Fishery Technology
2008, Vol. 45(2) pp : 163 - 170

Biodiversity Assessment of a Fringing Reef in Palk Bay, India

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Kathuvallimuni Reef, a fringing reef of Palk Bay was surveyed for the assessment of the coral cover and biodiversity during January-May 2005, following the Line Intercept Transect Method and their geographical positions were fixed using the Global Positioning System. The percentages of live and dead coral cover at each site were derived. A total of 20 hard coral species were found on the transects; *Platygyra lamellina* was the major species at 3 sites, followed by *Porites solida, Favites virens, Hydnophora exesa, H. microconus, Turbinaria mesenterina, Acropora hyacinthus* and *A. corymbosa* at each of the 7 sites. The total live and dead coral cover for the reef as a whole was estimated as 37.8% and 32.6% respectively and the remaining part was covered with seagrasses, sand and rubble. Dead coral cover was dominated by poritids. Further, relative abundance values were derived for each species and they were assigned status as dominant/abundant/common/uncommon/rare. *P.lamellina* belonged to the category "abundant" and all other species were either of "common" or "uncommon" status only. The Shannon indices of diversity in most of the sites were moderate varying from 1 to 2 and the reef as a whole showed a diversity of 2.8. The species richness and evenness values showed values of 5.23 and 0.9 respectively.

Key words: Fringing reef, Community analysis, Palk Bay, Coral biodiversity

Coral reefs are one of the world's most spectacular ecosystems. They straddle the tropics and cut a broad swathe around the globe (Spalding *et al.*, 2001). Coral reefs around the world are threatened by an onslaught of human activities. Many contemporary coral reefs increasingly fail to regenerate after natural and human impacts and have undergone rapid shift to an alternate state (Done, 1992).

Coral reefs of fringing type are found in the Palk Bay and Gulf of Mannar at the South Eastern coast of India. In Palk Bay, they lie along the eastern side of Rameswaram Island. Kumaraguru *et al.* (2003) studied the effect of bleaching due to the increased sea surface temperature (SST) in Palk Bay and reported the biophysical status of coral reefs after the bleaching phenomenon using the Line Intercept Transect Method. The Department of Ocean Development and Space Application Centre, Ahmedabad has produced coral reef maps of India (DOD & SAC, 1997), but species wise listing of live and dead corals in relation to depth of occurrence is lacking. The present study is an attempt to get insights into the health of this reef by deriving percentage of live and dead coral cover and diversity indices.

Materials and Methods

Kathuvallimuni Reef is a part of the fringing reef of Palk Bay which extends eastward upto Pamban Pass (ie., from 79°10′ E Long. 9°17′N Lat. to 79°12′ E Long. 9°17′N Lat.) (Fig.1). The western half of this fringing reef, which extends westward upto Thedai from Pamban pass, is called Velapertumuni reef. This reef is comparatively wider than the Kathuvallimuni reef.

Sampling was carried out during January-May 2005. Line Intercept Transect

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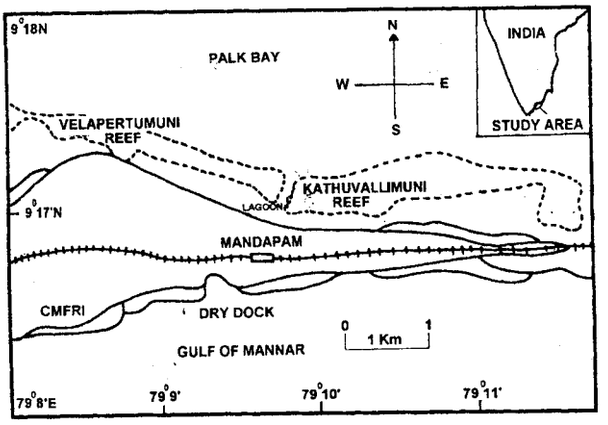

Fig. 1. Location of the study site.

Method (English *et al.*, 1994) was adopted for the assessment of live and dead coral cover. A 20m length of fiberglass tape was stretched parallel to the reef crest at 10 different sites and fraction of the length of the line intercepted by the coral was recorded. This measure of cover expressed as a percentage is considered to be an unbiased estimate of the proportion of the total area covered by that coral if the following assumptions apply; that the size of the object is small relative to the length of the line and that the length of the line is small relative to the area of interest (English *et al.*, 1994). The depth at which transects were taken varied from 1-5m where these fringing reefs occur. When necessary for identification, the colonies were sampled and identified (Pillai, 1967 a, b & c, 1973; Veron 1986, 2000; Venkataraman *et al.*, 2003). The diversity indices, dominance curve etc. were derived using PRIMER 5 Software.

The relative abundance (RA) of each species was calculated according to the contribution to living cover (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), dominant (RA>20).

The diversity of corals was calculated following the Shannon- Wiener index (Clarke and Warwick, 2001) using the formula

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

Where H′ is the species diversity in bits of information per individual, *ni* is the proportion of the samples belonging to the i^{th} species (number of individuals of the i^{th} species), and N is the total number of individuals in the collection and H′ is the summation. Species richness was calculated following the Margalef index (d) using the formula $d = (S-1)/\log_e N$, where S is the number of species and N the total number of corals. The evenness (J′) was computed using the following formula of Pielou :

$$J' = \frac{H'}{Log_2 S} \quad \text{or} \quad \frac{H'}{ln_2 S}$$

Where H′ is the species diversity in bits of information per individual and S is the total number of species.

K-dominance curves (Lambshead *et al.*, 1983) 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. K- dominance curve was constructed on the data sets.

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.

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

where MI is the mortality index.

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

Dissolved oxygen values were estimated by using dissolved oxygen pocket meter "Oxi 3i5i" model. Salinity values were estimated by "ATAGO" (Japan) handheld refractometer and light intensity values were studied by "TES" digital Lux meter. pH values were assessed by "Eutech" (Singapore) handheld pH meter and temperature values were monitored using an ordinary centigrade thermometer. Geographical position of each transect was fixed using "GARMIN Model 12XL" GPS.

Results and Discussion

Mean values of water quality parameters during the study period are given in Table 1. Average values of sea surface temperature and salinity were 30.6^{0}C and 34.5ppt respectively. Dissolved oxygen (surface) and pH showed average values of 6.23 and 7.85 respectively. Average value of light intensity was 38780 lux at 11:30 hours during sampling days. A total of 20 hard coral species was found on the transects (Table 2). *Platygyra lamellina* was the major species at three sites, followed by *Porites solida, Favites virens, Hydnophora exesa, Acropora hyacinthus, A. corymbosa, Turbinaria mesenterina* and *H. microconos* at second, fourth, fifth, seventh, eighth, ninth and tenth sites respectively. The results revealed that except for two sites the massive and foliose corals were dominant in all the other sites. Total percentage coral cover of each site was also derived (Table 3). *P. lamellina* showed the highest percentage coral cover. The life form categories of different coral species recorded in the transects showed that majority are massive and submassive corals (Table 3). The total live coral cover for the reef as a whole was found to be 37.8%. Total dead coral cover for the reef was derived as 32.6% (Table 4). Dead coral cover was dominated by poritids followed by acroporids. The percentage of bleached coral cover was found to be 17.1% with acroporids and faviids recording the maximum and minimum values respectively (Table 5). The diversity indices for the 10 sites were also derived (Table 6). Margalef & Fisher á (species richness) showed the highest value in sixth site (2.23 and 4.35 respectively). Another major component of diversity ie., evenness or equitability was highest in 8th site. Shannon index of diversity which is a more realistic estimate of biodiversity was found to be highest in 2nd site. Diversity indices for the whole reef were estimated for reef classification (Table 6). Margalef species richness and Pielou's evenness values were 5.2 and 0.9 respectively. Shannon diversity recorded a moderate value of 2.8. The coral mortality index at different sites and average value for the reef was also calculated (Table 7). Except at sites 2 and 4 coral mortality index was found to be greater than 0.33, with an average value of 0.46 for the reef.

Table 1. Average values of water quality parameters of sampling sites during study period

Water quality parameters	Values
Sea surface temperature (^{0}C)	30.6
Salinity (ppt)	34.5
Dissolved oxygen (surface) (ppm)	6.23
pH	7.85
Light intensity (Lux)	38780

A community analysis was carried out to discern the species status (Table 3). All twenty species of corals were classified into different categories in accordance with their relative abundance. *P. lamellina* was the only species which belonged to the "abundant" category. Relative abundance values of all other species were less than 10, giving them either common or uncommon species status. K– dominance curve was constructed on the data sets to find out the biodiversity pattern (Fig.2). It confirmed the moderate diversity

Table 2. Percentage living coral cover at 10 different sites

Species Lat: Long:	S1 9°17'17.3"N 79°9'48.2"E	S2 9°17'15"N 79°9'48" E	S3 9°17'13"N 79°9'47"E	S4 9°17'13.6"N 79°9'47.3"E	S5 9°17'27.5"N 79°9'19.2"E	S6 9°17'36.1"N 79°8'12.3"E	S7 9°17'40.3"N 79°8'30.6"E	S8 9°17'42"N 79°8'31.9"E	S9 9°17'42.7"N 79°8'32.1"E	S10 9°17'43"N 79°8'33"E
Depth (m)	3.4	3.2	3	4	5	2.3	3.7	4	1.9	3.1
Platygyra lamellina	23	11	12	0	2	10	7	0	4	2
Leptoria phrygia	0	0	0	0	5	3	0	3	5	0
Favites abdita	0	1	0	0	1	2	4	0	3	3
Favites virens	1	6	0	12	0	0	0	5	0	0
Montastrea valenciennesi	2	0	0	11	0	0	6	4	0	4
Hydnophora exesa	0	0	0	0	13	0	0	0	4	0
Hydnophora microconus	0	3	0	0	0	2	0	0	0	11
Goniastrea retiformis	0	0	0	0	8	0	0	2	4	0
Montipora digitata	0	4	5	0	0	0	3	0	0	0
Galaxea fascicularis	0	0	2	0	0	1	0	5	0	0
Symphyllia radians	19	5	0	0	0	0	0	0	0	3
Turbinaria mesenterina	5	3	0	0	0	0	0	0	9	0
Cyphastrea serailia	0	0	0	4	0	1	0	6	0	0
Cyphastrea microphthalma	0	12	0	6	0	0	0	0	0	0
Porites solida	0	16	0	0	0	1	3	0	2	0
Acropora nobilis	0	0	6	4	0	0	0	0	0	0
Acropora lamarcki	0	0	1	5	0	0	0	7	0	5
Acropora cytherea	0	0	2	2	0	0	0	0	0	0
Acropora hyacinthus	0	11	8	1	0	0	9	0	0	0
Pocillopora damicornis	0	0	0	0	0	3	0	0	0	0
Average										37.8

of this reef with its gentle slope and medium starting point.

Kumaraguru *et al.* (2003) determined the biophysical status of coral reefs using the Line Intercept Transect Method. They recorded live coral cover of 38.4, 42.9 and 40.7% from Rameswaram East, Rameswaram North and Pamban North respectively during bleaching recovery in August 2002. These three zones are part of Kathuvallimuni reef on which the present study was focused.

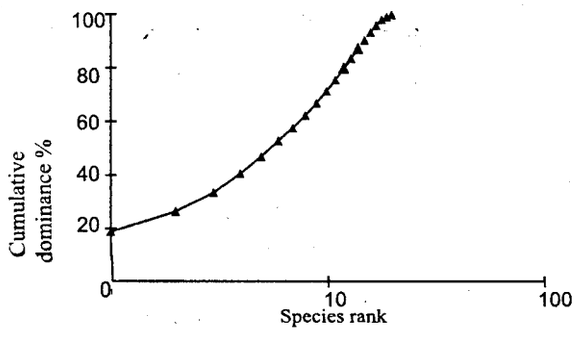

Fig. 2. K- dominance plot for Kathuvallimuni reef.

However, the authors could record a total live coral cover of 37.8% from Kathuvallimuni reef which indicates the stable condition of these coral reefs after bleaching recovery.

According to English & Wilkinson (1994), most reef surveys in Southeast Asia are conducted using the life-form Line Intercept Transect (LIT) method. In Southeast Asia, reefs are evaluated according to a linear scale of coral cover (Gomez and Yap, 1988), such that only those reefs with >75% live coral cover are considered to be "excellent" condition. Reefs with 50-75% live coral cover are considered to be in "good" condition ; reefs with 25 – 50% live coral cover "fair" condition ; and reefs with <25% live coral cover, "poor" condition. According to this classification the reef of the present study falls under the "fair" category with 37.8% live coral cover. Disturbance, competition and stress are the primary factors controlling diversity and abundance of plants and animals in natural

Table 3. Total percentage coral cover of each species, their life form categories and status according to relative abundance

Species	% cover	Life form categories	Relative abundance	Species status
Platygyra lamellina	7.1	massive	18.8	A
Leptoria phrygia	1.6	-do-	4.3	C
Favites abdita	1.4	foliose	3.7	C
Favites virens	2.4	massive	6.3	C
Montastrea valenciennesi	2.7	-do-	7.1	C
Hydnophora exesa	1.7	submassive	4.5	C
Hydnophora microconus	1.6	-do-	4.2	C
Goniastrea retiformis	1.4	massive	3.7	C
Montipora digitata	1.2	arborescent	3.2	C
Galaxea fascicularis	0.8	submassive	2.1	C
Symphyllia radians	2.7	massive	7.1	C
Turbinaria mesenterina	1.7	foliose	4.5	C
Cyphastrea serailia	1.1	massive	2.9	C
Cyphastrea microphthalma	1.8	-do-	4.8	C
Porites solida	2.2	-do-	5.8	C
Acropora nobilis	1	branching	2.6	C
Acropora lamarcki	1.8	-do-	4.8	C
Acropora cytherea	0.4	-do-	1.2	C
Acropora hyacinthus	2.9	-do-	7.7	C
Pocillopora damicornis	0.3	ramose	0.8	U

A=abundant, C= Common, U=Uncommon

communities (Houston,1994). Edinger & 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 the reef of present study only four species of branching corals belonging to the genus *"Acropora"*(ruderals) could be recorded. They belonged to the status "Common" according to relative abundance values (Table 3). All other corals belonged to the life form category "massive or submassive" (stress tolerators) except *F. abdiata* and *T. mesenterina* which belonged to "foliose" life form category (competitive dominants). Among the stress tolerators only *P. lamellina* belonged to "abundant" category and none of the other corals were included in "dominant" category. The abundance of stress tolerators in the reef of present investigation points to a need for a comprehensive study of anthropogenic and environmental factors regulating the biodiversity of this reef. 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.

In the present investigation in many of the sites the Shannon indices of diversity

Table 4. Kathuvallimuni reef-percentage of dead coral cover

Groups	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Poritids	12	3	15	3	17	14	23	12	15	9
Acroporids	5	1	8	5	13	15	15	19	11	13
Faviids	11	4	6	13	11	14	12	11	7	9
Average										32.6

Table 5. Kathuvallimuni reef-percentage of bleached coral cover

Groups	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Poritids	3	4	5	12	9	12	7	2	3	9
Acroporids	12	5	6	4	3	3	11	4	5	11
Faviids	2	1	2	6	5	4	4	8	7	12
Average										17.1

Table 6. Diversity indices for 10 sites and reef

Sample	S	N	d	J'	Fisher α	H'(log e)
S1	5	50	1.02	0.72	1.38	1.16
S2	10	72	2.10	0.90	3.15	2.08
S3	7	36	1.67	0.87	2.59	1.69
S4	8	45	1.84	0.9	2.83	1.86
S5	5	29	1.20	0.81	1.74	1.31
S6	8	23	2.23	0.83	4.35	1.73
S7	6	32	1.44	0.95	2.18	1.71
S8	7	32	1.73	0.96	2.76	1.88
S9	7	31	1.74	0.95	2.82	1.85
Whole reef	20	38	5.2	0.87	0.90	2.80

S = Total species, N = Total individuals, d = Margalef species richness, J' = Evenness, Fisher α = Species richness, H' = Shannon diversity

were low varying from 1.3 to 2.08 and the reef as a whole showed a diversity of 2.8. In ecological studies, diversity frequently refers not only to the number of taxa (taxon "richness") but also to a measure of equitability or evenness in the abundance of taxa. Within the continuum of spatial scales, three levels are often discussed with respect to taxonomic diversity: within habitat (alpha), between habitat (beta) and regional (gamma) diversity. The present study is focused on finer spatial scales because they address the immediate factors regulating the local co-existence of species in communities. Likewise, species richness and evenness recorded moderate values in this reef. The K-dominance curve showed gentle slope and medium starting point, indicating fair diversity (Fig.2). According to Kumaraguru et al. (2003), the summer of 2002 had the hottest days (32°C) in Palk Bay region causing reefs to bleach in late March which intensified during April and May 2002. However, the present authors could record a total bleached coral cover of 17% which is suggestive of the slow but continuous recovery of corals from bleaching. Pillai (1996) has attributed the poor reef growth in Palk Bay to the intense quarrying of coral from this reef in the sixties. Pillai (1969) has mostly referred in his studies that Velapertumuni reef is more exploited than Kathuvallimunai reef due to it's proximity. According to UNEP report (1985) the development of Tuticorin harbour, oil pollution and industry have caused significant damage in the Gulf of Mannar and Palk Bay area.

Table 7. Mortality Index of corals at the sampling sites and reef

Sites	Mortality Index
S1	0.36
S2	0.1
S3	0.45
S4	0.32
S5	0.59
S6	0.65
S7	0.61
S8	0.57
S9	0.52
S10	0.53
Average value for the reef	0.46

All indices of reef health considered here ie., the live coral cover (low live coral cover indicating poor condition), diversity indices, reef condition (domination by massive and submassive corals), and mortality index (Mortality index, MI >0.33) agreed on what constitutes a sick reef. This situation demands careful consideration from policy makers and planners. 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, we must understand the processes that maintain diversity at this scale. A major goal of management strategies is the protection of habitat over large, regional scale areas. The results of the present study point to a need to shift our focus from individual taxa to broader habitat based management strategies, and these highlight the need for national management of reef resources.

The authors wish to acknowledge Prof. Mohan Joseph Modayil, Director, CMFRI, Cochin for the encouragement and support to carry out this work. Acknowledgements are also due to Dr. N. Kaliaperumal, SIC, CMFRI, Mandapam for providing the facilities.

References

Clarke, K.R. and Warwick, R.M. (2001) *Changes in marine communities : An approach to statistical analysis and interpretation.* PRIMER – E, Plymouth, 112p.

DOD and SAC. (1997) *Coral reef maps of India.* Department of Ocean Development and Space Application Centre, Ahmedabad, India.

Done, T.J. (1992) Phase - shifts in coral reef communities and their ecological significance. *Hydrobiol.* **247,** pp 121-132

Edinger, E.N. and Risk, M.J. (2000) Reef classification by coral morphology predicts coral reef conservation value. *Biol. Conserv.* **92,** pp 1-13

English, D. and Wilkinson, C.R. (1994) *Monitoring coral reefs for global change. Reference methods for Marine Pollution Studies* No: 61, 72 p, UNEP/Australian Institute of Marine Science

English, S., Wilkinson, C. and Baker, V. (1994) *Survey Manual for Tropical Marine Resources.* 368 p, Australian Institute of Marine Science, Townsville, Australia.

Gomez, E.D. and Yap, H.T. (1988) Monitoring reef condition. In: *Coral reef management handbook,* (R.A. Kenchington and B.E.T. Hudson, Eds) pp 171-178 UNESCO regional office for science and technology for southeast Asia (ROSTSEA), Jakarta.

Gomez, E.D., Alino, P.M., Yap, H.T. and Lieuanan, W.Y. (1994) A review of the status of Philippine reefs. *Mar. Pollut. Bull.* **29,** pp 62-678

Grime, J.P. (1979) *Plant strategies and vegetation processes,* 222 p, John Wiley and Sons, Toronto

Houston, M.A. (1994) *Biological diversity : the coexistence of species on changing landscapes,* 681p, Cambridge Univ. Press, New York

Kumaraguru, A.K., Jayakumar, K. and Ramakritinan, C.M. (2003) Coral bleaching 2002 in the Palk Bay, South east coast of India. *Curr. Sci.* **85(12)a,** pp 1787-1793

Lambshead, P.J.D., Platt, H.M. and Shaw, K.M. (1983) The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *J. Nat. Hist.* **17,** pp 859-874

Loya, Y. (1972) Community structure and species diversity of hermatypic corals at Eilat, Red Sea. *Mar. Biol.* **13,** pp 100-123

Pillai, C.S.G. (1967 a) Studies on Indian corals – I. Report on a new species of *Montipora* (Scleractinia, Acroporidae). *J. Mar. Biol. Assoc. India,* 9, pp 399-401

———————(1967 b) Studies on Indian corals – 2. Report on a new species of *Goniopora* and three new species of *Porites* (Scleractinia, Poritidae). ibid, 9, pp 402-406

———————(1967 c) Studies on Indian corals – 5. Preliminary reports on new records of hermatypic corals of the suborder Astrocoeniina. ibid, 9, pp 412-422

———————(1969) The distribution of corals on a reef at Mandapam (Palk Bay), S. India. ibid, **11(1&2),** pp 62-72

——————— (1973) A review of the genus *Acropora* (Scleractinia, Acroporidae) with

the description of a new species. Ibid, **15**, pp 296-301

——————— (1996) Coral reefs of India : Their Conservation and Management. In: *Marine Biodiversity, Conservation and Management*. (C.S.G. Pillai and N.G. Menon, Eds) pp 16-31 CMFRI, Cochin, India.

Rilov, G. and Benayahu, Y. (1998) Vertical artificial structures as an alternative habitat for coral reef fishes in disturbed environments. *Mar. Environ. Res.* **45**, pp 431-451

Spalding, M.D., Ravilious, C. and Green, E.P. (2001) *World Atlas of Coral reefs*. 424 p, UNEP World Conservation Monitoring Centre, Cambridge, UK.

UNEP. (1985) *Environmental problems of the marine and coastal areas of India : National Report*. UNEP Regional Seas Reports and Studies. **59**, pp 33

Venkataraman, K., Satyanarayana, Ch., Alfred, J.R.B. and Wolstenholme, J. (2003) *Handbook on Hard corals of India*, 266 p, Zoological Survey of India, Kolkata.

Veron, J.E.N. (1986) *Corals of Australia and Indo-Pacific*, 644 p, Australian Institute of Marine Science, Townsville, Australia.

Veron J.E.N. (2000) *Corals of the World*, 1: 463p; 2:429 p; 3: 490 p. Australian Institute of Marine Science, Townsville, Australia.