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Diversity and distribution of scleractinian corals from Mandapam group of Islands in Gulf of Mannar marine national park, South East coast of India

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Abstract
The Mandapam group of Islands being a part of the Gulf of Mannar Marine National Park shows a variety of marine biodiversity in each of the seven Islands. A Scleractinian coral shows a rich diversity in the study islands during the study period. The present study will help us to get a summarized species distribution in the Mandapam group of Islands. The maximum percentage of hard coral cover was recorded in the Poomarichan Island followed by Single Island, Manoliputti Island, Manoli Island, Hare Island, Kurusadai Island and Pullivasal Island. A total of 69 species of scleractinian corals were listed from the coral reef Islands in the study sites of Mandapam group. Statistical analysis such as Principal Component Analysis and Correspondence Analysis supported the status of maximum coral cover in Poomarichan Island.

Keywords: Gulf of mannar, mandapam, coral, scleractinian, reef

Introduction
Scleractinian corals are commonly called as floating stone or nurai kal in Rameshwaram, southeast coast of India. Foote (1890) [1] reported the Rameshwaram formation by the coral reef. Brook (1893) [2] and Bernard (1897) [3] catalogued the corals collected by Thurston's from the Gulf of Mannar Islands at the British Museum Natural History (BMNH), London (Edward *et al.*, 2004) [4]. The coral reefs act as refuge habitats for many flora and fauna communities such as bacteria to mammalians (English *et al.*, 1997; Edward *et al.*, 2004; Geetha and Kumar, 2012; Mondal, 2018) [5, 4, 6, 7]. They are an exceptionally productive and valuable natural asset (Muller, 1997) [8]. The valuable ecosystem serves as breeding grounds, a nursery for important crustacean, fin-fish, shells and also provides food, cultural objects, fishing ground, building materials, and shoreline protection for the people living near the coast (Edward, *et al.*, 2005; Kumaraguru *et al.*, 2006) [9, 10].
In India, the study on coral taxonomy was initiated by Rink during 1847 (Sewell, 1922) [11] Wood-Mason and Alcock (1891a, b) [12, 13] reported deep water corals, the specimens collected by RIMS Investigator – I & II. Bernard (1897) [3] recorded eight species of *Acropora.* These two new species included and some *Porities* species were also reported from Thurston's Collections. Sewell (1922; 1925) [11, 14] reported corals from Nicobar Islands. Gravely (1927) [15] listed some corals from Krusadai Islands, Gulf of Mannar. Gopinathan Pillai was taking up a coral taxonomy and extensive exploration of hard corals from Indian water (Pillai, 1967, 1971a-c, 1972, 1977, 1983, 1986, 1987; Scheer and Pillai, 1974, Pillai and Patel, 1988; Pillai and Jasmine, 1989; Pillai, 2002) [16, 28]. Mahadevan and Nagappan Nayar (1972) [29] recorded hard corals from Thoothukudi and Vembar coast, followed by Santhanam and Venkatatamanujam (1996) [30] recorded 18 species from Thoothukudi group of Islands. Edward *et al.* (2002) [31] recorded 22 species from Thoothukudi group of Islands.
After these, Venkataraman *et al.* (2003) [32] reported the updated list of corals with 208 species from Indian water and Edward *et al.* (2004) [4] reported 104 species and updated list of 117 species of corals recorded from Gulf of Mannar Islands (Edward *et al.*, 2007) [33]. Marimuthu *et al.* (2010) [34] reported 48 species of hard corals and distribution details in Mandapam group of Islands and Geetha and Kumar (2012) [6] reported 103 species from Thoothukudi group of Island. The present study reporting the hard coral diversity and distribution with a list of species from the study islands in Mandapam group, Gulf of Mannar Marine National Park.

Material and Methods

Gulf of Mannar extending from Kanyakumari to Rameshwaram, southeast coast of India is the first Marine Biosphere Reserve in South East Asia, It was declared a Marine National Park in 1986 for the purpose of protecting marine fauna and flora. A total of 21 uninhabited reef islands are lying parallel to the coast from Thoothukudi to Rameshwaram, Tamil Nadu, India. The islands are divided into four groups, namely Thoothukudi group (3 islands), Vembar group (3 Islands), Keelakari group (7 islands) and Mandapam group (7 Islands) (Edward *et al.*, 2004; 2007, 2008) [4, 33, 35]. The present study was carried out on January 2020 in seven islands of the Mandapam group, Gulf of Mannar. The Line Intercept Transect (LIT) method (English *et al.*, 1997) [5] was carried out to assess the diversity of Scleractinian corals and associated faunal community in the 15 study sites, at seven islands (Fig. 1; Table 1). The benthic community was categorised such as the Hard Corals (HC), Soft coral (SC), Coral bleaching (CB), Algae (AA), Sponges (SP), Dead Corals (DC), Rubbles (RR), Sand (SD), Silt (SI) and Others (OT). The percentage of Scleractinian corals and the associated faunal cover were estimated and statistical analyses were carried out by using the PAST version 2.15 (Hammer, 2012) [36].

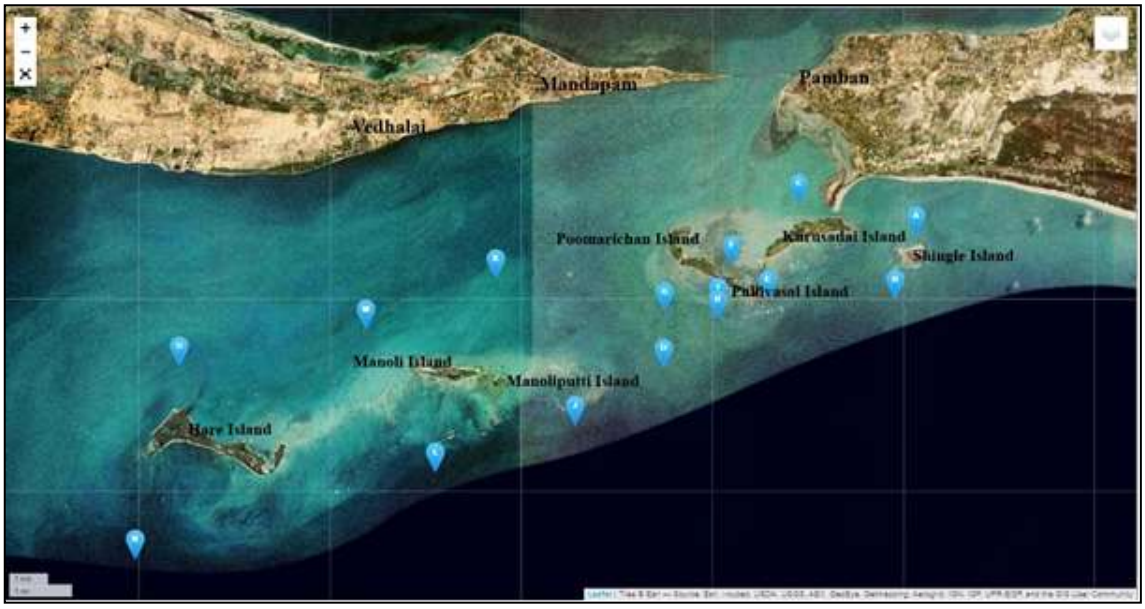


Fig 1: Study sites in Mandapam group of Islands in Gulf of Mannar Marine National Park (https://www.geoplaner.com/)

Table 1: Study area with GPS co-ordinations

S.No	Name of the Islands		Date of sampling	Latitude (in degree decimals)	Longitude (in degree decimals)
1.	Shingle Island	A	25.01.2020	Lat. N 09° 14.778’	Long. E 79° 14.169’
2.		B		Lat. N 09° 13.928’	Long. E 79° 13.884’
3.	Kurusadai Island	C	28.01.2020	Lat. N 09° 15.215’	Long. E 79° 12.547’
4.				Lat. N 09° 12.230’	Long. E 79° 09.452’
5.	Pullivasal Island	D	29.01.2020	Lat. N 09° 12.985’	Long. E 79° 10.691’
6.		E		Lat. N 09° 13.910’	Long. E 79° 12.115’
7.		F		Lat. N 09° 14.383’	Long. E 79° 11.626’
8.	Poomarichan Island	G	24.01.2020	Lat. N 09° 13.753’	Long. E 79° 10.697’
9.		H		Lat. N 09° 13.655’	Long. E 79° 11. 424’
10.		I		Lat. N 09° 13.818’	Long. E 79° 11. 437’
11.	Manoliputti Island	J	30.01.2020	Lat. N 09° 12.216’	Long. E 79° 09.461’
12.		K		Lat. N 09° 14.203’	Long. E 79° 08.369’
13.	Manoli Island	L	27.01.2020	Lat. N 09° 11.588’	Long. E 79° 07.536’
14.		M		Lat. N 09° 13.514’	Long. E 79° 06.577’
15.	Hare Island	N	26.01.2020	Lat. N 09° 10.405’	Long. E 79° 03.391’
16.		O		Lat. N 09° 13.023’	Long. E 79° 04.001’

Results

Present study recorded 41.3% of live coral cover in Mandapam group of Islands, of which maximum percentage of hard coral (HC) was recorded in Poomarichan Island (51.4%), followed by Shingle Island (47.5%), Manoliputti Island (45.8%), Manoli Island (41.1%), Hare Island (40.5%), Kurusadai Island (32.4%) and Pullivasal Island (30.6%) (Table 2; Fig. 2). The maximum coral bleaching (CB) was reported from Pullivasal Island (11.8%) followed by Kurusadai Island (9.2%), Manoliputti Island (8.1%), Poomarichan Island (5.9%), Manoli Island (5.5%), Hare Island (3.8%) and Shingle Island (3.1%). More number of dead corals (DC) was noted in Kurusadai Island (7.5%) and less number in Hare Island (5.5%). Soft corals (SC) cover was noted dominantly in Manoli Island and Hare Island, whereas sponges (SP) cover was recorded maximum in Manoli Island. The maximum percentage of algae (AA) cover was recorded in Pullivasal Island (12.3%) and minimum in Manoliputti Island (4.9%). The statistical multivariate analysis such as Principal Component Analysis (PCA) and Correspondence analysis confirmed the existence of more number of hard coral diversity in the Poomarichan Island (Fig. 3 & 4). Bray-

Curtis Cluster analysis was resulted based on the life-form cover; total of two major clusters with 81% similarity was formed. Among them, Kurusadai Island (KI) and Pullivasal Island (PI) present in one cluster with 92% similarity. The second cluster divided into two major divisions of which Manoli Island (MI) and Hare Island (HI) have 95% similarity. Manoliputti Island (MPI) and Poomarichan Island (POI) have 93% similarity, Shingle Island (SI) only 90% similarity with these two islands (Fig. 5).

On the basis of this extensive study in the Mandapam group of Islands, a total of 69 scleractinian corals belonging to 23 genera were identified from the seven islands (Table 2 & Fig. 6-9). The maximum number of species were reported from Poomarichan Island (40 sp.), followed by Manoliputti Island (20 sp.), Manoli Island (15 sp.), Shingle Island (15 sp.), Pullivasal Island (14 sp.), Hare Island (13 sp.) and Kurusadai Island (11 sp.). Among them, more number of species belong to the genus *Acropora* (16 sp.), followed by *Montipora* (10 sp.), *Platygyra* (5 sp.), *Favia* (5 sp.), *Porites* (4 sp.) respectively.

Table 2: Scleractinian coral and associated fauna from the study sites

	SI	KI	PI	POI	MPI	MI	HI	Average
HC	47.5	32.4	30.6	51.4	45.8	41.1	40.5	41.3
SC	11.3	10.0	7.5	9.8	11.9	13.1	13.1	10.9
CB	3.1	9.2	11.8	5.9	8.1	5.5	3.8	6.8
AA	9.4	12.3	11.9	5.8	4.9	5.8	7.6	8.2
SP	5.0	6.3	5.4	4.8	5.6	7.5	6.9	5.9
DC	5.6	7.5	6.6	5.6	5.6	7.0	5.5	6.1
RB	5.0	9.3	11.3	8.1	7.5	6.9	6.9	7.8
SD	5.0	5.0	8.8	5.0	6.9	9.4	12.5	7.5
SI	3.1	3.1	1.9	0.6	0.6	0.6	0.6	1.5
OT	5.0	5.0	4.4	3.1	3.1	3.1	3.1	3.8

HC – Hard corals, SC- Soft coral, CB- Coral bleaching, AA-Algae, SP – Sponges, DC-Dead corals, RB-Rubbles, SD- Sand, SI – Silt, OT-Others; SI –Shingle Island, KI – Kurusadai Island, PI – Pullivasal Island, POI – Poomarichan Island, MPI – Manoliputti Island, MI – Manoli Island, HI - Hare Island.

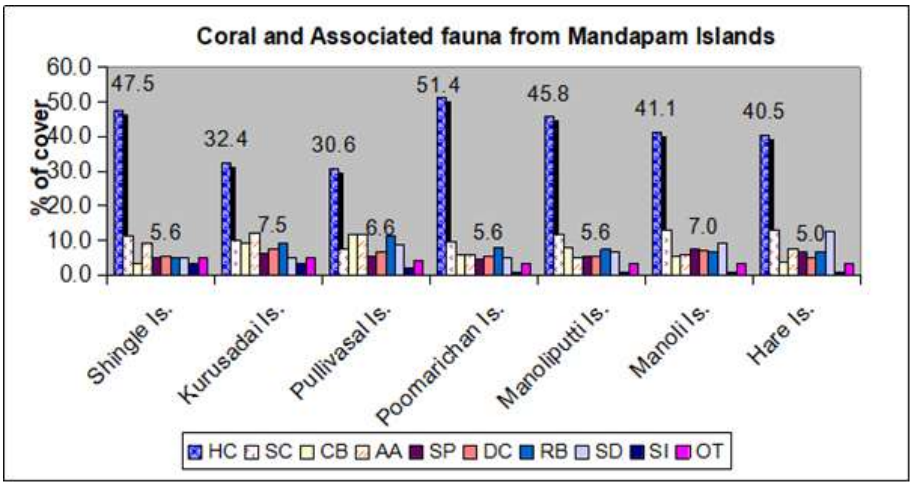


Fig 2: Distribution of coral and associated fauna in Mandapam group of Islands in Gulf of Mannar Marine National Park

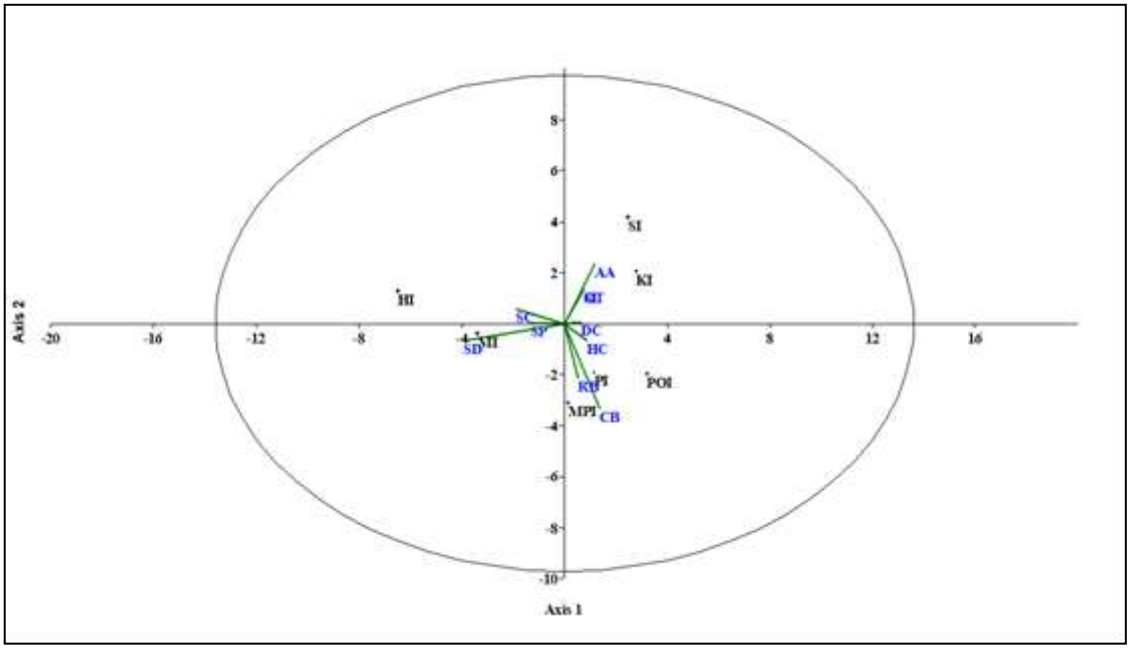


Fig 3: Principal Component Analyses (PCA) of life form categories recorded from the reef islands in Mandapam group, Gulf of Mannar Marina National Park. HC – Hard corals, SC- Soft coral, CB- Coral bleaching, AA-Algae, SP – Sponges, DC-Dead corals, RB-Rubbles, SD- Sand, SI – Silt, OT-Others, SI –Shingle Island, KI – Kurusadai Island, PI – Pullivasal Island, POI – Poomarichan Island, MPI – Manoliputti Island, MI – Manoli Island, HI - Hare Island.

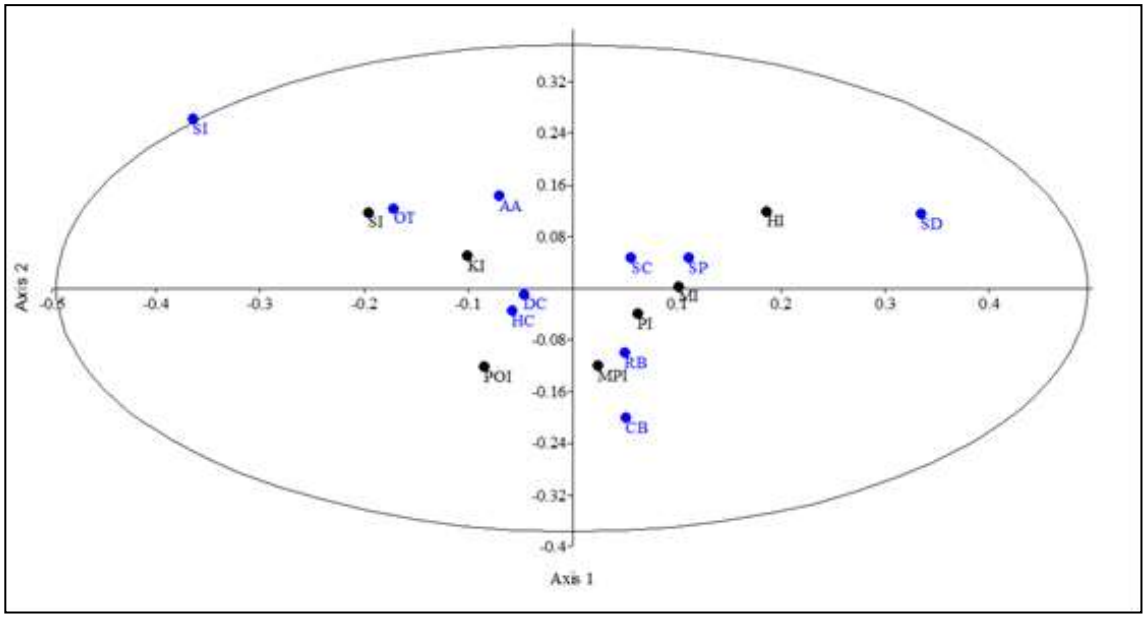


Fig 4: Correspondence Analyses of life form categories recorded from the reef islands in Mandapam group, Gulf of Mannar Marina National Park. HC – Hard corals, SC- Soft coral, CB- Coral bleaching, AA-Algae, SP – Sponges, DC-Dead corals, RB-Rubbles, SD- Sand, SI – Silt, OT-Others, SI –Shingle Island, KI – Kurusadai Island, PI – Pullivasal Island, POI – Poomarichan Island, MPI – Manoliputti Island, MI – Manoli Island, HI - Hare Island.

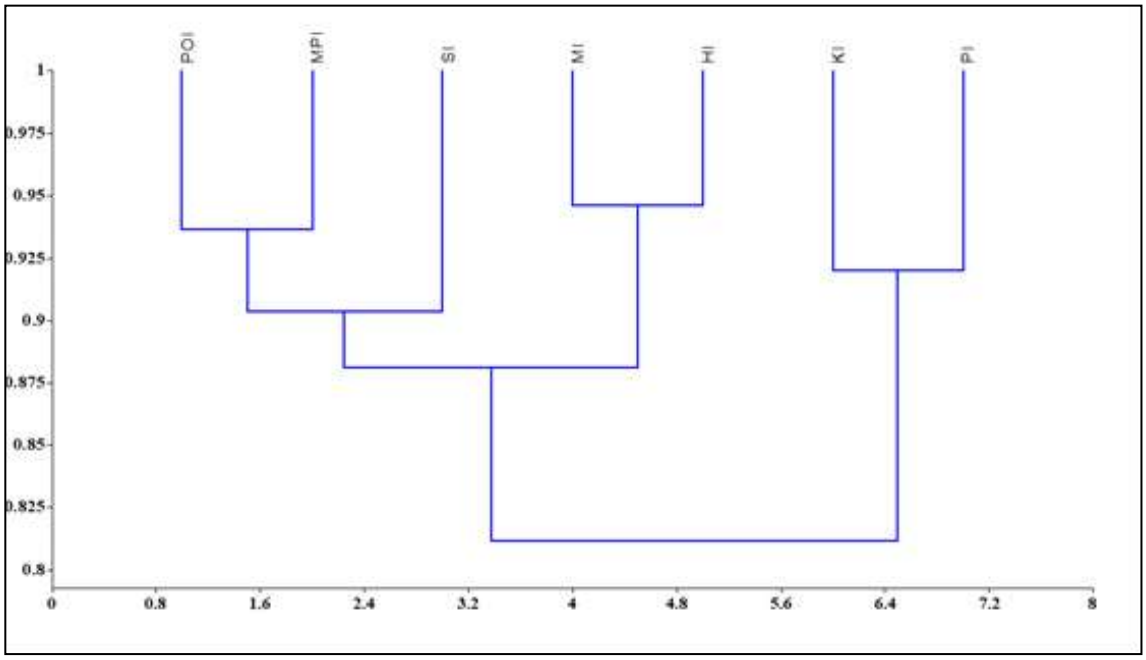


Fig 5: Bray-Curtis Cluster analyses of life form categories recorded from the reef islands in Mandapam group, Gulf of Mannar Marina National Park. (SI –Shingle Island, KI – Kurusadai Island, PI – Pullivasal Island, POI – Poomarichan Island, MPI – Manoliputti Island, MI – Manoli Island, HI - Hare Island)

Table 2 List of Scleractinian corals from the study sites in Mandapam group of Islands

S. No	List of Coral species	SI	KI	POI	PI	MPI	MI	HI
1.	*Acropora abrotanoides* (Lamarck, 1816)			✓				
2.	*Acropora cophodactyla* (Brook, 1892)					✓		
3.	*Acropora copiosa* (Nemenzo, 1967)					✓		
4.	*Acropora cuneata* (Dana, 1846)					✓		
5.	*Acropora cytherea* (Dana, 1846)	✓			✓	✓		✓
6.	*Acropora divaricata* (Dana, 1846)			✓				
7.	*Acropora florida* (Dana, 1846)			✓				
8.	*Acropora formosa* (Dana, 1846)	✓	✓	✓	✓	✓	✓	✓
9.	*Acropora gemmifera*, (Brook, 1892)	✓			✓			✓
10.	*Acropora hyacinthus* (Dana, 1846)	✓	✓			✓	✓	✓
11.	*Acropora millepora* (Ehrenberg, 1834)			✓				
12.	*Acropora nobilis* (Dana, 1846)			✓				
13.	*Acropora plantaginea* (Lamarck, 1816)	✓						
14.	*Acropora robusta* (Dana, 1846)			✓				

15.	*Acropora squarrosa* (Ehrenberg, 1834)			✓		✓		
16.	*Acropora verweyi* (Veron and Wallace, 1984)			✓		✓		
17.	*Astreopora myriophthalma* (Lamarck, 1816)			✓				
18.	*Montipora aequituberculata* (Bernard, 1897)				✓			✓
19.	*Montipora crassituberculata* (Bernard, 1897)			✓				
20.	*Montipora digitata* (Dana, 1846)	✓		✓		✓		
21.	*Montipora efflorescens* (Bernard, 1897)			✓				
22.	*Montipora flabellate* (Studer, 1901)			✓				
23.	*Montipora florida* (Nemenzo, 1967)			✓				
24.	*Montipora foliosa* (Pallas, 1766)			✓				
25.	*Montipora nodosa* (Dana, 1846)					✓		
26.	*Montipora peltiformis* (Bernard, 1897)			✓	✓			
27.	*Montipora tuberculosa* (Lamarck,1816)					✓		
28.	*Pavona gigantean* (Verrill, 1896)			✓				
29.	*Tubastreae coccinea* (Lesson, 1829) Fig.6H		✓		✓			✓
30.	*Turbinaria frondens* (Dana, 1846)						✓	
31.	*Turbinaria mesenterina* (Lamarck, 1816) Fig.7A	✓	✓	✓	✓	✓	✓	✓
32.	*Turbinaria peltata* (Esper, 1794) Fig.7B	✓	✓	✓	✓	✓	✓	✓
33.	*Diploastrea heliopora* (Lamarck, 1816)			✓				
34.	*Diploria strigosa* (Dana, 1848) Fig.7C			✓		✓		
35.	*Echinopora lamellose* (Esper, 1795) Fig.7D		✓					✓
36.	*Favia favus* (Forskal, 1775) Fig.7E	✓	✓	✓	✓	✓	✓	✓
37.	*Favia matthaii* (Vaughan, 1918)							✓
38.	*Favia speciosa* (Dana, 1846) Fig.7F	✓	✓	✓	✓	✓	✓	✓
39.	*Favia stelligera* (Dana, 1846)			✓				
40.	*Favia veroni* (Moll & Borel-Best, 1984)						✓	
41.	*Favites abdita* (Ellis & Solander 1786) Fig.7H					✓		
42.	*Favites complanata* (Eherenberg, 1834) Fig.8A						✓	
43.	*Favites halicora* (Eherenberg, 1834)Fig.8B				✓			
44.	*Goniastrea edwardsi* (Chevalier, 1971)					✓		
45.	*Goniastrea minuta* (Veron, 2000) Fig.8C				✓			
46.	*Goniastrea retiformis* (Lamarck, 1816)			✓				
47.	*Leptastrea purpurea* (Dana,1846)			✓				
48.	*Platygyra acuta* (Ellis & Solander, 1786) Fig.8E	✓		✓			✓	
49.	*Platygyra daedalea* (Ellis and Solander, 1786)			✓				
50.	*Platygyra lamellina* (Ehrenberg,1834)			✓				
51.	*Platygyra sinensis* (Milne Edwards and Haime,1849)		✓					
52.	*Platygyra verweyi* (Wijsman-Best, 1976)			✓				
53.	*Cycloseris cyclolites* (Lamarck, 1801)			✓				
54.	*Hydnophora exesa* (Pallas, 1766)			✓				
55.	*Hydnophora microconus* (Lamarck, 1816) Fig.8H	✓		✓			✓	
56.	*Hydnophora pilosa* (Veron, 1985)			✓				
57.	*Australomussa rowleyensis* (Veron, 1985)		✓					
58.	*Symphillia radians* (Milne Edwards & Haime, 1849) Fig.9A	✓				✓		
59.	*Symphillia recta* (Dana, 1846) Fig.9B	✓	✓		✓	✓		✓
60.	*Echinophyllia aspera* (Ellis & Solander, 1788) Fig.9C						✓	
61.	*Pocillopora damicornis* (Linnaeus, 1758) Fig.9D						✓	
62.	*Goniopora columna* (Dana, 1846) Fig.9E				✓			
63.	*Goniopora stokesi* (Milne Edwards and Haime, 1851)			✓				
64.	*Goniopora stutchburyi* (Wells, 1955)			✓				
65.	*Porites lobata* (Dana, 1846)			✓				
66.	*Porites lutea* (Milne Edwards and Haime, 1851) Fig.9F						✓	
67.	*Porites mayeri* (Vaughan, 1918)			✓				
68.	*Porites solida* (Forskal, 1775) Fig.9G	✓					✓	
69.	*Psammocora nierstraszi* (Horst, 1921) Fig.9H			✓				
	Total No. Species	15	11	40	14	20	15	13

(SI –Shingle Island, KI – Kurusadai Island, POI – Poomarichan Island, PI – Pullivasal Island, MPI – Manoliputti Island, MI – Manoli Island, HI - Hare Island)

Discussion

Scleractinian corals diversity and distribution are essential to evaluate the changes in the reef ecosystem of the Gulf of Mannar. The reef ecosystem has been declined by several factors such as coral bleaching, bio-invasion of exotic seaweed, harmful fishing practices like bottom trawling, coral diseases and space competition among the species, etc (Edward *et al.*, 2012; Kumar *et al.,* 2017) [37, 38]. Edward *et al.* (2008) [35] has reported 29% of coral diversity in the Thoothukudi group, 32% in the Vembar group, 44% in the Keelakarai group and 37% in the Mandapam group of Islands. Followed by Marimuthu *et al.* (2010) [34] reporting 65% of coral cover in the Manoli reef complex and 64% in the Kurusadai reef complex. Geetha and Kumar (2012) [6] reported 50.63% of live coral in Pulivinichalli Island in the Vembar group and 30.63% in Van Island, Thoothukudi group. Machendiranathan *et al.* (2016) [39] recorded 36% of live coral cover from the Mandapam group of Islands.

The result of the present study shows 41.3% of live coral covers in the Mandapam group of Islands. A maximum live corals reported in Poomarichan Islands and minimum in Pullivasal Islands. It might be due to the fact that the Poomarichan Island is located in a confined zone and less sediment deposition site and Pullivasal Islands is spacing seaward side, strong wave actions affecting the coral reef during the monsoon season. Kumaraguru *et al.* (2005) [40] explained that the coral cover declined during the natural disturbances like wave actions, monsoon effect, sedimentation rate etc. Marimuthu *et al.* (2010) [34] recorded 64% of live coral cover in the Kurusadai complex during 2006 to 2008 and a high sedimentation rate observed during the southwest monsoon period. Edward *et al.* (2012) [37] published coral bleaching impact in the Gulf of Mannar reef ecosystem, only 33.20% of live corals reported in 2010 bleaching and 37.31% of live coral in 2011. The statistical analysis of Principal Component Analyses and Correspondence Analysis also support the present result. The Bray-Curtis analyses shows Kurusadai Island and Pullivasal Island have more than 90% similarity, like that of the Manoli Island and Hare Island shows 95% similarity as both the islands are much closer. But Poomarichan Island and Manoliputti Island have 93% similarity, live coral cover 51.4% and 45.8% in the both Islands. The Shingle Islands have 90% similarity with Poomarichan Island and Manoliputti Island; the live coral cover also 47.5% and these three islands have a maximum live coral cover. Maybe these islands have good space for the coral settlement and a confined zone for coral reef ecosystem in the Mandapam group of Islands. Marimuthu *et al.* (2010) [34] recorded 48 species of scleractinian corals from the Mandapam group of Islands. During the study, the observed scleractinian corals were listed (Table 2; Fig.6-9). A total of 69 species of scleractinian corals were identified from the seven study Islands (Veron, 2000; Venkataraman *et al.*, 2003) [41, 32]. Further studies and regular monitoring of the reef ecosystem are required to formulate a suitable management strategy to conserve the reef ecosystem and assess the major factors that influence the abundance of reef diversity in the Gulf of Mannar reef Islands.

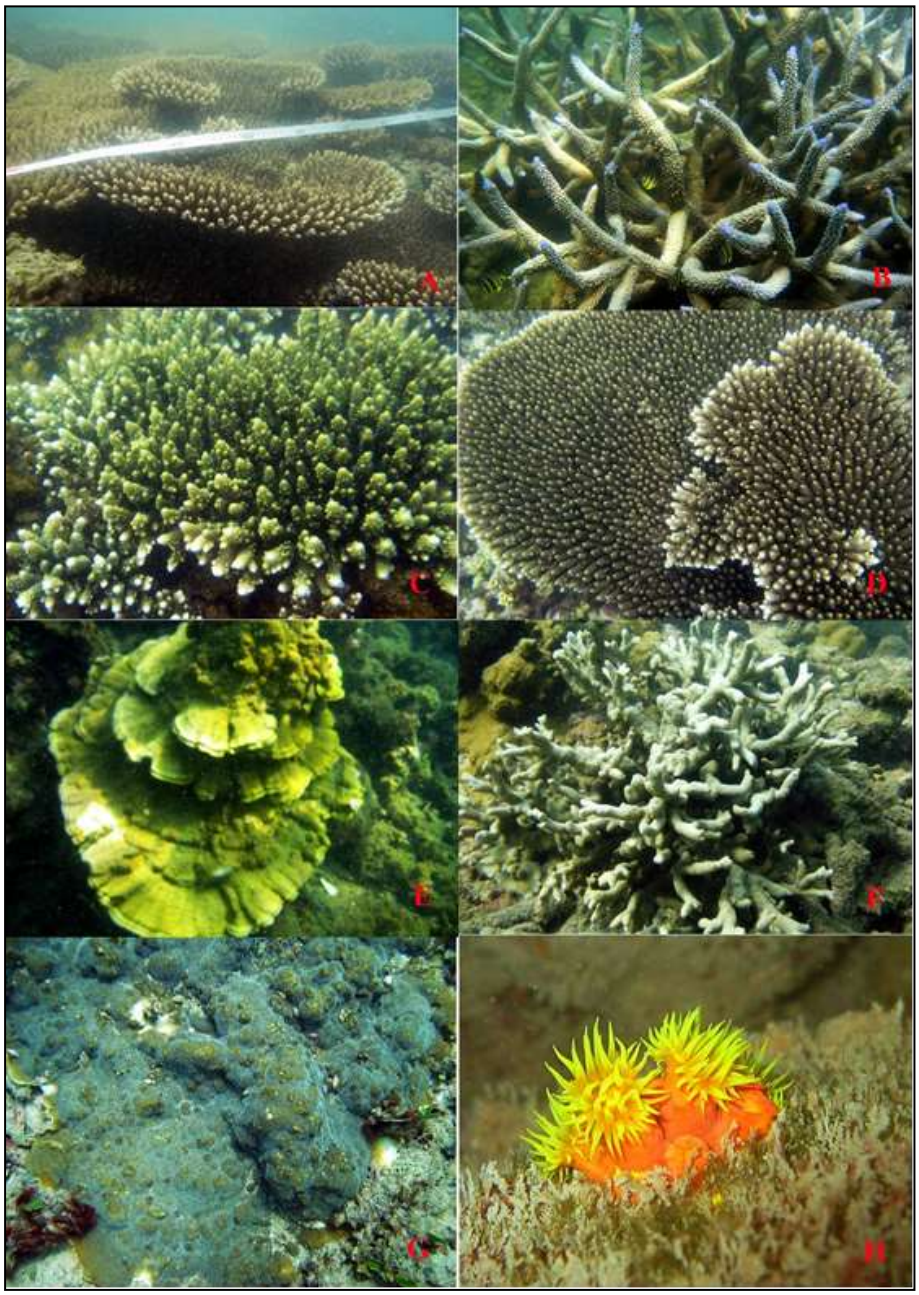


Fig 6A: D *Acropora sp.* E - G *Montipora sp.* H - *Tubastreae coccinea*

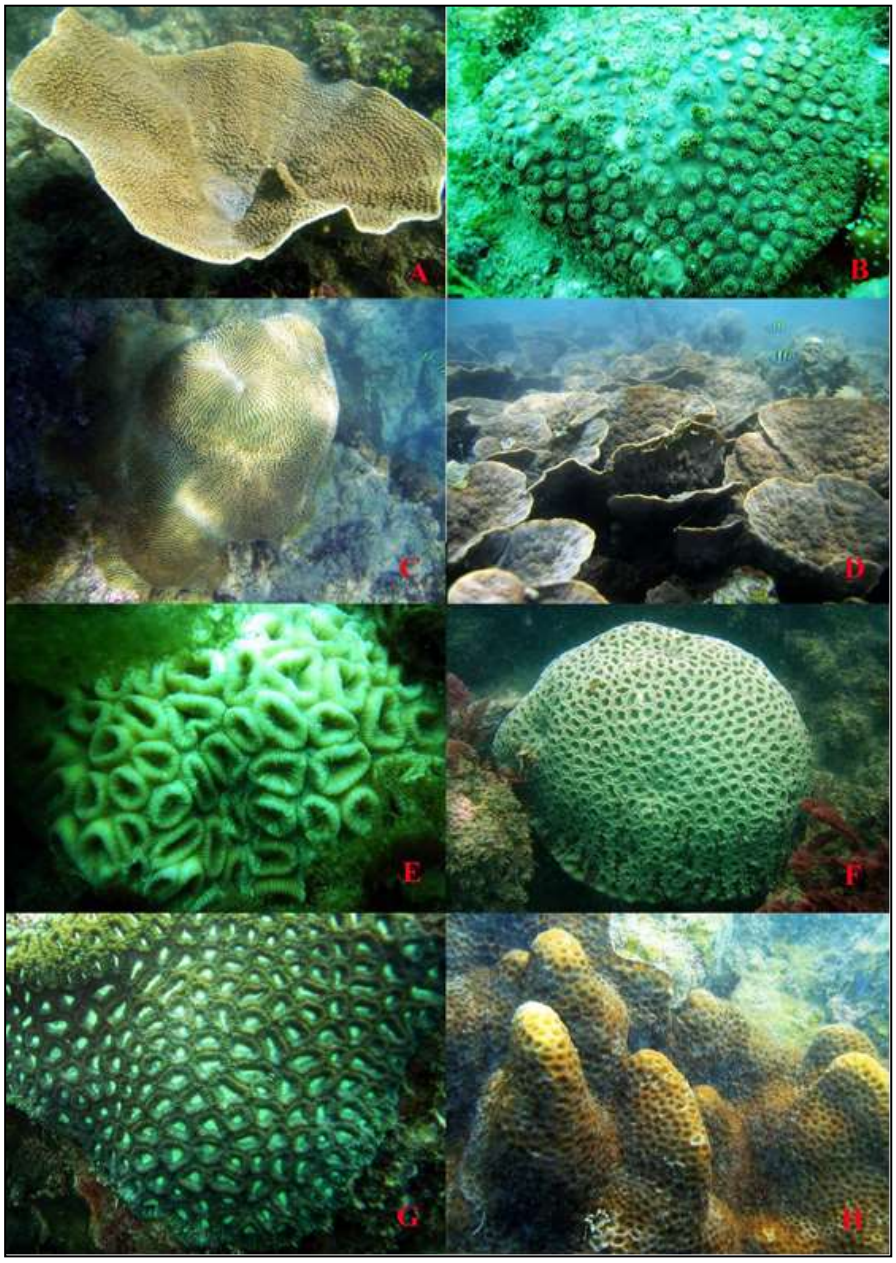
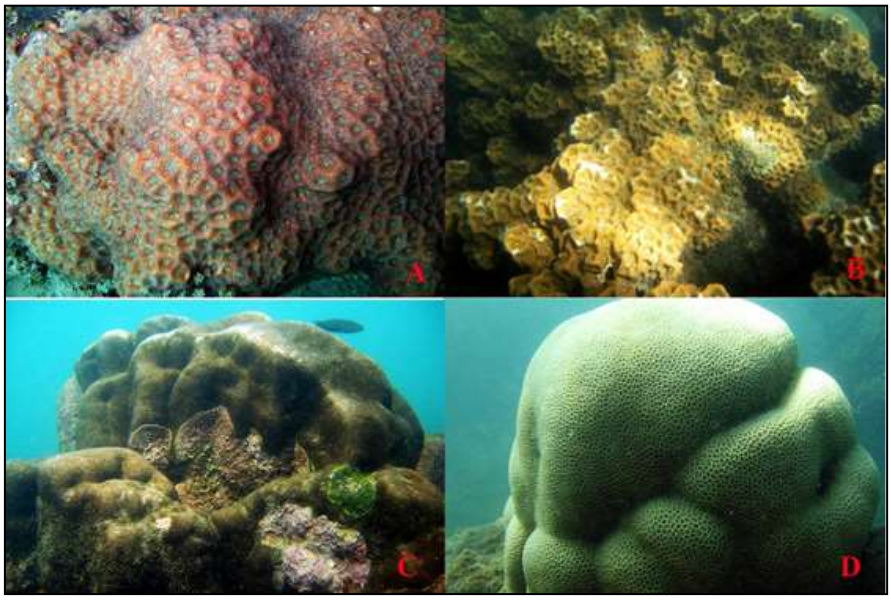


Fig 7A: *Turbinaria mesenterina*, B- *Turbinaria peltata*, C- *Diploria strigosa*, D- *Echinopora lamellose*, E- *Favia favus*, F- *Favia speciosa*, G- *Favia sp.*, H- *Favites abdita*



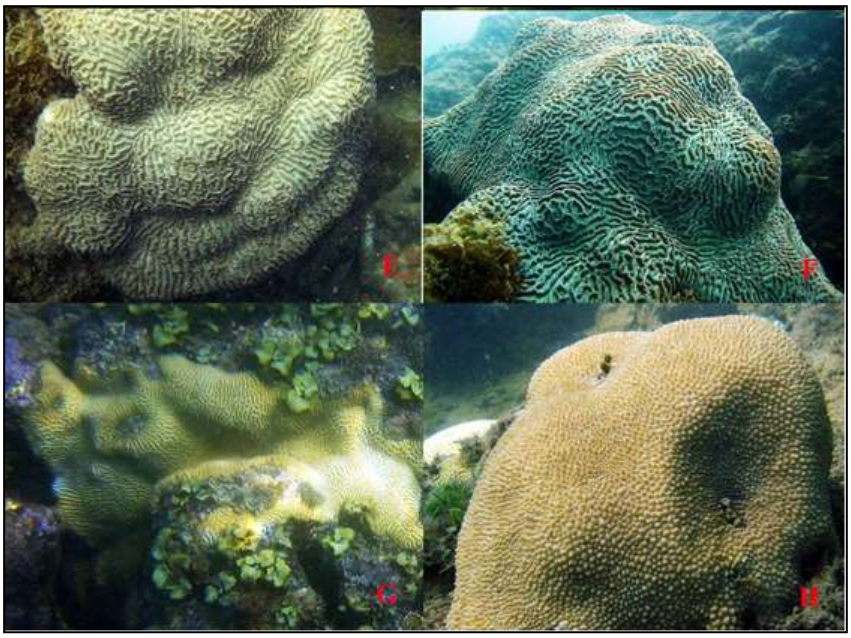


Fig 8A: *Favites complanata,* B- *Favites halicora,* C- *Goniastrea minuta,* D- *Goniastrea sp.,* E- *Platygyra acuta,* F- *Platygyra sp.* G- *Platygyra sp.,* H- *Hydnophora microconus*

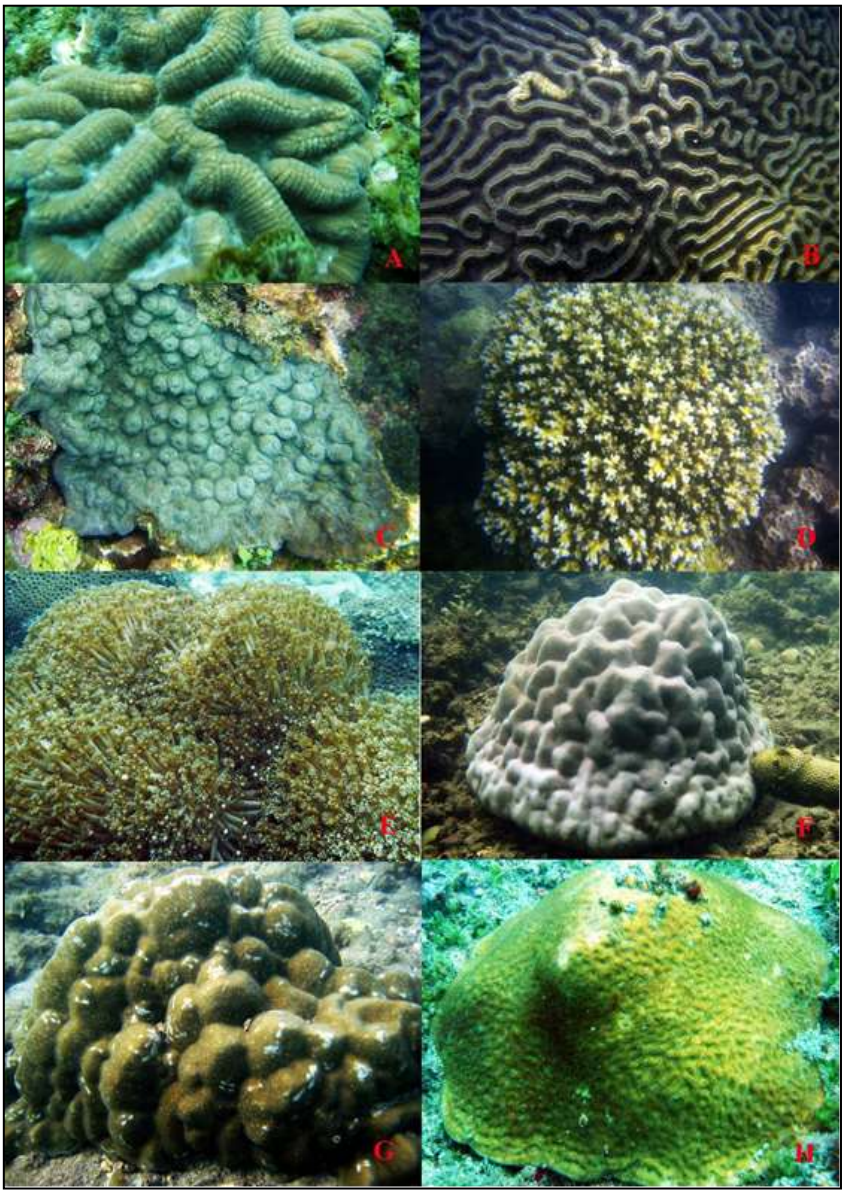


Fig 9A: *Symphillia radians,* B- *Symphillia recta,* C- *Echinophyllia aspera,* D- *Pocillopora damicornis,* E- *Goniopora columna,* F- *Porites lutea,* G- *Porites solida,* H- *Psammocora nierstraszi*

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