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THE DISTRIBUTION OF CORALS ON A REEF AT MANDAPAM (PALK BAY), S. INDIA *†

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SMALL coral reefs of fringing type are found in the Palk Bay and Gulf of Mannar at the south-eastern coast of India. They are located chiefly around the various islands lying between Tuticorin and Rameswaram in the Gulf of Mannar, and in Palk Bay at Mandapam and along the eastern side of Rameswaram Island. Early references to some of these reefs are made by Foote (1880) Thurston (1895) and Sewell (1932, 1935) who referred largely to the raised up reefs of the Rameswaram Island. In this account an attempt is made to describe the structure of a shallow-water reef at Mandapam (Palk Bay). The horizontal distribution of the various corals on the reef is discussed in relation to a few possible factors that might influence the distribution. This account is based on a study of the reef which was visited as and when conditions permitted, for over a period of three years.

Environmental conditions

Climate :

The area is under the spell of both south-west and north-east monsoons. The south-west monsoon contributes only very little towards the total annual rainfall of this area. Rain is moderate to heavy during October to mid-December with occasional gales. The mean annual rainfall varies from 762 mm. to 1270 mm. (Tampi, 1959). The monthly average atmospheric temperature varies from 25° C to 31° C. with the maxima and minima in May and January respectively (Prasad, 1954).

Hydrological conditions.:

The monthly averages of surface temperature of the waters of Palk Bay vary from 24.6° C. to 29.1° C with the lowest and the highest in January and April respectively. Prasad (*op. cit.*) has noted a regular seasonal cycle in the salinity of the waters of this area. It is low during January, gradually rising to the maximum in November followed by a decline in December. In most of the months it varies from 33 to 36‰. The tidal range is usually within an amplitude of a metre. The Palk Bay remains practically calm during most of the months except at the onset of north-east monsoon when turbulent conditions prevail. No fresh water streams dilute the sea near Mandapam.

Location and extent of the reef :

The reef in consideration runs parallel to the narrow strip of land lying between longitudes 79° 17′ 40″ E and 79° 8′ E at a latitude of 9° 17′ N. It lies in an east-west direction and is about 200 to 600 metres away from the shore at different places.

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The Palk Bay is a shallow basin with an average depth of 9 metres with mainly muddy bottom at inshore regions (Murthy and Varma, 1964). The depth at which the reef occurs ranges from 1 to 4 metres. The lagoon is shallow and can be waded through at low tides at several places. A narrow channel, almost at the mid-length of the reef, that permits the entry of the fishing vessels into the lagoon, separates the reef into an eastern and a western sector. The eastern half that extends up to the Pamban Pass is called the ' Kathuvallimuni Reef ' and the western half is called the ' Vellapertumuni Reef '. The former is comparatively wider. Because of their faunistic and structural similarities both are considered as a single biotope for subsequent considerations.

Description of the reef :

A profile view of the reef from the shore to the open Bay demarcates the following : The shore; the lagoon ; the shoreward side of the reef ; the reef crest and the sesward side of the reef.

The shore :

The sea shore here is mostly sandy mixed with occasional dead pieces of corals, except at the extreme eastern end near the ' Pamban Bridge ' where one can see traces of sand-stones. On the shore, about a kilometre west of the boat channel, there are remains of an elevated reef mostly composed of *Goniastrea retiformis, Favia pallida, Favites abdiata, Platygyra lamellina* and *Porites* spp. Sewell (1935) has paid attention to this and similar upraised coral structures of this region and has suggested a recent change of the relative levels of sea and land to an extent of 8 feet (2.5 metres) by means of a fall in the sea level. The vegetation on the shore comprises *Cocos nucifera, Borassus flabellifera, Casurina equisetifolia, Azadiracta indica* and a few other thorny shrubs. The sandy beach harbours are rich in fauna. The burrowing crabs *Dotilla myctiroides* and *Scopiomera proxima* are in plenty and are often found wandering near their burrows. The burrowing bivalves, *Donax* is represented here by at least two species. Sand dwelling *Polychaetes* are met with in large numbers. The gastropods *Cerithidea fluviatilis* occurs in large numbers with their larger dead shells occupied by hermit crabs.

The lagoon :

The width of the lagoon varies from 200 to 600 metres at different places with a depth of 1 to 2 metres. The bottom is sandy with molluscan shells and pieces of disintegrating corals. Living corals are practically absent in the lagoon probably due to the absence of any hard substratum on which coral planulae can settle. Sponges such as *Hercinia fusca, Dysidea fragilis, Spirastrella inconstans* and *Calispongia diffusa* are fairly common at the bottom. During July and August when the Bay remains calm large numbers of jelly-fish *Rhopilema hispidum* are found in the lagoon and at the outer side of the reef. The echinoderms *Pentaceraster australis, Holothuria atra* and *H. scabra* are common inhabitants of the sandy lagoon floor. The vegetation is composed of *Cymodocea* mixed with *Ulva reticulata, Turbinaria, Padina* etc. The calcareous *Halimeda* and *Amphiroa* are also common.

The shoreward side of the reef :

This part of the reef is composed of large boulders with intermittent sandy spaces. Scattered coral colonies, which are generally between 10 and 20 cm. in diameter are found on these rocks. They are mostly of the encrusting and massive types with comparatively large polyps, such as *Favia pallida, F. favus, Favites virens, Goniastrea pectinata, G. retiformis, Platygyra lamellina, Hydnophora* spp., *Cyphastrea*

spp., *Leptastrea* spp., *Symphyllia* spp. and *Goniopora* spp. Living colonies of *Porites* are rare and when they occur are all small in size. *Galaxea fascicularis* is sometimes seen in the crevices between rocks. *Turbinaria peltata* and *Pavonia varians* were collected once.

This part of the reef supports a good many reef-dwellers. Encrusting sponges, bryozoans and calcareous algae are common. Among the fleshy corals *Lobophytum* and *Sarcophytum* outnumber the others. The 'parasitisation' of polychaete worms here, are found to cause irregular nodular branches both on *Leptastrea transversa* and *Cyphastrea microphthalma*. The gastropids *Cerithidia fluviatilis*, *Murex* spp. and *Drupa* crawl over living corals. A living specimen of *Lambis truncata* once collected was found to have a small colony of *Favites virens* along with a few corallites of *Siderastrea savignyana* on the shell. The bivalves *Lithophaga* spp. and *Jouannetia* constitute the major coral boring molluscs of this area, the former being the most destructive inhabiting in both living and dead corals.

The reef crest :

The term 'crest' is here used to denote that part of the reef that lies between the shoreward and seaward sides of the reef. To put it in the words of Stephenson *et al.* (1931, p. 32) 'Its general level is slightly higher than that of the surrounding regions, and it constitutes, as it were, the backbone of the reef.' This part often get completely exposed at low tides. At Mandapam a boulder zone is apparently lacking. Corals are very rare at the crest of the reef probably due to the vivising influence of intermittent total exposure to sun. But under the rocks occasionally *Leptastrea transversa* and *Goniopora duofaciata* are seen.

The seaward side of the reef :

The reef-crest slopes to a depth of 3 to 4 metres. The coral growth at this part of the reef is comparatively richer than on the shoreward side. Majority of corals are of ramose type, of the genera *Pocillopora*, *Acropora* and *Montipora*. The encrusting and massive types that are found on the shoreward side are also seen. *Pocillopora damicornis*, *Acropora corymbosa* and *A. haimei* are the commonest, though none of them occur in any great abundance. At the mid-length of the Vellapertumuni Reef, *Acropora squamosa* occur in fair numbers, individual colonies varying from 30 to 40 cm. in greater diameter. *A. formosa* and *A. intermedia* are found at the eastern end of the Kathuvallimuni Reef. Several other species of *Acropora* also occur. *Montipora divaricata* forms arborescent colonies that exhibit a dark brown colour as against the tufted brown corallum of this species in the very shallow waters of the adjacent islands in the nearby Gulf of Mannar. The foliaceous species are presented by *Montipora foliosa* and *M. composita* but are not common.

Several reef-dwelling animals are seen in this part of the reef. The brilliantly coloured *Alpheus* spp. is represented by at least two species. A spider crab was recorded in abundance from *Pocillopora damicornis* and *Acropora corymbosa* in June and July, 1964. But during the same months in 1965 the crabs showed a remarkable reduction in their numbers. A small cirripede probably *Pyrogoma*, was often found at the tip of *A. corymbosa*. The coral seems to react to the presence of the intruder by coenenchymal overgrowth resulting in the apparent loss of the axial corallites. Such infested branchlets are irregularly swollen with thinner lamellate radials. The reef dwelling ichthyofauna of this reef is not rich as one may observe in any other tropical coral reef habitat. The vegetation comprises of *Turbinaria*, *Sargassum*, *Padina*, *Caulerpa* and rarely *Cymodocea*. *Halimeda* and a few other encrusting calcareous algae are commonly seen.

Horizontal distribution of corals on the Vellapertumuni Reef :

Most of the coral reefs, whatever may be their form i.e. fringing, barrier or atoll, show a tendency for the zonation of the various corals occurring on them, at their horizontal extent. Wells (1954, p. 396) has defined a zone as ' an area where local ecologic differences are reflected in the species association and signalised by one or more dominant species'. Various physical factors such as nature of the bottom, depth of water, temperature sedimentation and biological factors like inter-specific competitions and rate of growth of corals and availability of food may influence zonation on a reef. Several workers in the past (Mayer, 1918, 1924 ; Baker, 1925 ; Edmondson, 1928 ; Manton, 1935 ; Wells, 1954; Stoddart, 1962, 1966) have used both qualitative and quantitative analytical studies on reefs to record the zonation. Recently Stoddart (in press) has ably summarised these various field methods used by previous workers and this may be consulted for details.

A qualitative sample survey was undertaken in August 1965 with a view to studying the horizontal distribution of corals on the reef at Palk Bay. The survey was conducted at the Vellapertumuni Reef about a kilometre west of the boat-chellel. The spot was selected for the survey for the following reasons:

The lagoon in this area is moderately wide.
The reef at this place is of average width.
The growth and the representation of the various species of corals appeared to be comparatively better than any other part of the reef.

The technique used in recording data is similar to the one described by Rao (in press). The total length of the traverse is 450 metres from the lowest water mark at the shore to the outer edge of the reef. A square metre of the reef was sampled at 5 metre intervals using a square metre metal frame. The frame was placed along a rope stretched across the reef by means of two anchors. Every five metre intervals of the rope was marked with strips of cloth. The corals enclosed by the metal frame were counted with the help of a diving mask and snorkel. The number of colonies found at each station is given without regard to their actual differences in their size. Generally they were between 10 and 20 cm. in greater diameter, mostly between 10 to 15 cm. Since the present author has made a taxonomic study of the corals of this reef, prior to this survey, he experienced little difficulty in recognising the majority of the species in the field itself. However, a few doubtful specimens were brought to the laboratory for subsequent identification. The occurrence and abundance of the various species in between stations were also recorded. All the details regarding the analysis, such as the distances of stations from the shore, depth of water, nature of bottom and number of corals present if any, are presented in Table I.

The lagoon is 230 metres wide here and the appearance of the first reef rock is taken as its outward limit. The shoreward side of the reef was found to be 100 metres broad (from 230 to 330 metres in the traverse), the reef crest 30 metres (from 330 to 360 metres) and the seaward side 90 metres (360 to 450 metres). Beyond 450 metres in the line, the bottom is muddy without any coral growth. Regular sampling could be done only up to 425 metres after which the depth increased to 3 to 4 metres. A total of 40 stations was sampled. Out of these, 21 were on the shoreward side, 6 on the reef-crest and 13 on the seaward side.

Results of the sampling :

The depth of the shoreward side of the reef during survey at low tide varied from 0.75 to 1.0 metre at different stations. The first corals to appear in the line

TABLE I

Details of the analysis of the traverse

Distance in mtrs.	Depth in mtrs.*	Nature of the bottom	Name of corals present	No. of colonies of each species
0 to 20	0 to 0.75	Sandy. No vegetation	nil	—
20 to 150	0.75 to 1.5	Sandy. Covered by *Cymodocea*	nil	—
150 to 230	1.5 to 1.75	Surface sand loose and white, below black. Nullipore with occasional *Cymodocea*	nil	—
230	1.5	A large rock surrounded by sand	*Porites somaliensis*	2
			Favia pallida	1
235	1.5	Small rubbles with sandy interspaces	nil	—
240	1.25	Rocky	nil	—
245	1.5	Small rubbles with sandy interspaces	*Leptastrea transversa*	2
250	1.5	-do-	*Favia pallida*	1
			Leptastrea transversa	2
255	1.5	-do-	nil	—
260	1.5	-do-	*Favia pallida*	1
			Cyphastrea microphthalma	1
265	1.25	Rocky	nil	—
270	1.5	Sandy	nil	—
275	1.0	Rocky	*Leptastrea transversa*	4
			Favia pallida	1
			Favites virens	1
280	0.75	Rocky and sandy	*Leptastrea transversa*	5
			L. purpurea	1
			Favia pallida	4
285	0.75	Large rock	*Porites lichen*	2
			Leptastrea transversa	1
			Favites virens	1
			Acropora corymbosa	1
290	0.5	Large rock	*Cyphastrea microphthalma*	1
			Favia valenciennesii	1
295	0.75	Rocky and sandy	*Goniastrea pectinata*	1
300	1.0	-do-	nil	—
305	1.0	-do-	*Cyphastrea microphthalma*	1
310	1.0	-do-	*Leptastrea transversa*	7
315	1.0	-do-	*L. transversa*	4
320	1.0	-do-	*L. transversa*	8
325	1.0	-do-	nil	—
330 to 360 (7 stations)	0.5 to 0.75	-do-	nil	—
365	1.0	Rocky	*Favites virens*	1
370	1.0	-do-	nil	—
375	1.25	Rocky and sandy	*Acropora corymbosa*	2
380	1.25	-do-	*Pocillopora damicornis*	2
385	1.25	-do-	nil	—
390	1.5	-do-	*Montipora digitata*	1
395	1.25	-do-	nil	—
400	1.5	Rocky	*Pocillopora damicornis*	1
405	1.5	Rocky and sandy	*Montipora divaricata*	1
410	1.5	Rocky	*Acropora halmei*	1
415	1.75	-do-	nil	—
420	2.25	-do-	*Montipora foliosa*	1
425	2.5	Rocky and sandy	*Acropora corymbosa*	2

* Depth is given as it is measured during the survey.

were two colonies of *Porites somaliensis* (20 and 25 cm. in diameter) with a small colony of *Favia pallida*, at 230 metres. Between 230 and 245 metres no coral was present. Between 245 and 250 metres *Leptastrea transversa* and *Favia pallida* were present. At 260 metres one colony of *Favia pallida* and another of *Cyphastrea microphthalma* were noticed. No coral could be seen in between 260 and 270 metres. But the area between 270 and 280 metres possessed *Favia pallida* in fair numbers. From 280 metres onwards to 330 metres *Favia pallida, F. valenciennesii, Favites virens, Leptastrea transversa* and *Cyphastrea microphthalma* were noticed, *L. transversa* being the commonest. The only branching colony in the line on the shoreward side was noticed at 285 metres.

The area between 330 and 360 metres representing the reef crest in the traverse was hardly under 20 to 25 cm. of water at the time of the survey. No coral could be seen in the line.

Beyond 375 metres in the line *Acropora corymbosa* began to dominate with *Pocillopora damicornis, A. haimei* and *Montipora divaricata*. A small colony of *Montipora foliosa* was observed at 420 metres. Between 420 and 450 metres there was a preponderance of *Acropora corymbosa*.

Only 15 species of corals belonging to 9 genera were found in the 40 stations sampled out of the 63 species belonging to 22 genera recorded by the author from the entire reef (Table III). These 15 species are represented by 66 colonies, their growth-form and nature of polyps are as presented in Table II.

TABLE II

List of corals found in 40 stations with an analysis of their growth-form and nature of polyps.

S. No.	Name of species	Growth form	Nature of polyps	No. of colonies in 21 stations of the shoreward side	No. of colonies in 6 stations in reef crest	No. of colonies in 13 stations at the seaward side	Total no. of colonies in 40 stations sampled.
1.	*Pocillopora damicornis* ..	R	S	—	—	3	3
2.	*Acropora corymbosa* ..	R	S	1	—	4	5
3.	*A. haimei* ..	R	S	—	—	1	1
4.	*Montipora digitata* ..	R	S	—	—	1	1
5.	*M. divaricata* ..	R	S	—	—	1	1
6.	*M. foliosa* ..	R	S	—	—	1	1
7.	*Porites somaliensis* ..	M	S	2	—	—	2
8.	*P. lichen* ..	E	S	2	—	—	2
9.	*Favia pallida* ..	M	L	8	—	—	8
10.	*Favia valenciennesii* ..	EM	L	1	—	—	1
11.	*Favites virens* ..	EM	L	2	—	1	3
12.	*Goniastrea pectinata* ..	EM	L	1	—	—	1
13.	*Leptastrea purpurea* ..	EM	L	1	—	—	1
14.	*L. transversa* ..	EM	L	32	—	—	32
15.	*Cyphastrea microphthalma* ..	EM	L	4	—	—	4
	Total : encrusting and massive with colonies ..			53	—	1	54
	Total : Ramose colonies ..			1	—	10	11
	Total : Foliaceous colony			—	—	1	1
	Grand Total ..			54	—	12	66

R—Ramose; F—Foliaceous; EM—Encrusting and Massive; M—Massive; L—Large; S—Small.

TABLE III

Systematic list of corals from the reef at Mandapam (Palk Bay)

The classification followed is that of Wells, 1956

Order Scleractinia

Suborder Astrocoeniina

Family Pocilloporidae

Pocillopora damicornis (Linnaeus)

Family Acroporidae

Acropora corymbosa (Lamarck)
A. digitifera (Dana)
A. sp. cf. *exigua* (Dana)
A. formosa (Dana)
A. haimei (Milne Edwards and Haime)
A. humilis (Dana)
A. hyacinthus (Dana)
A. indica (Brook)
A. intermedia (Brook)
A. obscura (Brook)
A. polymorpha (Brook)
A. squamosa (Brook)
A thurstoni (Brook)
Acropora sp.
Montipora composita Crossland
M. digitata (Dana)
M. divaricata (Brüggemann)
M. edwardsi Bernard
M. explanata Brüggemann
M. exserta Quelch
M. foliosa (Pallas)
M. informis Bernard
M. spumosa (Lamarck)
M. verrilli Vaughan

Suborder Fungiina

Superfamily Agariciicae

Family Agariciidae

Pavona varians Verrill

Family Siderastreidae

Siderastrea radians (Pallas)
S. savignyana Milne Edwards and Haime
Coscinaraea monile (Forskål)

Superfamily Poriticae

Family Protidae

Goniopora duofaciata Thiele
G. nigra Pillai
G. stokesi Milne Edwards and Haime
Porites compressa (Dana)
P. lichen (Dana)
P. lutea Milne Edwards and Haime
P. solida (Forskål)
P. somaliensis Gravier

Suborder Faviina

Superfamily Faviicae

Family Faviidae

Subfamily Faviinae

Favia favus (Forskål)
F. pallida (Dana)
F. valenciennesii Milne Edwards and Haime
Favites abdiata (Ellis and Solander)
F. halicora (Ehrenberg)
F. virens (Dana)
Goniastrea pectinata (Ehrenberg)
G. retiformis (Lamarck)
Platygyra lamellina (Ehrenberg)
Hydnophora exesa (Pallas)
H. grandis Gardiner
H. microconos (Lamarck)

Subfamily Montastreinae

Leptastrea purpurea (Dana)
L. transversa Klunzinger
Cyphastrea chalcidicum (Forskål)
C. microphthalma (Lamarck)
C. seralia (Forskål)

Family Oculinidae

Galaxea clavus (Dana)
G. fascicularis (Linnaeus)

Family Merulinidae

Merulina ampliata (Ellis and Solander)

Family Mussidae

Symphyllia radians Milne Edwards and Haime
S. recta (Dana)

Family Pectinidae

Mycedium tubifex (Dana)

Suborder Caryophyllina

Superfamily Caryophyllidae

Family Caryophyllidae

Subfamily Thecocyathinae

Paracyathus profundus Duncan
Polycyathus verrilli Duncan

Suborder Dendrophyllina

Family Dendrophyllidae

Turbinaria peltata (Esper)

Discussion

The above sampling analysis as well as the general picture of the reef already presented, clearly indicates a marked difference in the major coral species of the seaward and shoreward sides of the reef at Mandapam (Palk Bay).

The zonation of corals in this reef is indistinct, as such no attempt is made to demarcate any zone based on the preponderance of any species. The poor representation of corals, on the reef as well as the widely spaced nature of the colonies indicate that the reef in consideration is not an actively growing one. The shoreward side of the reef possesses mostly encrusting and massive corals having comparatively large polyps, whereas the seaward side harbours small-polyped ramose forms along with large-polyped encrusting and massive species. Yonge (1940) has pointed out that generally more solidly built corals have a tendency to occur on the seaward side of the reef while branching and foliaceous forms in sheltered places. It is interesting to note that the more fragile forms such as *Acropora, Pocillopora* and *Montipora* shows a tendency to establish at the seaward side of the reefs at Palk Bay while the inner protected side harbours mostly the more solid species. As already pointed out elsewhere in this paper, Palk Bay remain practically calm except during the north-east monsoon. Even during the agitated period the mechanical force of wave action is not of such a magnitude as to influence the coral growth at the outer side of the reef. The colonisation of the delicately branching species on the outer side itself is an indication of the limited destruction caused to them by wave action. Temperature is a factor that might influence the horizontal zoning of corals on a reef (Mayer, 1918 ; Yonge, 1958). Surface temperature recorded at noon on random date in the lagoon and then on the outer and inner sides of the reef at Mandapam during July to October 1966 shows no marked variation at low tides, being uniform throughout the width of the reef. It varied from 29°C. on cloudy days to 31°C. on sunny days. It appears that temperature is a factor of little importance here.

The detrimental effect of sedimentation on coral growth is well known, though this is not a factor that makes the existence of corals impossible (Gardiner, 1936). According to Yonge (1940, p. 362) ' Falling sediment certainly represents one of the great dangers to which corals are exposed, but the animals are highly specialised for removing it from the coenosteum by means of the cilia with which this is covered.' The widely spaced corals on a reef is suggestive of an adverse environmental condition (Mayer, 1918). The widely spaced and poor growth of corals at Palk Bay indicate that the existing ecological factors are not very congenial for a luxuriant growth of corals. Mayer (1918) has pointed out a similar condition at Thursday Island where corals are widely separated due to serious interference of silt.

The shore as well as the lagoon bottom in the Palk Bay being sandy, a large quantity of silt is stirred up during the period of north-east monsoon, the wind at this period mostly crossing the shore in a north-east direction. The stirred up sand and silt get suspended and the lagoon waters look muddy during this period. The south-west monsoon is less harmful here. It is possible that the deleterious effect of falling silt due to the wave action is more felt on the lagoon and on shoreward side of the reef than at the seaward side. It has already been mentioned that the majority of corals occurring on the shoreward side of the reef are members of Faviina with large polyps. Marshall and Orr (1931) have shown that generally corals with large polyps are more efficient in removing the falling silt on them by means of ciliary action or by mere expansion of their polyps, than the small-polyped ones. The ramose species with small polyps depend for this purpose more on water movements

than on their own ciliary currents. Moreover, the slender branching forms are more effective against sediments than thick stemmed ones. It appears only reasonable to deduce from Table II that at Mandapam, the large-polyped corals which can combat the falling silt, somehow manage to thrive on the shoreward side of the reef, while the ramose small-polyped forms retreat to the outer side where water is deeper and more clear. Any visitor to this reef after the north-east monsoon can observe large numbers of freshly killed corals, especially on the inner side of the reef. The present author himself has noted this for three consecutive seasons. Further, the living colonies show a large number of buds at the onset of calm period indicating a state of active growth. It may be the factors causing this recurrent mortality that prevents a luxuriant growth at present here. However, the influence of sedimentation on coral growth, in general need not be over-emphasised.

Summary and Conclusion

The morphology of a shallow-water fringing reef in Palk Bay at the south-east coast of India is described.

The major reef-building and reef-dwelling fauna on the different parts of the reef is briefly considered. The results of a qualitative sampling survey across the reef to study the horizontal zoning of corals on this reef are given. The shoreward and seaward sides of the reef showed marked difference in their coral fauna, the former with mostly massive and encrusting species and the latter with ramose forms dominating. The factors that might influence the distribution of corals on this reef are discussed.

Zonation of corals in this reef is indistinct. The paucity of small-polyped corals at the shoreward side of the reef is explained as due to their inability to combat the deleterious effect of falling sediment. The effect of silt during north-east monsoon is of a marked degree here, which prevents a healthy growth of corals. The reef in consideration is one which is fast dying out where the destructive forces overpower the constructive forces.

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