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Systematic account of scleractinian corals

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Abstract

Coral reefs are ecosystems of high biological productivity. Owing to the rich biological diversity and the services they render, they have been centres of scientific research since many decades. In India, most of the earlier studies on coral diversity and distribution focused on major coral reef areas like the Lakshadweep, Andaman & Nicobar Islands, the Gulf of Mannar, Palk Bay and the Gulf of Kutch. Occurrence of coral reefs along the south-west coast of India was once considered meagre to non-existent; however, recent studies indicated that coral communities are present along this coast. Underwater surveys were carried out off Enayam to Kollam along the south-west coast of India during 2008-2012 and a total of 15 species of stony corals belonging to 6 genera and 5 families were recorded. A detailed systematic account of all the recorded species is given in this chapter.

Keywords: *Coral diversity, Scleractinian corals, Systematics*

Introduction

Planet earth is losing two thousand and seven hundred species approximately every year (Wilson, 2002) and we are now inching towards the prospect of total extinction. India is signatory to various international instruments focusing on biodiversity issues including the Convention on Biological Diversity (CBD), and is obliged to develop, protect, conserve and manage the country's marine habitat. However, very little has been done to protect our marine biodiversity heritage. Coral reefs are one of the most important links in the chain of pristine habitats that form the foundation for human existence. The value of coral reefs, for the biosphere as well as for the human race has been clearly established.

Coral reefs formed centres of scientific research since many decades as these ecosystems are areas of very high biodiversity, high biological productivity, sites of CO_2 sink, and source of huge deposits of $CaCO_3$ and are also protectors of the shoreline. Additionally, they provide us with many natural raw materials for pharmacological products and life-saving drugs. Another important aspect is the value of coral reefs as places of tourist interests. However, the country has made very little effort to utilize them in a judicious manner, except for overexploiting limestone and the resources they harbour. It is essential that we initiate steps towards protection of the flora and fauna inhabiting our coral reefs. A strong database on species available in these eosystems must be built up prior to formulation of actions to protect them. An account on these lines is, therefore, the need of the hour which is also a step towards protecting and conserving our habitat.

Research on various aspects of corals and coral reefs of the seas around India, including the oceanic and continental Islands, have a span of more than a century and studies on the taxonomy of Indian corals started as early as 1847 by Rink. Subsequently, Brook (1893) recognised eight species of *Acropora* from Rameswaram, out of which three were described as new. Thereafter, substantial contributions to the inventory of coral species were made by Bernard (1897), Alcock (1898), Gardiner (1904, 1905), Matthai (1924), Gravely (1927), Sewell (1935) and Pillai (1967). Contemporary studies on corals are those of Pillai (1986, 1996), Pillai and Jasmine (1989, 1995), Venkataraman *et al.* (2003) and Patterson *et al.* (2007) which list a total of 218 species under 60 genera and 15 families. More than hundred scientific reports on the reef corals and coral reefs of India and also on the reef associated living resources of our waters are available in various national as well as international publications.

The major reef formations in India are restricted to the Gulf of Mannar, the Palk Bay, the Gulf of Kutch, Andaman & Nicobar and the Lakshadweep Islands. There are patches of reefs in the intertidal areas of central west coast of India. Coral patches have been recorded in the intertidal regions of Ratnagiri, Malvan and Redi, south of Mumbai (Qasim and Wafar, 1979) and at the Gaveshani Bank (Netrani) 100 km off Mangalore (Nair and Qasim, 1978; Zacharia *et al*., 2006). Hermatypic corals along the shore are reported from Kollam in the Kerala coast to Enayam in Tamil Nadu (Pillai and Jasmine, 1995).

Only a few papers have been published on the coral reefs of India with emphasis on their conservation and management (Kumaraguru, 1991; Pillai, 1996; Venkataraman *et al.,* 2003). Except for the taxonomic contributions by Pillai, the taxonomic database has not widened to any recognizable extent. The ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), Kochi in 2005 initiated an in-house research

project entitled *'Studies on the Coral Biodiversity of the Gulf of Mannar Marine Biosphere Reserve (GOMBR)'* which envisaged the qualitative and quantitative appraisal of the corals and coral associated bioresources of the GOMBR and this study revealed a total of 80 species of hard corals with 4 new records to India and 4 species of *Acropora* new to science (Rani and Sandhya, 2007). Simultaneously, Patterson *et al.* (2004) as well as Raghuram and Venkataraman (2005) also registered new records to GOMBR. However, only very little attention has been paid so far to inventorise the deep water corals and therefore only 44 species are known till date from the Indian seas (Venkataraman *et al*., 2003).

Among the Scleractinia (Cnidaria: Anthozoa), the genus *Acropora* (family: Acroporidae) is the most speciose with 170 species the world over (Veron, 2000) of which 47 are recorded from the reefs of India. *Montipora* is the second largest coral genus in the family Acroporidae with 72 species recorded globally. In India, 20 species have been recorded of which nineteen are found in the east coast and thirteen in the west coast. Species of the family Acroporidae are also highly polymorphic and have always carried problems of identification. The taxonomy of the genus *Acropora* was revised by Wallace and Willis (1994), Wallace and Wolstenholme (1998), Wallace (1999) and the neotype for the type species *Acropora muricata* was created. This work established the criteria for synonymising species names representing variants within species that are recognisable as morphologically continuous in the field. Furthermore, Veron (2000) reinstated several species out of synonymy and later in 2003 added 16 new species to the biodiversity map of the world. Although a review of the genus *Anacropora* with description of a new species was published by Pillai (1973), the need for a comprehensive taxonomic account on the families Acroporidae and Pocilloporidae, with the aid of photomicrographs of specimens recorded from India, was felt in order to facilitate proper identification of species. Therefore, as a part of in-house project of ICAR-CMFRI, the present investigation examined collections made during field surveys conducted from 2008 to 2012, specifically to look at the species composition of hard corals in the patchy reef areas of the south-west coast of India. The occurrence of coral reefs along the south-west coast was once considered meagre to non-existent, but recent observations have shown that there are many patchy reefs and coral communities in the area. The stony corals of the south-west coast have not so far been studied in detail. Coral patches occur in intertidal locations and submerged banks on the continental shelf along the region. Their diversity in these sites is generally restricted to a few genera. The likelihood of establishment of coral colonies is more when firm and immobile substrata are available which proved true off Vizhinjam where almost all the colonies collected were seen attached to breakwater boulders, with the exception of members of the genus *Montipora* that were found attached to the sea bottom (Jasmine *et al.*, 2009). An earlier study made by Pillai and Jasmine (1995) revealed a patchy reef with good growth of pocilloporid corals at Enayam and

also a few colonies from the Vizhinjam Bay attached to boulders. During the present study, underwater surveys were conducted in selected areas along the south-west coast of India to record the diversity of scleractinian corals and to provide a complete description of the available species.

Veron (2000, 2003) reported 18 families, 111 genera and 793 species of Scleractinia from the world oceans while Wallace (1999) described 114 species of the genus *Acropora*. Of the 793 or so reef corals that are known globally, 600 are found in the region bound by Indonesia, Malaysia, the Phillipines and southern Japan.

Coral diversity and distribution in India

The scleractinian corals of India have a richer diversity when compared to the other reefs of the tropical world. Pillai (1996), the pioneer in Indian coral research, recorded a total of 199 species distributed among 71 genera (Table 1).

Table 1. List of genera and species of corals of India (Pillai, 1996)

Area	No. of Genera	No. of Species	Source
Lakshadweep	27	105	Pillai and Jasmine (1989)
Gulf of Kutch	24	37	Pillai and Patel (1988)
South-east coast of India	37	94	Pillai (1986)
Andaman and Nicobar Islands	59	135	Pillai (1983)
West coast of Kerala and Tamil Nadu	17	29	Pillai and Jasmine (1995)
Total	71	199	

The revisions of families and genera by Wallace (1999) and Veron (2000, 2003) have synonymised some of the earlier reported species in the country. Venkataraman *et al.* (2003), conducted extensive studies throughout India and reported a total of 208 species under 15 families and 60 genera (Table 2). Subsequently, Rani and Sandhya (2007) reported four new records of stony corals to India and four species of *Acropora* new to science from the Gulf of Mannar Biosphere Reserve (GOMBR). Furthermore, Raghuraman *et al*. (2012) reported on the hard coral diversity in Andaman and Nicobar Islands in comparison with other Indian reefs (Table 3).

Table 2. Distribution of total number of families, genera and species of Scleractinian corals in the four major coral reefs of India (Venkataraman *et al*., 2003)

	Gulf of Kutch	Lakshadweep	Palk Bay and Gulf of Mannar	Andaman and Nicobar Islands	Total
Families	8	12	13	15	15
Genera	20	34	27	57	60
Species	36	91	82	177	208

Table 3. Comparison of the scleractinian corals in the major reefs of India (Raghuraman *et al*., 2012)

	Gulf of Kutch	Lakshadweep	Palk Bay and Gulf of Mannar	Andaman and Nicobar Islands	Total
Families	10	13	14	19	19
Genera	27	37	40	86	89
Species	49	104	117	424	478

Materials and methods

The present account on hard coral diversity is mainly based on collections made during field surveys from the patchy reef areas from Enayam to Kollam along the south-west coast of India. Underwater surveys were conducted by scuba diving in four different study locations *viz*., Enayam, Vizhinjam, Thirumullavaram and Thangassery. Life-form line intercept transect (LIT) method was adopted for the surveys (English *et al*., 1994). Conspicuous benthic life forms underlying the transect lines were monitored but since cover by organisms other than hard corals *i.e*., macro-algae, soft corals, coralline algae and sponges constituted less than 1% of total cover, reference is made only to scleractinian corals (hard corals) in this account. The transects, placed randomly in the patchy reef areas, ran parallel to the shore and to each other at fixed intervals of 2 m depth, with three replicates at each depth. A total of ten 20 m transects with three replicates each were placed and all hard corals intercepted by the transect were recorded, their maximal projected lengths 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 Pillai (1967a-c, 1986); Wallace (1999), Veron (1986, 2000, 2003) and Venkataraman *et al*. (2003).

The field work was carried out during 2008 to 2012 totalling 300 dives. Coral colonies were photographed in the field using an underwater camera and a portion of each colony was collected during dives made at the study sites. A set of specimens was deposited in the Marine Biodiversity Museum (MBM), Vizhinjam, India, and duplicates of these specimens were deposited in the Designated National Repository at ICAR-CMFRI, Kochi, India. The specimens were registered in the database of MBM and compared with specimens from the reference collections (Pillai, 1967, 1983,1986). Specimens were examined by light microscopy using a stereozoom microscope with eyepiece graticule and lit by fiber-optic lighting. Skeletal dimensions are based on those given in Pillai (1967, 1986), Wallace (1999) and Veron and Wallace (1984), modified to incorporate any variations seen in the Indian specimens.

Systematics of Species

PHYLUM: Cnidaria Hatschek

Class	:	Anthozoa Ehrenberg
Subclass	:	Zoantharia Blainville
Order	:	Scleractinia Bourne
Suborder	:	Astrocoeniina Vaughan & Wells

Family : Acroporidae Verrill

All growth forms are colonial and hermatypic. Only three genera *viz*., *Acropora*, *Montipora* and *Astreopora* are represented along the Indian coast, while only two genera namely *Acropora* and *Montipora* were recorded in the study area. A prominent cylindrical central axial corallite present in *Acropora* with radial corallites both immersed and projecting. In *Montipora,* axial corallite absent, radial corallite non-protuberant and generally in level with the surface coenenchyme. Both genera possess poorly developed septa in two cycles.

Genus *Acropora* Oken

Type species *Millepora muricata* Linnaeus

Genus name and type species officially validated (Boschma, 1961)

Generic characters: Colonial, ramose, rarely massive or encrusting, branching with an axial or leading corallite (or corallites) larger than the more numerous radial corallites, both immersed and projecting; united by coenosteum, flaky, reticulate, spinose or pseudocostate or costate. Columella and dissepiments absent; septa in two cycles.

Acropora efflorescens (Dana)

Madrepora efflorescens Dana 1846, p. 441; pl. 33, fig. 6.; Brook, 1893, p.35 (synonymy).

Materials examined: A portion of the colony from Enayam (Fig. 1).

Diagnostic characters: Colonies are extensive flat plates which are solid except towards the perimeter which usually consists of highly fused irregular branches. They may exceed 2 m across. Axial and radial corallites are not differentiated; all have sharp rims. Corallites at plate margins are mostly horizontal, those on upper plate surfaces are short, compact and upward facing. Underside with verruciform, immersed or rarely tubular corallites. Hence there is little or no development of corallites on the undersurfaces of plates. The branchlets on the upper

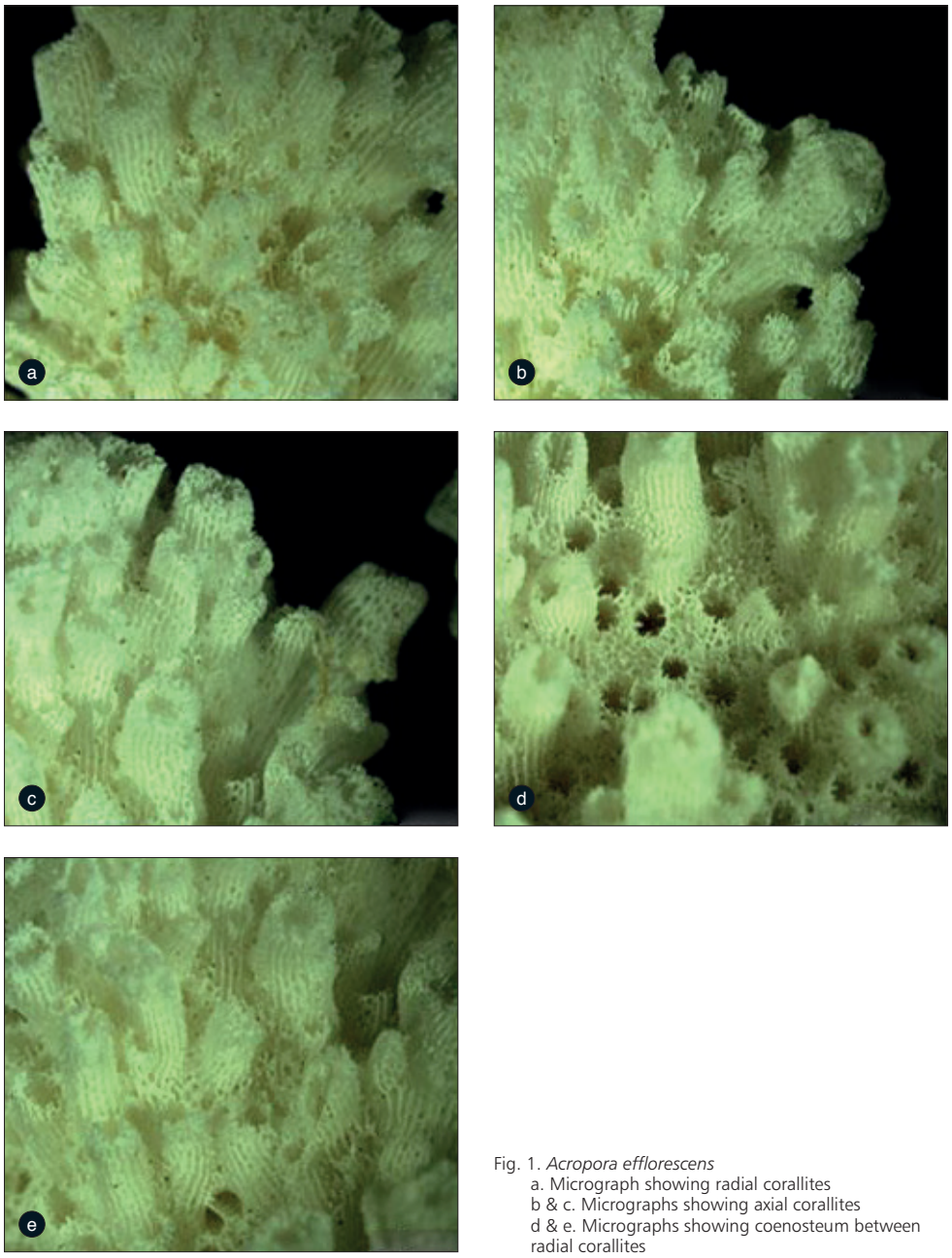

Fig. 1. *Acropora efflorescens*
a. Micrograph showing radial corallites
b & c. Micrographs showing axial corallites
d & e. Micrographs showing coenosteum between radial corallites

side 8 to 10 mm long and 3 to 4 mm thick. Axial corallites 1 to 1.5 mm in diameter, 2 to 3 mm long. Radial corallites labellate, ascending, 2 to 3 mm long and 1 to 1.5 mm broad. There are 12 septa in the axial corallites. Radials have poorly developed septa, hardly recognisable in many corallites.

The distinguishing features of this species are the flabellate corallum with small upper branchlets (better called *prolilerous* corallites) and prominent labellate ascending radial corallites.

Colour: Uniform dark grey.
Locality: Recorded only from Enayam.
Distribution:
India: Only one colony observed and collected earlier from Minicoy and Enayam (present report).
Elsewhere: Maldives, Singapore, Sri Lanka.

Remarks: Uncertain taxonomic status since Wallace (1999) considers this species a junior synonym of *Acropora cytherea* while it is considered valid by Veron (2000). This recent taxonomic uncertainty will affect data on distribution and abundance and, therefore, this species is listed as Data Deficient (IUCN, 2017). Distribution records and taxonomy of this species need to be verified by further studies. The present study clearly indicates that *A. efflorecens* is a valid species as in the radial corallites, 6 primary septa are distinct whereas in *A. cytherea* primary septa are either absent or just visible in some. The species appears to be rare in Minicoy from where only one colony was recorded earlier.

Genus *Montipora* Quoy and Gaimard

Type species: *Montipora verrucosa* Quoy and Gaimard

Generic characters: Colonial, hermatypic, encrusting, massive, ramose or foliaceous. Axial corallite not differentiated, unlike in *Acropora*. Corallites usually level, about 1 mm. Septa fundamentally in two cycles. Surface coenenchyme smooth, foeveolate, papillate or tuberculate. Columella absent.

Montipora aequituberculata Bernard

Montipora aequituberculata Bernard, 1897, p.130-131.
Montipora composite Crossland, 1952, p.195, pl.28, figs.1,5; Veron, 2000, p.76-77, pl. 1-8; Venkataraman *et al*. (2003), p.39-40.

Materials examined: A portion of the colony from Vizhinjam and Enayam (Fig. 2).

Diagnostic characters: Corallum encrusting with large horizontal fronds arranged one above the other or composed of thin unifacial lamimae often arranged in oblique overlapping whorls and sometimes forming tubes; edges of fronds 2-3mm thick but upto 10 mm at the central portion. Corallites with calices 0.7-1 mm diameter; immersed or exsert and surrounded by thecal tubercles, frequently fused into short ridges

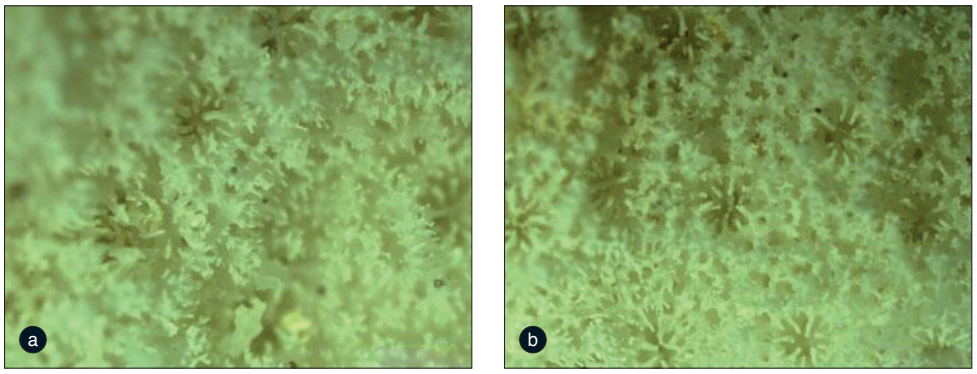

Fig. 2. *Montipora aequituberculata*
a. Micrograph of immersed and exsert corallites
b. Micrograph showing coenosteum tubercles thick and fused

near margins and form hoods over the corallites; tubercles slender and tongue-shaped, 1-1.5 mm or slightly more in height, groups of them found on warty prominences at intervals all over corallum; six to eight tubercles surround a calyx; primary septa (6) well developed, present upto 3/4R, only the directives or all the six meet deep down in the fossa over a rudimentary columella; secondary septa (6) small, visible upto 1/4R. Coenosteum reticulate; tubercles thick and fused.

Colour: Brown, cream.
Locality: Enayam.
Distribution:
India: Gulf of Mannar, Palk Bay, Lakshadweep and Andaman & Nicobar Islands.
Elsewhere: Indo-Pacific from East Africa to Coral Sea.
Remarks: Similar to *M. peltiformis*, especially the corallites and to *M. foliosa* in growth form. This species is represented in the Indian postal stamp.

Montipora verrilli Vaughan

Montipora verrilli Vaughan, 1907, p.168, pl.63, figs. 2-2b; pl.64, figs.1, 1a; Pillai, 1967c, p.420; Pillai, 1986, p.142, pl.11, fig.3 (synonymy); Veron, 2000, p.107, pl. 3,5.

Materials examined: A portion of the colony from Vizhinjam (Fig. 3).

Diagnostic characters: Corallum thin and encrusting with explanate base, maximum thickness upto 2 cm, upper surface gives rise to irregularly anastomosing branches upto 15 cm long and 3 cm thick, but the majority slender and short; branches enclose a worm tube; interstitial

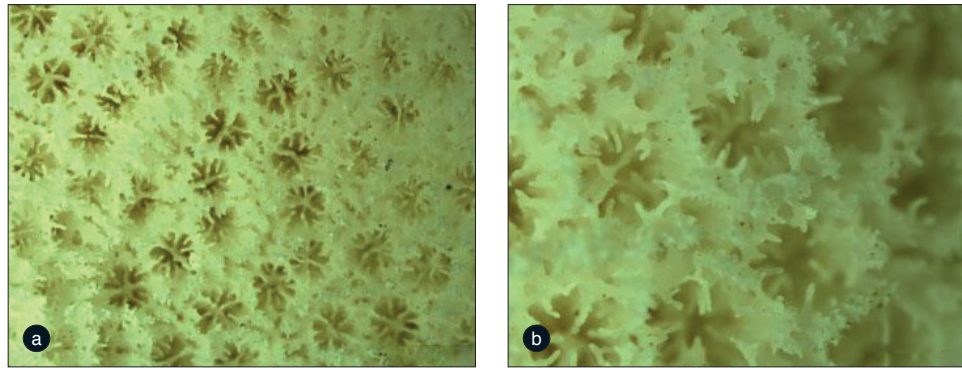

Fig. 3. *Montipora verrilli*
a. Micrograph of corallite details
b. Micrograph showing coenosteum between corallites

tubercles smaller. Corallites having calices immersed, approximately 1 mm (0.75 mm) diameter and close together, 2 mm apart and mostly submerged in the coenosteum; corallite tubercles slender, evenly spaced with 6-8 papillae (1 to 2 mm height) around a calyx; primary septa in two cycles and primaries often almost meeting at the centre of the calyx, secondary cycle smaller and generally incomplete, tubercles around the wall either remain free or their basal parts fuse together giving an elevated look to the calyx. Coenosteum surface is covered by smaller and distinct tubercles, which gives a coarse appearance.

Colour: Brown.
Locality: Enayam and Vizhinjam.
Distribution:
India: Gulf of Mannar.
Elsewhere: Marshall Islands, Fanning Island, Samoa and Hawaii.
Remarks: Similar to *M. hispida* in growth form.

Montipora hispida (Dana)

Manopora hispida Dana, 1846, p.496, pl. 46, fig.5.
Montipora hispida Bernard, 1897, p.134, pl. 26, pl. 34, fig.4; Pillai and Scheer, 1974, p.457; Pillai, 1986, p.143 (synonymy); Veron, 2000, p.148-149, pl. 1-6; Venkataraman *et al*., 2003, p.45.

Materials examined: A portion of the colony collected from Enayam and Vizhinjam (Fig. 4).

Diagnostic characters: Corallum encrusting with digitiform branches, submassive; fronds with no uniformity in their thickness in different colonies. Corallites with calices both immersed and exsert, the latter having prominent thecal tubercles; septa in two cycles, primary septa fuse each other over a rudimentary columella like structure; tubercles 1

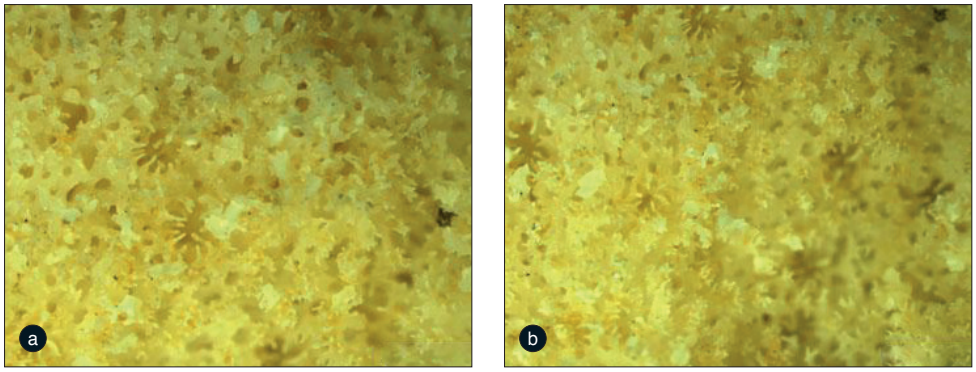

Fig. 4. *Montipora hispida*
a & b. Micrographs showing corallites and coenosteum

or 2 mm high, 6 to 8 tubercles placed around a calyx; primary septa (6) present upto 3/4R, directives large, secondary septa incomplete to 1/4R. Coenosteum having coarse reticulum with shorter tubercles.

Colour: Dull green or brown.
Locality: Enayam (N 9˚11'; E 78˚56')
Distribution:
India: Gulf of Mannar, Palk Bay, Lakshadweep, Andaman & Nicobar Islands.
Elsewhere: Tropical Pacific, east of Hawaii and also Indian Ocean, West Sri Lanka.
Remarks: Similar to *M. verrilli* and *M. informis.*

Montipora turgescens Bernard

Montipora turgescens Bernard, 1897, p.53, pl. 6, fig. 2, pl. 32, fig. 11; Pillai, 1969, p.418 (synonymy); Scheer and Pillai, 1974, p.14 (synonymy)

Materials examined: A portion of the colony from Enayam (Fig. 5).

Diagnostic characters: Corallum encrusting, 20 cm in greater spread with a maximum thickness of 10 mm. Edges very thin, followed by an epitheca. Calices 0.5 to 0.6 mm in diameter with a solid thecal wall. Septa in two cycles, first cycle larger than the second. Surface swells up around the calices forming ramparts. Under the lens, it reveals a close-net reticulum with minute echinulations.

Locality: Enayam.
Distribution:
India: Gulf of Mannar.
Elsewhere: Central Indian Ocean Islands, Great Barrier Reef, Solomon Islands, Philippines, Marshall Islands

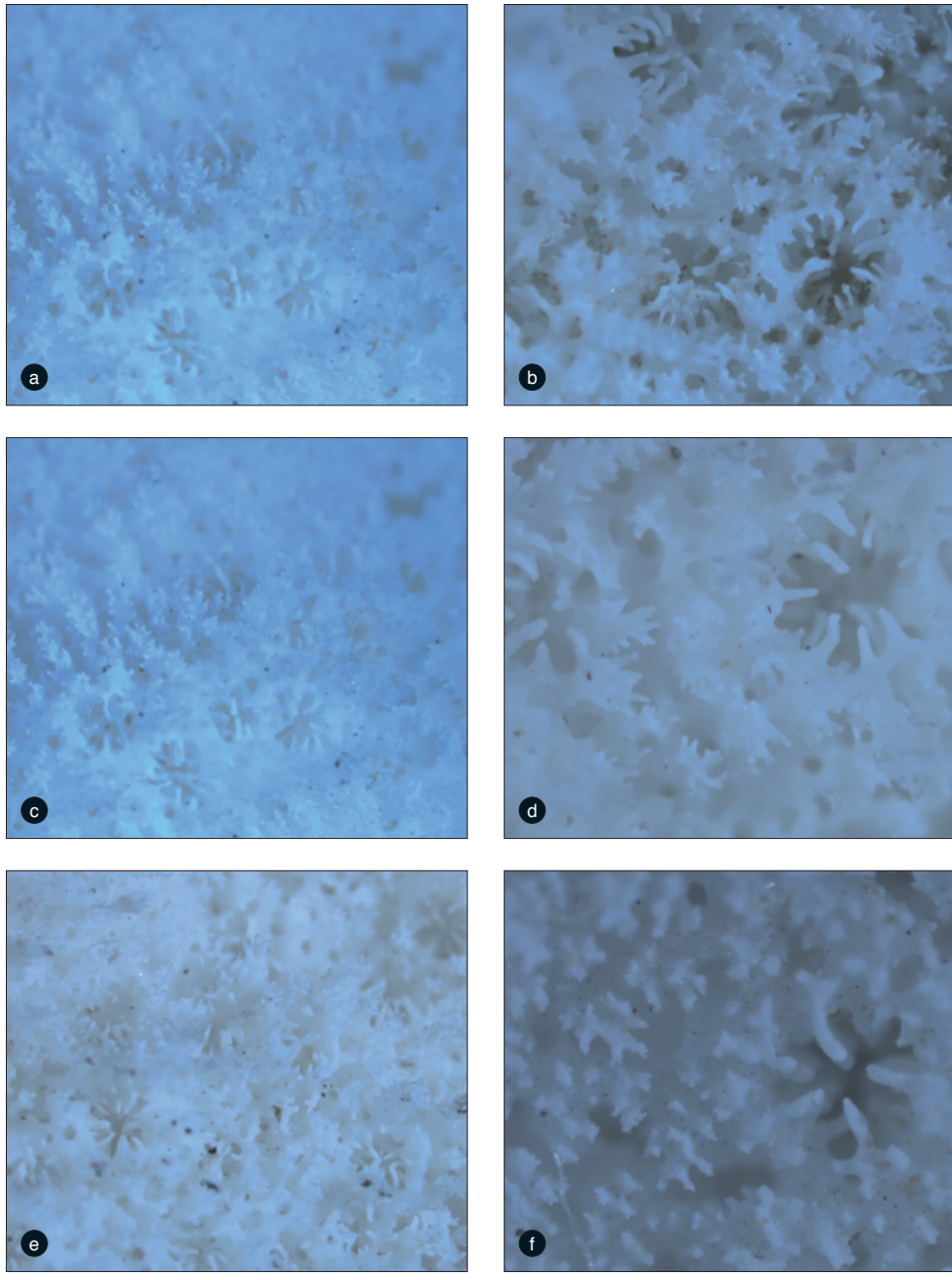

Fig. 5. *Montipora turgescens*
a & b. Micrographs showing corallites
c to f. Micrographs showing coenosteum between corallites

Montipora millepora Crossland

Montipora subtilis Bernard,1897, p.21, pl. 31, fig. 2; Wells, 1954, p.433, pl. 142, figs. 3, 4.

Montipora millepora Crossland, 1952; Veron,1986, p.99, figs. 1-2; Veron, 2000, p.125, figs. 4-5.

Materials examined: A portion of the colony collected from Vizhinjam (Fig. 6).

Diagnostic characters: Colonies are massive or encrusting. Corallites very small and immersed. Coenosteum has tuberculae which seldom contain corallites.

Colour: Dark greenish brown.
Locality: Only in Vizhinjam Bay.

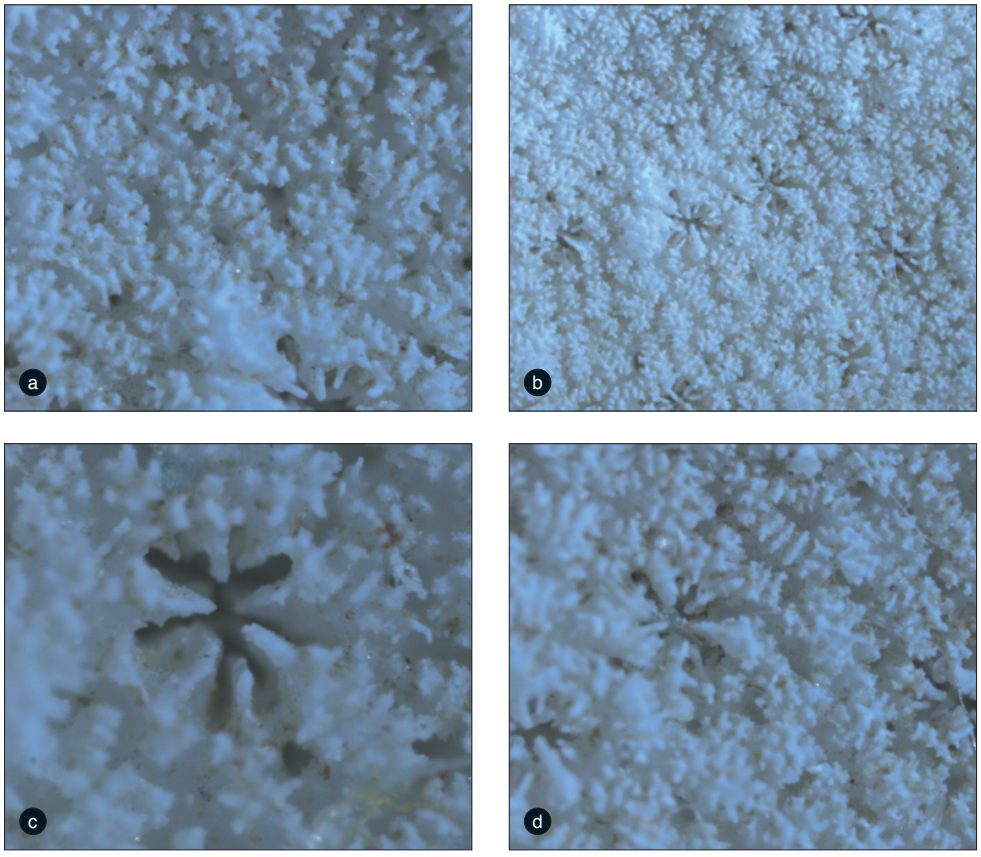

Fig. 6. *Montipora millepora*
a to d. Micrographs showing very small immersed corallites & corallites with distinct septa

Distribution:

India: First record to India

Elsewhere: Records from the eastern central Pacific are doubtful.

Remarks: Similar to *Montipora floweri*, which has evenly distributed corallites.

Family: POCILLOPORIDAE Gray

Characters: Colonial and mostly hermatypic. Colonies are submassive, ramose or arborescent. Corallites are immersed to conical, small, have well developed columellae and neatly arranged septa of two cycles or less, some usually fused with the columellae. The coenosteum is covered with spinules.

Genus *Pocillopora* Lamarck

Type Species: *Pocillopora acuta* Lamarck

Generic characters: Usually ramose with broad branches, rarely some species are submassive. Coenosteum non-porous. Corallites 1 to 2 mm in diameter; circular or polygonal. Septa and columella poorly developed as a rule. Surface of the coenenchyme rises into small (2 to 7 mm) calicle bearing mouths (verrucae). This genus is known to represent along the Indian coast by five species, to be separated as follows:

1. Ramose, tufted, basal parts of branchlets. Verrucae irregular 2 to 5 mm high and thick. Calices more or less 1 mm in diameter, circular at the basal parts; septa and columella sometimes moderately developed… *P. damicornis*.

2. Branches broad, compressed, expanding towards the top, 3 to 5 cm broad at the tip. Verrucae large, irregularly shaped upto 7 mm high and thick, corallites 1 to 1.5 mm long. Septa and columella not generally visible... *P. verrucosa*.

3. Branches stout, thick, expanding. Verrucae more uniform in size, top of verrucae more or less rounded (blunt). Calices more or less 1 mm in diameter with two cycles of well developed septa and a columella... *P. eydouxi.*

4. Branches have a sprawling form, uniformly dividing branches, verrucae distinct, rounded, medium-sized... *P. meandrina.*

5. Branches irregular, oar shaped, coenosteum heavily granulated... *P. woodjonesi.*

Pocillopora damicornis (Linnaeus)

Pocillopora damicornis Linnaeus, 1758, p.971 (Type locality, Asiatic Ocean)
Pocillopora damicornis Hoffmeister, 1925, p. 15, pl. 1, fig. 1 (synonymy); Yabe, Gugiyama and Eguchi, 1936, p.12, pl.4, figs. 3-5, pl. 5, figs. 3,4, pl. 7, figs. 2,5; Pillai and Scheer, 1976, 21 (synonymy); Veron and Pichon, 1976, p.41, figs. 52-68.

Materials examined: A portion of the colony from Enayam and Vizhinjam (Fig.7).

Diagnostic characters: Corallum caespitose, ramose, hemispherical in outline. Colonies attain a size of upto 20 cm in height and diameter. Branches cylindrical at the base, expand towards the top (1 to 1.5 cm broad at the top) with large verrucae. Verrucae fewer at the lower parts of the branches. Calices circular at the basal parts of the colony, polygonal at the upper parts; more or less 1 mm in diameter, shallow. As a rule, septa and columella are absent but traces of two cycles of septa present in some old calices. Surface of the coral echinulate, the spines being 0.1 to 0.2 mm apart.

Colour: Pinkish brown.
Locality: This species is found both in Vizhinjam and Enayam waters.

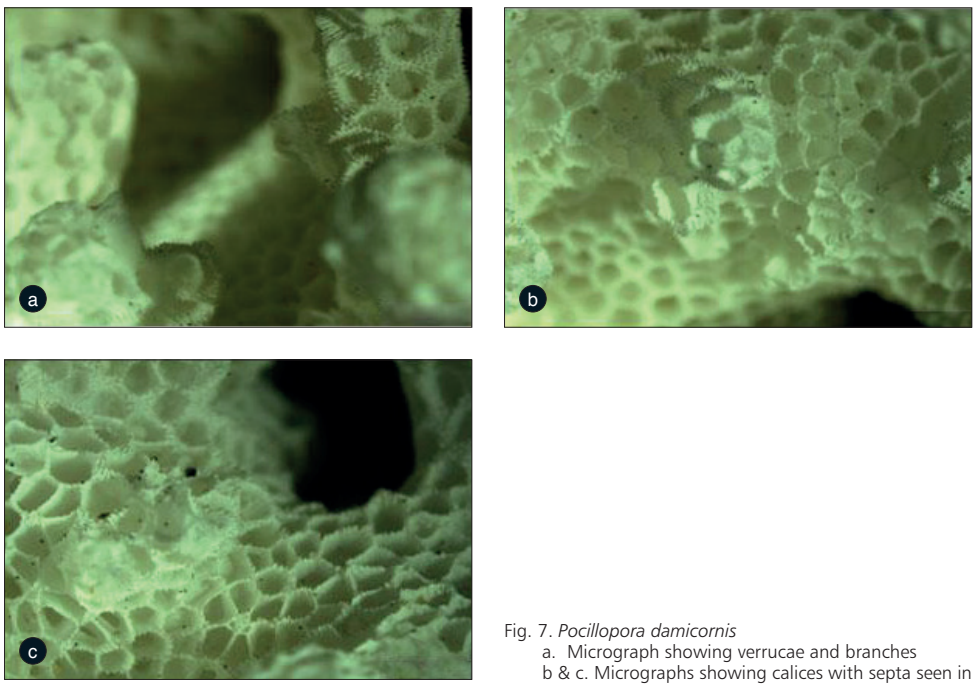

Fig. 7. *Pocillopora damicornis*
a. Micrograph showing verrucae and branches
b & c. Micrographs showing calices with septa seen in a few

Distribution:

India: One of the most widely distributed species in all major reefs of India.

Elsewhere: Widely distributed species from Red Sea to Panama in the Indo-Pacific.

Remarks: In addition to the species listed, *P. suffruticosa* Gardiner, 1898 (Type in Zoology Museum of Cambridge Univ.) and *P. paucistella* Quelch, 1886 (Type in British Museum Nat. Hist. London 1886, 12.9.29 from Ternate) are also synonyms of this species.

Pocillopora verrucosa (Ellis and Solander)

Pocillopora favosa Klunzinger, 1879, pt. 2, p. 68, pl. 7, fig. 2, pl. 8, fig. 10
Pocillopora verrucosa Ellis and Solander, 1786.
Pocillopora verrucosa Dana, 1846, p.529, pl. 50, figs. 3, 3a (synonymy); Vaughan, 1918, p.77, pl. 23, figs. 1,2,2a; Wells, 1954, p.413, pl. 98, figs. 5, 6; Pillai and Scheer, 1976, p.23; Veron and Pichon, 1976, p.48, figs. 69-79.

Materials examined: A portion of the colony collected from Enayam and Vizhinjam (Fig. 8).

Diagnostic characters: Corallum bushy, branches compressed, expanding towards the top, thickness 1 to 2 cm, width 2 to 5 cm, growing edges with or without verrucae. Verrucae large, 3 to 7 mm long, ascending, distance between adjacent ones 3 to 5 mm. Calices over the verrucae and top of branches polygonal, 1 to 1.25 mm long, rather deep and are circular towards the older parts of the branches. Septa and columella as a rule not seen, however, the primary cycle of septa may be visible in older calices.

Colour: Yellowish green/brownish pink.
Localities: Common in Enayam and Vizhinjam.
Distribution:

India: Gulf of Mannar, Palk Bay, Lakshadweep and Andaman and Nicobar Islands.

Elsewhere: A wide spread Indo-Pacific species from Red sea to Cook Islands and Tahiti.

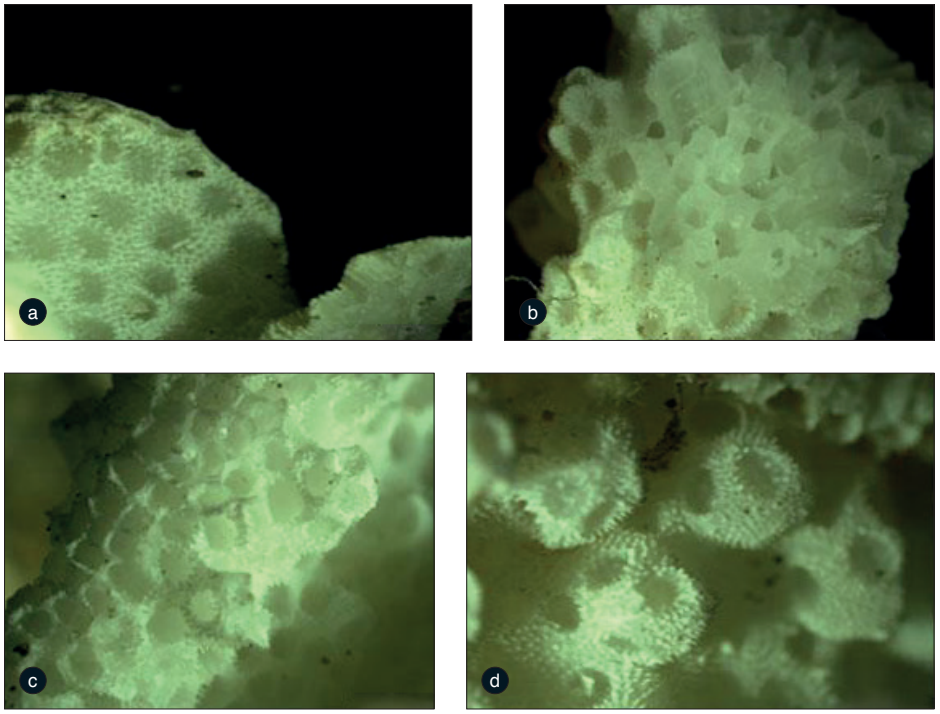

Fig. 8. *Pocillopora verrucosa*
a & d. Micrographs showing verrucae and calices
b & c. Micrographs showing calices and septa not visible

Pocillopora woodjonesi Vaughan

Pocillopora woodjonesi Vaughan,1918, pl. 22, fig. 3, pl. 24, fig. 3.

Materials examined: A portion of the colony collected from Enayam and Vizhinjam (Fig. 9).

Diagnostic characters: Corallum somewhat similar in growth form to *P. eydouxi*, but the branches tend to be more dwarfed and to become fan-shaped instead of elongate. Branches are short, more or less contorted plates. Widest branch rapidly narrows towards its base; verrucae well developed or obsolete on the sides of the branches, usual diameter at base about 3mm; distance apart about 2.5 mm; one large verruca has basal diameter of 4 to 5 mm, height 3.5 mm; in certain places they may be fused at their bases so as to form a longitudinal series. Calices on branches separated by 0.5 to 7 mm diameter. On verruca walls: 0.25 to 0.5 mm; the diameter of calices as much as 1 mm. Calicular fossa rather deep. Septa very distinct in the calices on the sides of the branches, but situated rather deep down; number 12, subequal in size, do not reach the centre. Columella a minute style. Coenenchyme thin; granulations radially compressed, often forming costal striations. The coenenchyme striations are different from that of *P. eydouxi*.

Colour: Brown.
Locality: Found in Enayam and Vizhinjam.
Distribution:
India: First record to India
Elsewhere: Widely distributed throughout the Indo-Pacific, from Bay of Bengal to French Polynesia.
Remarks: This species is similar to *Pocillopora eydouxi*, but the latter

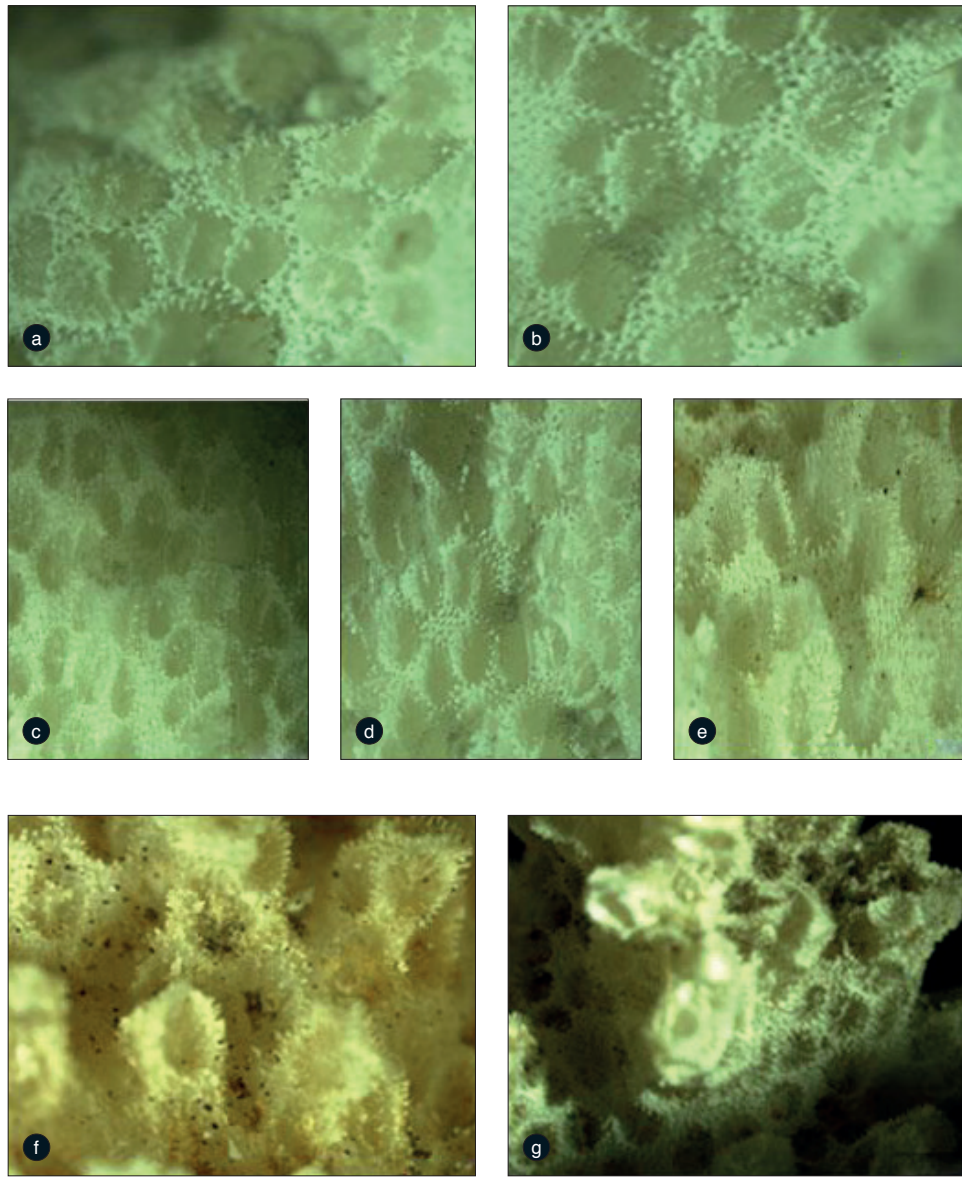

Fig. 9. *Pocillopora woodjonesi*
a to e. Micrographs where calices are distinct and deep, coenosteum heavily granulated
f & g. Micrographs showing well developed verrucae.

usually has more elongated and spread branches. However, it is difficult to distinguish the two unless they co-occur.

Pocillopora meandrina Dana

Pocillopora verrucosa Dana, 1846, p. 520, pl. 1, figs. 3, 3a.
Pocillopora meandrina Dana, 1846, p. 533, pl. 1, figs. 6, 6a, 6b.
Pocillopora meandrina Studen, 1901, p. 400.

Material examined: A portion of the colony collected from Enayam and Vizhinjam (Fig. 10).

Diagnostic characters: Caespitose, neatly hemispherical; branches lamellar, nearly simple, 1/3 to ½ an inch thick, 1 to 3 inches broad, neatly verrucose, summits naked. Corallum with the verrucae a little oblong, angular, sometimes proliferous; columella indistinct. The verrucae are very neatly even and cover the sides of the branches nearly or quite to their base.

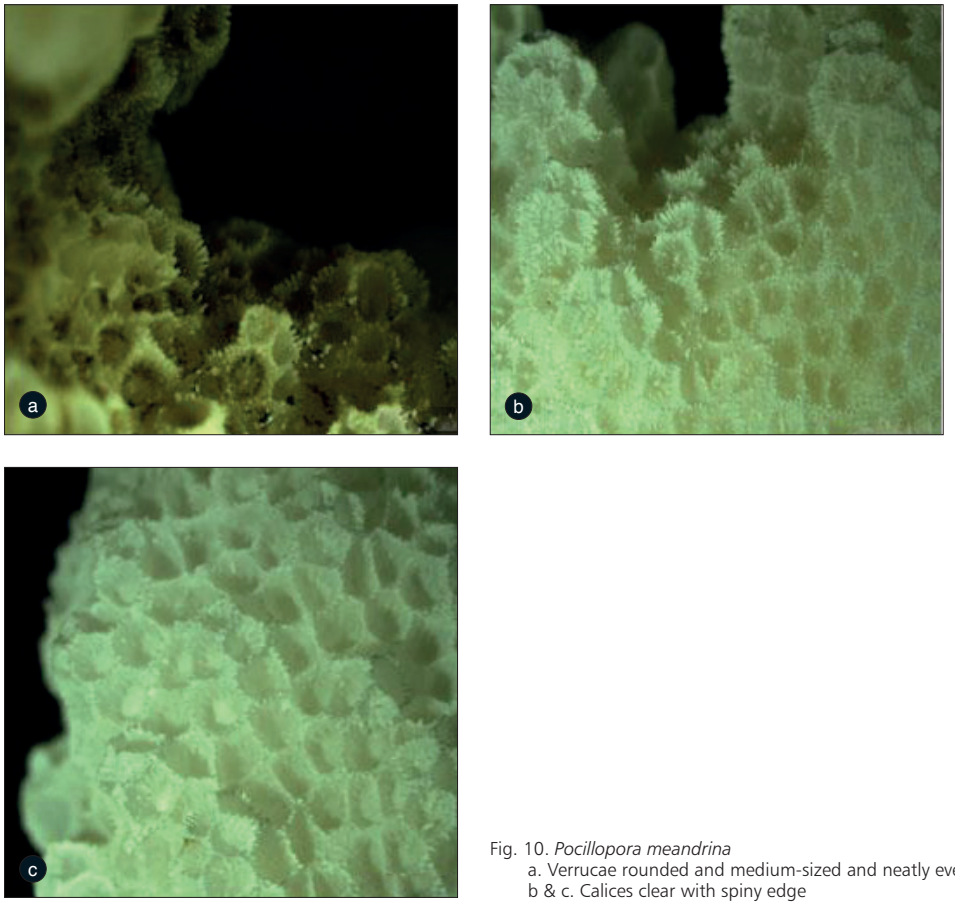

Fig. 10. *Pocillopora meandrina*
a. Verrucae rounded and medium-sized and neatly even
b & c. Calices clear with spiny edge

Colour: Light brown.
Locality: Found in Enayam and Vizhinjam.
Distribution:
India: Lakshadweep, Andaman and Nicobar Islands.
Elsewhere: *P. meandrina* occurs in the Indian and Pacific oceans and is found across a range of habitats that include exposed reefs, protected lagoons and lower reef slopes.

Pocillopora eydouxi Milne Edwards and Haime

Pocillopora dane Vaughan, 1918, p. 77, pl. 22, figs. 1, 1a, 2; Pillai, 1972, p. 198.

Pocillopora hemprichi Klunzinger, 1879, pt. 2, p. 69, pl. 7, fig. 1, pl. 8. fig. 13.

Pocillopora eydouxi Milne Edwards and Haime,1860

Pocillopora eydouxi Milne Edwards, 1860, p. 306, pl. F4, figs. 1, 1a; Vaughan, 1918, p.79, pl. 24, figs. 1, 2, 2a; Yabe, Sugiyama and Eguchi, 1936, p.13, pl. 12, fig. 5, pl. 6, figs. 4,5, pl. 7, figs. 4-6; Umbgrove, 1939, p.22; Umbgrove, 1940, p.273, pl. 21, figs. 3, 5, 8; Scheer and Pillai, 1974, p.15, pl. 1, fig. 5, pl. 2, figs. 1,2 (synonymy); Pillai and Scheer, 1976, p.23; Veron and Pichon, 1976, p.52, figs. 80-85.

Materials examined: A portion of the colony collected from Enayam and Vizhinjam (Fig.11).

Diagnostic characters: Corallum composed of stout palmate branches with verrucae all over. Verrucae more or less uniform in size, 3 to 5 mm high and thick, tops of verrucae rounded. Calices about 1 mm in diameter; circular, moderately deep with two cycles of prominent septa and a styliform columella. Surface coenenchyme spiny. The present species differs from *P. verrucosa* in having thicker branches, more uniform sized verrucae and in the presence of well developed septa and columella.

Colour: Light brown.
Locality: Found in Enayam and Vizhinjam.
Distribution:
India: Gulf of Mannar, Lakshadweep, Andaman and Nicobar Islands
Elsewhere: Aldabra, Maldives, Sri Lanka (Ridley, 1883), Malacca, Cocos-Keeling Islands, Great Barrier Reef, East Indies, Solomon Islands, Marshall Islands, Loyalty Islands, Philippines (Faustino, 1927), Funafuti, Rotuma, Samoa, Fiji, Hawaii.

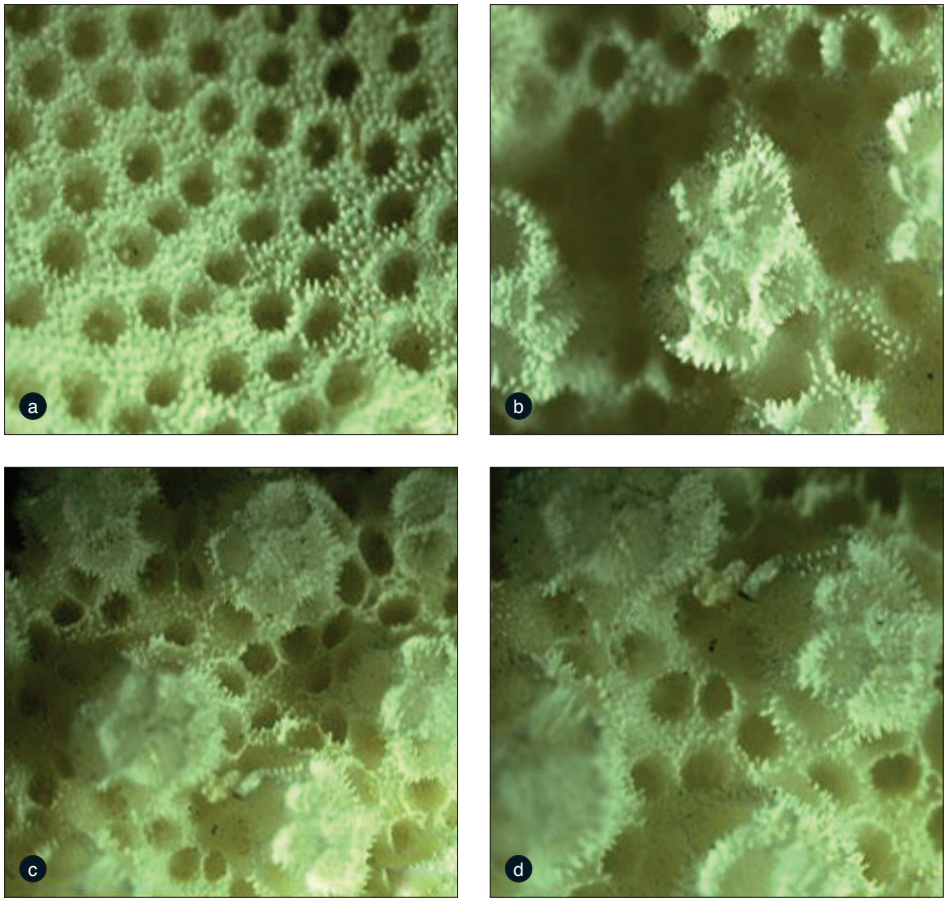

Fig. 11. *Pocillopora eydouxi*
a. Calices clear and coenosteum spiny
b, c & d. Micrographs showing verrucae of uniform size and well developed septa

Family: PORITIDAE Gray

Characters: Colonial, hermatypic, mostly extant. Colonies usually massive, laminar or ramose. Corallites have a wide size range but are usually compacted with little or no coenosteum. Walls and septa are porous.

Genus *Porites* Link

Type species: *Porites polymorphus* Link

Generic characters: Colonial, encrusting, massive or ramose. Corallites polygonal, 1 to 2 mm in diameter, intercorallite wall thin. Septa 12 arranged as a dorsal directive, four pairs of laterals and a ventral triplet. Pali and synapticulae present. Columella trabecular or styliform.

Porites lutea Milne Edwards and Haime

Porites lutea Vaughan, 1918. p. 198, pl. 88, figs. 1-1b (synonymy); Scheer and Pillai, 1974, p.43 (synonymy).

Materials examined: A portion of the colony collected from Enayam and Vizhinjam (Fig. 12).

Diagnostic characters: Massive surface with undulations. Calices and corallites polygonal, 1 to 1.25 mm in length. Wall thin, zig-zag or straight. Mural denticles roughly double the number of septa. Septa thin,

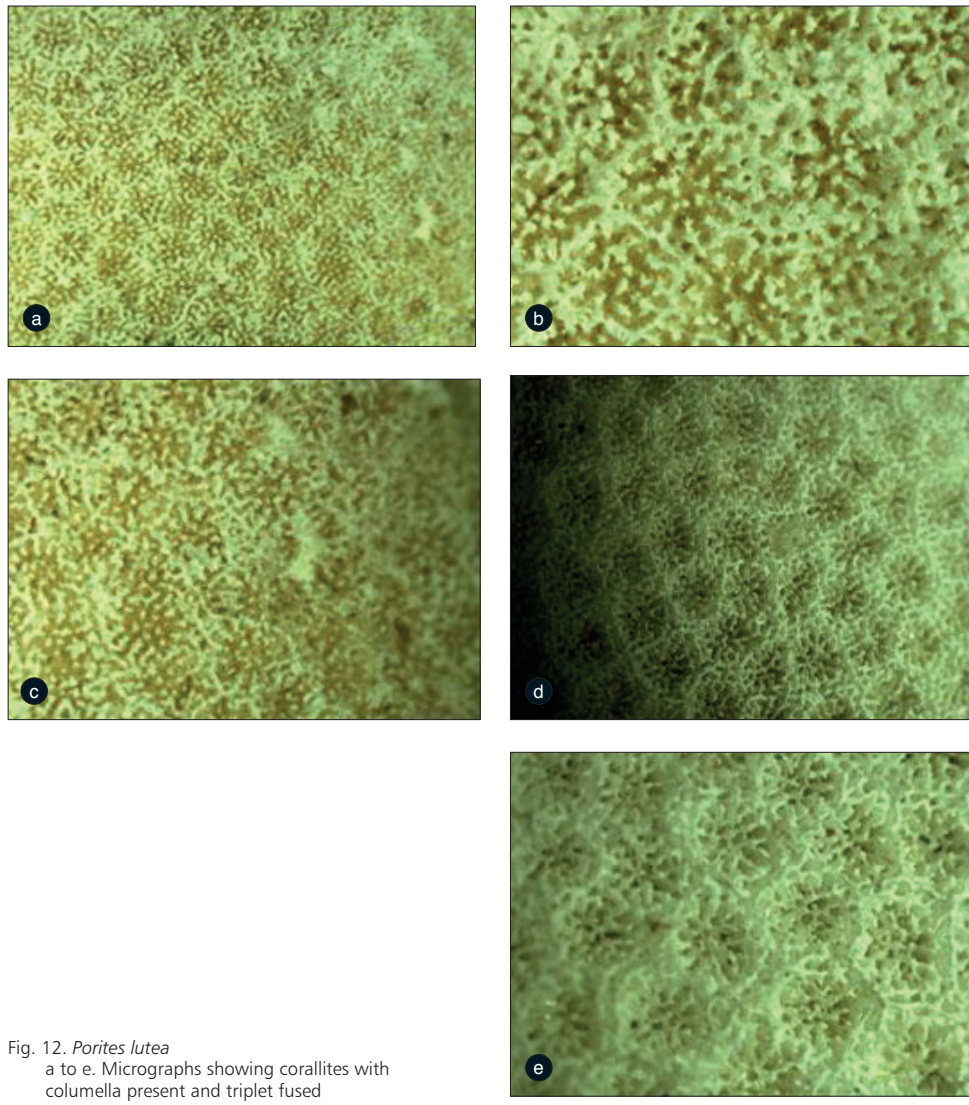

Fig. 12. *Porites lutea*
a to e. Micrographs showing corallites with columella present and triplet fused

the ventral triplet form a trident. A single septal denticle. Two rings of synapticulae. Pali 8, those of the lateral pairs of septa larger. Columella a single style, compressed to the plane of the ventral directive. Fused ends of septa joined to the columella by radii.

Colour: Light green.
Locality: Found in Enayam and Vizhinjam.
Distribution:
India: Fairly common in both Palk Bay and Gulf of Mannar upto Tuticorin.
Elsewhere: Red Sea eastward to Tuamotu Archipelago.

Porites lichen Dana

Goniopora kluzingeri von Marenzeller, 1907
Manopora lichen Dana, 1846
Porites (Porites) lichen Dana, 1846
Porites eridani Umbgrove, 1940
Porites purpurea Gardiner, 1898
Porites reticulata Dana, 1846
Porites viridis Gardiner,1898

Materials examined: A portion of the colony collected from Enayam (Fig. 13).

Diagnostic characters: Corallum encrusting, in some places the surface rising to small gibbosites. Calices and corallites shallow, polygonal or circular, 0.8 to

Fig. 13. *Porites lichen*
Micrograph showing corallite structure

1.2 mm in diameter. Intercorallite wall thin, continuous. Septal arrangement irregular in the observed specimen. Columella very small, absent in some. Septa thick, the ventral triplet not fused. A single septal denticle. Two rings of synapticulae. Pali 6, those of the lateral pairs of septa larger.

Colour: Green.
Locality: Found in Enayam.
Distribution:
India: Fairly common in both Palk Bay and Gulf of Mannar upto Tuticorin and Lakshadweep.
Elsewhere: Red Sea eastward to Marshall Islands and Samoa.

Family: FAVIIDAE Gregory

Characters: All extant species are hermatypic and colonial. Septa, paliform lobes, columellae and wall structures when present, all appear to be structurally similar. Septal structures are simple, columellae are a simple tangle of elongate septal teeth, walls are composed of thickened septa and crossed linkages.

Genus *Goniastrea* Milne Edwards and Haime

Generic characters: Encrusting, massive, ceroid or meandroid. Corallites polygonal; wall solid. Septa of equal thickness at the top of the wall steeply descending. A feeble crown of paliform lobe present. Asexual reproduction by mono to tristomodaeal budding.

Type species: *Astrea retiformis* Lamarck.

Goniastrea pectinata (Ehrenberg)

Astrea pectinata Ehrenberg, 1834, p.320
Goniastrea pectinata Matthai, 1914, p.120, pl. 28, fig. 6, pl. 37, fig. 1 (synonymy); Pillai and Scheer, 1976, p.58 (synonymy).
Goniastrea planulata Matthai, 1914, p.120, pl. 28, fig. 5, pl. 31, fig. 7, 8 (synonymy).

Materials examined: A portion of the colony collected from Enayam (Fig. 14).

Diagnostic characters: Encrusting, explanate, tending to become massive. Corallites and calices polygonal, intercorallite wall 1 to 3 mm thick. Size of the calices vary in different specimens and range from 7 to 12 mm in length, upto 9 mm wide and 4-6 mm deep. Septa vary from 30 to 45 in different cases, exsert ends continuous over the wall, edges dentate, side spinulose. The last septal tooth form a prominent palus. Thirteen to sixteen septa reach the columella. Columella trabecular, 1-3 mm in diameter.

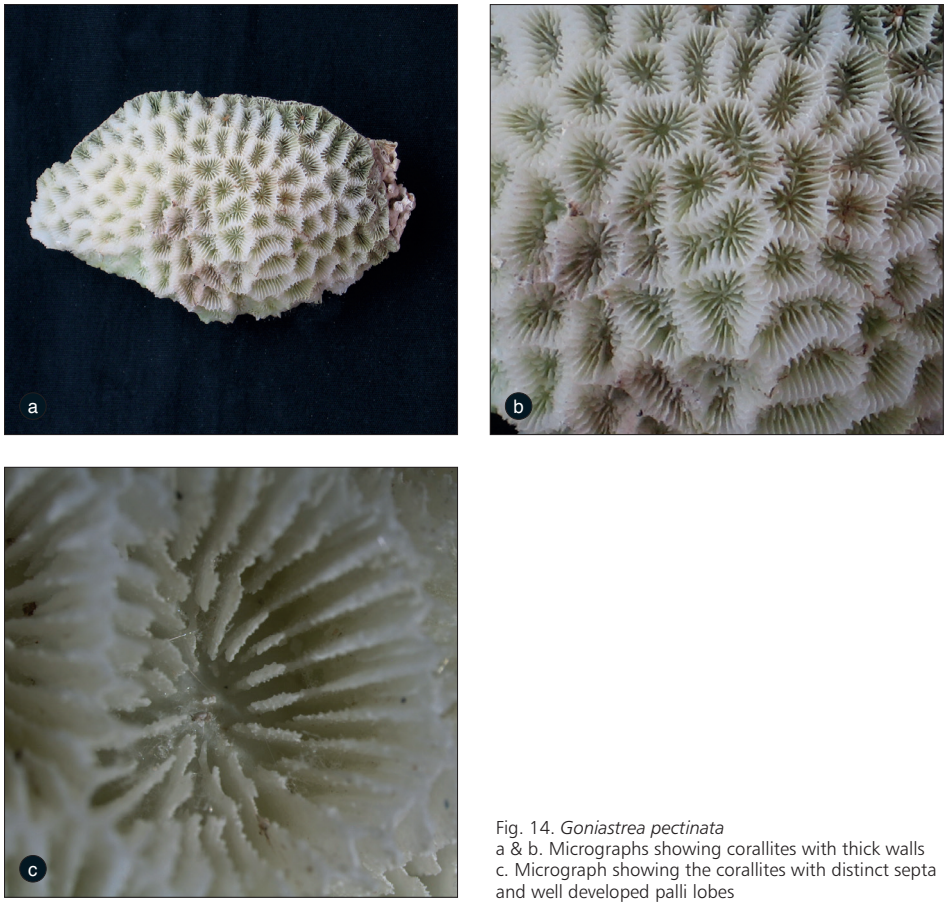

Fig. 14. *Goniastrea pectinata*
a & b. Micrographs showing corallites with thick walls
c. Micrograph showing the corallites with distinct septa and well developed palli lobes

Colour: Chocolate brown.
Locality: Enayam.
Distribution:
India: Fairly common in both Palk Bay and the Gulf of Mannar around Mandapam.
Elsewhere: Widespread from Red Sea eastward to Samoa and Cook Islands.
Remarks: The present suite of specimens display wide range of skeletal variations both in calicular size and septal numbers. Some past workers have separated these ecomorphs and named them separately.

Family: DENDROPHYLLIIDAE Gray

Characters: solitary or colonial, mostly ahermatypic. Corallite walls are porous, usually composed of coenosteum. Septa are fused in a distinctive pattern (Pourtales Plan) at least in immature corallites.

Genus *Turbinaria* Oken

Generic characters: Colonial, explanate, crateriform, submassive or foliaceous. Corallites united by porous coenosteum. Surface with a well-defined system of ridges and furrows. Calices range from 2 to 10 mm in diameter. Columella conspicuous.

Type species: *Madrepora crater* Pallas.

Turbinaria mesenterina (Lamarck)

Explanaria mesenterina Lamarck, 1816, p.255.
Turbinaria mesenterina Milne Edwards and Haime, p.166; Klunzinger, 1879, p.50; Bernard, 1896, p.57 (synonymy); Scheer and Pillai, 1976, p.73; Scheer and Pillai, 1983; Pillai, 1986, p.193.
Turbinaria undata Pillai, 1986, p.193 (synonymy).

Materials examined: A portion of the colony collected from Enayam (Fig. 15).

Diagnostic characters: Corallum foliaceous or encrusting, sometimes the edges forming curled cylindrical folding. Corallites unifacial; rarely few are found in underside of folia. Corallites projecting 2-3 mm in diameter, slightly broader at the base; septa 18-24, depending on size of the corallites, 18 septa joining the columella. Septal edges granular, columella projecting, honeycomb shaped, coenenchyme finely echinulate, spines very closely set, ridge and furrow system conspicuous.

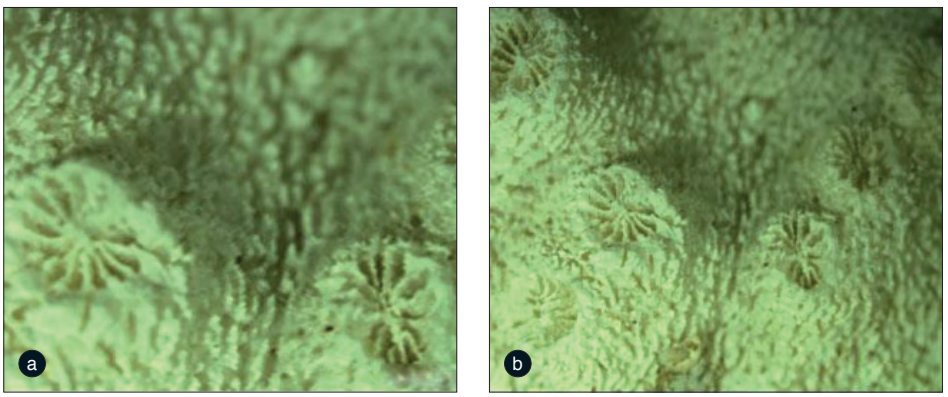

Fig. 15. *Turbinaria mesenterina*
a & b. Micrographs showing corallites slightly exsert and crowded; septa distinct

Colour: Brown.
Locality: Enayam.
Distribution:
India: Northern Lakshadweep (Pillai, unpubl.) and Gulf of Mannar
Elsewhere: Red Sea, Somaliland, Rodriguez, Maldives, Carolina Island, Marshall Islands, Australia.

Remarks: The synonymies of this species are not fully worked out. This species was described by Pillai (1986) from South India under the name *Turbinaria undata. Turbinaria frondens*, *Turbinaria speciosa* (Bernard), *Turbinaria cinarecens* (Ehrenberg,1834) and *Turbinaria reniformis* (Bernard) all seem to belong to *T. mesenterina* and possibly to *T. crater*.

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2

Distribution, diversity and abundance of scleractinian corals

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Abstract

Three extensive surveys were conducted for the assessment of scleractinian coral diversity along Enayam to Kollam waters in southern India during the period 2008-2012 (*i.e.,* in three phases), using the Line Intercept Transect (LIT) method. A total of 15 coral species belonging to 5 families and 6 genera were recorded and the relative abundance values were derived for each species and were assigned the status as dominant/ abundant/ common/ uncommon/rare. The genera *Pocillopora* and *Montipora* were represented by five species each. In Vizhinjam waters, the total coral cover was only 16.2% of the surveyed area in the first phase of the study period. Subsequent studies revealed a decline in coral growth due to construction of a wharf and also by the removal of pocilloporids by divers. But during the third phase of the survey, new colonies were observed in the area resulting in increased coral cover in Vizhinjam Bay. Though during the first phase, 83% of coral cover was observed at Enayam, a decline in the coral cover (75% only) was recorded in the second phase of the study due to replacement of pocilloporids by the luxurious growth of brown mussels and encrusting zooanthids. The incidence of bleached corals was found to have increased considerably after the initial study. An important observation recorded was that though the decline was noticed among the pocilloporids, an increase in coverage was noticed for other groups such as acroporids and poritids. The present paper presents an overview of coral resources along the south-west coast of India, their distribution and diversity and climatic as well as anthropogenic stress on coral growing areas.

Keywords: *Coral diversity, Distribution, Health status, Scleractinian corals*

Introduction

The coral reefs found in different parts of the coasts of the Indian mainland include the sensitive fringing reef ecosystems in the Gulf of Mannar, Palk Bay, the Gulf of Kutch, the atolls of the Lakshadweep Islands and the continental island reefs of Andaman and Nicobar, covering an estimated area of about 2375 km^2. Apart from these main reefs, there are patches of reefs in the intertidal areas of the west coast. There is a lacuna in knowledge regarding the spatio-temporal distribution of coral species and biodiversity parameters in these reef areas of the mainland coast of India. Along the south-west coast of India, Alcock (1893, 1898) recorded deep-water ahermatypes from the Travancore coast and Pillai and Jasmine (1995) listed a total of 29 species belonging to 17 genera of scleractinians, of which 13 were hermatypes collected from the patchy growth along Vizhinjam and Enayam and 16 ahermatypes, all of which were collected during research cruises on board FORV Sagar Sampada. But an extensive study by Jasmine *et al*. (2009) recorded only 13 species from Vizhinjam and Enayam areas.

Materials and methods

Coral diversity and distribution along Thangassery and Thirumullavaram in Kollam and along Vizhinjam and Enayam on the south-west coast of India have been investigated during 2008 to 2012. The Vizhinjam Bay is an enclosed bay (Lat. 08º 22′ 529″ N; Long.76º 59′ 466″ E) with the seaward side having huge granite and concrete boulders as wave breakers with coral colonies attached to them, apart from those found at the bottom of the Bay waters. At Enayam (Lat.08º 12′ 92″ N; Long.77º 10′ 906″ E), there is a patchy reef formed around a rock about 500 m from the shore. The coral growth along Kollam coast extend from Thirumullavaram to Thangassery (08º 54′ 450″ N; 76º 32′ 422″ E to 08º 52′ 263″ N; 76º 35′ 006″ E). Thangassery is also an enclosed bay like Vizhinjam and here also coral colonies were observed on the huge granite and concrete boulders laid as wave breakers. In Thirumullavaram, coral growth was observed on the rocks along the intertidal area. Life-form Line Intercept Transect method (LIT) was adopted for the survey at all these sites. In Enayam, areas around the reefs were chosen at random and 20 m long transects were sampled along the depth contours and the areas covered by live and dead corals and other substrates were recorded. At Vizhinjam, corals were found mostly on the granite and concrete blocks and here 20 m long transects were placed along the shore line at different depths. Transects were sampled in two sites, in the Vizhinjam Bay and in the harbour area. At Thangassery also, 20m long transects were placed along the tetrapods of the breakwaters. At Thirumullavaram, all the rocks having coral growth were estimated using random transects of 20m, parallel to the shore line. All hard corals intercepted by the

transects were recorded and their lengths measured. The colonies were sampled and identified following Scheer and Pillai (1983), Pillai (1986), Veron (2000) and Rani and Sandhya (2007). The relative abundance of each species was calculated according to living coral cover and the methodology adopted was as described in Sandhya *et al*. (2008).

Results and discussion

Hard coral diversity

During the present study, a total of 15 species of hard corals belonging to 5 families and 6 genera were identified from the inshore waters of Enayam to Kollam, on the southern coast of India (Fig.1). The most common genus recorded from the study area was *Pocillopora* and the families Pocilloporidae and Acroporidae were represented by five and six species, respectively; Poritidae with two species and Faviidae and Dendrophyllidae with one species each. However, Pillai and Jasmine have recorded 29 species of scleractinians belonging to 17 genera from this area. Out of these, 13 species falling under six genera were hermatypes and the rest 16 species of 11 genera were ahermatypes. Details on percentage coral cover and relative abundance of hard coral species recorded during the present study are given in Table 1. Distribution of various species so far recorded from the south-west coast of India are summarised in Table 2. It is interesting to note that the most dominant genus in terms of both abundance and species diversity was *Pocillopora* and all the species of *Pocillopora* have been already recorded from Lakshadweep in the past. As evident from Table 2, the coral fauna of the present study was more related to that of the Gulf of Mannar Biosphere Reserve (GOMBR) than any other part of India as confirmed by Pillai and Jasmine (1995).

List of species hitherto reported from south-west coast of India including present collection (Fig. 1 a-o)

Phylum: Cnidaria Hatscheck
Class: Anthozoa Ehrenberg
Subclass: Zoantharia Blainville
Order: Scleractinia Bourne
Sub order: Astrocoenina Vaughan & Wells