

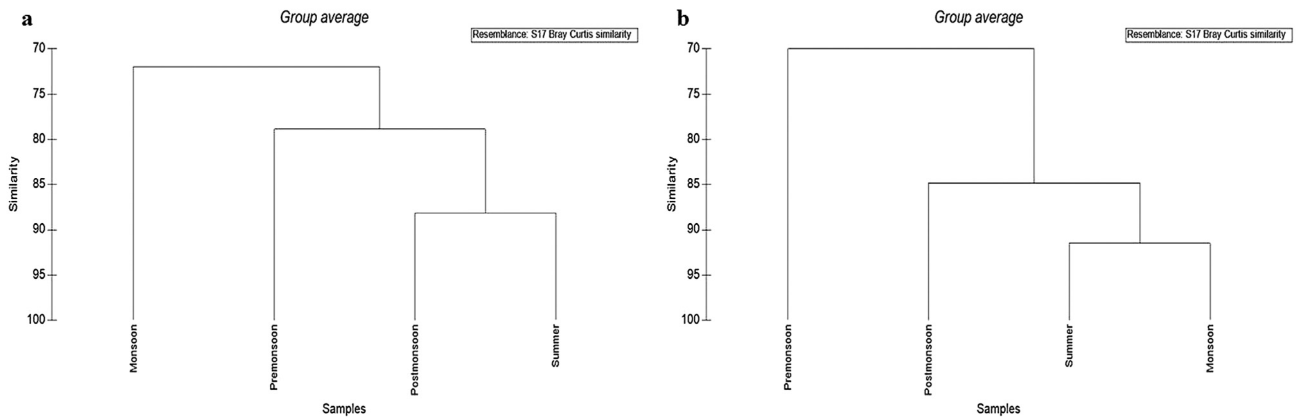

Fig. 4. Dendrogram showing similarity in species composition of coral reef associated fishes recorded in the various seasons in site 2 (a) 2012 (b) 2013.

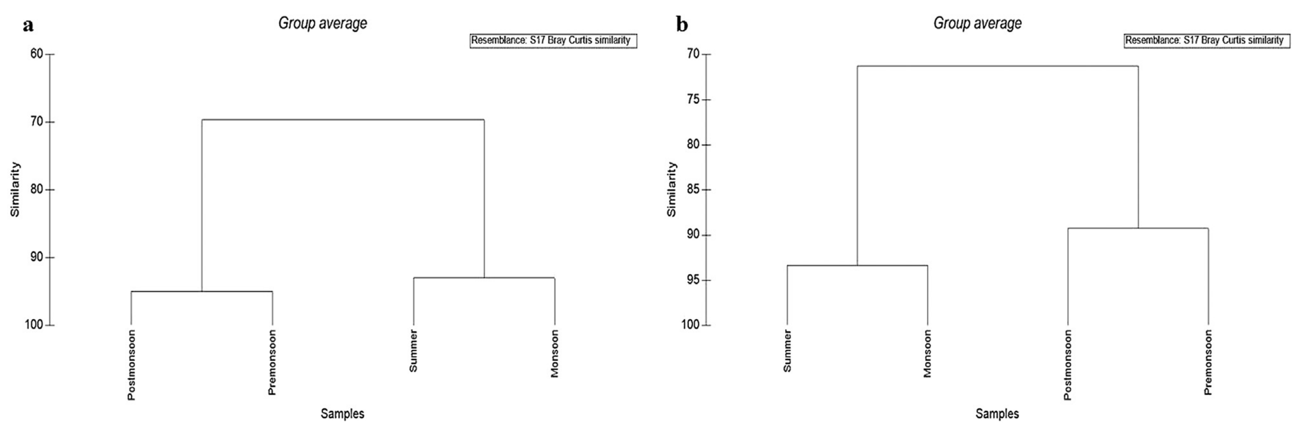

Fig. 5. Dendrogram showing similarity in species composition of coral reef associated fishes recorded in the various seasons in site 3 (a) 2012 (b) 2013.

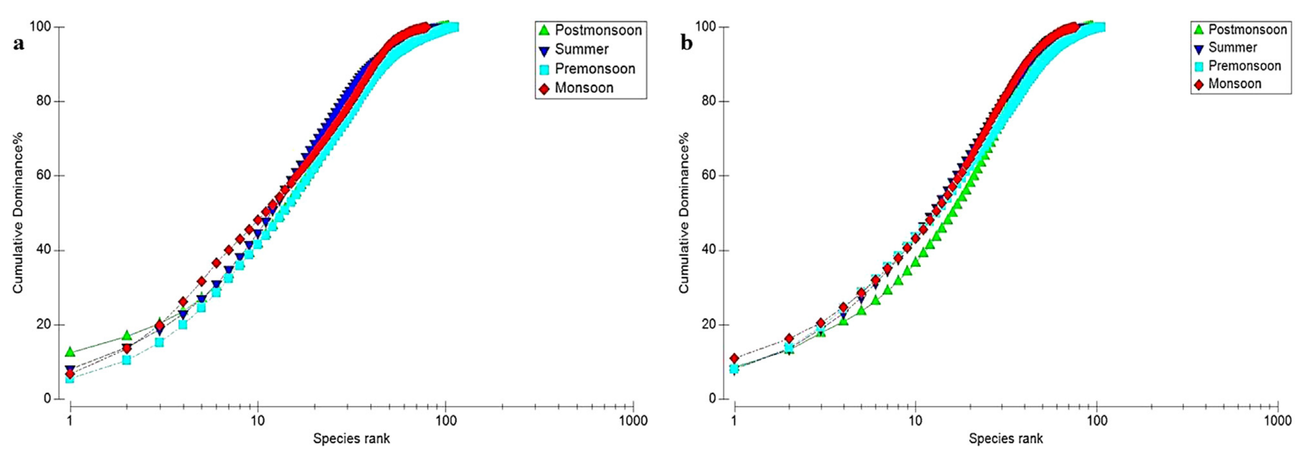

Fig. 6. Dominance plot for coral reef associated fishes recorded during various seasons in site 1 (a) 2012 (b) 2013.

3 and 6 was 66.45%; between groups 4 and 5 was 66.93%; between groups 4 and 6 was 71.69 and between groups 5 and 6 was 69.62.

Similar findings were reported elsewhere (Klaoudatos et al., 2010; Purusothaman et al., 2016). Trawling and overfishing has significant impact on primary production, a river plume may have an indirect effect on ground-fish assemblages through other components of the ecosystem such as sediment type and primary production. In temperate systems, the temporal succession of stratification (density-gradient induced between marine and freshwaters) and vertical mixing (wind-induced) enhances primary production (Cushing, 1989) and, through the food web, increases ground-fish production (Mann, 1993).

Analysis of data undertaken with conventional tools like univariate and multivariate methods clearly revealed the healthy nature of diversity of coral reef associated fishes along the Cuddalore (site 1), Parangipettai (site 2) and Nallavadu (site 3) coast.

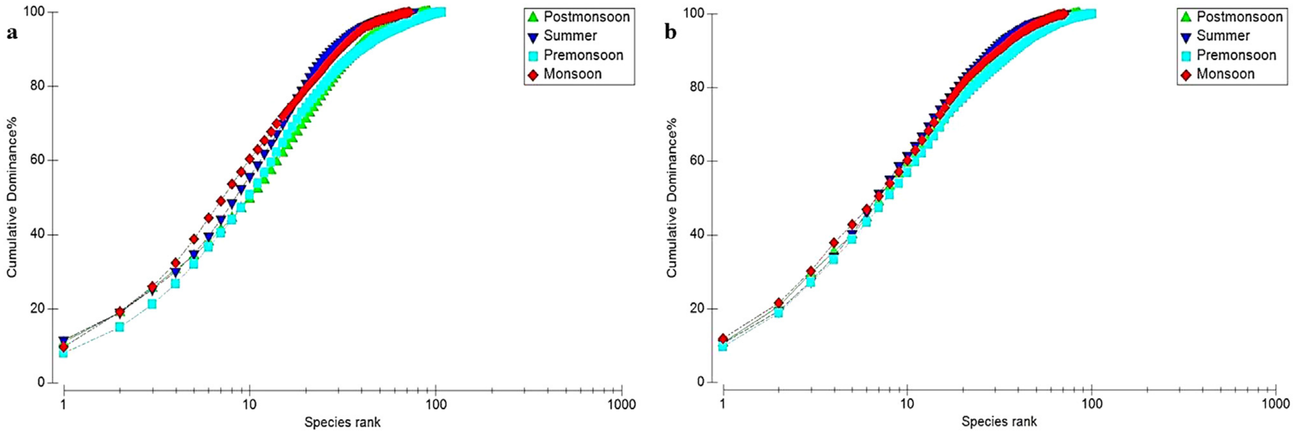

Fig. 7. Dominance plot for coral reef associated fishes recorded during various seasons in site 2 (a) 2012 (b) 2013.

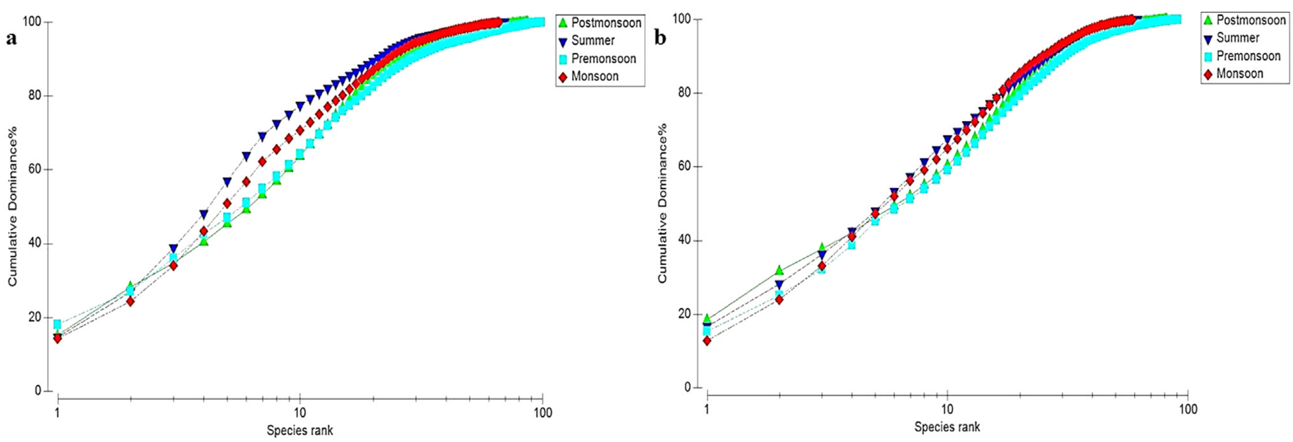

Fig. 8. Dominance plot for coral reef associated fishes recorded during various seasons in site 3 (a) 2012 (b) 2013.

4. Conclusion

The present study provided information regarding the biodiversity of coral reef associated fishes along the Cuddalore, Parangipettai and Nallavadu coast. There are 162 species of coral reef associated fishes were recorded during January 2012 to December 2013. Hence, the present study clearly revealed the vigorous amount of fish species and also shown that there may be increased level of coral reef patches along these areas. Therefore proper monitoring and necessary steps to be taken to enhance the healthy nature of the marine living resources especially coral reefs which serve as a habitat for various commercially important species along these areas.

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Conflict of interest

Authors declare that there is no conflict of interest.

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