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Diversity of Scleractinian Corals in Middle and North Andaman Archipelago

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Abstract: The islands of Andaman & Nicobar groups are with a variety of consequently evolving rich several ecosystems and its ecological status denoting areas on Andaman Sea. This study aims to characterize the coral communities and to identify and compare the scleractinian species diversity in the study area. A total 224 species of Scleractinian corals were recorded from different stations of Middle and North Andaman. Shannon-Weaver Diversity index (H¯) of Scleractinian corals of the islands is in between 3.633 and 7.05, indicating very high coral diversity of those places. On the basis of Sørensen similarity index (QS), it could be seen that the islands have a wide range of similarity in species composition as the values ranges from 0.206 to 0.784. Simpson's species density index (D) reveals that the density of species of the areas are in healthy stage as the value of index ranges from 0.873 to 0.99 which is very near to the maximum value. Pielou's Species evenness index (J') indicates that the species evenness in the community of the islands is quite enrich as the value ranges from 0.956 to 0.840.

Key words: Scleractinian Coral · Species Diversity · Species Density · Species Evenness · North and Middle Andaman

INTRODUCTION

The physical structure of most ecological communities is formed by plants and, on some marine hard substrates, by sessile animals such as corals, anemones, bryozoans, ascidians, molluscs and barnacles. Variations in the abundance of these ''structural species'' are critical to the dynamics of the whole community, including the associated ''interstitial species,'' such as mobile animals [1]. It is now widely appreciated that ecosystem functioning is dictated to a large degree by biodiversity and the community structure that result from factors such as the richness and evenness of the diversity. Diversity at all levels, including infra-specific or genetic diversity that characterize populations of a species, species diversity that characterize communities and in turn community diversity that characterize an ecosystem, all play a major role in this. Worldwide interest in the role of biodiversity in marine ecosystem processes is relatively more recent [2]. In the Indian context, studies on the taxonomic diversity of marine organisms have had a long tradition [3]. Increasing concern on destruction of marine habitats, bio-invasions and alterations to the diversity of various life forms make it necessary now for the management to understand the relation between biodiversity and ecosystem functioning in our coastal and offshore waters. The Andaman & Nicobar Islands are a low mountain chain of islands, which rise from a submerged north-south trending ridge separating the sea from Bay of Bengal between 6°-14° N and 92°-94° E. There are 572 islands in the chain, some of which are volcanic. The islands occupy an area of 8293 km^2 with a coastline of 1962 km and account for 30% of the Indian Exclusive Zone [4]. A living coral reef is one of the most glorious and fantastic sights on our planet [5]. Corals have been an important structural feature of reefs in shallow tropical seas since the days of the dinosaurs 100 million years ago. Coral reefs of the type we see today have been around for about 25 million years. They are highly productive and biologically diverse. Coral reefs are ecologically important fragile ecosystem restricted to warm seas, essentially between the tropics of Cancer and Capricorn, where minimum water temperature do not fall below 20°C. Although coral reefs are geographically restricted to tropical seas and their occurrence limited to 0.2% of the ocean area on the earth's surface [6, 7]. They

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are home to members of all the phyla or major groups of the animal kingdom. Put simply, they are a key part of the natural heritage and of the stock of biological diversity of the world. The productivity of healthy coral reefs sustains a rich interlinked network of species which has been the main source of food and resources for many tropical coastal and island people since the time of the first humans. The biological diversity of reefs is a natural treasure which may support future activities yet undreamed of. Already reef species are yielding powerful chemicals effective in treatment of disease. In the future reefs may add to the range of species that can be cultivated to provide food, materials and economic support for people of tropical developing countries. Coral reefs form natural breakwaters protecting the fertile coastal lands and human settlements of many island and continental nations from erosion by storm waves. The beauty and diversity of coral reefs have long been a source of wonder to coastal and inland people and visiting mariners. For many communities they have a deep cultural aesthetic and spiritual significance. Measurements of coral growth rates (as vertical extension) are used regularly as reef health indicators, especially in environments characterized by high terrigenous sediment input [8]. Over the past three decades, a decline in reef coral abundance and diversity has been observed globally [9-13] due to anthropogenic and natural causes. The ability of coral reef ecosystems to exist in balanced harmony with other naturally occurring competing/limiting physico-chemical and biological agents has been severely challenged in the last several decades by the dramatically increased negative and synergistic impacts from poorly managed anthropogenic activities [14]. The present study was undertaken to inventories the scleractinian corals present in the region. The present paper deals with the documentation of the scleractinian coral of the various surveyed places. The quantitative data of the surveyed corals indicates the diversity, density and evenness of species in a community, present status as well as their relationship among themselves in the various areas of middle and north Andaman Archipelago. This documentation of status is very essential for the effective management and conservation of this unique marine ecosystem.

MATERIALS AND METHODS

The study was conducted in various sites of North and Middle Andaman during the period of March, 2009 to October 2011. The place of studies are Ross Island (Lat. 13° 18. 167'N & Long. 93° 04.261'E), Smith Island (Lat. 13° 18. 406'N & Long. 93° 04.207'E), Ariel Bay (Lat. 13° 16. 093'N & Long. 93° 02.433'E), North Reef Island (Lat. 12° 56. 084'N & Long. 92° 57.345'E), Interview Island (Lat. 12° 59. 125'N & Long. 92° 42.981'E), Avis Island (Lat. 12°54.917'N & Long. 92°55.954'E), Karlo Island (Lat. 12°56.282'N & Long. 92°53.541'E), Sound Island (Lat. 12°56.167'N & Long. 92°58.113'E), Rail Island (Lat. 12°59.033'N & Long. 92°54.137'E). Map coordinates of the surveyed places showed in Table 1 were measured by handheld Global Positioning System (GPS) unit of Garmin.

Each island was surveyed primarily using "Manta tow" study method [15, 16]. A series of 20 m transects were placed at random sampling method to continue Line Intercept Transect Method [17]. As well as Quadrate methods [18] was also applied to investigate the diversity of the scleractinian corals of the surveyed areas. For the purpose of this study each location and depth combination was considered an individual "site".

Data were collected by Self Contained Underwater Breathing Apparatus (SCUBA) diving and snorkeling during the above said study period. A 1 m^2 PVC framed quadrate was placed at 0 m, 1 m and 2 m on the shoreward side of each transect. Belt transect method was applied to get the data of the diverse scleractinian corals. Each quadrate was photographed with a housed digital camera (Sony-Cyber shot, Model-T900, marine pack, 12 megapixels) oriented toward the start of transect. Wherever possible, the entire quadrate was photographed in a single image. Occurrence of coral species in each quadrate was recorded. Corals were photographed within each quadrate when first encountered. In some cases, corals not recorded inside quadrates were photographed to document their presence in the study area. Species individual photo quadrates were identified in conjunction with Veron [19], Wallace [20] and labeled according to the Islands.

The species diversity of corals was evaluated following Shannon-Weaver diversity index formula as described below [21].

$$H' = -\Sigma pi \log_e pi$$

Where, pi = Proportion of number of individual of a particular species and total number of individual of all the species, H'= diversity of a theoretically infinite population.

Similarity Index is the simple measure of the extent to which two habitats species in common. The Sørensen index, also known as Sørensen's similarity coefficient, is a statistic used for comparing the similarity of two samples [22].

Table 1: Diversity and distribution of Scleractinian Corals of Middle and North Andaman

Sl. No	Species Name	AV	SN	RL	KR	IT	NR	SM	RS	AR
	Family ACROPORIDAE Verrill, 1902									
	Genus *Acropora* Oken, 1815									
1.	*Acropora austera* (Dana,1846)	+	+	-	-	+	+	+	+	+
2.	*Acropora abrotanoides* (Lamarck, 1816)	-	+	+	-	+	+	+	-	+
3.	*Acropora awi* Wallace and Wolstenholme,1998	-	-	-	-	-	-	+	-	-
4.	*Acropora cerealis* (Dana, 1846)	+	+	-	-	+	+	+	+	+
5.	*Acropora chesterfieldensis*(Veron and Wallace)	-	-	-	-	-	-	+	-	-
6.	*Acropora copiosa* Nemenzo,1967	+	+	+	-	+	+	-	-	-
7.	*Acropora aspera* (Dana, 1846)	+	+	+	+	+	+	+	+	+
8.	*Acropora cytherea* (Dana, 1846)	+	+	-	+	+	+	+	+	+
9.	*Acropora fastigata* Nemenzo, 1967	+	+	-	-	-	+	-	-	-
10.	*Acropora forskali* (Ehrenberg,1834)	+	+	-	-	+	+	+	-	-
11.	*Acropora formosa* (Dana, 1846)	+	+	+	+	+	+	+	+	+
12.	*Acropora inermis* (Brook, 1891)	-	-	-	-	+	+	+	+	+
13.	*Acropora plantaginea* (Lamark, 1816)	-	-	-	-	-	-	+	-	+
14.	*Acropora haimei* (Milne Edwards & Haime, 1860)	-	-	-	-	-	+	+	-	+
15.	*Acropora humilis*(Dana, 1846)	+	+	-	-	+	+	+	-	+
16.	*Acropora hyacinthus* (Dana, 1846)	+	+	-	-	+	+	+	-	-
17.	*Acropora intermedia* (Wallace, 1999)	-	-	-	-	-	-	+	-	-
18.	*Acropora kosurini* Wallace, 1994	-	-	-	-	-	-	+	-	+
19.	*Acropora kimbeensis* Wallace, 1999	+	-	-	-	+	+	+	-	+
20.	*Acropora latistella* (Brook, 1891)	+	-	-	-	-	+	+	+	+
21.	*Acropora loripes* (Brook, 1892)	+	-	-	-	+	+	-	-	-
22.	*Acropora longicyathus* (MED & H, 1860)	-	-	-	-	-	-	+	-	-
23.	*Acropora lutkeni* Crossland, 1952	-	+	-	-	-	+	-	-	+
24.	*Acropora mirabilis* (Quelch,1886)	-	+	-	-	-	-	-	-	-
25.	*Acropora millepora*(Ehrenberg, 1834)	+	+	-	-	+	+	+	+	+
26.	*Acropora monticulosa* (Bruggemann, 1879)	+	+	+	-	+	+	+	+	+
27.	*Acropora microclados* (Ehrenberg, 1834)	-	+	-	-	+	+	+	+	+
28.	*Acropora microphthalma* (Verrill, 1859)	-	+	-	-	+	+	+	+	+
29.	*Acropora nasuta* (Dana, 1846)	+	+	-	-	+	+	-	+	+
30.	*Acropora nobilis* (Dana 1846)	+	+	-	-	+	+	+	+	+
31.	*Acropora ocellata* (Bernard, 1896)	-	-	-	-	-	-	+	+	+
32.	*Acropora paniculata* Verrill, 1902	-	-	-	-	-	-	-	-	+
33.	*Acropora palamrae* Wells, 1954	+	-	-	-	+	+	+	-	-
34.	*Acropora palifera* (Lamarck, 1816)	+	+	+	-	-	+	+	+	+
35.	*Acropora pulchra* (Brook, 1891)	-	+	-	-	-	+	+	+	+
36.	*Acropora polystoma* (Brook, 1891)	-	-	-	-	+	-	+	-	+
37.	*Acropora rudis* (Rehberg, 1892)	+	+	-	-	+	+	+	+	+
38.	*Acropora robusta* (Dana, 1846)	+	+	+	-	+	+	+	+	+
39.	*Acropora selago* (Studer, 1878)	-	-	-	-	-	-	-	-	+
40.	*Acropora speciosa* (Quelch, 1886)	-	-	-	-	-	-	+	+	+
41.	*Acropora subglabra* (Brook,1891)	-	+	-	-	+	-	-	-	+
42.	*Acropora wallaceae* (Veron, 1990)	+	-	-	-	-	-	+	+	-
43.	*Acropora vaughani* Wells, 1954	+	+	-	-	+	+	-	-	-
44.	*Acropora aspera* (Dana, 1846)	+	+	+	-	+	+	+	+	+
45.	*Acropora brueggemanni* (Brook, 1893)	-	+	-	-	-	+	-	-	-
46.	*Acropora multiacuta* (Nemenzo, 1967)	-	-	-	-	-	-	-	-	+
47.	*Acropora carduus* (Dana, 1846)	-	-	-	-	-	+	+	+	-
48.	*Acropora digitifera* (Dana, 1846)	-	-	-	-	+	+	+	-	+
49.	*Acropora divaricata* (Dana, 1846)	+	-	-	-	+	+	+	+	+
50.	*Acropora florida* (Dana, 1846)	+	+	-	-	+	+	+	+	+
51.	*Acropora yongei* (Veron & Wallace, 1984)	-	-	-	-	-	-	+	-	+
52.	*Acropora schmitti* (Wells, 1950)	+	-	-	-	+	+	+	+	+
53.	*Acropora samoensis* (Brook, 1891)	-	-	-	-	-	-	+	-	-
54.	*Acrpora spicifera* (Dana, 1846)	+	+	+	-	+	+	+	-	-

Table 1: Continued

55.	*Acropora gemmifera* (Brook, 1892)	+	+	+	-	+	+	+	+	+
56.	*Acropora dendrum* (Bassett-Smith, 1890)	-	+	-	-	+	+	-	-	+
57.	*Acropora grandis* (Brook, 1892)	+	+	-	-	+	+	+	+	+
58.	*Acropora teres* (Verrill, 1866)	-	-	-	-	-	+	-	-	-
59.	*Astreopora myriophthalma* (Lamarck,1816)	+	+	-	-	+	+	+	-	-
60.	*Astreopora suggesta* Wells,1954	-	-	-	-	+	+	-	-	+
	Genus *Montipora* de Blainville, 1830									
61.	*Montipora aequituberculata* Barnard, 1897	+	+	-	-	+	+	+	+	+
62.	*Montipora caliculata* (Dana, 1846)	-	-	-	-	+	+	+	-	-
63.	*Montipora capitata* Dana, 1846	+	+	-	-	+	+	+	-	-
64.	*Montipora delicatula* (Veron, 2000)	-	-	-	-	-	-	+	-	-
65.	*Montipora digitata* (Dana, 1846)	-	+	-	-	+	-	+	+	+
66.	*Montipora exserta* Quelch, 1886	-	-	-	-	-	+	-	-	-
67.	*Montipora foveolata* (Dana, 1846)	-	-	-	-	+	+	+	-	+
68.	*Montipora foliosa* (Pallas, 1766)	+	+	-	-	+	+	+	+	+
69.	*Montipora hemispherica* (Veron, 2000)	-	-	-	-	+	-	+	-	+
70.	*Montipora hispida* (Dana, 1846)	+	+	-	-	+	+	+	+	+
71.	*Montipora informis* Bernard, 1897	+	+	-	-	+	+	+	+	+
72.	*Montipora grisea* (Bernard, 1897)	-	-	-	-	-	-	+	-	-
73.	*Montipora jonesi* Pillai, 1969	-	-	-	-	+	-	-	-	-
74.	*Montipora manauliensis* Pillai, 1967	+	+	-	-	-	-	-	-	+
75.	*Montipora meandrina*(Ehrenberg,1834)	-	+	-	-	+	+	+	+	+
76.	*Montipora monasteriata* (Forskal, 1775)	-	-	-	-	-	+	+	-	-
77.	*Montipora peltiformis* Benard, 1897	+	+	+	-	+	+	+	+	+
78.	*Montipora spumosa* (Lamarck, 1816)	-	+	-	-	-	-	-	-	-
79.	*Montipora undata* Bernard, 1897	-	+	-	-	+	+	+	-	-
80.	*Montipora mollis*(Bernard, 1897)	-	+	-	-	-	+	-	-	+
	Family AGARICIIDAE Gray, 1847									
	Genus *Coeloseris* Vaughan,1918									
81.	*Coeloseris.mayeri* Vaughan, 1918	-	-	-	-	+	-	-	-	-
	Genus *Gardineroseris* Scheer & Pillai, 1974									
82.	*Gardineroseris.plannulata* (Dana, 1846)	-	-	-	-	-	+	+	-	+
	Genus *Leptoseris* MED & H,1849									
83.	*Leptoseris explanata* Yabe & Sugiyama, 1941	+	+	+	-	+	+	+	+	+
84.	*Leptoseris cucllata* (Ellis & Solander, 1786)	-	-	-	-	+	-	-	-	+
85.	*Leptoseris hawaiensis* Vaughan, 1907	-	-	-	-	-	+	-	-	+
86.	*Leptoseris incrustans* (Quelch,1886)	-	+	-	-	+	+	+	+	+
	Genus *Pachyseris* MED & H, 1849									
87.	*Pachyseris gemmae* Nemenzo, 1955	+	+	+	-	+	+	+	+	+
88.	*Pachyseris foliosa* Veron, 1990	-	-	-	-	-	+	+	+	+
89.	*Pachyseris rugosa* (Lamarck,1801)	-	-	-	-	+	+	+	-	-
90.	*Pachyseris speciosa* (Dana, 1846)	-	+	-	-	+	+	+	-	+
	Genus *Pavona* Lamarck,1801									
91.	*Pavona danai* (Milne Edwards & Haime, 1860)	-	-	-	-	-	-	+	-	-
92.	*Pavona decussarata* (Dana, 1846)	-	-	-	-	-	-	-	-	-
93.	*Pavona duerdeni* Vaughan, 1907	+	+	-	-	+	+	+	+	+
94.	*Pavona explanulata* (Lamarck, 1816)	-	-	-	-	-	+	+	+	+
95.	*Pavona rugosa* (Lamarck, 1801)	+	+	-	-	+	+	+	-	-
96.	*Pavona maldivensis* (Gardiner, 1905)	-	-	-	-	-	-	-	-	+
97.	*Pavona minuta* Wells, 1954	+	+	+	-	+	+	-	-	-
98.	*Pavona varians* Verrill,1846	-	-	-	-	-	-	+	-	-
99.	*Pavona venosa* (Ehrenberg, 1834)	-	-	-	-	+	+	-	-	+
	Family ASTROCOENIIDAE Koby, 1890									
	Genus *Stylocoeniella* Yabe & Sugiyama, 1935									

Table 1: Continued

100.	*Styloceniella guentheri* Basset Smith 1890	-	-	-	-	-	+	-	-	-
	Family DENROPHYLLIIDAE Gray, 1847									
	Genus *Tubastrea* Lesson, 1829									
101.	*Tubastrea mesenterina* (Lamarck, 1816)	-	-	-	-	-	+	-	-	-
	Family EUPHYLLIDAE Veron, 2000									
102.	Genus *Euphyllia* Dana, 1846									
103.	*Euphyllia glabrescens*(Chamisso & Eyscenhardt, 1821)	+	+	-	-	+	+	+	-	-
	Genus *Physogyra* Quelch, 1884									
104.	*Physogyra lichtensteini* (MED & H, 1851)	-	-	-	-	+	-	-	-	-
	Genus *Plerogyra* Milne-Edwards and Haime, 1848									
	Family FAVIIDAE Gregory, 1900									
	Genus *Barabattoia* Yabe and Sugiyama, 1941									
105.	*Barabattoia amicorum* (Milne Edwards & Haime,1850)	-	+	-	-	+	+	+	-	-
106.	*Barabattoi laddi* (Wells, 1954)	-	-	-	-	-	+	+	-	-
	Genus *Cyphastrea* MED & H, 1848									
107.	*Cyphastera japonica* Yabe and Sugiyama,1932	-	-	-	-	+	+	+	-	+
108.	*Cyphastera microphthalma* (Lamarck, 1816)	-	+	-	-	+	+	+	-	-
	Genus *Diploastrea* Matthai, 1914									
109.	*Diploastrea helipora* (Lamarck, 1816)	+	+	-	-	+	+	+	-	+
	Genus *Diploria* MED & H, 1848									
110.	*Diploria strigosa* (Dana,1848)	-	-	-	-	-	-	+	-	+
	Genus *Echinopora* Lamarck, 1816									
111.	*Echniopora fruticulosa* (Ehrenberg,1834)	-	-	-	-	-	-	+	+	+
112.	*Echniopora gemmacea* Lamarck, 1816	-	-	-	-	-	-	+	-	+
113.	*Echniopora horrida* Dana, 1846	-	-	-	-	-	-	-	-	+
114.	*Echniopora lamellosa* (Esper,1795)	-	-	-	-	+	+	-	-	+
	Genus *Favia* Oken, 1815									
115.	*Favia favus* (Forskal, 1775)	+	+	+	-	+	+	+	+	+
116.	*Favia helianthoides* Wells, 1954	-	-	-	-	+	+	+	-	-
117.	*Favia lacuna* Veron,Turak and DeVantier, 2000	-	+	-	-	+	+	+	+	+
118.	*Favia laxa* (Klunzinger, 1879)	-	-	-	-	+	-	+	+	+
119.	*Favia matthaii* Vaughan, 1918	+	+	+	+	+	+	+	+	+
120.	*Favia lizardensis* Veron and Pichon, 1977	+	+	-	-	+	+	+	+	+
121.	*Favia pallida* (Dana, 1846)	+	+	+	+	+	+	+	+	+
122.	*Favia maritima* (Nemenzo, 1971)	-	-	-	-	-	+	+	-	
123.	*Favia truncates* Veron, 2000	-	+	-	-	-	+	-	-	-
	Genus *Favites* Link, 1807									
124.	*Favites abdita* (Ellis & Solander, 1786)	-	+	-	-	+	+	+	-	-
125.	*Favites complanata* (Ehrenberg, 1834)	+	+	+	-	+	+	+	+	+
126.	*Favites flexuosa* (Dana, 1846)	+	+	-	-	-	+	+	-	+
127.	*Favites halicora* (Ehrenberg,1834)	+	+	+	-	+	+	+	+	+
128.	*Favites micropentagona* Veron, 2000	-	-	-	-	-	-	+	-	+
129.	*Favites chinensis* (Verrill, 1866)	-	-	-	-	+	+	-	-	-
130.	*Favites pentagona* (Esper,1794)	-	+	-	-	+	-	-	+	+
	Genus *Goniastrea* MED & H, 1848									
131.	*Goniastrea australensis* (MED &H, 1857)	-	-	-	-	+	-	+	-	+
132.	*Goniastrea edwardsi* Chevalier,1971	+	+	+	+	+	+	+	+	+
133.	*Goniastrea favulus* (Dana,1846)	-	-	-	-	+	+	-	-	-
134.	*Goniastrea pectinata* (Ehrenberg, 1834)	-	-	-	-	+	-	-	-	+
135.	*Goniastrea retiformis* (Lamarck, 1816)	+	+	+	+	+	+	+	+	+
	Genus *Leptoria* MED & H,1848									
136.	*Leptoria irregularis* Veron,1990	+	+	-	-	+	+	+	+	+
137.	*Leptoria phrygia* (Ellis & Solander, 1786)	-	-	-	-	+	+	+	+	+
	Genus *Leptastrea* MED & H, 1848									

Table 1: Continued

138.	*Leptastrea aequalis* Veron, 2000	+	+	-	-	+	+	+	-	-
139.	*Leptastrea purpurea* (Dana, 1846)	-	-	-	-	-	-	+	+	+
140.	*Leptastrea transversa* Klunzinger, 1879	-	-	-	-	-	-	+	-	-
	Genus *Montastrea* de Blainville, 1830									
141.	*Montastrea curta* (Dana, 1846)	+	+	-	-	+	+	+	-	-
	Genus *Oulophyllia* MED &H, 1848									
142.	*Oulophyllia crispa* (Lamarck, 1816)	-	+	-	-	+	+	+	+	+
	Genus *Oulastrea* MED & H, 1848									
143.	*Oulastrea crispata* (Lamarck, 1816)	-	+	-	-	+	-	-	-	-
	Genus *Platygyra* Ehrenberg, 1834									
144.	*Platygyra acuta* Veron, 2000	-	+	-	-	+	+	+	-	+
145.	*Platygyra crosslandi* Matthai, 1928	+	+	-	-	+	+	+	-	-
146.	*Platygyra daedalea* (Ellis & Solander, 1786)	-	-	-	-	-	-	+	+	+
147.	*Platygyra lamellina* (Ehrenberg, 1834)	+	+	-	-	+	+	+	-	-
148.	*Platygyra pini* Chevalier, 1975	-	+	-	-	+	+	+	-	+
149.	*Platygyra sinensis* (MED & H, 1849)	+	+	+	-	+	+	-	-	+
150.	*Platygyra verweyi* Wijsman-Best, 1976	-	-	-	-	-	-	-	-	+
	Family FUNGIIDAE Dana,1846									
	Genus *Cycloseris* MED & H,1849									
151.	*Cycloseris cyclolites* (Lamarck, 1801)	-	+	-	-	+	+	+	-	-
152.	*Cycloseris curvata* (Hoeksema, 1989)	+	+	+	-	+	-	+	-	-
153.	*Cycloseris costulata* (Ortmann, 1889)	-	+	-	-	+	+	-	-	-
154.	*Cycloseris patelliformis* (Boschma, 1923)	-	+	-	-	-	-	-	-	-
155.	*Cycloseris sinensis* MED & H, 1849	-	-	-	-	-	-	+	-	+
156.	*Cycloseris somervillei* (Gardiner, 1909)	-	+	-	-	-	-	+	-	+
157.	*Cycloseris tenuis*(Dana,1846)	+	+	+	-	+	+	-	-	+
	Genus Ctenactis Verrill, 1864									
158.	*Ctenactis crassa (Dana, 1846)*	+	+	+	+	+	+	+	+	+
159.	*Ctenactis echinata (Pallas, 1766)*	+	+	+	+	+	+	+	+	+
	Genus Diaseris MED& H,1849									
160.	*Diaseris distorta* (Michelin, 1843)	-	+	-	-	+	+	+	-	+
161.	*Diaseris fragilis* (Alcock, 1893)	-	-	-	-	-	-	+	-	-
	Genus Fungia Lamarck,1801									
162.	*Fungia concinna* Verrill, 1864	+	+	+	+	+	+	+	+	+
163.	*Fungia corona* Doderlein, 1901	-	+	+	+	+	-	+	+	+
164.	*Fungia danai* MED & H,1851	+	+	+	+	+	+	+	-	-
165.	*Fungia fralinae* Nemenzo,1955	-	-	-	-	-	+	-	-	+
166.	*Fungia fungites* (Linnaeus,1758)	+	+	+	+	+	+	+	+	+
167.	*Fungia granulosa* Klunzinger, 1879	-	+	-	-	+	+	+	-	+
168.	*Fungia horrida* Dana, 1846	-	+	-	-	-	-	-	-	+
169.	*Fungia klunzingeri* Doderlein, 1901	+	+	-	-	-	+	-	-	+
170.	*Fungia moluccensis* Horst, 1919	-	-	-	-	-	+	-	-	-
171.	*Fungia paumotensis* Stutchbury, 1833	+	+	+	+	+	+	+	+	+
172.	*Fungia repanda* Dana, 1846	+	+	+	+	+	+	-	+	+
173.	*Fungia scutaria* Lamarck,1801	-	-	-	-	-	+	-	-	-
174.	*Fungia scabra* (Doderlein,1901)	+	-	-	-	+	+	+	-	+
175.	*Fungia taiwanensis* Hoeksema and Dai,1991	-	+	-	-	-	-	-	-	-
	Genus *Halomitra* Dana,1846									
176.	*Halomitra pileus* (Linnaeus, 1758)	-	-	-	-	-	+	+	-	-
	Genus *Cantharellus* Höksema and Best, 1984									
177.	*Cantharellus jebbi* (Hoeksema, 1993)	-	-	-	-	-	-	+	-	-
	Genus *Herpolitha* Eschscholtz, 1825									
178.	*Herpolitha limax* (Houttuyn, 1772)	+	+	-	-	+	+	+	-	-
179.	*Herpolitha weberi* Horst,1921	-	+	-	-	+	+	+	-	+
	Genus *Lithophyllon* Rehberg, 1892									

Table 1: Continued

180.	*Lithophyllon lobata (*Horst, 1921)	-	+	+	-	+	+	+	-	-
181.	*Lithophyllon undulatum* Rehberg, 1892	+	+	+	-	+	+	+	-	+
	Genus *Podabacia* MED & H,1849									
182.	*Podabacia crustacea* (Pallas,1766)	-	-	+	-	+	-	-	-	-
183.	*Podabacia sinai* Veron, 2000	-	-	+	-	-	+	-	-	-
184.	*Podabacia lanakensis* Veron, 2000	-	-	-	-	-	+	-	-	-
185.	Genus *Sandalolitha* Quelch, 1884									
186.	*Sandalolitha dentata* Quelch, 1884	-	+	-	-	-	-	-	-	-
187.	*Sandalolitha robusta* (Quelch,1886)	-	-	-	-	-	+	+	-	+
	Family MERULINIDAE Verrill,1866									
	Genus *Hydnophora* Fischer de Waldheim,1807									
188.	*Hydnophora exesa* (Pallas,1766)	-	-	-	-	+	+	-	-	+
189.	*Hydnophora grandis* Gardiner, 1904	+	+	+	-	-	+	+	+	+
190.	*Hydnophora microconos* (Lamarck, 1816)	+	+	-	-	+	+	+	+	+
191.	*Hydnophora rigida* (Dana,1846)	-	+	-	-	+	+	+	-	-
	Genus *Merulina* Ehrenberg, 1834									
192.	*Merulina ampliata* (Ellis & Solander, 1786)	+	+	-	-	+	+	+	-	-
193.	*Merulina scabricula* Dana, 1846	-	-	-	-	+	+	-	-	+
	Family MILLEPORIDAE									
	Genus *Millepora* Linnaeus,1785									
194.	*Millepora exaesa*(Forskal,1775)	-	+	-	-	-	-	-	+	-
195.	*Millepora dichotoma* (Forskal,1775)	-	-	-	-	+	-	+	+	-
196.	*Millepora intricata* Edwards,1857	-	-	-	-	-	-	+	-	-
	Family MUSSIDAE Ortmann, 1890									
	Genus *Lobophyllia* de Blainville, 1830							-		
197.	*Lobophyllia corymbosa* (Forskal,1775)	+	+	+	-	+	+		+	+
198.	*Lobophyllia hemprichii* (Ehrenberg, 1834)	-	+	-	-	-	+	+	-	+
199.	*Lobophyllia robusta* Yabe and Sugiyama,1936	-	-	-	-	+	+	+	-	-
	Genus *Symphyllia* MED & H, 1848							+		
200.	*Symphyllia agaricia* MED & H, 1849	+	+	+	-	+	+		+	-
201.	*Symphyllia hassi* Pillai and Scheer, 1976	-	-	-	-	+	+	+	-	+
202.	*Symphyllia erythraea* (Klunzinger, 1879)	-	-	-	-	-	+	+	-	-
203.	*Symphyllia radians* MED & H,1849	-	+	-	-	+	+	-	-	-
204.	*Symphyllia recta* (Dana,1846)	-	-	-	-	+	-	-	-	-
	Family OCULINIDAE Gray,1847							+		
	Genus *Galaxea* Oken, 1815									
205.	*Galaxea astreata* (Lamarck, 1816)	-	+	-	-	-	+		-	+
206.	*Galaxea fascicularis* (Linnaeus, 1767)	+	+	+	+	+	+	+	+	+
	Family PECTINIIDAE Vaughan & Wells, 1943							+		
207.	Genus *Echinophyllia* Klunzinger,1879									
208.	*Echinophyllia aspera* (Ellis & Solander,1786)	-	-	-	-	-	-		-	-
	Genus *Oxypora* Saville Kent,1871							+		
209.	*Oxypora crassispinosa* Nemenzo, 1979	-	-	-	-	+	-		-	+
210.	*Oxypora lacera* (Verrill, 1864)	-	-	-	-	+	+	+	-	-
	Genus *Pectinia* Oken, 1815							-		
211.	*Pectinia alcicornis* (Saville-Kent,1871)	+	+	-	-	+	+		-	-
212.	*Pectinia lactuca* Pallas, 1766	-	+	-	-	+	+	-	-	-
213.	*Pectinia paeonia*,(Dana,1846)	-	+	-	-	+	+	+	-	+
	Family PORITIDAE Gray, 1842							+		
	Genus *Alveopora* de Blainville, 1830									
214.	*Alveopora superficialis* Pillai & Scheer, 1976	-	+	-	-	-	-		-	+
	Genus *Goniopora* de Blainville, 1830							-		
215.	*Goniopora columna* Dana, 1846	+	+	-	-	+	+		-	+
216.	*Goniopora pendulus* (Veron, 1985)	-	-	-	-	-	+	+	-	+
217.	*Goniopora stutchburyi* Wells, 1955	-	-	-	-	-	-	-	-	-

Table 1: Continued

218.	Genus *Porites* Link, 1807							+		
219.	*Porites annae* Crossland, 1952	-	+	-	-	-	-		+	+
220.	*Porites arnaudi* Reyes-Bonilla & Carricart-Ganivet, 2000	-	-	-	-	+	-	+	-	-
221.	*Porites cylindrica* Dana, 1846	+	+	-	-	+	+	-	+	+
222.	*Porites heronensis* (Veron, 1985)	-	+	-	-	-	+	+	-	+
223.	*Porites latistella* Quelch,1886	-	+	-	-	+	-	-	-	-
224.	*Porites lobata* Dana, 1846	+	+	+	+	+	+	+	+	+
225.	*Porites lichen* Dana, 1846	+	-	-	-	-	+	+	-	-
226.	*Porites mannarensis* Pillai, 1969	-	-	-	-	+	-	+	-	+
227.	*Porites monticulosa* Dana,1846	-	+	-	-	+	+	-	-	+
228.	*Porites rus* (Forskal,1775)	+	-	-	-	+	-	+	-	-
229.	*Porites solida* (Forskal, 1775)	+	+	+	+	+	+	+	+	+
230.	*Porites vaughani* Crossland, 1952	-	-	-	-	-	+	+	-	-
	Family POCILLOPORIDAE Gray, 1842							+		
	Genus *Pocillopora* Lamarck, 1816									
231.	*Pocillopora damicornis* Linnaeus, 1758	+	+	+	+	+	+		+	+
232.	*Pocillopora eydouxi* MED & H, 1860	-	-	-	-	+	-	+	-	-
233.	*Pocillopora meandrina* Dana, 1846	-	+	-	-	+	-	+	-	+
	Genus *Seriatopora* Lamarck, 1816							-		
234.	*Seriatopora aculeate*(Quelch,1886)	-	-	-	-	+	-		+	-
235.	*Seriatopora hystrix* Dana, 1846	+	+	-	-	-	-	+	+	+
236.	*Seriatopora stellata* Quelch, 1886	-	-	-	-	+	-	+	-	+
237.	Genus *Stylophora* Schweigger, 1819							-		
238.	*Stylopora pistillata* Esper, 1797	+	+	+	+	+	+		+	+
	Family SIDERASTERIDAE Vaughan & Wells, 1943							+		
	Genus *Coscinaracea* MED & H,1848									
239.	*Coscinaraea columna* (Dana, 1846)	-	-	-	-	+	-		-	+
240.	*Coscinaraea monile* (Forskal, 1775)	-	-	-	-	+	+	-	-	+
	Genus *Psammocora* Dana, 1846							-		
241.	*Psammocora contigua* (Esper, 1797)	+	+	-	-	+	+		+	+
242.	*Psammocora digitata* MED & H,1851	-	-	-	-	-	+	+	-	+
243.	*Psammocora explanulata* van der Horst, 1922	+	+	-	-	+	+	-	-	+
	Genus *Pseudosiderastrea* Yabe & Sugiyama, 1953							-		
244.	*Pseudosiderastrea tayami* Yabe & Sugiyama, 1935	+	+	-	-	-	+		-	-
	Total Number of Species	91	134	44	20	152	164	166	80	145
	Total Number of individual of all species	627	900	185	64	1031	1032	953	254	665
	Shannon –Weaver Index (H¯)*	6.199	6.648	4.478	3.633	6.869	6.911	7.05	5.958	6.569
	Simpson's Diversity Index (D)	0.983	0.987	0.952	0.873	0.989	0.989	0.990	0.975	0.985
	Pielou's Evenness Index (J')	0.952	0.940	0.893	0.840	0.947	0.939	0.956	0.942	0.913

* Since P_i is the proportion of a given category, its maximum value is 1 and its minimum approaches 0. For any base, the log of 1 is 0 and the log of any value between 0 and 1 is a negative number. By reversing the sign, the index becomes positive and is easier to understand.

[AV- Avis Island, SN- Sound Island, RL- Rail Island, KR- Karlo Island, IT- Interview Island, NR- North Reef Island, SM- Smith Island, RS- Ross Island, AR- Arial Bay]

It has been formulated below

QS = (2C/A + B)

Where, *A* and *B* are the species numbers in station A and B, respectively and *C* is the number of species shared by the two stations. This expression is easily extended to abundance instead of incidence of species. This quantitative version of the Sørensen index is also known as *Czekanowski index*.

Simpson's diversity index [23] is one of the truthful indices to calculate the species diversity of any study site. It has been applied to calculate the species diversity of scleractinian corals of those islands.

The formula for the Simpson index is:

$$D = 1 - \sum_{i=1}^{s} \frac{ni(ni-1)}{N(N-1)}$$

Where S is the number of species, N is the total percentage cover or total number of organisms and n is the percentage cover of a species or number of organisms of a species. In this form, D ranges from 1 to 0, with 1 representing infinite diversity and 0 representing no diversity.

Evenness of a community was described by the Pielou's Evenness Index (J'). The formula of the index is [24]:

$$J' = H'/H'_{max}$$

Where H' is the number derived from the Shannon diversity.

RESULTS

Several extensive studies were conducted on nine sites of Middle and North Andaman Archipelago. As a result a total of two hundred and forty-four species of scleractinian corals (Table 1) were recorded from the nine sites. However the number of species of different study areas such as Avis Island - 91, Sound Island- 134, Rail Island- 44, Karlo Island- 20, Interview Island- 152, North Reef Island- 164, Smith Island-166, Ross Island- 80 and Arial Bay- 146. The highest number of species was recorded in Smith Island and lowest number in Karlo Island (Fig. 1).

A total number of scleractinian coral colonies were quantified from the study area are Avis Island - 627, Sound Island- 900, Rail Island- 185, Karlo Island- 64, Interview Island- 1031, North Reef Island- 1032, Smith Island-953, Ross Island- 254 and Arial Bay- 665. North Reef Island showed highest number of individual while Karlo Island lowest (Fig. 2).

The species diversity ranged from 3.633 to 7.05 (Table 1). However it is observed that, Smith Island show he highest (7.05) and Karlo Island showed the lowest (3.633) degree of species diversity among all the surveyed areas of Middle and North Andaman Archipelago (Table, 1 and Fig. 3).

Similarity index (S) has been calculated between the islands and the values are depicted in Table, 2. The maximum similarity index (0.784) was observed for significantly wide range of distribution of scleractinian corals between North Reef and Interview Island and the minimum index (0.206) was observed North Reef and Karlo Island. The islands also have great deal of similarity in their species composition which can be seen through the result of similarity index. Most of the values of the similarity index of scleractinian corals between islands falls under a range of 0.4- 0.6. Moderate number of values are observed in between the range of 0.2 - 0.4 and 0.4- 0.6 (Table 1).

The Simpson's species diversity index ranged from 0.99 at Smith Island to 0.873 at Karlo Island. The indices of the other islands are shown as Avis Island- 0.983, Sound Island- 0.987, Rail Island- 0.952, Interview Island- 0.989, North Reef Island- 0.989, Ross Island-0.975 and Arial Bay- 0.985 (Fig. 3).

Species evenness (J') of a community was measured by applying the Pielou's Evenness Index of the areas studied (Table 1). On the basis of this index, it was calculated that the Smith Island (0.956) shows a great deal

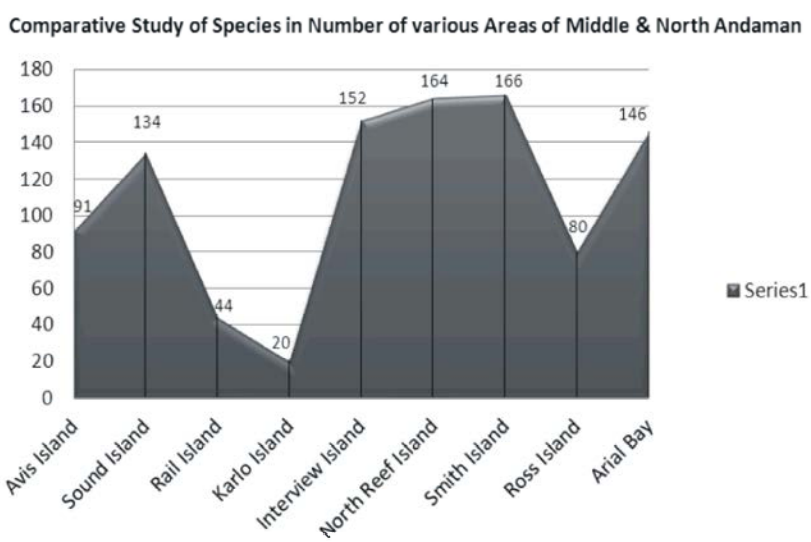

Fig. 1: Comparative Study of Species in Number of various Areas of Middle and North Andaman

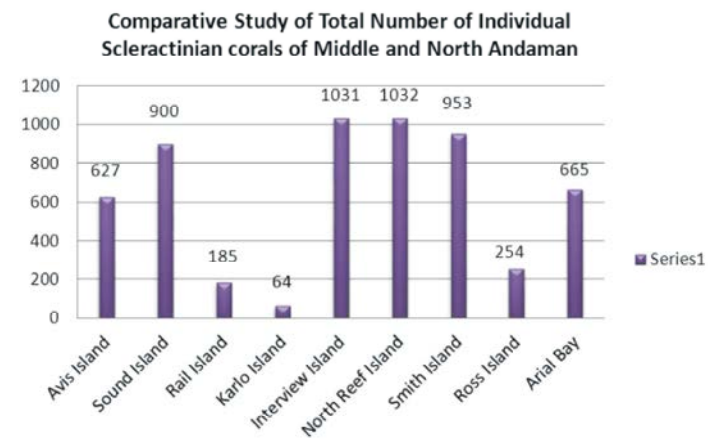

Fig. 2: Comparative Study of Total Number of Individual Scleractinian corals of Middle and North Andaman

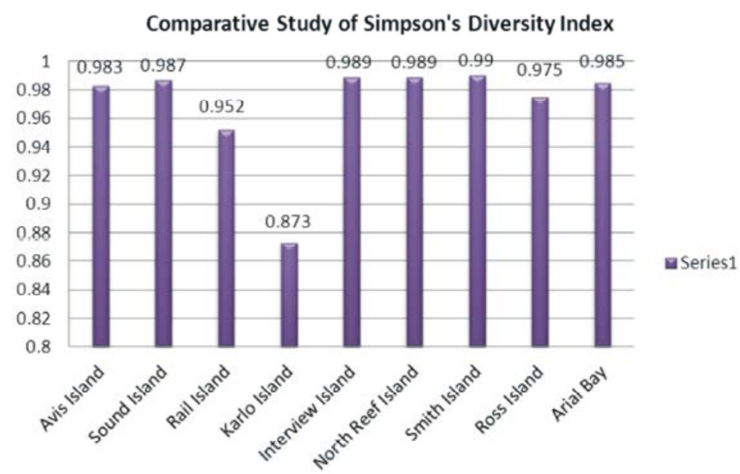

Fig. 3: Comparative Study of Simpson's Diversity Index

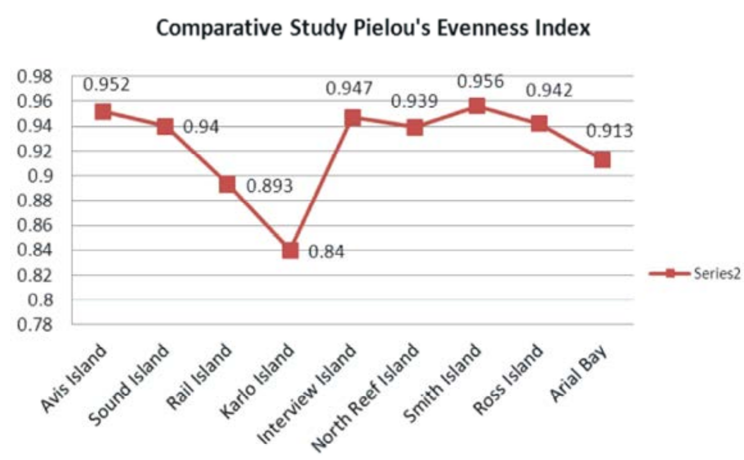

Fig. 4: Comparative Study of Pielou's Evenness Index

of evenness and the Karlo Island (0.840) shows the least evenness of species composition of a community in comparison with other sites of our surveyed such as Avis Island- 0.952, Sound Island- 0.940, Rail Island- 0.893, Interview Island- 0.947, North Reef Island- 0.939, Ross Island-0.942 and Arial Bay- 0.913 (Fig. 4).

Table 2: Percentage of Species similarity index among islands in Middle and North Andaman

	Avis Island	Sound Island	Rail Island	Karlo Island	Interview Island	North Reef Island	Smith Island	Ross Island	Arial Bay
Avis Island		0.737	0.577	0.342	0.666	0.674	0.607	0.643	0.565
Sound Island			0.460	0.259	0.762	0.751	0.686	0.626	0.642
Rail Island				0.593	0.416	0.365	0.352	0.564	0.375
Karlo Island					0.232	0.206	0.204	0.380	0.240
Interview Island						0.784	0.723	0.551	0.691
North Reef Island							0.745	0.540	0.677
Smith Island								0.617	0.716
Ross Island									0.654
Arial Bay									

DISCUSSION

Change in species diversity (the number, identity and relative abundances of species) across space and time is one of the oldest and best studied subjects in ecology. Despite this, there is little agreement about the underlying causes of many diversity patterns [25-27]. Differences in taxonomic composition and diversity among regions can be explained in part by present day condition. Thus, habitat area clearly plays a role with about 85% of the world area of reefs lying in the Indo-Pacific, compared with only 15% in the Atlantic [6]. Beta diversity indicates the degree of difference in species composition between sites [28]. Coral reef ecosystems are the most diverse and complex aquatic communities. Although they are diverse as a whole this diversity is not evenly distributed among habitat types within the reef [29]. Extensive surveys on corals in middle and north Andaman Archipelago reveal that the diversity is not evenly found throughout the areas. The diversified species of the Sclearactinians were quantitatively recorded from the site of interest were observed in the order of Smith Island > North Reef Island> Interview Island> Arial Bay> Sound Island> Avis Island > Ross Island> Rail Island> Karlo Island. From the data it is clear that the highest number of species is present in Smith Island and lowest number in Karlo Island. However, a total number of individual was observed in a wide magnitude with a trend of North Reef Island> Interview Island > Smith Island > Sound Island > Arial Bay> Avis Island > Ross Island> Rail Island> Karlo Island. The values of the diversity indices indicated the highly diverse coral species in study areas. For a keystone species, the corals, diversity was found to be greatest on reef slopes, mid-level on crests and lowest on reef flats in a study in the region [29]. These islands are interlinked with each other in respect of scleractinian corals diversity from 0.206 to 0.784. The peak value of similarity index (0.784) was observed for significantly wide range of distribution of scleractinian corals between North Reef and Interview Island and the lowest index (0.206) was observed for significantly wide range of distribution of scleractinian corals between North Reef and Karlo Island. One of the challenges of coral survey work is balancing taxonomic resolution with sufficient sampling effort. In this survey, the task of recording taxa within survey quadrats left little time for random swims which would undoubtedly add to the list of taxa in the survey area. Coral reefs are relatively unique in that they operate as non-equilibrium ecosystems where competitive exclusion by a few faster growing species is prevented by intermittent disturbance events. This has been called the “intermediate disturbance hypothesis” [30]. One of the most common and influential forms of ecosystem disturbance and selection near the surface is wave energy, which strongly selects for corals with increased structural strength capable of resisting the hydraulic stress [31]. The density of the scleractinian corals of those islands shows high level of values which is very near to the maximum value 1. The Simpson’s species diversity index was ranges from 0.99 at Smith Island to 0.873 at Karlo Island. The indices of the other areas are as follows, Avis Island- 0.983, Sound Island- 0.987, Rail Island- 0.952, Interview Island- 0.989, North Reef Island- 0.989, Ross Island-0.975 and Arial Bay- 0.985. This value ranges supports the scleractinian density on that successive places wining the unfavorable hazards in ecological point of view. It is also simultaneously acceptable that the marine ecological niche of those areas is oligo-tropic in nature for the scleractinian. Smith Island (0.956) shows a maximum of evenness and the Karlo Island (0.840) shows the minimum evenness of species composition of a community in comparison with other sites of our surveyed area. During large wave events, wave energy extends to greater depths, selectively damaging coral morphologies that might have a greater advantage under normal baseline conditions [1]. However, once below the wave base other environmental factors have greater influence on reef morphology. The most important of these is light and the interaction between coral polyps and their zooxanthellae. It has been suggested that these corals use their ability to grow tall quickly to shade out their competitors. However, this strategy requires a large amount of available sunlight because the narrow branching structure is not ideal for light gathering. At increasing depths columnar and upright plate structures are found with larger surface areas that can absorb more light [32]. The presence of highly diversed corals implies all the hydrological as well as environmental parameters suitable for healthy reef. The characteristics of physical environment overshadow the influence of differences in biodiversity of the functioning of the coral reefs, as long as the representatives of each of the performers of key ecological roles are present. In order to conserve the coral reefs of middle and north Andaman Archipelago, several extensive surveys are required in near future to get much more information about the species composition, richness etc. And also the awareness on the importance of coral reef ecosystem to the general public will help to protect marine biodiversity.

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