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Community Structure and Spatial Patterns in Hard Coral Biodiversity in Selected Islands in the Gulf of Mannar, India

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Abstract

The major reefs of the Gulf of Mannar Biosphere Reserve extend from the Tuticorin group of islands (Long.78^{0}9’E, Lat.8^{0}48’N) to the Shingle Island (Long. 79^{0}14’E, Lat.9^{0}14’N) in Mandapam, India. These reefs are under increasing threats from anthropogenic interventions. In view of this, a comparative study was conducted to deduce the spatial patterns in the hard coral biodiversity and community structure of five islands of the Mandapam group. The islands studied are Shingle, Krusadai, Pullivasal, Manauli and Hare. Univariate community parameters, Shannon–Wiener diversity index (H’e), Simpson diversity index, and Pielou’s evenness index were calculated for each reef in each sampling station. The highest and lowest percentage of live coral cover was recorded in the reefs of the Shingle (60.8%) and Pullivasal Islands (13.9%) respectively. Shannon index of diversity recorded maximum value in the reefs of Manauli Island (3.01) and the minimum in Pullivasal Island (1.8). Mortality indices were also derived for each island reef and the condition of the reefs was assigned as either good/sick. Relative abundance values were derived for each species and they were assigned Dominant/Abundant/ Common/Unc

ommon/Rare species status. Conservation classes (CC’s) of 1,2,3 or 4 were assigned to reef sites dominated by massive and submassive corals (CC1), foliose or branching non *Acropora* corals (CC2), *Acropora* corals (CC3), or approximately equal mixes of these three end – members(CC4). Similarities between reefs were studied by Bray–Curtis similarity coefficients and maximum similarity was found between the Manauli and Hare Island reefs (56.47). The similarity matrix was subjected to ordination analysis. There was a distinct separation of reefs in the Pullivasal Island from other reefs in the MDS plot. SIMPER analysis enabled the authors to find out the species important in the community structure of each reef. From the present study it was concluded that certain coral reefs in the Gulf of Mannar ecosystem is on the threshold of degradation.

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Introduction

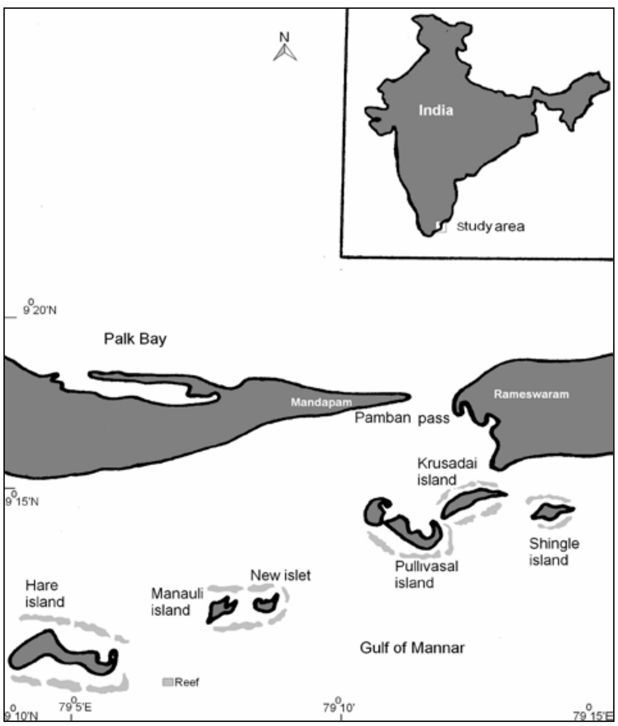
Coral reefs are among the most productive and biologically diverse ecosystems on earth (Connell 1978). They supply vast number of people with goods and services such as seafood, recreational possibilities, coastal protection as well as aesthetic and cultural benefits (Done et al.1996). Almost three quarters of the world's coral reefs are thought to be deteriorating as a consequence of environmental stress (Mumby et al. 2001). The reefs in the Gulf of Mannar Biosphere Reserve and Palk Bay are the only major coral formations along the mainland coast of India. A discontinuous barrier termed Mannar Barrier extends over a distance of 140 Km. from Tuticorin to Pamban in the Gulf of Mannar. The Mannar barrier possesses a chain of 20 islands all along its length with fringing reefs around them. All major coral reef areas in India, including the Gulf of Mannar, Lakshadweep, Andaman and Nicobar Islands, and the Gulf of Kutch are under increasing threat from human activities (Arthur 2000). In addition, the coral bleaching event in 1998 caused a significant decline in the cover of live coral in most areas (Wafar 1999; Arthur 2000). Bleaching of extensive areas was recorded also during 2002 in Palk Bay, the Gulf of Mannar, and the Andaman Islands (Kumaraguru et al. 2003). Venkataraman (2002) reiterated the observations of Pillai (1996) by stating that the magnitude of destruction of the marine environment in the Gulf of Mannar may be unprecedented. Destructive fishing methods (including blast fishing), near – shore trawling, sedimentation and pollution are causing considerable damage to the coral reefs, threatening the reef fisheries of the Gulf of Mannar. Kumaraguru et al. (2005) described the impact of tsunami of December 2004 on the coral reefs of Gulf of Mannar. Although the coral fauna and geomorphology of the Gulf of Mannar reef system has been described by Pillai (1972), Stoddart (1973), Venkataraman (2002) and Venkataraman et al. (2003), no comprehensive study has yet examined in detail the community structure and spatial patterns in biodiversity of stony corals across reef flats of this ecosystem. This study aimed to describe the species diversity, richness, hard coral cover (live and dead), within group similarities and the spatial patterns of the ecological communities in fringing reefs of Mandapam group of islands in the Gulf of Mannar. Further, studies have shown that definitions based solely on percentage of live coral cover should be supplemented with other indices such as conservation class that accurately predict biodiversity value and fisheries potential (Edinger and Risk 2000) and therefore special emphasis was given to classify reef communities into conservation classes as assessing the conservation value of natural habitats is important to formulate conservation policy particularly for tropical biodiversity. The analysis of community structure will also help in determining whether different ecological communities exist between neighbouring reef structures.

Materials and Methods

Study sites

The present study was focused on five islands of Mandapam group (Fig. 1) viz., Shingle, Krusadai, Pullivasal, Manauli, and Hare spread around areas of 13, 66, 48, 27 and 160 hectares respectively, was undertaken during September 2004 to June 2005. The northern and southern sides of these islands are fringed with coral reefs with exception to Pullivasal Island where only the southern side is fringed with coral reefs. The western and eastern sides are mostly sandy with seagrass beds.

Fig.1. Location of the study site



Sampling method

Life–form Line Intercept transect method was adopted for the survey (English et al. 1994). All conspicuous benthic lifeforms underlying the transect lines have been monitored but since cover by organisms other than corals (ie., macroalgae, soft corals, coralline algae and sponges) constitutes less than 1% of total cover, reference is made only to scleractinian corals in this paper. The transects, placed randomly on the reefs, ran parallel to shore of the island at each side and to each other at fixed intervals of 2m. depth, with three replicates at each depth. Transects were taken in the following order; 3 transects from inner reef flats, 4 transects from middle reef flats and 3 transects from outer reef flats. A total of ten 20m transects (with 3 replicates each) were placed around each island (southern and northern sides) and all hard corals intercepted by the transect were recorded and their maximal projected length were measured and an individual colony of a hard coral was defined as any colony growing independently of its neighbours (Loya 1972). When necessary for identification, the colonies were sampled and identified following the publications of Pillai (1967 a, b & c, 1973); Veron (1986, 2000 1, 2 &3); Venkataraman et al. (2003).

The field work was carried out during September 2004 – June 2005.

Univariate analysis

Univariate community parameters, Shannon – Wiener diversity index (H'e), Simpson diversity index, and Pielou's evenness index were calculated for each reef from each sampling station. The significance of differences of diversity indices between each island was assessed using one way ANOVA. Coral Mortality Index (Gomez et al. 1994) for each site was calculated as the ratio of standing dead coral cover to total cover of both live and dead corals.

$$\text{MI (Mortality Index)} = \frac{\text{Dead corals}}{\text{(Live corals + Dead corals)}}$$

If MI > 0.33, the mortality index is considered to be high and the reef is classified as sick.

Multivariate analysis

A triangular matrix of similarities between samples was computed using the similarity coefficient of Bray and Curtis (1957), the cnidarian data first being transformed [ln(x+1)] in order to reduce the influence of dominant taxa. The similarity matrix was subjected to ordination analysis using the PRIMER package (Carr 1996). Ordination was by non–metric multidimensional scaling (MDS). The contribution of species to dissimilarities between the groupings observed in the ordination analysis was examined using the SIMPER procedure (similarity percentages; Clarke 1993). Species falling above the 50% similarity threshold were considered to be those most important in determining community structure. K-dominance curves (Lambshead et al. 1983) were constructed for finding out the diversity profile of the reef complexes.

Community analysis

A community analysis was carried out by finding the relative abundance (RA) values of each species (Rilov and Benayahu 1998).

$$RA = \frac{Pi}{P\ total} \times 100$$

Pi = pooled living coverage of the i^{th} species from all transects at a given site.
P total = pooled total living coverage of all species in all transects at a given site.

The resulting values were transformed into abundance categories (%): not recorded (RA=0), rare (0<RA<0.1), uncommon (RA=0.1-1), common (RA=1-10), abundant (RA=10-20) and dominant (RA>20). Conservation classes (CC's) of 1,2,3 or 4 were assigned to reef sites dominated by massive and submassive corals (CC1), foliose or branching non *Acropora* corals (CC2), *Acropora* corals (CC3), or approximately equal mixes of these three end – members(CC4) (Edinger and Risk 2000).

Results

Reefs around the Shingle and Pullivasal Islands recorded the highest and lowest average coral cover percentages of 60.8 and 13.9% respectively (Table 1). Maximum number of hard coral species was recorded from reefs around Krusadai Island (35) and minimum from Pullivasal (11). Shingle, Manauli and Hare Island reefs recorded 23, 30 and 25 species of hard corals respectively. According to relative abundance values (Table 2), *Montipora digitata* was dominant in Shingle and Hare Islands, and *Porites mannarensis* in Pullivasal Island. Average mortality index (MI) was highest in Pullivasal Island reef (0.83) and lowest in Shingle Island reef (0.21), Shannon diversity index showed the highest value in reefs of Krusadai Island (3.05) and lowest value in Pullivasal Island (1.8) (Table 3). Simpson diversity index also followed the same trend with values of 0.95 and 0.78 respectively for Krusadai and Pullivasal Island reefs. Pielou's evenness value was maximum (0.886) in Manauli Island reefs and minimum (0.7) in Shingle Island reefs. Conservation class 1 was assigned to Pullivasal Island reefs, CC2 to Shingle and Hare Island reefs, CC3 to Krusadai Island reefs and CC4 to Manauli Island reefs (Fig. 2).

Multivariate analysis was conducted on the pooled data of all islands. K-dominance curve constructed on the data sets (Fig. 3) showed the diversity pattern of different island reefs. Manauli Island reefs showed a low starting point and gentle slope indicating high diversity. Pullivasal Island scleractinian fauna showed a high starting point and steep slope indicating very low diversity. The similarities in species composition between different islands were in the range of 18.45 – 56.47 with the highest between Manauli and Hare and lowest between Shingle and Pullivasal (Table 4). MDS ordination (Fig. 4) based on [ln(x+1)] transformed values and Bray – Curtis similarities (stress value 0.01) illustrated the distinctness of Pullivasal Island reefs from other reefs with the separate grouping. SIMPER analysis (Table 5) showed the species *M. digitata* (51.9%) along with *Montipora foliosa* (26.48%) to be most responsible for within – group similarity in Shingle Island reefs. The average similarity in species composition of Shingle Island reefs was found to be 33.64%. *A. formosa* (33.95%) along with *Acropora humilis*, (15.85%) *P. mannarensis* (12.97%) and *M. digitata* (12.07%) were responsible for within – group similarity among Krusadai Island reefs. The average similarity in species composition was found to be 20.5%. *P. mannarensis* (90.59%) was found to be most responsible for within group similarities in reefs around Pullivasal Island. The average similarity in species composition was found to be 9.45%. The species *Acropora hyacinthus* (24.65%) along with *Acropora cytherea* (17.61%), *A.formosa* (9.44%) and *Favites abdita* (8.45%) was most responsible for within – group similarities in Manauli Island reefs. Average similarity in species composition within the reef was found to be 24.93%. The species *M. digitata* along with *A. hyacinthus* and *Porites solida* was found to be most responsible for within – group similarity on the reefs of Hare Island. Average similarity in species composition within the reefs of this island was found to be 14.29%.

SIMPER analysis (Table 6) showed the highest average dissimilarity between Shingle and Pullivasal Island reefs as 96.26. Lowest average dissimilarity was found between Shingle and Hare (81.12).

Table 1. Average percentage live coral cover of Scleractinians from reefs around five islands

Species/Sites	Shingle	Krusadai	Pullivasal	Manauli	Hare
Family : Acroporidae					
Acropora cytherea	0.2	0.2	0	2.09	1
A. divaricata	2.1	0.33	0	0.1	0
A. intermedia	0	4.3	0	0	0
A. formosa	0.8	8.48	0	5.73	0
A. humilis	2.5	4.33	0	0	0
A. digitifera	0	1.16	0	0	0
Acorpora sp.	0	1.66		0	0
A. hemprichii	0	2.9	0	0	0
A retusa	0	0.7	0	0	0.09
A. haimei	0	1.8	0	0	0
A. lamarcki	2.3	3.1	0.7	5.44	2.5
A. secale	0.6	0.81	0	0	0
A. hyacinthus	0.45	0.3	0.6	4.13	4.85
A. globiceps	0	0	0	0.18	0
A. lutkeni	0	0	0	0	0.09
A. florida	0	0	0	0.14	0
A. valida	0	0.2	0	0	0
A. nasuta	0	0.3	0	0	0
Montipora verrucosa	0	0.7	0	0	1.2
M. venosa	0	0.3	0	0	0
M. digitata	21.02	5.12	0.3	2.8	17.92
M. tuberculosa	0.5	0.9	0	0.8	1.2
M. aequituberculata	0.9	1.4	0	0	0
M. spumosa	0.9	0	0	0	0
M. foliosa	12.05	2.6	0	4.4	1
M. informis	0	0	0	1.1	0.2
M. explanata	1.4	0	0	0	0
M. peltiformis	0	1.2	0	0	0
Family: Pocilloporidae					
Pocillopora damicornis	4	0.61	0.9	2.84	1.2
Family : Agaricidae					
Pavona divaricata	0	0.2	0	0	0
P. decussata	0	0.4	0	0	0
Family : Merulinidae					
Merulina ampliata	0	0.3	0	0.6	0.3
Hydnophora exesa	0	1.1	0	0.5	0
H. microconos	0	0	0	0.8	0.6

Table 1. Contd.

Species/Sites	Shingle	Krusadai	Pullivasal	Manauli	Hare
Family : Faviidae					
Favia pallida	0.08	0	0.17	4.31	1.5
F. favus	0	1.2	0	0	1.3
Favites abdita	0	0	0	3.2	0.7
F. complanata	0	0	0	0	0.2
Montastrea valenciennesi	0	0	0	1.2	0
Platygyra lamellina	0	0.7	0	0.4	0.75
Cyphastrea microphthalma	0.2	0.6	0	0.1	0
Leptastrea transversa	0.1	0	0.8	1	0
L. purpurea	0	0	0	0.8	0
Echinopora gemmaceae	0.5	0	0	0.425	0
E. lamellosa	0.5	0	0	0.79	0.3
Goniastrea retformis	0	0	0	1.3	0
Family : Caryophyllidae					
Polycyathus verrilli	0	0.3	0	0	0
Family : Poritidae					
Porites mannarensis	0.7	4.5	6.75	4.02	3
P. compressa	0	0.23	0.8	0	0
P. solida	0	0.9	0	2.97	6
P. lutea	4.2	1.1	0	2.95	0
P. exserta	0	0	1.75	0	0
P. lichen	0	0	1	0	1.7
P. somaliensis	3.4	0	0	0	0
Family : Siderastreidae					
Psammocora contigua	0.2	0	0	0	0
Family : Oculinidae					
Galaxea fascicularis	0	0	0.2	0	0
Family : Mussidae					
Symphyllia radians	0	0	0	0	1.1
Family :Dendrophylliidae					
Turbinaria crater	0	0	0	0	0.5
T. peltata	0		0	0.7	0
T. mesenterina	0	0	0	0.9	1.1

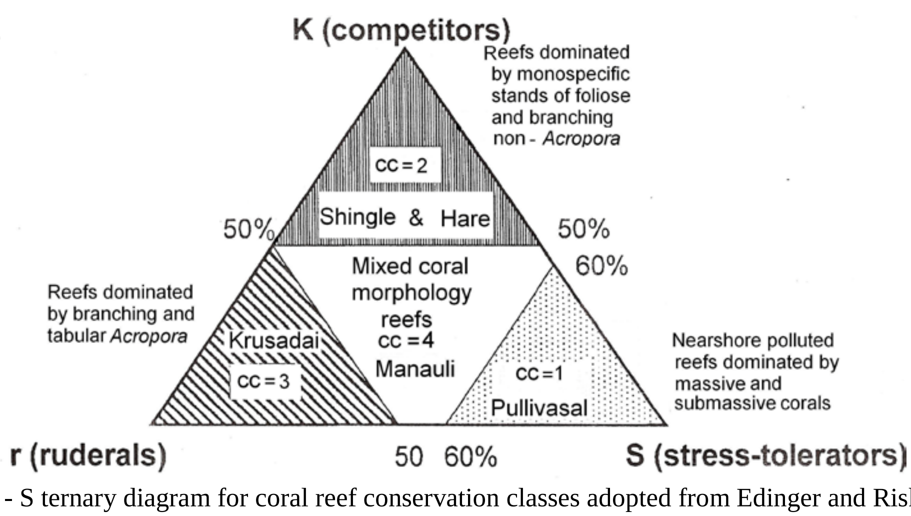


Fig. 2. r - K - S ternary diagram for coral reef conservation classes adopted from Edinger and Risk (2000)

Table 2. Relative abundance (RA) of hard corals occurring in the transects at each of the study sites, according to their contribution to living coverage

Species/Sites	Shingle	Krusadai	Pullivasal	Manauli	Hare
Family : Acroporidae					
Acropora stoddarti	**	**	-	***	***
A .reticulata	***	**	-	**	-
A .intermedia	-	***	-	-	-
A .formosa	***	****	-	***	-
A .humilis	***	***	-	-	-
A .brevicollis	-	***	-	-	-
A .valenciennesii	-	***	-	-	-
A .hemprichi	-	***	-	-	-
A .brueggemanni	-	***	-	-	**
A .haimei	-	***	-	-	-
A .cytherea	***	***	***	***	***
A .digitifera	**	***	-	-	-
A .hyacinthus	**	**	***	***	***
A .globiceps	-	-	-	**	-
A .lutkeni	-	-	-	-	**
A .florida	-	-	-	***	-
A .valida	-	**	-	-	-
A .nasuta	-	**	-	-	-
Montipora verrucosa	-	***	-	-	***
M .turgescens	-	**	-	-	-
M .digitata	*****	***	***	***	*****
M .tuberculosa	**	***	-	***	***
M .aequituberculata	***	***	-	-	-
M .spumosa	***	-	-	-	-
M .foliosa	****	***	-	***	***
M .informis	-	-	-	***	**
M .verrucosa	***	-	-	-	-
M. venosa	-	***	-	-	-
Family: Pocilloporidae					
Pocillopora damicornis	***	***	***	***	***
Family : Agaricidae					
Pavona divaricata	-	**	-	-	-
P. decussata	-	**	-	-	-
Family : Merulinidae					
Merulina ampliata	-	**	-	***	**
Hydnophora exesa	-	***	-	**	-
H.microconos	-	-	-	***	***

- not recorded, * rare, ** uncommon, *** common, **** abundant, ***** dominant

Table 2. (Contd.)

Species/Sites	Shingle	Krusadai	Pullivasal	Manauli	Hare
Family : Faviidae					
Favia pallida	**	-	***	***	***
F. favus	-	***	-	-	***
Favites abdita	-	-	-	***	***
F.complanata	-	-	-	-	**
M.valenciennesii	-	-	-	***	-
Platygyra lamellina	-	***	-	**	***
Cyphastrea microphthalma	**	***	-	**	-
Leptastrea transversa	**	-	***	***	-
L.purpurea	-	-	-	***	-
Echinopora gemmaceae	**	-	-	**	-
E.lamellosa	**	-	-	***	**
Goniastrea retformis	-	-	-	***	-
Family : Caryophyllidae					
Polycyathus verrilli	-	**	-	-	-
Family : Poritidae					
Porites mannarensis	***	***	*****	***	***
P.compressa	-	**	***	-	-
P.solida	-	***	-	***	****
P.lutea	***	***	-	***	-
P.exserta	-	-	****	-	-
P.lichen	-	-	***	-	***
P.somaliensis	***	-	-	-	-
Family : Siderastreidae					
Psammocora contigua	**	-	-	-	-
Family : Oculinidae					
Galaxea fascicularis	-	-	***	-	-
Family : Mussidae					
Symphyllia radians	-	-	-	-	***
Family :Dendrophylliidae					
Turbinaria crater	-	-	-	-	**
T.peltata	-	-	-	***	-
T.mesenterina	-	-	-	***	***

- not recorded, * rare, ** uncommon, *** common, **** abundant, ***** dominant

Table 3. Univariate community parameters of reefs around different islands.

Sites	**J'**	**H'(loge)**	**1-Lambda'**	**MI**
Shingle	0.703	2.20	0.83	0.21
Krusadai	0.86	3.04	0.95	0.22
Pullivasal	0.75	1.78	0.78	0.83
Manauli	0.89	3.01	0.95	0.30
Hare	0.75	2.41	0.85	0.44

J' = Pielou's evenness, H' = Shannon diversity index, 1- Lambda' = Simpson diversity index, MI = Mortality index

Table 4. Bray –Curtis similarity for Scleractinian corals from study sites

	Shingle	Krusadai	Pullivasal	Manauli	Hare
Shingle	0	43.81	18.45	43.09	36.92
Krusadai	43.81	0	19.99	43.10	37.02
Pullivasal	18.45	19.99	0	24.97	30.15
Manauli	43.09	43.1	24.97	0	56.47
Hare	36.92	37.02	30.15	56.47	0

Table 5. Species causing similarities within groups based on Bray – Curtis similarity in five reefs. Species are listed in ascending order according to percent contributions to respective similarity.

Group shingle			**Group Pullivasal**		
Average similarity : 33.64			Average similarity : 9.45		
species	Cont.%	Cum.%	species	Cont.%	Cum%
M. digitata	51.9	51.9	*P. mannarensis*	90.59	90.59
M. foliosa	26.48	78.38	**Group Manauli**		
P. damicornis	5.36	83.74	Average similarity : 24.93		
Acropora sp.	2.11	85.85	*A. hyacinthus*	24.65	24.65
Group Krusadai			*A. cytherea*	17.61	42.26
Average similarity : 20.58			*A. formosa*	9.44	51.7
A. formosa	33.95	33.95	*F. abdita*	8.45	60.15
A. humilis	15.85	49.80	**Group Hare**		
P. mannarensis	12.97	62.77	Average similarity : 14.29		
M. digitata	12.01	74.77	*M. digitata*	68.21	68.21
A. cytherea	6.56	81.33	*A. hyacinthus*	9.90	78.11
			P. solida	8.81	86.92

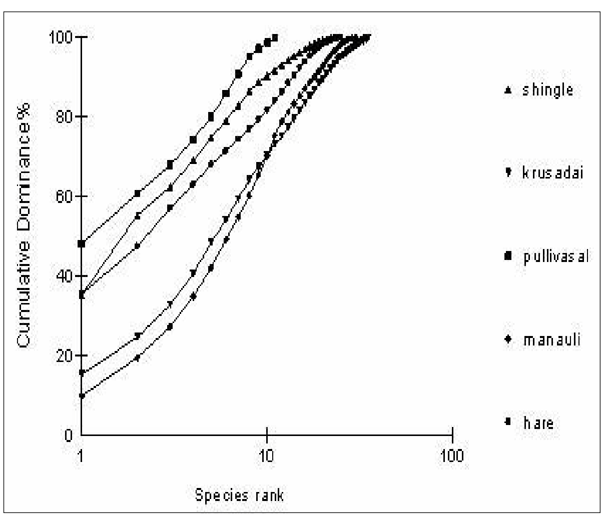


Fig. 3. K-dominance curves for the different reefs.

Fig. 4. MDS ordination of community data for scleractinians from the reefs of Mandapam group of islands based on Bray – Curtis similarities.

Table 6. Species causing dissimilarities among groups based on Bray – Curtis dissimilarity indices in five reefs. Species are listed in ascending order according to percent contributions to respective dissimilarity.

Groups Shingle and Krusadai			**Groups Shingle and Pullivasal**		
Average dissimilarity :82.64			Average dissimilarity: 96.26		
Species	Cont.(%)	Cum.(%)	Species	Cont.(%)	Cum.(%)
M. digitata	11.45	11.45	*M. digitata*	22.25	22.25
M. foliosa	9.61	21.06	*M. foliosa*	15.84	38.09
A .formosa	8.64	29.7	*P. mannarensis*	7.61	45.70
A. humilis	5.84	35.54	*P. damicornis*	6.93	52.63
P. mannarensis	5.13	40.67	*A. cytherea*	3.76	56.38
Groups Krusadai and Pullivasal			**Groups Shingle and Manauli**		
Average dissimilarity : 94.42			Average dissimilarity : 82.10		
A. formosa	13.72	13.72	*M. digitata*	11.42	11.42
P. mannarensis	8.71	22.43	*M. foliosa*	8.70	20.13
A. humilis	7.39	29.82	*A. cytherea*	6.45	26.58
M. digitata	6.80	36.63	*A. hyacinthus*	6.15	32.73
A. cytherea	5.74	42.36	*P. damicornis*	5.41	38.14
Groups Krusadai and Manauli			**Groups Pullivasal and Manauli**		
Average dissimilarity : 84.1			Average dissimilarity : 91.33		
A. formosa	7.02	7.02	*A. cytherea*	9.18	9.18
A. hyacinthus	6.16	13.18	*A. hyacinthus*	8.44	17.63
A. cytherea	6.04	19.22	*P. mannarensis*	8.23	25.86
P. mannarensis	5.42	24.64	*M. foliosa*	6.79	32.65
M. digitata	5.40	30.04	*A. formosa*	6.43	39.07
Groups Shingle and Hare			**Groups Krusadai and Hare**		
Average dissimilarity : 81.12			Average dissimilarity : 89.61		
M. digitata	12.9	12.9	*M. digitata*	9.89	9.89
M. foliosa	12.36	25.26	*A. formosa*	9.59	19.49
P. damicornis	6.00	31.26	*P. mannarensis*	5.98	25.46
A. hyacinthus	5.16	36.42	*A. humilis*	5.77	31.23
A. cytherea	5.01	41.43	*A. cytherea*	5.26	36.50
Groups Pullivasal and Hare			**Groups Manauli and Hare**		
Average dissimilarity : 95.04			Average dissimilarity : 83.77		
M. digitata	19.23	19.23	*M. digitata*	9.89	9.89
P. mannarensis	10.42	29.65	*A. hyacinthus*	7.51	17.39
A. hyacinthus	7.34	36.99	*A. cytherea*	7.41	24.80
P. solida	6.24	43.23	*P. mannarensis*	5.87	30.68
A. cytherea	5.57	48.80	*P. solida*	5.68	36.35

Discussion

In the present study the authors adopted both univariate and multivariate methods to assess the reef condition (Finkel and Benayahu 2004) as these methods are helpful in providing a complete community profile of the reefs. Further, Edinger and Risk (2000) asserted the utility of indices such as conservation classes in predicting biodiversity and conservation values of reefs; when applied to 15 Indonesian coral reefs it was found that, the average of the conservation class of all sites on a reef was a reliable predictor of coral species richness, habitat complexity, and rare coral species occurrence. Therefore, in the present investigation, the authors combined univariate and multivariate methods with conservation class indices and when used collectively it provided a better reef assessment tool box for efficient reef management.

Edinger and Risk (2000) defined *Acropora* corals as disturbance adapted "ruderals", due to their rapid growth and mechanical fragility. Branching non – *Acropora* corals and foliose corals, which grow and recruit more slowly than *Acropora*, are the competitive dominants, and they are defined as competition adapted. Massive and submassive corals more tolerant to high sedimentation and/or eutrophication are defined as stress tolerators. In Shingle Island reefs *M. digitata* belonged to the category "dominant" and *M. foliosa* belonged to the category "abundant" and are the competitive dominants. Edinger and Risk (2000) assigned reefs dominated by competitive dominants into conservation class 2 (CC2) (Fig. 2). These reefs are less stressed compared to reefs dominated by stress tolerators. Further CC2 reefs will provide optimum dive sites, especially those in locations sheltered from wave impact. The average mortality index for the reef was less than 0.33(0.21) indicating good condition of the reef. The Shannon index of diversity of Shingle Island from the pooled data showed a comparatively low value of 2.1. K-dominance curve showed high starting point and steep slope indicating low diversity. So even though the live coral cover and mortality index is in conformity to the healthy condition of reef, the number of species recorded (23) and diversity indices pointed to a need for proper management of these reef resources which otherwise will lead to degradation in the immediate future. In Krusadai Island there were no corals belonging to the category "dominant" according to relative abundance values. However, *A. formosa* belonging to the category "abundant" with a relative abundance value of 15.4 was observed. Since this reef was composed mainly of ruderals this reef belonged to conservation class 3 (CC3) of Edinger and Risk (2000) classification (Fig. 2). The mortality index values agreed with the good condition of this reef with a value (0.22) less than 0.33. Shannon diversity index for the reef from the pooled data showed a comparatively high value of 2.87 and the K-dominance curve showed a low starting point and gentle slope indicating high diversity. Maximum numbers of scleractinians were recorded from this island (35). Krusadai Island was once described as biologist's paradise due to richness of flora and fauna. But due to its proximity compared to other islands this island was always the favored destination of many scholars and researchers which in due course has contributed to the deterioration of the scleractinian fauna. However, delicate branching *Acropora* corals (CC3) are more susceptible to diver damage than structurally stronger branching *Porites*, (Rouphael and Inglis 1997), suggesting that diving should not be concentrated on *Acropora* dominated CC3 reefs. Pullivasal Island reefs showed the dominance of massive corals with their live coral cover value greater than 60%. They are the stress tolerators and this reef belonged to conservation class 1 of Edinger and Risk (2000) classification (Fig. 2). The resilience of reef flats dominated by massive corals can be attributed to the “immunity” of large colonies to whole colony mortality (Hughes et al. 1992); to their likely fecundity (Babcock 1984); and to the recruitment and survival of juvenile corals, many of which may emerge unscathed from environmental disturbances. Massive corals are physiologically and morphologically more adapted to desiccation and environmental stresses. According to Grime (1979), stress tolerators tend to be slow growing organisms that are able to survive in nearly all habitats, but only dominate in habitats where physiological stress precludes or slows the growth of ruderals and competitors and this condition is typical of Pullivasal Island reefs. Pillai (1973) has proposed that this area was prone to excessive mining during the sixties which might have caused the large scale destruction and deterioration of coral reefs of this area. The dead coral cover was also highest in these reefs (72.5%) and in visual observation it was found that most of the dead corals were covered with algae and seagrasses which may point to a need for a comprehensive study of ecological succession taking place in this reef. From the present investigation it could be concluded that live corals in this island reefs are only remnants of mining. In Manauli Island, there were no corals belonging to the category “dominant” or “abundant”. All the corals belonged to “Common” or “Uncommon” species status. Among them *A. formosa* showed the highest relative abundance value of 10. This reef belonged to the conservation class 4 with mixed coral morphologies (Edinger and Risk 2000) (Fig. 2). Average mortality index of 0.3 makes it difficult to arrive at a conclusion about the condition of this reef from MI.. The Shannon index of diversity showed the highest value (3.01) compared to all the other reefs and K-dominance curve showed the lowest starting point and gentle slope indicating highest diversity. Manauli Island reefs are less accessible due to the distance from mainland and this may be a reason for comparatively higher diversity and live coral cover. As conservation class 4 reefs had the highest coral species diversity, habitat complexity and rare species occurrence, it suggested that they have the highest conservation value and are most likely to provide optimum fish habitat and maximum fisheries potential. In Hare Island, *M. digitata* belonged to the classification “dominant” and *P. solida* belonged to the category “abundant” with relative abundance values of 35.6 and 11.9 respectively. Since the competitive dominants were dominant in this reef it belonged to conservation class 2 of Edinger and Risk (2000) (Fig. 2). Average mortality index of 0.44 indicates the sick condition of this reef. Shannon index of diversity showed comparatively low value (2.4) and K-dominance curve showed high starting point and steep slope. This reef is easily accessible from Vedalai and the intense trap fishing, seaweed collection etc. may be a reason for the sick condition of this reef. Also the northern sides of this reef were intensely quarried in the past.

Conclusion

Jordan – Dahlgren (2002) noted that several factors (larval availability and transport, ecological connectivity, substrate suitability for settlement and local oceanic conditions) may explain observable gradients in scleractinian communities. According to UNEP (1985) the developments of Tuticorin harbor, oil pollution and industry have caused significant damage in the Gulf of Mannar and Palk Bay area. According to Pearson (1981) mechanically damaged reefs not subjected to pollution may be able to recover from damage by protection in a reserve, while others may require more active remediation efforts such as transplantation. As Gulf of Mannar Biosphere Reserve is already protected there is a possibility of this reef to recover. Global warming, coral bleaching and overfishing are all responsible for changing reef biodiversity and reducing the quality of reefs over large areas and to protect the biodiversity, it is necessary to understand the processes that maintain diversity at this scale. A detailed study on the ecosystem resilience and processes of these reefs will help in chalking out measures for conservation of what is left of the reefs.

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