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Community structure and spatial patterns of hard coral biodiversity in Kilakarai group of islands in Gulf of Mannar, India

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Abstract

The major reefs of Gulf of Mannar Biosphere Reserve extends from Tuticorin group of islands ($08^0 48'$ N lat. $78^0 9'$ E long.) to Shingle island ($09^0 14'$N lat., $79^0 14'$ E long.) in Mandapam. A comparative study was conducted on Kilakarai group of islands of this reef to deduce the spatial patterns in hard coral biodiversity and community structure. The field work was carried out during September 2004 – June 2005. The islands studied were Valai, Mulli, Appa, Valimunai and Anaipar. The highest and the lowest percentage of live coral cover was recorded by the reefs of the Mulli (40.1%) and Anaipar islands (25.0%) respectively. Shannon index of diversity recorded the maximum value in the reefs of Mulli island (2.53) and the minimum in Anaipar island (1.72). 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 members (CC4). In the present study the reefs around Valai, Mulli, Appa and Valimunai islands were classified as CC2 and reef around Anaipar island was classified as CC4. Maximum similarity in species composition was found between Valai and Valimunai island reefs (58.1%). Mortality indices of all reefs classified them into the category "sick" and so further efforts should be focused on implementation of conservation strategies.

Keywords: Coral reefs, community structure, biodiversity, Gulf of Mannar, spatial patterns

Introduction

The 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; Muley, 2002). 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 again during 2002 in Palk Bay, the Gulf of Mannar, and the Andaman Islands (Kumaraguru *et. al*., 2003). Destructive fishing methods (including blast fishing), nearshore trawling, sedimentation and pollution are causing considerable damage to the coral reefs, threatening the reef fisheries of the Gulf of Mannar. Although the coral fauna and geomorphology of the Gulf of Mannar reef system have been described by Pillai (1972), Stoddart (1973), Venkataraman (2002) and Venkataraman *et al.* (2003), no comprehensive study has examined in detail the community structure and spatial patterns in biodiversity of stony corals across reef flats of this ecosystem. This study was 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 Kilakarai group of islands in 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). 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 studies on community structure will also help in determining the difference in ecological communities between neighbouring reef structures.

Material and Methods

The present study was focused on five islands of Kilakarai group (Fig. 1) *viz*., Valai and Talaiari (considered together due to proximity and mentioned as Valai), Mulli, Appa & Poovarasanpatti (considered together due to proximity and mentioned as Appa), Valimunai and Anaipar.

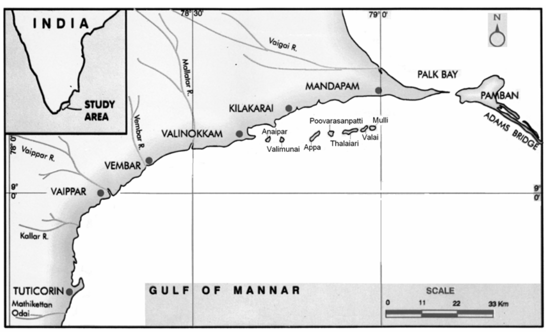

Fig. 1. Location of the study site

Life – form line intercept transect method was adopted for the survey (English *et al*., 1994). The transects were positioned randomly over the reefs and a depth of 2m-10m (reef flat) was covered in the present study. All conspicuous benthic life forms underlying the transect lines were monitored, but species wise distribution was studied only for scleractinian corals. A total of ten 20m transects (with 3 replicates each) was placed randomly around each island and all hard corals intercepted by the transect were recorded and their maximal projected length measured. When necessary for identification, the colonies were sampled and identified following the publications of Pillai (1967 a, b, c, 1973), Veron (1986, 2000) and Venkataraman *et al.* (2003) .The field work was carried out during September 2004 – June 2005.

Univariate community parameters, Shannon – Wiener diversity index (H′e), Simpson richness index, and Pielou's evenness index were calculated for each reef from each sampling station. 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.

A triangular matrix of similarities between samples was computed using the similarity coefficient of Bray and Curtis (1957). The cnidarian data were transformed [ln(x+1)] in order to reduce the influence of dominant taxa. The similarity matrix was subjected to ordination analysis using the PRIMER (Plymouth Routines in Multivariate Ecological Research) package (Carr, 1996). Ordination was by non–metric multidimensional scaling (MDS). The contribution of species to dissimilarities between the groupings observed in the cluster and ordination analysed was examined using the SIMPER procedure (similarity percentages; Clarke, 1993). Species above the 50% similarity threshold were considered to be those most important in determining the community structure. K-dominance curves (Lambshead *et al*., 1983) were constructed for finding out the diversity profile of the reef complexes. K-dominance curves present the different species ranked in order of dominance according to their contribution to living coverage on the x-axis (logarithmic scale) with percentage dominance on the y-axis (cumulative scale). The starting point of the curve and its inclination are indicative of the diversity profile of the examined community; for example, a steep slope with high starting point reflects low diversity.

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

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

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), 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 Mulli and Anaipar islands recorded the highest and lowest average coral cover of 40.1 and 25.0%, respectively. Maximum number of hard coral species was recorded from reefs around Valimunai Island (19) and minimum from Anaipar (8). Valai, Mulli and Appa island reefs recorded 16, 18 and 12 species of hard corals respectively. *Montipora digitata* was the dominant coral species in Mulli, Valimunai and Anaipar islands with 10.2%, 8.0% and 8.5% of average live coral cover respectively (Table 1). *Montipora foliosa* contributed the maximum live coral cover of 7.4% and 12.5% respectively in Valai and Appa Island reefs. Average mortality index (MI) was the highest in Anaipar island reef (0.71) and the lowest in Mulli Island reef (0.52) (Table 2). Conservation class 2 was assigned to Valai, Mulli, Appa and Valimunai reefs. Conservation class 4 was assigned to Anaipar Island (Fig. 2).

Shannon diversity index showed the highest value in reefs of Mulli Island (2.53) and the lowest value in Anaipar Island (1.72) (Table 2). Simpson richness index also followed the same trend with values of 0.91 and 0.81 respectively for Mulli and Anaipar island reefs. Pielou's evenness value was the maximum (0.88) in Mulli island reefs and minimum (0.81) in Valimunai island reefs.

K-dominance curve constructed on the data sets (Fig. 3) showed the diversity pattern of different Island reefs. Whereas Mulli island reefs showed a low starting point and gentle slope indicating high diversity, Anaipar Island reefs 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 38.5 – 58.1% with the highest between Valai and Valimunai and the lowest between Appa and Mulli (Table 3). SIMPER analysis (Table 4) showed that *M. digitata* (30.6%) along with *Montipora foliosa* (23.9%) was responsible for within – group similarity in Valai Island reefs. The average similarity in species composition of Valai island reefs was found to be 17.4%. The species *M. digitata* (30.7%) along with *M. foliosa* (15.1%) was responsible for within – group similarity among Mulli Island reefs. The average similarity in species composition was found to be 17.5%. The species *M. foliosa* (45.4%) and *M. digitata* (14.6%) were found to be most responsible for within group similarities in reefs around Appa Island. The average similarity in species composition was found to be 26.9%. The species *M. digitata* (34.8%) along with *M. foliosa* (34%) was most responsible for within – group similarities in Valimunai Island reefs. Average similarity in species composition within the reef was found to be 24.2%. The species *M. digitata* (50.6%) along with *A. formosa* (26.8%) was found to be most responsible for within – group similarity on the reefs of Anaipar island. Average similarity in species composition within the reefs of this island was found to be 39.3%. SIMPER analysis (Table 5) showed the highest average dissimilarity between Valai and Anaipar island reefs as 85.5%. Lowest average dissimilarity was found between Valimunai and Anaipar (74.8%).

Discussion

In the present study, we adopted both univariate and multivariate methods to assess the reef condition. According to Finkel and Benayahu (2004), 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

Table 1. Average percentage live coral cover and relative abundance (RA) of scleractinians from reefs around five islands

Species	Valai		Mulli		Appa		Valimunai		Anaipar	
Family : Acroporidae	**%**	**RA**	**%**	**RA**	**%**	**RA**	**%**	**RA**	**%**	**RA**
Acropora cytherea	0.3	**	0.2	**	0	-	0.4	***	0	-
A. rudis	0.8	***	0	-	0	-	0.1	**	0	-
A. hyacinthus	1.7	***	3.9	***	1.8	***	3.4	***	3.2	****
A. formosa	0	-	2.8	***	0	-	2.7	***	7.1	*****
A. humilis	0	-	2.2	***	0	-	0	-	0	-
A. divaricata	0	-	2.4	***	0	-	0	-	0	-
A. intermedia	0	-	2.3	***	0	-	0	-	0	-
A. lamarckii	0	-	2.6	***	0	-	0	-	0	-
A. retusa	0	-	0	-	0	-	0.1	**	0	-
A. stoddarti	0	-	0	-	0	-	1.1	***	0	-
A. scherzeriana	0	-	0	-	0	-	0.7	***	0	-
A. globiceps	0	-	0	-	0	-	0	-	0.6	***
Montipora foliosa	7.4	*****	3.6	***	12.5	*****	7.2	*****	0	-
M. divaricata	1.5	***	1.2	***	0	-	0	-	0	-
M. aequituberculata	1.2	***	0	-	0	-	0.9	***	0	-
M. digitata	6.2	****	10.2	*****	3.4	****	8.0	*****	8.5	*****
M. verrilli	0	-	1.3	***	0	-	0	-	0	-
M. informis	0	-	0.9	***	0	-	0	-	0	-
M. hispida	0	-	0.5	***	0	-	0	-	0	-
M. peltiformis	0	-	0.2	**	0	-	0.2	**	0	-
M. anguilata	0	-	0	-	0	-	0.9	***	0	-
Family:Pocilloporidae										
Pocillopora damicornis	2	***	1.3	***	1.7	***	0.6	***	0	-
Pocillopora eudoxi	2.2	***	0	-	0	-	0	-	0	-
Family : Agaricidae										
Pavona varians	0	-	0	-	0.6	***	0	-	0	-
Family : Merulinidae										
Merulina ampliata	0	-	0	-	1.2	***	0	-	0	-
Family : Faviidae										
Favia pallida	1.7	***	1.5	***	1.8	***	2.1	***	1.6	***
Favites abdiata	1	***	1.6	***	0.4	***				
Echinopora gemmaceae	1.3	***	1.6	***	0	-	2.1	***	0	-
E. lamellosa	0	-	0	-	5.3	****	0	-	0	-
Cyphastrea microphthalma	1	***	0	-	0	-	0	-	0	-
Leptastrea purpurea	0	-	0	-	0	-	0.3	**	0	-
Family : Poritidae										
Porites lichen	1.2	***	0	-	0	-	0	-	0	-
P. mannarensis	1.2	***	0	-	2.3	***	0	-	1.4	***
P. thurstoni	0	-	0	-	1.6	***	0	-	0	-
P. solida	0	-	0	-	0	-	1.3	***	0	-
Goniopora sp.	0	-	0	-	0	-	0	-	1	***
Family:Dendrophylliidae										
Turbinaria mesenterina	0.4	***	0	-	1.2	***	2.4	***	1.6	***
Total	31.1		40.1		33.8		34.7		25.0	

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

Table 2.Univariate community parameters of reefs around different islands

Sites	J'	H'(loge)	1-Lambda'	MI
Valai	0.87	2.41	0.91	0.63
Mulli	0.88	2.53	0.91	0.52
Appa	0.82	2.04	0.84	0.61
Valimunai	0.81	2.37	0.89	0.62
Anaipar	0.83	1.72	0.81	0.71

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

Table 3. Bray –Curtis similarity (%) for scleractinian corals from study sites

Sites	Valai	Mulli	Appa	Valimunai	Anaipar
Valai	-	52.4	56.4	58.1	40.8
Mulli	52.4	-	38.5	55.2	42.3
Appa	56.4	38.5	-	48.7	44.2
Valimunai	58.1	55.2	48.7	-	54.1
Anaipar	40.8	42.3	44.2	54.1	-

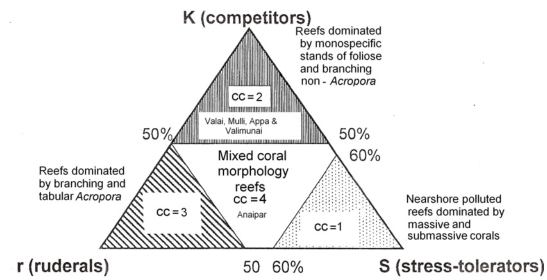

Fig. 2. r - K - S ternary diagram for coral reef conservation classes adopted from Edinger and Risk (2000)

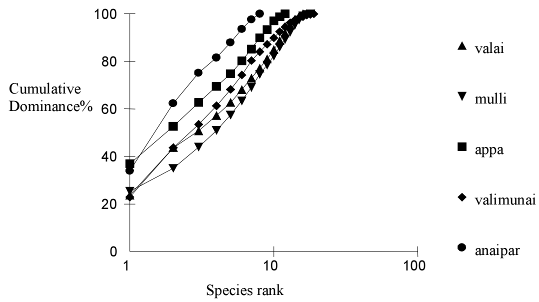

Fig. 3. K- dominance curves for the different reefs

Table 4. Species causing similarities (%) within groups based on Bray – Curtis similarity in five reefs. Species are listed in descending order according to per cent contributions to respective similarity

Group: Valai			**Group: Appa**		
Average similarity : 17.42			Average similarity: 26.85		
Species	Cont.%	Cum.%	Species	Cont.%	Cum.%
M. digitata	30.6	30.6	*M. foliosa*	45.4	45.4
M. foliosa	23.9	54.5	*M. digitata*	14.6	60.0
P. damicornis	11.4	65.9	*E. lamellosa*	12. 8	72.7
P. eudoxi	8.3	74.1	**Group: Valimunai**		
M. divaricata	7.2	81.3	Average similarity: 24.18		
Group: Mulli			*M. digitata*	34.8	34.8
Average similarity : 17.52			*M. foliosa*	34.0	68.7
M. digitata	30.7	30.7	*A. hyacinthus*	5.7	74.4
M. foliosa	15.1	45.8	*T. mesenterina*	5.5	79.8
A. hyacinthus	9.5	55.4	**Group: Anaipar**		
E. gemmaceae	6.5	61.8	Average similarity: 39.27		
A. formosa	6.3	68.1	*M. digitata*	50.6	50.6
A. divaricata	5.4	73.5	*A. formosa*	26.8	77.3
			A. hyacinthus	8.7	86.0

Table 5. Species causing dissimilarities (%) among groups based on Bray – Curtis dissimilarity indices in five reefs. Species are listed in descending order according to per cent contributions to respective dissimilarity

Groups Valai and Mulli			**Groups Appa and Valimunai**		
Average dissimilarity :83.63			Average dissimilarity: 75.91		
Species	Cont.(%)	Cum.(%)	Species	Cont.(%)	Cum.(%)
M. digitata	11.8	11.8	*M. foliosa*	12.3	12.3
M. foliosa	11.1	22.9	*M. digitata*	11.4	23.8
E. gemmaceae	6.43	29.4	*E. lamellosa*	7.8	31.6
A. hyacinthus	6.0	35.4	*A. hyacinthus*	7.5	39.1
P. damicornis	6.0	41.3	*T. mesenterina*	6.8	45.9
Groups Valai and Appa			**Groups Valai and Anaipar**		
Average dissimilarity: 81.10			Average dissimilarity : 85.49		
M. foliosa	14.5	14.5	*M.digitata*	13.1	13.1
M. digitata	10.6	25.1	*A. formosa*	12.5	25.6
E. lamellosa	8.1	33.2	*M. foliosa*	10.2	35.7
P. damicornis	6.8	40.0	*A. hyacinthus*	7.8	43.5
F. pallida	5.8	45.8	*F. pallida*	6.0	49.5
Groups Mulli and Appa			**Groups Mulli and Anaipar**		
Average dissimilarity: 84.16			Average dissimilarity : 80.76		
M. foliosa	13.0	13.0	*M. digitata*	14.8	14.8
M. digitata	11.3	24.3	*A. formosa*	12.7	27.5
E. lamellosa	7.5	31.8	*A. hyacinthus*	8.9	36.3
A. hyacinthus	6.6	38.5	*M. foliosa*	6.8	43.1
F. pallida	5.4	43.8	*F. pallida*	6.0	49.2
Groups Valai and Valimunai			**Groups Appa and Anaipar**		
Average dissimilarity: 78.36			Average dissimilarity : 83.54		
M. foliosa	12.5	12.5	*M. foliosa*	15.9	15.9
M. digitata	11.5	23.9	*M. digitata*	12.8	28.8
A. hyacinthus	6.8	30.8	*A. formosa*	12.5	41.2
E. gemmaceae	6.4	37.1	*E. lamellosa*	8.4	49.6
F. pallida	5.9	43.0	*A. hyacinthus*	8.3	57.9
Groups Mulli and Valimunai			**Groups Valimunai and Anaipar**		
Average dissimilarity: 78.37			Average dissimilarity : 74.84		
M. digitata	12.0	12.0	*M. foliosa*	14.0	14.0
M. foliosa	11.0	23.0	*A. formosa*	12.2	26.3
A. hyacinthus	7.7	30.7	*M. digitata*	11.7	38.0
A. formosa	6.9	37.5	*A. hyacinthus*	9.5	47.5
E. gemmaceae	6.4	44.0	*T. mesenterina*	7.7	55.2

species occurrence. Therefore, in the present investigation, we combined the 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) classified reefs into conservation classes based on coral morphology. They 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 Valai island reefs, *M. foliosa* and *M. digitata* belonged to the category "dominant" and so this reef belongs to the conservation class 2 (CC2) of Edinger and Risk classification (Fig. 2). These reefs are less stressed compared to reefs dominated by stress tolerators. Further, CC2 reefs provide optimum dive sites especially those in locations sheltered from wave impact. The average mortality index for the reef (0.63) was more than 0.33 indicating sick condition of the reef. The Shannon index of diversity of Valai Island from the pooled data showed a comparatively low value of 2.41. K-dominance curve showed low starting point and gentle slope indicating fair diversity. All indices of reef health considered here points to the sick condition of this reef.

In Mulli Island, *M. digitata* belonged to the category "dominant". All other corals were with "abundant", "common" or "uncommon" species status. This reef also belonged to CC2 (Fig. 2). The mortality index values agreed with the sick condition of this reef with a value (0.52) greater than 0.33. Shannon diversity index for the reef from the pooled data showed a comparatively high value of 2.53 and the K-dominance curve showed a low starting point and gentle slope indicating fair diversiy. Appa Island reefs showed the dominance of *M. foliosa* grouping them into conservation class 2 along with other reefs (Fig. 2).

In Valimunai island, *M. digitata* and *M. foliosa* belonged to the category dominant and this reef also belonged to CC2 (Fig. 2). Average mortality index (0.62) was higher than 0.33 indicating sick condition of this reef. K-dominance curve showed the high starting point and steep slope indicating low diversity. In Anaipar island, *M. digitata* and *A. formosa* belonged to the classification "dominant" with relative abundance values of 33.94 and 28.42 respectively. Since both ruderals and competitive dominants belonged to the category "dominant" this reef can be classified as CC4. Average mortality index (0.44) was greater than 0.33 indicating the sick condition of this reef. Shannon index of diversity showed comparatively low value (1.72) and K-dominance curve showed high starting point and steep slope. The present study revealed that all the reefs of Kilakarai group of islands are in stressed condition with all the diversity indices showing low values. This points to the need for an effective strategy for the management of these reef resources. Pillai (1996) proposed that Gulf of Mannar was prone to excessive mining during the 1960s which might have caused the large scale destruction and deterioration of coral reefs of this area. Rapid decline of reef systems calls for a suite of more vigorous, innovative and adaptive management strategies. Responding to the global coral reef crisis requires active management of human activities that modify essential ecological processes. It also requires an ability to scale up management and governance systems to secure the future of functional groups and their roles in supporting resilience of coral reefs.

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