CORAL FAUNA OF LAKSHADWEEP WITH SPECIAL REFERENCE TO AGATTI ATOLL

Thesis submitted to Goa University
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by

Shakuntala Caeiro, M.Sc.

Department of Marine Science & Biotechnology
Goa University, Goa 403 206

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Certified that all corrections suggested by examiners if any have been incorporated in the thesis

4-2-2000

4/2/2000
(GUIDE)

STATEMENT

I hereby state that this thesis for the Ph.D. degree on "CORAL FAUNA OF LAKSHADWEEP WITH SPECIAL REFERENCE TO AGATTI ATOLL" is my original contribution and that the thesis and any part thereof has not been previously submitted for the award of any degree, diploma of any University or Institute. To the best of my knowledge, the present study is the first comprehensive study of its kind from this area.

The literature pertaining to the problem investigated has been duly cited. Facilities availed from other sources are duly acknowledged.

(Shakuntala Caeiro)

Department of Marine Science & Biotechnology
Goa University
Taleigao Plateau
Goa 403 206

CERTIFICATE

This is to certify that the thesis entitled "CORAL FAUNA OF LAKSHADWEEP WITH SPECIAL REFERENCE TO AGATTI ATOLL" submitted by Smt. Shakuntala Caeiro for the award of the degree of Doctor of Philosophy in MARINE SCIENCE is based on the results of investigations carried out by the candidate under my supervision. The thesis or any part thereof has not been previously submitted for any other degree or diploma of any University or Institute. The material obtained from other sources has been duly acknowledged in the thesis.

8/3/99

(Dr. C.L. Rodrigues)

Research Supervisor

Department of Marine Science & Biotechnology
Goa University
Taleigao Plateau
Goa 403 206

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Caeiro

(Shakuntala Caeiro)

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CHAPTER ONE

INTRODUCTION

1.1 CORAL REEFS

Coral reefs are exotic ecosystems populated by a diverse group of organisms. Representatives of almost all phyla can be encountered in this dynamic underwater world. Reefs are manifestations of inexorably slow growth of minute coral polyps. For their genesis and maintenance, the environment has to fulfil a certain set of conditions, the fundamental one being temperature. Corals flourish where temperature ranges from 23-25°C, salinity is over 30‰ and water is free from silt. Coral reefs of the world are therefore restricted to the warm tropical belt between the tropics of Cancer and Capricorn (30°N and 30°S) bounded by the 20°C isotherm. The skeleton of these polyps which is the major component that gives solidarity to the reefs is exclusively made up of calcium carbonate. The typical high temperatures, medium salinity and low carbon dioxide concentration prevailing in tropical waters allows the precipitation of calcium from the waters to form hard skeletal parts of corals (Wood, 1983).

Corals are restricted to the marine environment. Both solitary and colonial forms are present, the majority colonial forms being termed as hermatypic. Hermatypic corals harbour zooxanthellae (dinoflagellates belonging to the genera *Symbiodinium* and *Amphidinium*) in their tissues and are the major reef builders. Zooxanthellae require sunlight for photosynthesis and hence hermatypic corals are confined to depths less than 50m in the oceans (Vaughan & Wells, 1943). Ahermatypic forms are solitary, cup-shaped, do not possess zooxanthellae, are not restricted to tropical waters, and have been reported from depths down to about 6000m (Moore *et al.*, 1952).

The three major types of coral reefs in the world are fringing reefs, barrier reefs and atolls. Fringing reefs are outward extensions of the continental coast with a shallow water channel between the reef and sea. In contrast, barrier reefs are much further away from land and separated from it by a deep water channel. Atolls are ring-shaped structures of volcanic origin resting on underwater platforms about 180m deep and harbouring a shallow water lagoon. The lagoons have inlets and outlets at certain points along their perimeter, facilitating the flow of seawater into and out of the lagoon.

Coral reefs occupy an estimated 617,000 km², equivalent to 0.17% of the total world ocean area, a little more than half of it lying in the Mediterranean region and the Indian ocean (Smith, 1978). They are considered the most productive marine ecosystems, with an annual gross production amounting to 2000-5000 gC/m² (Mann, 1982) and annual yield of about 9% of the world fisheries (Smith, 1978). Recent estimates by the World Conservation Monitoring Centre (United Kingdom) using geographic information systems (GIS) technology suggest that the global coral reef area is only 255,000 km², a revised estimate influenced by 'reef' definition (Spalding & Grenfell, 1997).

1.2. CORAL EVOLUTION

The growth of modern reefs is considered to have begun between 6000 to 9000 yr. B.P. and these reefs are still undergoing post-Pleistocene successional changes (MacIntyre & Glynn, 1976; Adey, 1978). These reef building scleractinians are believed to be descendants of primordial rugose corals which were simple, solitary and discoidal forms, made up of flat or gently rounded calcareous skeleton built by the ectoderm of the base. The upward and inward foldings of the ectoderm resulted in structures presently termed septa. These basic elements developed in ontogeny giving rise to present day scleractinians which differ from their ancestors primarily in the mode of addition of septa, which appear in regular cycles. Fossils of scleractinians have been excavated from many Mesozoic and Cainozoic rocks, the oldest being reported from Middle Triassic. The most successful of modern reef builders are those species belonging to the families Acroporidae and Poritidae.

There are two major hypotheses put forward to understand the evolution of present day scleractinians. According to the first hypothesis, all corals had a common ancestor in unknown Cambrian or older primitive anthozoans. This gave rise to two branches, *viz.* the Rugosa branch which culminated and died before the Triassic era and the Scleractinia branch which later acquired capabilities to secrete hard parts. The second hypothesis suggests that scleractinians are direct descendants of the rugose corals. The close similarity of scleractinians with sea anemones, except for the skeleton, support the first hypothesis while the strong dissimilarity between astrocoeniids, among the oldest known scleractinians recorded in Middle Triassic rocks, and rugose corals support the second hypothesis. The evolution of corals has been discussed by several authors (Moore *et al.*, 1952; Veron, 1986, 1993).

1.3 BIOLOGY AND ECOLOGY OF CORALS

1.3.1 Morphology

Corals are comparable to sea anemones in morphology, with well developed body tissues. The basic unit is a polyp which is cylindrical in shape. The mouth is present at the top of the cylinder, surrounded by one or more rings of tentacles bearing stinging cells. Internally, the mouth leads into the stomodaeum, divided longitudinally into mesenteries bearing the gonads. In case of colonies, adjacent polyps are joined by tissue that is a part of extensions of the gastrovascular cavity. The skeleton of the coral is termed the corallite and consists of a basal plate from which arise partitions, the septa.

From the centre of the basal plate arises a structure called the columella, which extends into the corallite.

Corals can be either solitary or colonial, the former generally having a cylindrical or oval growth form. Coral colonies can have various growth forms, the principal being encrusting, massive, foliaceous or branching. Coral morphology and growth forms can vary according to the environment. For instance a massive species may become flattened or foliaceous in deeper, dimly lit portions of the sea (Goreau, 1963; Dustan, 1975). Wide horizontal plates are the best structures as far as utilization of incident radiation is concerned (Goreau, 1963; Barnes, 1973; Wallace, 1978).

1.3.2 Nutrition

Doubts still exist on the nutritional aspects of coral reef environment, considering the rich biodiversity of this ecosystem and the observation that atolls are located in nutrient deficient seas. Hermatypic corals harbour in their tissues symbiotic zooxanthellae, which are either inherited from the parent or infected by it during the free living larval stage. The relationship between the two organisms still remains to be adequately explained. In exchange for shelter and other metabolic by-products of the corals utilized by the algae, 94-98% of all organic carbon produced by the algae leaches out for utilization by corals. In addition, the excess oxygen produced by the algae is used by the corals for respiration. Symbiosis in corals has been recently reviewed by Muller-Parker and D'Elia (1997).

Corals also resort to heterotrophy and as their nutrition source they depend on zooplankton and detritus brought in by tides. Experiments have indicated that corals have a sense of smell, sensing their food by chemical means (Mariscal & Lenhoff, 1968). They have evolved several mechanisms for procurement of food. Some corals utilize tentacles to capture prey and pass the food directly to the mouth while in others, food is carried away by ciliary tracts. In yet others, nutrition is obtained through digestive filaments, a derivative of the mesenteries, ejected from the mouth or through some other openings in the body wall, which target neighbouring corals.

1.3.3 Reproduction

A few species of corals are hermaphrodites while others are heterosexual with some species changing their sex as they develop (Wood, 1983). For their establishment and propagation corals resort to both sexual (Richmond & Hunter, 1990) and asexual (Highsmith, 1982) mode of reproduction. Sexual reproduction is particularly necessitated for the establishment of corals over long distances. There are several recent reviews on the reproduction and recruitment in corals (Harrison & Wallace, 1990; Richmond, 1997).

Sexual reproduction results in the production of drifting planula larvae. In this type of reproduction, the male parent releases the sperms in the surrounding water, which then swim towards the female parent for fertilization or both male and female gametes are released in the water for external fertilization. Some species spawn throughout the year while others are discrete annual breeders. Many species breed in tune with the lunar cycle during neap tides when tides are at their weakest and when water temperature increases rapidly (Veron, 1985a). In another form of sexual reproduction, the parent corals harbour broods of larvae which settle soon after their release or drift for a short or long time before they settle and develop into new colonies (Jackson, 1986).

Once the planula places itself on a suitable substrate, colony propagation begins. Addition of polyps takes place either through intratentacular or extratentacular budding.

During intratentacular budding, the oral disc invaginates to produce a new polyp within the parental oral disc while in the latter, new buds are formed at the periphery of the oral disc of the parent.

The majority of corals propagate asexually by fragmentation of part of the parent colony, which then grows in the close vicinity of its parent colony, or produces larvae asexually. *Goniopora stokesi* produces satellite colonies within the soft tissues of the parent colony while *Fungia* produces daughter polyps from the parent under conditions of stress. *Diaseris* reproduces by natural autotomy wherein a single parent individual breaks up into several wedge-shaped daughter segments.

1.3.4 Coral Associations

The skeleton of corals provides shelter to many organisms. Some of these are temporary inhabitants while others are permanent dwellers. These associations range from casual associates to predators and include flatworms, molluscs, feather stars, shrimps, crabs, fishes *etc.*. Competition for space is intense and many species resort to commensalism (sharing of space) epitomized by the symbiotic relationship between corals and zooxanthellae.

Many of the permanent associates lodge themselves inside the calcareous skeleton of the corals when young, utilizing the cavity for their own growth, thereby affecting the calcification of corals, *e.g.*, the giant clam, *Tridacna*. Some animals such as crabs and fishes are very selective as far as their host is concerned. Some crabs that form conspicuous associates among corals are *Trapezia*, *Tetralia*, *Cymo*, *Domecia*, *Chlorodiella*, *Percnon*, *Thalamitra*, *etc.*. The hectic activity of some of the portunid crabs can cause local damage, which may result in the breakage of the colonies. Some of the predatory corallivorous fishes include *Chaetodon*, *Heniochus*, *Rhinecanthus*, *Tetraodon*, *Oxymonacanthus*, *Canthigaster*, *etc.*. The types of associates also serve as indicators of the health of the reef and affect coral community structure (see Glynn, 1990; Paulay, 1997).

1.4 REEFS OF INDIA

Around the Indian sub-continent, reefs are located in the Gulf of Kachchh (Kutch) in Gujarat, off Rameshwaram in the Gulf of Mannar and the Palk Bay, in the Andaman and Nicobar islands and in Lakshadweep (Laccadives) (Pillai, 1996). Andaman and Nicobar island reefs are typical examples of fringing reefs. However, the most dominant types of reefs in the Indian Ocean are the atolls of Lakshadweep, Maldives, and the Chagos archipelago. Isolated coral patches have also been reported at several localities along the west coast of India:- Malvan, Malpe, Ratnagiri, Quilon, Enayam and Goa (Qasim & Wafar, 1979; Pillai & Jasmine, 1995; Rodrigues *et al.*, 1998). The total area occupied by reefs in India, based on remote sensing estimates, is approximately 1220 km^2 (Baldev Shai, 1994, as cited in Pillai, 1996).

1.4.1 Lakshadweep

The Lakshadweep archipelago (Fig. 1.1) lying between 8°-12°30'N and 71°-74°E has a total area of 32km^2, with an Exclusive Economic Zone of about 400,000km^2 (Mannadiar, 1977). The seas around this archipelago form a part of the southeastern Arabian sea. The archipelago comprises thirty six islands of which eleven are inhabited, sixteen are uninhabited, four are newly formed islets and five are submerged banks. The islands are predominantly of coral origin. The inhabited islands consist of the northern Amindivi islands comprising Amini, Kadmat, Chetlat, Kiltan, Bitra, Agatti, Bangaram and southern Malabar islands that include Minicoy, Kavaratti, Kalpeni and Andrott. Kavaratti is the administrative headquarters of Lakshadweep.

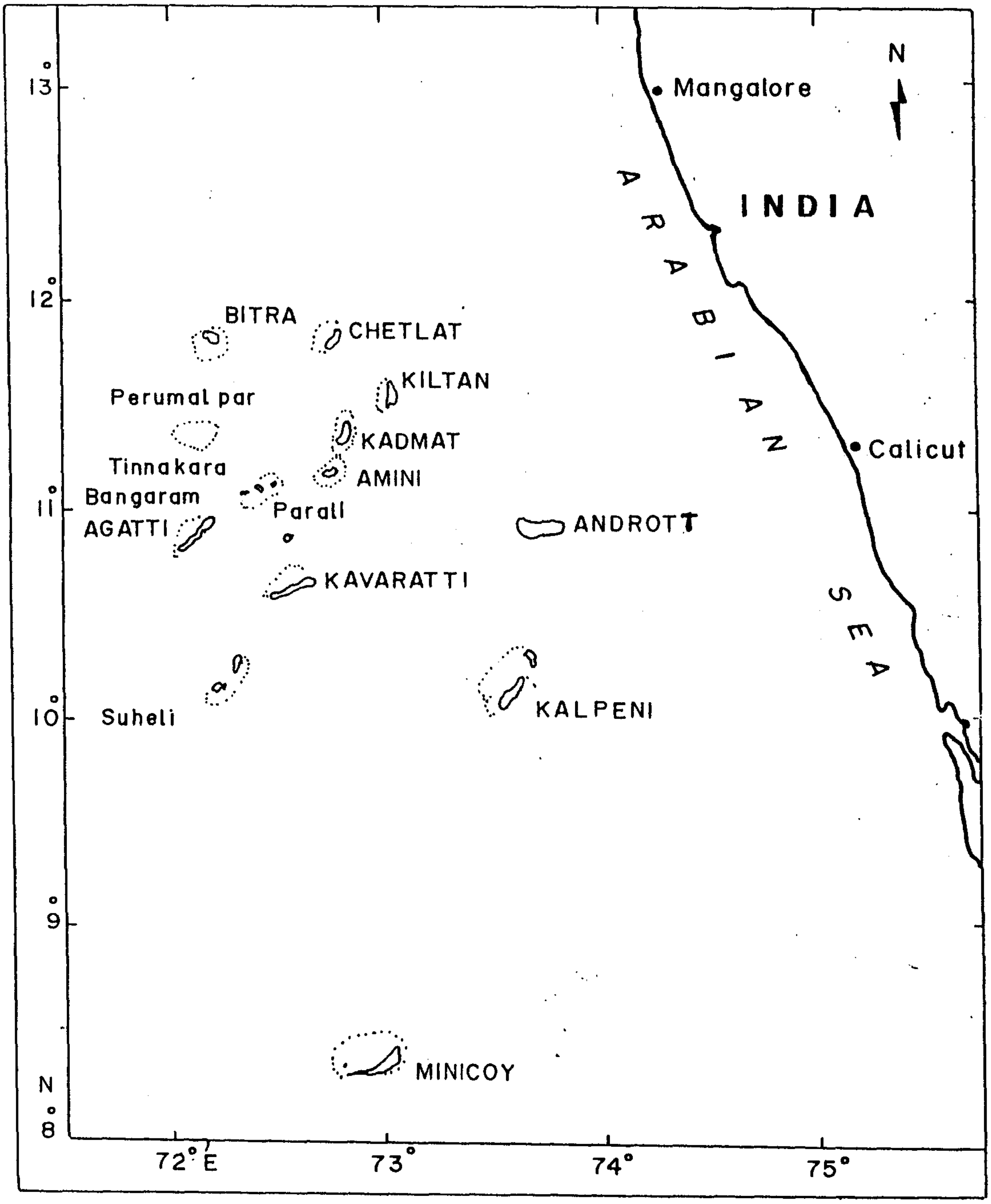

Fig. 1.1 Map of the Lakshadweep archipelago.

The islands are barely raised above 2m and rest on underwater platforms nearly 180m deep, associated with the Aravalli mountain range (Stoddart, 1973). The Lakshadweep group of islands is one of the northern components of the 3000km uninterrupted, linear, aseismic, N-S directed Chagos Laccadive ridge (Glennie, 1936; Francis & Shor, 1966). The ridge is separated from the Malabar shelf by the Lakshadweep sea and merges with the shelf at some places between 11° - 14°N. The ridge has a number of gaps, the prominent being the 9° channel, which separates the atoll of Minicoy from other islands in the Lakshadweep archipelago. Seismic refraction and gravity anomalies have revealed that the Laccadive ridge consists of coral limestone capping massive volcanics (Glennie, 1936; Francis & Shor, 1966). It has been suggested that the volcanism responsible for this ridge moved northwards over time to culminate in the outpourings of the Deccan traps, which are largely Paleocene-Eocene (Wellman & McElhinny, 1970). The Lakshadweep archipelago is believed to have originated in the Tertiary and Quarternary eras on a volcanic platform and the present day reefs are believed to be manifestation of the sea level changes that had taken place during the Pleistocene and Holocence ages (Stoddart, 1973).

Most of the islands are situated on the windward reef flat and are oriented in the North-South direction. Minicoy, Kalpeni, Kadmat, Kiltan, Chetlat are typical atolls. The continental shelf around Lakshadweep is limited to about 4336km². Remote sensing estimates suggest a total reef flat and lagoon area of 78.1km² and 150.2km², respectively (Bahuguna & Nayak, 1994). Outer edges of atolls have very steep slopes, which drop to the ocean floor. The eastern sides of these islands are usually sheltered from wind and current.

The plankton productivity rates around Lakshadweep are estimated to be 8-34 mg C/m³/day (Nair *et al.*, 1986a). The major living resource of the archipelago are fishes, particularly the skipjack tuna, *Katsuwonus pelamis* (Linnaeus). As per the latest figures, the annual fisheries yield of Lakshadweep is around 9000t, of which tunas constitute 7000t. The potential total fish yield of Lakshadweep is estimated to be 90,000t (Jones & Banerji, 1973) and the potential tuna yield 50,000t (George *et al.*, 1977). The total live bait catch, required for the pole and line tuna fishing method adopted in Lakshadweep, has been estimated as around 125t (Pillai *et al.*, 1995). Although the catch has tripled since 1980 and its value appreciated sixteen fold, there appears to be no overfishing (Rodrigues, 1997). Besides fishing, coconut farming is the other occupation around which the lives of the people of Lakshadweep appears to revolve. A brief description of the inhabited islands surveyed in the present study is presented below:

Agatti (10°51'N and 72°11'E): It is the most westerly located island of the group and is club-shaped with a broad northern part and a narrow southern strip. The island is 6km long and 1km wide at its broadest point, covering an area of 2.71km². There are no storm beaches on its eastern side and clean sandy belts occur in the intertidal zone. The lagoon is extensive on the western side. While the reef flat occupy an area of 14.4km², the lagoon is 11.7km² (Bahuguna & Nayak, 1994). Thick coconut groves abound on the northern side while the southern part supports short shrub jungles culminating in spiny grasses on the shore. The only airport of the archipelago is located on this island.

Amini (11°7'N and 72°44'E): The island is oblong and completely fills the interior of the atoll. Sandy beaches surround the island. It is 3km long, 1.5km wide at its broadest point and 2.59km² in area. The lagoon is narrow, being comparatively broad on the northern side with four entrance channels.

Andrott (10°49'N and 73°41'E): This island is closest to the Indian mainland. It is disposed in the east-west direction and is the easternmost island of the archipelago. The island has virtually no lagoon. It is the largest island of the archipelago, about 6km long, 0.7km in maximum width and 4.84km² in area. The reef flat gets fully exposed at low tide all around the island except for the northeastern part.

Bangaram (10°56'N and 72°17'E): This formerly uninhabitated island, 0.58km² in area, has now a total population of 61 persons (1991 Census). It is situated within an extensive lagoon, 6 x 10km in size. Beautiful sandy beaches and an extensive lagoon all around have made it a tourist centre catering to Indian and international visitors.

Bitra (11°36'N and 72°10'E): It is the northwesternmost and smallest inhabited island with the largest lagoon in the archipelago. The land is spindle-shaped with an area of 0.10km² while its magnificent lagoon is 42km² in area (Bahuguna & Nayak, 1994). The island lies at the northern end of the lagoon. Freshwater is rationed on this island. Wide coralline sandy beaches occur all around.

Chetlat (11°41'N and 72°43'E): It is the northernmost inhabited island of the group with an area of 1.04km². The lagoon is shallow, 2.0 x 1.2km in size, with two entrance channels on the reef. The eastern bank of the island is subject to heavy storms which results in wide stretches of coral debris. These debris belts cover the entire southern end of the island.

Kadmat (11°13'N and 72°47'E): The island is 8km in length, 0.5km in width and 3.12km² in area. It is spindle-shaped, broadest in the middle and tapers to a narrow strip at the southern end. The lagoon on the western side is large, narrow on the eastern side and gets fully exposed at low tide along with a 100m wide reef. Thick formations of hard coral stone are seen.

Kalpeni (10°5'N and 73°39'E): It lies 87km south of Andrott. An extensive lagoon encloses the island with three islets of Cheriyam, Tilakkam and Pitti, situated on the eastern side. Narrow channels separate these islets. The 34km² lagoon on the western side is the second largest in the archipelago (Bahuguna & Nayak, 1994). The island is 2.28km² in area and supports storm banks of coral debris on the eastern side. Coral boulders and pebbles are conspicuous all over.

Kavaratti (10°33'N and 72°38'E): It is the capital of the union territory and occupies an almost central geographical position in the archipelago. It lies 404km from Kochi (Cochin) on the mainland. The island is about 6km in length, 1.3km in maximum width in the north and tapers down to a strip on the southwest. It has a land area of 3.63km². Wide sandy beaches present on the lagoon side of the island are exposed during low tide.

Kiltan (11°29'N and 73°E): The island is about 3.0km long and 1.63km² in area. The northern, southern as well as eastern sides have storm beaches. The lagoon, 900m wide, runs along the whole length of the island, is shallow and full of coral rocks.

Minicoy (8°17'N and 73°4'E): This island located at the southern end of the Lakshadweep archipelago is 4.37km² in area. It is oval in shape with its pointed end directed northeast. The lagoon is large, 28.2km² in area (Bahuguna & Nayak, 1994), with fine sandy beaches. Screw-pine jungles are present on the southern part of this island.

1.4.2 Climatology and physico-chemical parameters

The climate of Lakshadweep is comparable to that of coastal areas of Kerala and is warm and humid. Girijavallabhan *et al.* (1989) recorded salinities ranging from

29.5‰ to 39.5‰ in lagoons at various islands while dissolved oxygen ranged from 2.80 to 6.70ml/l and sea surface temperature between 32-38°C. The archipelago is subject to both the northeast and southwest monsoons, receiving a marginally higher rainfall in the south. The total annual rainfall ranges from 1,500 to 1,600mm. As with the northern Indian Ocean the pattern of circulation involves the monsoon current, equatorial current and the equatorial counter current, with a general flow of water towards the west (Malik, 1979). Occasional minor cyclonic storms have been reported in Lakshadweep in 1891, 1922, 1948, 1963 and 1965, although not comparable in magnitude with the most severe cyclone that ever struck Lakshadweep on April 15th 1847 causing widespread devastation in Kalpeni and Andrott (Mannadiar, 1977; Jones, 1986).

1.5 BRIEF REVIEW OF RESEARCH ON LAKSHADWEEP CORAL REEFS

Research in Lakshadweep commenced when the surgeon naturalist Dr. Alcock aboard the ship *R.M.S. Investigator* set sail in 1891 and cruised Lakshadweep and Maldives for a period of two months. This study resulted in an understanding of the geographical aspects of the islands. During 1899-1900, Sir Stanley Gardiner undertook his first expedition covering Minicoy and Maldives. The information collected was later published in two volumes entitled 'The fauna and flora of Maldives and Lakshadweep' (Gardiner, 1903-1906).

The geographical aspects, terrestrial flora and fauna, history *etc.* are reported by Ellis (1924), Stoddart (1973) and Mannadiar (1977). The geomorphology and sedimentology of the islands is described by Siddiquie (1975, 1980). Jones and Kumaran (1980) published a compedium of the fishes of the archipelago, documenting 603 species. Nair *et al.* (1986b) described the environmental features of the seas around Lakshadweep. The Zoological Survey of India (ZSI) carried out extensive surveys in 1982-87 and published in 1991, a volume on the fauna (except corals) of Lakshadweep

(State fauna series 2). Likewise, the Central Marine Fisheries Institute (CMFRI), Kochi, carried out a survey from January to March 1987 to study the fishery potential which culminated in the publication of a special issue on Lakshadweep (CMFRI Bulletin 43, 1989). The National Institute of Oceanography (NIO) has also carried out some studies and these and other investigations conducted in Lakshadweep so far have recently been compiled by Bakus *et al.* (1994).

Taxonomic studies on corals of Lakshadweep were conducted by Gardiner (1903-1906), Cooper (1906) and Pillai (1971a,b, 1972, 1983a, 1986a). Pillai (1983a) reported seventy eight species of corals from Minicoy and Kiltan. The number of scleractinian coral species recorded in Lakshadweep has been raised to 104 species with the most recent publication of Pillai and Jasmine (1989). The status of Lakshadweep coral reefs has been discussed recently by Pillai (1996) and Rodrigues (1996).

1.6 OBJECTIVES OF THE PRESENT STUDY

The present study was undertaken to meet the following objectives:

- To prepare an updated check-list of scleractinian and non scleractinian corals of the Lakshadweep archipelago.
- To compare the coral fauna of Lakshadweep with those of other localities in south Asia.
- To collect quantitative data on the distribution and abundance of corals on the reef flat at Agatti atoll with a view to investigate the community structure and diversity of corals on the reef flat at Agatti atoll.
- To study coral-coral and coral-macrophyte interactions on the reef flat at Agatti atoll.

CHAPTER TWO

TAXONOMIC STUDY OF CORALS IN LAKSHADWEEP

2.1 INTRODUCTION

A major recent major contribution to the systematic study of corals in the Lakshadweep archipelago has been by Pillai (1971a,b, 1972, 1983a, 1986a,b) and Pillai & Jasmine (1989). However, these studies were centered on Minicoy, Kiltan and Chetlat islands. Pillai (1983a) reported seventy eight species of corals from Minicoy and Kiltan. Pillai and Jasmine (1989) continued their exploration of the coral fauna of other islands in Lakshadweep. Their study updated the number of coral species to 104, with 26 new additions.

The taxonomical classification of corals adopted in the present study is that of Vaughan and Wells (1943) as modified by Wells (1956), Chevalier (1971) and Veron (1992). Chevalier (1971) excluded the subfamily Montastreinae Vaughan and Wells while Veron (1992) shifted the genus *Psammocora* from family Thamnasteriidae to family Siderastreidae, on the basis of affinities. Similarly, *Hydnophora* which was considered to belong to family Faviidae is now placed under family Merulinidae due to its closer affinities with the latter (Veron, 1992).

2.2 METHODOLOGY

Field studies were carried out on several islands in Lakshadweep during 1993-1995 (Table 2.1) to investigate the coral fauna of the archipelago. Representative corals were collected from reef flats as well as lagoons. Field surveys were conducted on reef

Table 2.1 Synopsis of field surveys conducted.

Survey	Period	No. of days	Islands surveyed
I	27-02-93 to 12-04-93	45	Agatti, Kalpitti, Bangaram
II	14-10-93 to 5-12-93	53	Agatti, Tinnakara Parali, Kavaratti
III	7-03-94 to 30-04-94	55	Kalpeni, Tilakkam, Pitti, Cheriyam, Andrott, Agatti Kavaratti
IV	15-10-94 to 6-12-94	53	Agatti, Bangaram, Kadmat, Kiltan
V	14-03-95 to 26-04-95	44	Minicoy, Chetlat, Bitra, Kavaratti, Agatti
VI	18-10-95 to 16-11-95	30	Minicoy, Viringili, Agatti, Kalpitti
		280	

flats during low tide, and in lagoons using boats and by snorkeling.

Identification of corals was done with the help of the recent literature available (Pillai, 1967a-g; Pillai & Scheer, 1976; Scheer & Pillai, 1983; Veron *et al.*, 1977; Veron & Pichon, 1980, 1982; Veron, 1985b; Veron & Wallace, 1984). The identification was based on microscopic examination of the coral skeletal structures, type of asexual reproduction, colouration as well as clues provided by their habitat.

2.3 RESULTS AND DISCUSSION

Ninety six species of corals belonging to 34 genera, including 28 new records, were recorded during the surveys (Table 2.2). These coral species were generally observed at all islands and localities of new records are indicated in the table (Table 2.2). A key to the taxonomic identification of scleractinian coral species so far recorded in Lakshadweep is presented in Appendix 1. A descriptive account of only the new record of coral species obtained in the present study is outlined below. Their synonymies and distribution as documented in recent publications are also indicated. A world map depicting the Indo-Pacific region is sketched in Fig. 2.1 to facilitate locations of coral reef areas.

Phylum Cnidaria Hatschek (1888)

Class Anthozoa Ehrenberg (1834)

Subclass Zoantharia Blainville (1830)

Order Scleractinia Bourne (1900)

Family Acroporidae Verrill (1902)

Genus Acropora Oken (1815)

Type species: *Millepora muricata* Linnaeus (1758)

Table 2.2 Coral species recorded in Lakshadweep.
(Localities of new records indicated in brackets)

Phylum Cnidaria Hatschek (1888)
  Class Anthozoa Ehrenberg (1834)
    Order Scleractinia Bourne (1900)
      Suborder Astrocoeniina Vaughan & Wells (1943)
        Family Pocilloporidae Gray (1842)
          Pocillopora damicornis (Linnaeus, 1758)
          Pocillopora eydouxi Edwards & Haime (1860)
          Pocillopora verrucosa Ellis & Solander (1786)
          Stylophora pistillata Esper (1797)
        Family Acroporidae Verrill (1902
          Acropora aspera (Dana, 1846)
          **Acropora austera* (Dana, 1846) (Agatti, Bangaram, Kadmat, Kalpeni)
          **Acropora cerealis* (Dana, 1846) (Chetlat)
          Acropora corymbosa (Lamarck, 1816)
          Acropora danai (Edwards & Haime, 1860)
          Acropora efflorescens (Dana, 1846)
          Acropora formosa (Dana, 1846)
          Acropora forskali (Ehrenberg, 1834)
          Acropora granulosa (Edwards & Haime, 1860)
          Acropora humilis (Dana, 1846)
          Acropora hyacinthus (Dana, 1846)
          **Acropora ?millepora* (Ehrenberg, 1834) (Agatti)
          Acropora ?monticulosa (Bruggemann, 1879)
          Acropora nasuta (Dana, 1846)
          Acropora nobilis (Dana, 1846)
          Acropora (Isopora) palifera (Lamarck, 1816)
          **Acropora pulchra* (Brook, 1891) (Agatti, Andrott, Bangaram)
          Acropora robusta (Dana, 1846)
          **Acropora selago* (Studer, 1878) (Agatti)
          **Acropora tenuis* (Dana, 1846) (Chetlat)
          Acropora teres (Verrill, 1866)
          **Acropora valida* (Dana, 1846) (Agatti, Kavaratti)
          Astreopora listeri Bernard, 1896
          Astreopora myriophthalma (Lamarck, 1816)
          **Astreopora ocellata* Bernard (1896) (Agatti)
          Montipora foliosa (Pallas, 1766)
          **Montipora foveolata* (Dana, 1846) (Agatti, Kiltan)
          Montipora tuberculosa (Lamarck, 1816)
          Montipora turgescens Bernard (1897)
          Montipora venosa (Ehrenberg, 1834)
      Suborder Fungiina Verrill (1865)
        Family Agariciidae Gray (1847)
          Gardineroseris planulata (Dana, 1846)
          **Pachyseris speciosa* (Lamarck, 1801) (Kavaratti)
          **Pavona decussata* (Dana, 1846) (Agatti)
          Pavona varians Verrill (1864)
          **Pavona venosa* (Ehrenberg, 1834) (Agatti)

Family Siderastreidae Vaugan & Wells (1943)
Psammocora contigua (Esper,1797)
Psammocora profundacella Gardiner (1898)
Family Fungiidae Dana (1846)
**Fungia (Verrillofungia) concinna* Verrill (1864) (Chetlat)
Fungia (Fungia) fungites (Linnaeus, 1758)
**Fungia (Danafungia) scruposa* Klunzinger (1879) (Bangaram)
Fungia (Pleuractis) scutaria Lamarck (1801)
Family Poritidae Gray (1842)
**Goniopora lobata* Edwards & Haime (1860) (Agatti, Bitra)
Goniopora stokesi Edwards & Haime (1851)
**Porites compressa* Dana (1846) (Agatti, Bangaram, Kalpeni)
**Porites lichen* Dana (1846) (Agatti, Kavaratti, Chetlat, Kiltan)
Porites lutea Edwards & Haime (1860)
Porites minicoiensis Pillai (1967)
**Porites nigrescens* Dana (1848) (Agatti, Kavaratti)
Porites solida (Forsskal, 1775)
Porites (Synarea) convexa Verrill (1864)
Suborder Faviina Vaughan & Wells (1943)
Family Faviidae Gregory (1900)
Cyphastrea microphthalma (Lamarck, 1816)
Cyphastrea serailia (Forsskal, 1775)
Diploastrea heliopora (Lamarck, 1816)
Echinopora lamellosa (Esper, 1795)
Favia ?favus (Forsskal, 1775)
Favia pallida (Dana, 1846)
Favites abdita (Ellis & Solander, 1786)
Favites complanata (Ehrenberg, 1834)
Favites flexuosa (Dana, 1846)
**Favites russelli* (Wells, 1954) (Agatti, Kavaratti)
**Goniastrea aspera* Verrill (1865) (Agatti)
**Goniastrea edwardsi* Chevalier (1971) (Agatti, Kalpeni, Minicoy)
Goniastrea pectinata (Ehrenberg, 1834)
Goniastrea retiformis (Lamarck, 1816)
Leptastrea purpurea (Dana, 1846)
Leptastrea transversa Klunzinger (1879)
Leptoria phrygia (Ellis & Solander, 1786)
**Montastrea curta* (Dana, 1846) (Agatti, Chetlat)
**Montastrea magnistellata* Chevalier (1971) (Agatti)
Montastrea valenciennesi (Edwards & Haime, 1848) (Agatti)
Platygyra daedalea (Ellis & Solander, 1786)
Platygyra lamellina (Ehrenberg, 1834)
Platygyra sinensis (Edwards & Haime, 1849)
Family Oculinidae Gray (1847)
**Galaxea astreata* (Lamarck, 1816) (Agatti)
Galaxea fascicularis (Linnaeus, 1767)
Family Merulinidae Verrill (1866)
**Hydnophora exesa* (Pallas, 1766) (Agatti)
Hydnophora microconos (Lamarck, 1816)
Family Mussidae Ortmann (1890)
Acanthastrea echinata (Dana, 1846)

Lobophyllia corymbosa (Forsskal, 1775)
Symphyllia radians Edwards & Haime (1849)
Symphyllia nobilis (Dana, 1846)
Suborder Caryophylliina Vaughan & Wells (1943)
Family Caryophylliidae Gray (1847)
Euphyllia glabrescens (Chamisso & Eysenhadt, 1821)
**Paracyathus* sp. (Agatti)
Suborder Dendrophylliina Vaugan & Wells (1934)
Family Dendrophylliidae Gray (1847)
Tubastrea aurea (Quoy & Gaimard, 1833)
**Tubastrea micranthus* Ehrenberg (1834) (Kadmat)
**Turbinaria frondens* (Dana, 1846) (Agatti)
Turbinaria mesenterina (Lamarck, 1816)
Order Stolonifera Hickson (1833)
Family Tubiporidae Ehrenberg (1828)
Tubipora musica Linnaeus (1758)
Order Coenothecalia Bourne (1895)
Family Helioporidae Mosely (1876)
Heliopora coerulea (Pallas, 1766)
Class Hydrozoa Owen (1843)
Order Milleporina Hickson (1901)
Family Milleporidae Fleming (1828)
Millepora exesa (Forsskal, 1775)
Millepora dichotoma (Forsskal, 1775)
Millepora platyphylla Hemprich & Ehrenberg (1834)

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* indicates new distribution records for Lakshadweep

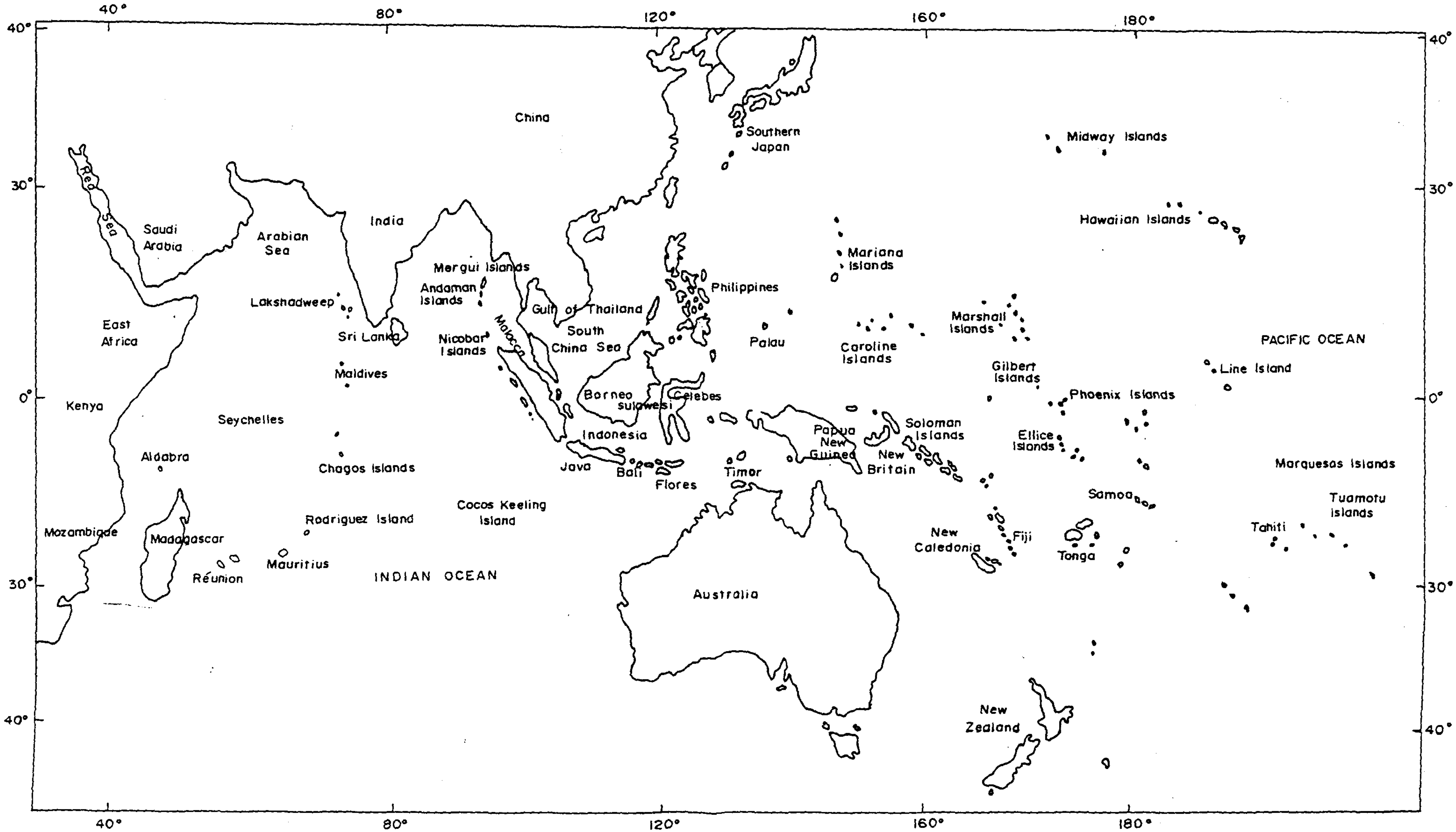

Fig. 2.1 Map of the Indo-Pacific region.

2.3.1. ***Acropora austera*** (Dana, 1846) (Plate2.1, Photo 1-2)

Specimens Examined: Bangaram 2; Kadmat 2; Minicoy 1; Kalpeni 1.

Synonymy

Madrepora austera Dana (1846); Brook (1893)

Madrepora multiramosa Nemenzo (1967)

Madrepora scherzeriana Brueggemann; not Brueggemann (1877a,b); Brook (1893)

Acropora austera (Dana, 1846); Verrill (1902); Faustino (1927); Wallace (1978); Veron & Wallace (1984)

Colonies are arborescent with very thick branches measuring about 4cm in thickness.

Axial corallites are thick walled, about 4mm in diameter and up to 3mm exert. Radial corallites show a wide range in size, shape and orientation. They are appressed to tubular, the former with nariform openings. The coenosteum is coarse and spongy.

Living colonies are brown to creamish in colour and this species is usually encountered in lagoons.

Distribution: Red Sea, Saudi Arabia and Australia.

2.3.2. ***Acropora cerealis*** (Dana, 1846) (Plate2.1, Photo 3-4)

Specimens Examined: Agatti 1; Chetlat 1.

Synonymy

Madrepora cerealis Dana (1846); Brook (1893)

Madrepora hystrix Dana (1846); Brook (1893)

Madrepora tizardi Brook (1892, 1893)

Acropora cerealis (Dana, 1846); Faustino (1927); Nemenzo (1967); Wallace (1978); Veron & Wallace (1984)

Acropora hystrix (Dana, 1846); Wells (1954)

Acropora tizardi (Brook, 1893); Wells (1954); Zou (1975)

Colonies are caespitose to caespito-corymbose with the branches approximately 10mm thick.

Axials are not more than 1mm exert and about 2mm thick. Radials are strongly appressed at the base of the branch becoming tubo-nariform at the tips. Radials are 1-1.5mm in diameter. Immersed corallites are present in between larger corallites.

This species was collected from lagoons at Chetlat and Agatti. Colonies are creamish in colour when live.

Distribution: Maldives, Philippines, Marshall Islands, Indonesia, Tonga and Australia.

2.3.3. ***Acropora ?millepora*** (Ehrenberg, 1834) (Plate2.1, Photo 5-6)

Specimens Examined: Agatti 2.

Synonymy

Heteropora millepora Ehrenberg (1834)

?*Madrepora convexa* Dana (1846); Brook (1893)

Madrepora millepora (Ehrenberg, 1834); Brook (1893)

?*Madrepora prostrata* Dana (1846)

Madrepora spathulata Brook (1891, 1893)

Madrepora squamosa Brook (1892, 1893)

Acropora librata Nemenzo (1967)

Acropora millepora (Ehrenberg, 1834); Verrill (1902); Thiel (1932); Nemenzo (1967); Wallace (1978); Veron & Wallace (1984)

?*Acropora prostrata* (Dana, 1846); Faustino (1927); Wells (1954)

Acropora sarmentosa (Brook), not Brook (1892); Vaughan (1918)

Acropora singularis Nemenzo (1967)

Acropora squamosa (Brook); Vaughan (1918); Matthai (1923); Crossland (1952); Stephenson & Wells (1955); Pillai (1967e)

The colony was corymbose with a side attachment bearing short branches.

Axial corallites are 2-4mm in diameter and slightly exert with six primary septa, well discernible. Radial corallites are usually subimmersed to immersed. Walls of both axial and radial corallites are spinulose.

Of the two specimens collected and examined, one of them is part of a young colony and hence its identity could not be conclusively ascertained. Perhaps, it is only an ecomorph of *A. corymbosa*.

Specimens were collected from the reef flat at Agatti.

Distribution: Gulf of Mannar, Andaman, Sri Lanka, Maldives, Thailand and Australia.

2.3.4. ***Acropora pulchra*** (Brook, 1891) (Plate2.1, Photo 7-8)

Specimens Examined: Agatti 6; Bangaram 1; Andrott 1.

Synonymy

Madrepora pulchra Brook (1891, 1893)

Acropora pulchra (Brook); Vaughan (1918); not Crossland (1952); Stephenson & Wells (1955); ?Nemenzo (1967); Chevalier (1968); Zou (1975); Wallace (1978); Veron & Wallace (1984)

Colonies are arborescent, usually with thin branches.

Axial corallites are 1-2mm exert and 2-3mm in diameter. Radials are of mixed sizes with the upper wall not developed and the lower wall lip like. Openings of the corallites may be nariform or dimidiate. The directive septa are prominent. Corallites are costate with a porous coenosteum in between made up of flattened spinules.

Specimens were collected from reef flats as well as from lagoons. Live colonies are brownish in colour, paler at the tips.

Distribution: Cocos-Keeling Islands, Mozambique, Reunion and Australia.

2.3.5. ***Acropora selago*** (Studer, 1878) (Plate2.2, Photo 1-2)

Specimen Examined: Agatti 1.

Synonymy

Madrepora delicatula Brook (1891, 1893)

Madrepora selago Studer (1878)

Acropora delicatula (Brook, 1891); Wells (1954), not Stephenson & Wells (1955); Wallace (1978); Veron & Wallace (1984)

Colonies are caespito-corymbose bearing main branches less than 1cm thick and giving rise to small branchlets.

Axials are less than 1.5mm exert and 1.8-2mm thick. Radials are neatly arranged, ascending, dimidiate, with flaring outer lips.

Live colonies are brown in colour. The specimen was collected from the reef flat.

Distribution: Sri Lanka, Marshall, Solomon Islands and Australia.

2.3.6. ***Acropora tenuis*** (Dana, 1846) (Plate2.2, Photo 3-4)

Specimen Examined: Chetlat 1.

Synonymy

?Madrepora africana Brook (1893)

Madrepora bifaria Brook (1892, 1893) *Madrepora kenti* Brook (1892, 1893)

Madrepora macrostoma Brook (1891, 1893)

Madrepora tenuis Dana (1846); Brook (1893)

Acropora africana (Brook); Crossland (1948)

Acropora kenti (Brook); Wells (1954)

Acropora macrostoma (Brook); Crossland (1952); Nemenzo (1967)

Acropora plana Nemenzo (1967)

Acropora tenuis (Dana, 1846); Faustino (1927); Wallace (1978); Veron & Wallace (1984)

Colonies are caespito-corymbose with the main branches dividing into 2-3 branchlets, 8-10mm thick.

Axials are 1-2mm exert. Radial corallites are large, usually of one size, with wide openings. Corallites are 2-3mm thick at the base of the branches, becoming smaller towards the tips. A few immersed corallites are present on the lower parts of the bases.

Distribution: Widely distributed in the tropical Indo-Pacific; from Sri Lanka, Mauritius, Marshall Islands to Australia.

2.3.7. ***Acropora valida*** (Dana, 1846) (Plate2.2, Photo 5-6)

Specimens Examined: Agatti 1; Kavaratti 1.

Synonymy

Madrepora coalescens Ortmann (1889); Brook (1893)

Acropora concinna (Brook); Verrill (1902); Searle (1956)

Acropora dissimilis (Verrill, 1902); Faustino (1927); Nemenzo (1967); Zou (1975)

?Madrepora rousseauii Edwards & Haime (1860); Brook (1893)

Madrepora valida Dana (1846); Brook (1893)

Madrepora variabilis Klunzinger (1879); Brook (1893)

Acropora dissimilis Verrill (1902)

Acropora rousseauii (Edwards & Haime, 1860); Marenzeller (1907)

Acropora valida (Dana, 1846); Verrill (1902); Hoffmeister (1925); Wells (1954); Nemenzo (1967); Zou (1975); Grigg *et al.* (1981); Veron & Wallace (1984)

Acropora variabilis (Klunzinger, 1879); Verrill (1902); Marenzeller (1907); Vaughan (1918); Matthai (1923); Faustino (1927); Wells (1950, 1955); Crossland (1952); Rossi (1954); Stephenson & Wells (1955); Searle (1956); Scheer (1964b); Chevalier (1968); Scheer & Pillai (1974); Pillai & Scheer (1976); Wallace (1978)

Colonies form compact bushes with the branches about 8mm thick at their tips.

Axial corallites are 2mm thick and 1-2mm exert. Radials are strongly appressed with oval to nariform openings.

Specimens were collected from the reef flat. Colonies are usually creamish in colour when live.

Distribution: West coast of India, Gulf of Mannar, Andamans, Sri Lanka, Maldives, Red Sea, Hawaii and Australia

Genus *Astreopora* Blainville (1830)

Type species: *Astrea myriophthalma* Lamarck (1816)

2.3.8. ***Astreopora ocellata*** Bernard (1896) (Plate2.2, Photo 7-8)

Specimen Examined: Agatti 1.

Synonymy

Astraeopora ocellata Bernard (1896) *Astreopora ocellata* Bernard (1896); Mayer (1918); Vaughan (1918); Yabe & Sugiyama (1941); Wells (1954); Pillai & Scheer (1976); Veron & Wallace (1984)

Astraeopora ovalis and *Astraeopora kenti* Bernard (1896)

Colonies are massive, cushion shaped or flattened. Calices are large, up to 4mm in diameter, with thick rounded openings. Smaller sized corallites are seen between the large corallites.

The specimen was collected from the reef flat. When live, the colony is brown in colour.

Distribution: Maldives, Chagos, Palau Island and Australia.

Genus *Montipora* Blainville (1830)

Type species: *Porites verrucosa* Lamarck (1816)

2.3.9. ***Montipora foveolata*** (Dana, 1846) (Plate2.3, Photo 1)

Specimens Examined: Agatti 3; Kiltan 1.

Synonymy

Manopora foveolata Dana (1846)

Montipora foveolata (Dana, 1846); Edwards & Haime (1851a); Quelch (1886); Whitelegge (1898); Gardiner (1898); Bernard (1897); Crossland (1952); Wells (1954); Ma (1959); Nemenzo (1967); Veron & Wallace (1984)

Montipora socialis Bernard (1897); Gardiner (1898); Crossland (1952); Wells (1954)

Corallum is massive with the surface coenochyme raised into foveolations. The thecal pappilae that form the rim of the thecae may or may not completely encircle the calices. Calice openings are 1-2mm in diameter. Two cycles of septa are clearly discernible. The ends of the primary septa fuse at the calice centre. Septa are reduced to spines. The coenosteum is made up of spinules. Those on the thecal pappillae have highly elaborate tips.

Distribution: Distributed throughout the central and western Pacific including Australia.

Suborder Fungiina Verrill (1865)

Family Agariciidae Gray (1847)

Genus *Pachyseris* Edwards & Haime (1849)

Type species: *Agaricia rugosa* Lamarck (1801)

2.3.10. ***Pachyseris speciosa*** (Lamarck, 1801) (Plate2.3, Photo 2)

Specimen Examined: Kavaratti 1.

Synonymy

Agaricia speciosa Dana (1846)

Agaricia levicollis Dana (1846)

Pachyseris clementei Nemenzo (1955)

Pachyseris involuta Studer (1878); Horst (1921)

Pachyseris levicollis Horst (1922a); Hoffmeister (1925); Scheer & Pillai (1974); Pillai & Scheer (1976)

Pachyseris speciosa (Dana, 1846); Edwards & Haime (1851b, 1860); Studer (1881); Duncan (1884); Quelch (1886); Ortmann (1888); Vaughan (1918); Horst (1921); Matthai (1924, 1948a); Hoffmeister (1925); Yabe *et al.* (1936); Eguchi (1938); Crossland (1952); Wells (1954); Pichon (1964); Chevalier (1968); Scheer (1972); Scheer & Pillai (1974, 1983); Veron & Pichon (1980); Head (1980)

A small dead colony was found washed ashore at Kavaratti.

The specimen was plate-like, approximately 10mm thick. The calices run parallel to each other with the distance from centre to centre ranging from 2-3mm. Septo-costae are confluent between the centres, heavily granulated. Most septo-costae cannot be differentiated into orders except in some region where two orders are distinguishable. Columella is well developed, solid and discontinuous.

Distribution: Nicobar, Maldives, Chagos, Red Sea, Aldabra, E. Africa, Marshall Islands, Cargados (Mauritius), Saya de Malha (Seychelles), Mergui, Indonesia, Philippines, Palau Island, Samoa, Tahiti and Australia.

Genus *Pavona* Lamarck (1801)

Type species: *Madrepora cristata* Ellis & Solander (1786)

2.3.11. ***Pavona decussata*** (Dana, 1846) (Plate2.3, Photo 3-4)

Specimens Examined: Agatti 5.

Synonymy

Lophoseris cristata Edwards & Haime (1860)

Pavonia angularis Klunzinger (1879); Marenzeller (1906)

Pavonia crassa Dana (1846); Matthai (1924)

Pavonia decussata Dana (1846); Quelch (1886); Bedot (1907)

Pavonia lata Dana (1846); Matthai (1924)

Pavona crassa Dana (1846)

Pavona decussata (Dana); Horst (1922a,b); Matthai (1924, 1948b); Hoffmeister (1925); Faustino (1927); Yabe *et al.* (1936); Umbgrove (1940); Crossland (1952); Stephenson & Wells (1955); Nemenzo (1955); Utinomi (1965, 1971); Scheer (1967); Loya & Slobodkin (1971); Pillai & Scheer (1973); Veron & Pichon (1980); Head (1980); Scheer & Pillai (1983); Pillai (1986b)

Pavona lata Dana (1846); Pillai & Scheer (1974)

Pavona seriata Brueggemann (1879); Yabe *et al.* (1936)

Colonies are either encrusting, massive or foliaceous.

Calices are deep, in close proximity to each other and usually arranged in rows with the distance between the adjacent rows ranging from 1-3mm. Septa are arranged in two cycles and heavily granulated. Columella is poorly developed, styliform.

Live colonies are cream :h in colour. Specimens were collected from the reef flat.

Distribution: Gulf of Mannar, Andaman & Nicobar, Sri Lanka, Red Sea, Saudi Arabia, Kenya, Tulear, Mauritius, Rodriguez Island, Cocos Keeling, Mergui Archipelago, Thailand, Australia and Samoa.

2.3.12. ***Pavona venosa*** (Ehrenberg, 1834) (Plate2.3, Photo 5-6)

Specimens Examined: Agatti 2.

Synonymy

Polyastra venosa Ehrenberg (1834)

Pavonia calcifera Gardiner (1898)

Tichoseris obtusata Quelch (1884)

Pavona (Polyastra) obtusata (Quelch); Wells (1936); Umbgrove (1940); Nemenzo (1955); Stephenson & Wells (1955); Scheer (1964b)

Pavona (Polyastra) venosa (Ehrenberg, 1834); Wells (1936); Nemenzo (1955)

Pavona venosa (Ehrenberg, 1834); Veron & Pichon (1980)

Corallum is massive, encrusting or columnar.

Calices are arranged in valleys or placed in groups. Three orders of septa are present. Septa are granulated on the sides and bear dentate margins. Columella is absent or poorly developed.

Specimens were collected from the reef flat.

Distribution: Sri Lanka, Chagos, Red Sea, Saudi Arabia, Kenya, Reunion, Thailand, Indonesia, Australia, Celebes, Marshall Islands and several other Pacific Islands.

Family Fungiidae Dana (1846)

Genus *Fungia* Lamarck (1801)

Type species: *Madrepora fungites* Linnaeus (1758)

2.3.13. ***Fungia (Verrillofungia) concinna*** Verrill (1864) (Plate2.3, Photo 7-8)

Specimen Examined: Chetlat 1.

Synonymy

Fungia agariciformis Dana (1846)

Fungia concinna Verrill (1864); Quelch (1886); Doederlein (1902); Gardiner (1909); Vaughan (1918); Horst (1921); Boschma (1925); Faustino (1927); Hoffmeister (1929); Thiel (1932); Umbgrove (1939, 1940); Yabe & Sugiyama (1941); Wells (1954); Nemenzo (1955); Stephenson & Wells (1955); Scheer & Pillai (1974, 1983); Veron & Pichon (1980); Head (1980)

?Fungia granulosa Vaughan (1906)

Fungia patella Verrill (1864)

Fungia plana Studer (1878); Quelch (1886); Doederlein (1902); Gravier (1907, 1911); Marenzeller (1907); Yabe & Sugiyama (1935)

Fungia serrulata Verrill (1864)

The corallum is circular and convex measuring 13cm in length.

Lower order septa are exert, approximately 1mm thick near the central fossae and show small triangular dentations. Higher order septa show lobed dentations. The sides of the septa show minute conical spines. Costae are unequal. The major ones decrease in size towards the centre. They have a hirsute appearance and tend to bifurcate at the tips. The corallum is imperforate.

Distribution: Andaman and Nicobar Islands, Chagos, Red Sea, Kenya, Mozambique, Thailand, Australia and Tuamotu Archipelago.

2.3.14. ***Fungia (Danafungia) scruposa*** Klunzinger (1879) (Plate2.4, Photo 1-2)

Specimen Examined: Bangaram 1.

Synonymy

Fungia scruposa Klunzinger (1879); Doederlein (1902); Marenzeller (1907); Horst (1921); Matthai (1924); Yabe & Sugiyama (1935, 1941); Rossi (1956); Schuhmacher (1979); Veron & Pichon (1980); Head (1980); Scheer & Pillai (1983)

A single specimen belonging to this species was collected from the Bangaram lagoon.

The corallum measured 8cm in greatest breadth and was perforate. Lower order septa are markedly exert at the centre and at the periphery. The septa are large dentations with pointed tips. All septa are heavily granulated. Higher order septa do not form costae and can be traced at the periphery of the corallum. The two to three orders of septa are made up of slender spines. Spines are either single or bifurcate at the tips. Unlike *F. fungites* with which this species is usually confused, the sides of the costae bear spinules. Columella is trabecular.

Distribution: Red Sea, Chagos and Australia.

Family Poritiidae Gray (1842)

Genus *Goniopora* Blainville (1830)

Type species: *Goniopora pedunculata* Quoy & Gaimard (1833)

2.3.15. ***Goniopora lobata*** Edwards & Haime (1860) (Plate2.4, Photo 3-4)

Specimens Examined: Agatti 6; Bitra 1.

Synonymy

Goniopora columna Dana (1846); *sensu* Scheer & Pillai (1974)

?*Goniopora hirsuta* Crossland (1952)

Goniopora lobata Edwards & Haime (1860); Duncan (1889); Bernard (1903); Bedot (1907); Vaughan (1907, 1918); Hoffmeister (1925); Crossland (1948, 1952); Wells (1955); Stephenson & Wells (1955); Searle (1956); Veron & Pichon (1982)

?*Goniopora traceyi* Wells (1954)

Colonies are massive and hemispherical.

Calices are rounded or polygonal, 3mm in diameter, with porous walls. Septa are arranged in three cycles. The septal edges are dentate and sides are granular. The peritheca is thick and porous. Columella consists of a few twisted trabeculae.

Specimens were collected from the reef flats as well as from lagoons. When live colonies are brownish in colour.

Distribution: Gulf of Mannar, Sri Lanka, Maldives, Red Sea, Saudi Arabia, Eastern Africa, Seychelles, Reunion, Mauritius, Rodriguez Island, Thailand, Australia, Mergui Archipelago, Fiji and Samoa.

Genus *Porites* Link (1807)

Type species: *Porites polymorphus* Link (1807) = *P. porites* Pallas (1766)

2.3.16. ***Porites compressa*** Dana (1846) (Plate2.4, Photo 5-6)

Specimens Examined: Agatti 1; Bangaram 1; Kalpeni 1.

Synonymy

Porites compressa Dana (1846); Vaughan (1907); Nemenzo (1955); Pillai (1967f, 1986b); Pillai & Scheer (1973, 1974); Scheer & Pillai (1983); Pillai & Patel (1988)

Colonies are branched with the branches 3-4cm long and 10-25mm thick at the base.

Calices are polygonal, approximately 1.6-2mm in diameter, with thin walls made up of frosted denticles. The pali are well developed. The ventral triplet is not fused into a trident. A single denticle is seen on the upper margin of the septa.

Columella is a compressed plate flattened in the direction of the directive septa.

Distribution: Gulf of Kachchh, Gulf of Mannar, Red Sea, Arabian Gulf, Strait of Malacca, Philippines, Palau, Hawaii, Mascarene Islands and Mozambique.

2.3.17. ***Porites nigrescens*** Dana (1848) (Plate2.4, Photo 7-8)

Specimens Examined: Agatti 2; Kavaratti 1.

Synonymy

`*Porites* Fiji 8'; Bernard (1905)

Porites nigrescens Dana (1848); Edwards & Haime (1851a, 1860); Rathburn (1887); Rehberg (1892); Bernard (1905); Vaughan (1918); Faustino (1927); Yabe & Sugiyama (1932, 1935); Eguchi (1938); Umbgrove (1940); Nemenzo (1955); Searle (1956); Ma (1959); Pichon (1964, 1978); Zou (1975); Faure (1977)

Porites saccharata Brueggemann (1878); Studer (1881); Ortmann (1888); Bernard (1905)

`*Porites* Singapore 7' Bernard (1905)

Porites suppressa Crossland (1952); Scheer & Pillai (1974)

`*Porites* Tonga 10' Bernard (1905)

Colony is free, ramose with short, anastomosing branches which are constricted at their base and broadened at their tips.

Calices are about 1mm in diameter and separated from each other by a thin ridge made up of mural denticles which are finely echinulate. A single denticle is present between the wall and the pali. Columella is in the form of a style. Septal denticles and columella appear frosted due to the presence of echinulations similar to those on the mural denticles. This species was usually encountered in lagoons.

Distribution: Andaman and Nicobar Islands, Red Sea, Saudi Arabia, Chagos, Kenya, Mozambique, Tulear, Aldabra, Seychelles, Reunion, Mauritius, Cocos Keeling, Thailand, Madagascar, Mascarene Islands, South China Sea, Fiji and Tonga.

2.3.18. ***Porites lichen*** Dana (1846) (Plate2.5, Photo 1)

Specimens Examined: Agatti 2; Kavaratti 1; Chetlat 1; Kiltan 1.

Synonymy

Porites lichen Dana (1846); Quelch (1886); Rathburn (1887); Whitelegge (1898); Bernard (1905); Vaughan (1907, 1918); Yabe & Sugiyama (1932, 1935); Wells (1954); Scheer (1964a); Wells & Davies (1966); Eguchi (1968); Pillai & Scheer (1976); Pillai (1986b); Veron & Pichon (1982)

Goniopora? lichen Edwards & Haime (1851a, 1860)

Goniopora lichen Klunzinger (1879)

'*Porites* Ellice Islands' Bernard (1905)

Porites eridani Umbgrove (1940); Pillai & Scheer (1974)

'*Porites* Fiji 16, 17, 18' Bernard (1905)

'*Porites* Great Barrier Reef 32' Bernard (1905)

Porites klunzingeri Marenzeller (1907)

Porites purpurea Gardiner (1898); Bernard (1905); Yabe & Sugiyama (1932, 1935)

Porites reticulosa Dana (1846); Rathburn (1887); Bernard (1905); Vaughan (1907); Chevalier (1968)

Porites viridis Gardiner (1898); Bernard (1905); Vaughan (1918); Eguchi (1938); Umbgrove (1940)

Colonies are encrusting. The surface of the corallum is irregular and hillocky.

Calices average 1mm in diameter with the walls about 0.5-1mm thick. Pali are weakly to well developed with these variations occurring in the same corallum. The ventral directive septum is free or fused. The palar synapticular ring is well developed.

The columella is either present, in the form of a single style fused to the septa by radii, or absent.

This species was recorded on reef flats as well as in lagoons.

This species was recorded on reef flats as well as in lagoons.

Distribution: Widely distributed throughout the tropical Indo-Pacific; from the Gulf of Kachchh, west coast of India, Gulf of Mannar, Maldives, Red Sea, Ellice, Marshall Islands, Fiji, Samoa to Australia.

Suborder Faviina Vaughan & Wells (1943)

Family Faviidae Gregory (1900)

Genus *Favites* Link (1807)

Type species: *Favites astrinus* Link (1807)

2.3.19. ***Favites russelli*** (Wells, 1954) (Plate2.5, Photo 2)

Specimens Examined: Agatti 1; Kavaratti 1.

Synonymy

Favites rufa.Wijsman-Best (1972, 1976)

Plesiastrea russelli Wells (1954)

Favites russeli Veron *et al.* (1977)

The corallum is submassive with cerioid corallites.

Corallites are either round or slightly polygonal with thick theca, 4-7mm in diameter. Septa are arranged in three orders. Primary septa show well developed paliform lobes which are separated from the septa by a deep notch. Septa exhibit regular fan shaped dentations. All septa are granular. Septa are adjoined over the thecae, with the primary septa becoming secondary in the adjacent corallites. The columella is spongy.

Specimens were collected from the reef flat. Live colonies display a gray colouration.

Distribution: Marshall Islands, New Caledonia, Indonesia and Australia.

Genus *Goniastrea* Edwards & Haime (1848)

Type species: *Astrea retiformis* Lamarck (1816)

2.3.20. ***Goniastrea aspera*** Verrill (1865) (Plate2.5, Photo 3)

Specimen Examined: Agatti 1.

Synonymy

Prionastraea spectabilis Verrill (1872) = *Astraea (Fissicella) magnifica* Dana (1846)

Favites aspera Verrill (1865)

Favites spectabilis Verrill (1865)

Goniastrea aspera Verrill (1865); Yabe & Sugiyama (1935); Yabe *et al.* (1936); Eguchi (1938); Veron *et al.* (1977)

Goniastrea equisepta Nemenzo (1959)

Goniastrea incrustans Duncan (1889); Matthai (1924); Foidart (1971); Chevalier (1971)

Goniastrea mantonae Crossland (1952); Stephenson & Wells (1955); Nemenzo (1959); Foidart (1971)

Goniastrea spectabilis (Verrill, 1872); Wijsman-Best (1972)

Corallum is encrusting with the cerioid calices having a cellular appearance.

Calices are 6.5-9mm in diameter. Septa are arranged in two alternating cycles. Primary septa have paliform lobes that descend vertically. Secondary septa are present as ridges down the walls. Septa have dentate margins and granular sides.

Columella is compact and spongy. Adjacent septa are not continuous over the walls.

Distribution: Sri Lanka, Mozambique, Reunion, Mauritius, Rodriguez Island, Mergui

Archipelago, Thailand, Indonesia, Philippines, Australia, Palau and New Caledonia.

2.3.21. ***Goniastrea edwardsi*** Chevalier (1971) (Plate2.5, Photo 4-5)

Specimens Examined: Agatti 3; Kalpeni 1; Minicoy 1.

Synonymy

Astraea parvistella Dana (1846)

Goniastrea edwardsi Chevalier (1971); Wijsman-Best (1976); Veron *et al.* (1977)

Goniastrea parvistella (Dana); *sensu* Vaughan (1918); Yabe & Sugiyama (1935); Yabe *et al.* (1936); Nemenzo (1959); Foidart (1970a, 1970b, 1972); Wijsman-Best (1972)

Goniastrea solida (*pars*); Edwards & Haime (1848); (*pars*) Edwards & Haime (1857); Gardiner (1899, 1904); Matthai (1914)

Colonies massive.

Calices are polygonal and exhibit a neat cellular arrangement. Calices are of an even size, 3-7mm in diameter. Septa are arranged in three distinct orders. The first order septa are slightly exert, reach the columella and develop prominent paliform lobes. Second order septa run deep within the calice and do not fuse with the columella. The theca is thin and shows the presence of a ridge.

Pillai (1983a) considered *G. edwardsi* to be a synonymy of *G. retiformis*. During the present surveys, these two species occurred in the same biotope, suggesting that they are distinct species. They are thus treated separately.

Distribution: Sri Lanka, Red Sea, Mozambique, Seychelles, Chagos, Thailand, Australia and Loyalty Islands.

Genus *Montastrea* Blainville (1830)

Type species: *Astrea guettardi* Defrance (1826)

2.3.22. ***Montastrea curta*** (Dana, 1846) (Plate2.5, Photo 6-7)

Specimens Examined: Agatti 1; Chetlat 1.

Synonymy

Orbicella curta Dana (1846); Gardiner (1899, 1904); Vaughan (1917, 1918); Hoffmeister (1925); Yabe & Sugiyama (1935); Yabe *et al.* (1936); Eguchi (1938); Umbgrove (1940); Crossland (1952)

Orbicella coronata Dana (1846); Gardiner (1899)

Astraea lamarckiana Edwards & Haime (1849)

Astraea 'laperousiana Edwards & Haime (1849)

Astraea solidior Edwards & Haime (1849); Gardiner (1899); Matthai (1914)

Astraea quadrangularis Edwards & Haime (1849)

Orbicella funafutensis Gardiner (1899)

Orbicella rotumana Gardiner (1899)

Orbicella vacua Crossland (1952)

Orbicella wakayana Gardiner (1899); Matthai (1914)

Montastrea curta (Dana, 1846); Chevalier (1971); Wijsman-Best (1977); Veron *et al.* (1977)

Corallum is masssive with irregularly distributed plocoid or ploco-cerioid corallites.

Corallites are rounded, 5-12mm in diameter. Septa are arranged in three orders. The first order septa have irregular dentations that increase in size towards the columella. The inner dentations give rise to one or two paliform lobes. Second and third order septa do not reach the columella. The sides of the septa as well their dentations are heavily granulated. Costae are unequal and correspond to the septa.

Columella is made up of loosely entangled trabeculae.

Distribution: Sri Lanka, Red Sea, Saudi Arabia, Thailand, Tulear, Chagos, Reunion, Mauritius, Madagascar, Tuamotu and Australia.

2.3.23. ***Montastrea magnistellata*** Chevalier (1971) (Plate2.5, Photo 8)

Specimens Examined: Agatti 2.

Synonymy

Montastrea magnistellata Chevalier (1971); Wijsman-Best (1977); Veron *et al.* (1977)

Colonies are encrusting or massive.

Corallites are plocoid, large, 7-12mm in diameter. Septa are arranged in two orders, with large septal dentations. Second order septa are reduced and discernible as ridges down the thecae. Primary septa bear dentations that increase in size towards the centre where they form one or more paliform lobes.

Columella is trabecular or spongy. Costae are unequal and dentate. Both septa and costae show dentations on their sides.

Living colonies are greenish in colour.

Distribution: Red Sea, Seychelles, Thailand, Indonesia, New Caledonia and Australia.

Family Oculinidae Gray (1847)

Genus *Galaxea* Oken (1815)

Type species: *Madrepora fascicularis* Linnaeus (1767)

2.3.24. ***Galaxea astreata*** (Lamarck, 1816) (Plate2.6, Photo 1-2)

Specimens Examined: Agatti 2.

Synonymy

Anthophyllum clavus Dana (1846)

Anthophyllum musicale (Linnaeus, 1767); Dana (1846)

Caryophyllia astreata Lamarck (1816)

?*Madrepora musicalis* Linnaeus (1767)

Sarcinula organum Lamarck (1816)

Galaxea astreata (Lamarck, 1816); Chevalier (1971); Scheer & Pillai (1983);

Galaxea cf astreata Veron & Pichon (1980)

Galaxea clavus Dana (1846); Edwards & Haime (1857); Vaughan (1918); Faustino (1927); Crossland (1952); Chevalier (1971); Pillai (1986b)

Galaxea lamarcki Edwards & Haime (1857); Klunzinger (1879); Matthai (1914); Pillai & Scheer (1976)

Galaxea musicalis (Linnaeus); Edwards & Haime (1857); Matthai (1914); Thiel (1932); Yabe *et al.* (1936)

Colonies are encrusting or massive.

Corallites are circular or oval, 3-6mm in diameter, up to 4mm exert and 2-4mm apart. Septa are arranged in three cycles. Up to 28 septa are seen in most calices. About 12 septa reach the columella, the latter being made up of a solid mass or a few dentations. Costae corresponding to the septa can be traced up to the base of the corallite.

The coenosteum is finely blistered with vesicles in between.

This species was encountered on the reef flat.

Distribution: Gulf of Mannar, Andaman & Nicobar, Maldives, Sri Lanka, Red Sea, Saudi Arabia, Chagos, Tulear, Seychelles, Mauritius, Mergui Archipelago, Thailand, Australia, Samoa and Fiji.

Family Merulinidae Verrill (1866)

Genus *Hydnophora* Fischer de Waldheim (1807)

Type species: *Hydnophora demidovii* Fischer de Waldheim (1807)

2.3.25. ***Hydnophora exesa*** (Pallas, 1766) (Plate2.6, Photo 3-4)

Specimens Examined: Agatti 8.

Synonymy

Merulina folium (Lamarck, 1816); Dana (1846)

Madrepora exesa Pallas (1766); (*pars*); *non* Ellis & Solander (1786); Esper (1789)

Monticularia exesa (Pallas, 1766); Schweigger (1820)

Monticularia folium Lamarck (1816); Blainville (1830, 1834)

Monticularia microcons Lamarck (1816)

Monticularia meandrina Lamarck (1816)

Hydnophorella exesa (Pallas, 1766); (*pars*) Bedot (1907)

Hynophorella microcons (Lamarck, 1816); *non* Gravier (1911)

Hydnophora contignatio (Forskal); Klunzinger (1879); Marenzeller (1907); Matthai (1928, 1948b); Umbgrove (1939)

Hydnophora demidovii Fisher de Waldheim (1807, 1830-1837); Edwards & Haime (1848, 1849, 1857); Quelch (1886)

Hydnophora ehrenbergi Edwards & Haime (1849, 1857)

Hydnophora exesa (Pallas, 1766); Verrill (1864); Studer (1881); Gardiner (1899); Matthai (1924, 1928, 1948b); Vaughan (1918); Faustino (1927); Yabe & Sugiyama (1935); Yabe *et al.*, 1936; Eguchi (1938); Umbgrove (1939); Searle (1956); Nemenzo (1959); Wijsman-Best (1972, 1976); Scheer & Pillai (1974, 1983); Mergner & Schuhmacher (1974); Chevalier (1975); Pillai & Scheer (1976); Veron *et al.* (1977); Head (1980); Pillai (1986b); Pillai & Patel (1988) *Hydnophora grandis* Gardiner (1904); Matthai (1928); Yabe *et al.* (1936)

Hydnophora gyrosa Edwards & Haime (1849, 1857)

Hydnophora lobata (Lamarck); Lamouroux (1821); Dana (1846); Edwards & Haime (1849, 1857); Klunzinger (1879); Gardiner (1899, 1904)

Hydnophora maldivensis Gardiner (1904)

Hydnophora pallassii Fisher de Waldheim (1807)

Hydnophora polygonata (Lamarck); Dana (1846); Edwards & Haime (1849, 1857)

Hydnophora tennella Quelch (1886); Matthai (1928); Umbgrove (1940)

Colonies are encrusting or laminar tending to be massive or columnar.

Monticules are well developed, conical or elongated. The height of the monticules is 5-7mm with a basal length of about 2-10mm. On some parts of the coralla, the monticules are long and sinuous. Adjacent monticules are 3-6mm apart.

6-12 septa reach the top of the colline. Edges of septa are finely dentate. Columella consist of twisted trabeculae.

Specimens were collected from the reef flat as well as from the lagoon. Live colonies are brownish in colour.

Distribution: Gulf of Kachchh, Gulf of Mannar, Andaman and Nicobar Islands, Sri Lanka, Maldives, Red Sea, Ellice Islands, Australia, Fiji and Samoa.

Suborder Caryophylliina Vaughan & Wells (1943)

Family Caryophylliidae Gray (1847)

Genus *Paracyathus* Edwards & Haime (1848)

Type species: *Paracyathus procumbens* Edwards & Haime (1848)

2.3.26. ***Paracyathus*** sp. (Plate2.6, Photo 5)

Specimen Examined: Agatti 1.

Corallites are solitary and cryptic in nature, usually found attached under dead coral boulders.

Corallites are 2.6-3mm in diameter and 1.8-2mm in height. Septa are arranged in three alternating orders. First order septa bear paliform lobes. All septa are heavily granulated. Columella is made up of papillae. Costae are unequal and granulated. They are discernible up to the base of the corallite wall.

Suborder Dendrophylliina Vaughan & Wells (1934)

Family Dendrophylliidae Gray (1847)

Genus *Tubastrea* Lesson (1834)

Type species: *Tubastrea coccinea* Lesson (1829)

2.3.27. ***Tubastrea micranthus*** (Ehrenberg, 1834) (Plate2.6, Photo 6)

Specimen Examined: Kadmat 1.

Synonymy

Coenopsammia micranthus Klunzinger (1879); Ortmann (1888)

Coenopsammia nigrescens Edwards & Haime (1860)

Dendrophyllia micranthus Horst (1922b, 1926); Crossland (1952); Rossi (1954); Scheer & Pillai (1974, 1983); Head (1980); Ditlev (1980)

Dendrophyllia nigrescens Dana (1846); Vaughan (1918)

Tubastrea micranthus Loya & Slobodkin (1971); Mergner & Schuhmacher (1974)

The single arborescent colony was collected by some fishermen from Kadmat Island. A portion of the colony had accidentally broken whilst fishing, being towed aboard, attached to the net.

Corallites are exert and somewhat arranged in rows. Main branches give rise to branchlets, formed by budding of mature corallites. The distance between adjacent corallites is 3-15mm. Septa are arranged in two orders. The walls of the corallites are costate. The septa have granular sides. Columella is made up of trabeculae.

The dead specimen (not cleaned) was blackish in colour.

Distribution: Nicobar Islands, Sri Lanka, Maldives, Red Sea, Seychelles, Aldalbra, Mauritius, Cocos-Keeling, Philippines, Japan, Palau, Fiji and the Great Barrier Reef.

Genus *Turbinaria* Oken (1815)

Type species: *Madrepora crater* Pallas (1766)

2.3.28. ***Turbinaria frondens*** (Dana, 1846) (Plate2.6, Photo 7-8)

Specimens Examined: Agatti 5.

Synonymy

Gemmipora frondens Dana (1846)

Turbinaria abnormalis Bernard (1896)

Turbinaria aurantiaca Bernard (1896)

?*Turbinaria contorta* Bernard (1896); Eguchi (1938, 1968); Yabe & Sugiyama (1941); Ma (1959); Utinomi (1965)

?*Turbinaria danae* Bernard (1896); Gardiner (1898); Wells (1955); Ma (1959)

Turbinaria edwardsi Bernard (1896); Ma (1959)

Turbinaria foliosa Bernard (1896); Yabe & Sugiyama (1941); Nemenzo (1962)

Turbinaria frondens Dana, (1846); (as *T. frondescens*) Edwards & Haime (1860); Bernard (1896); ?Gravely (1927); Crossland (1952); Stephenson & Wells (1955); Nemenzo (1962); Veron & Pichon (1982)

Turbinaria magna Bernard (1896); Ma (1959)

Turbinaria pustulosa Bernard (1896), Ma (1959); Nemenzo (1962)

?*Turbinaria ramosa* Yabe & Sugiyama (1941)

?*Turbinaria rugosa* Bernard (1896); Yabe & Sugiyama (1941); Ma (1959);

Eguchi (1968)

Colonies are either massive or encrusting.

Corallites are of irregular size and of various shapes. They are packed loosely together or up to 3mm apart. They are either immersed or approximately 4mm exert. Budding takes place at the periphery of the corallum. Corallites are 3-4mm in diameter. Septa are arranged in a single order. Some septa show bifurcation at the corallum wall. The columella is spongy and hemispherical.

Specimens were collected from the reef flat. Live colonies are brownish in colour.

Distribution: Red Sea, Saudi Arabia, Arabian Gulf, Chagos, Kenya, Tulear, Mauritius, Mergui Archipelago and Thailand.

2.4 CONCLUSIONS

The present surveys conducted on several islands in Lakshadweep revealed ninety six coral species spread over thirty four genera (Table 2.2). Of the thirty four genera reported, thirty two are hermatypic while two are ahermatypic. Twenty eight species recorded in the present study are reported for the first time from the Lakshadweep archipelago. The majority of new records belong to the family Acroporidae. Two new genera are reported from Lakshadweep: *Pachyseris* and *Paracyathus*, a hermatypic and an ahermatypic coral genus respectively. A third new genus *viz. Montastrea* reported in the present study has earlier been recorded in Lakshadweep by its synonym *viz. Favia valenciennesi*, by Pillai and Jasmine (1989).

Montastrea and *Plesiastrea* have been at the centre of a taxonomic debate due t their very close similarities. Vaughan and Wells (1943) and Wells (1956) consider

Montastrea as an Atlantic genus, absent in the Indo-Pacific. Chevalier (1971) opined that *Plesiastrea* has true pali and its polyps apparently lacked directive mesenteries, distinguishing it from *Montastrea*. He was of the view that *Montastrea* also occurs in the Indo-Pacific, a view that is more or less widely accepted and adopted in the present work. Further, Chevalier (1971) did not recognize any subfamilies within the Faviidae, such as Montastreinae and Faviinae, and remarked that in *Favia*, intra and extra-tentacular reproduction occurred. Typical examples are *Favia laxa* (Kluzinger), *Favites pentagona* (Esper) and *Montastrea valencennesi* (Edwards & Haimes) belonging to family Faviinae but displaying extra-tentacular budding. Due to the predominance of extra-tentacular budding, the latter species has been accordingly placed in the genus *Montastrea*.

Among the new records, 5 species *viz. Montipora foveolata*, *Fungia (Danafungia) scruposa*, *Favites russelli*, *Montastrea magnistellata* and *Turbinaria frondens* are reported from south Asia for the first time. Ten species are being reported from Indian waters for the first time (*Acropora austera*, *A. cerealis*, *A. pulchra*, *A. selago*, *A. tenuis*, *Astreopora ocellata*, *Pavona venosa*, *Porites nigrescens*, *Goniastrea edwardsi* and *Montastrea curta*). The large number of additional coral species recorded in the present study re-affirm the view that more extensive surveys are likely to reveal additional genera/ species.

Many genera, *viz. Alveopora*, *Cycloseris*, *Plesiastrea*, *Merulina*, *Caryophyllia*, *Stephanocyathus* and *Flabellum* reported by Pillai and Jasmine (1989) were not observed during the present surveys. Some of them, *e.g. Merulina*, *Caryophyllia*, *Stephanocyathus* and *Flabellum* reported by them are mainly from deep water collections made by Alcock (1898) and Gardiner (1903-1906) during their investigations in Lakshadweep. The inclusion of genera reported by these workers increases the number of documented genera in Lakshadweep to forty three. One of the controversial coral species recorded in the present study is *Porites (Synarea) convexa.* This species has been considered as a synonym of *Porites (Synarea) rus* (Veron & Pichon, 1982; Sheppard, 1987). The identities of these two species have been retained as their growth forms differ: *Porites (Synarea) convexa* is branching while *Porites (Synarea) rus* is massive (Dr. Pillai, personal communication).

Pillai and Scheer (1976) have considered *A. irregularis* to be a valid species. However, a scrutiny of the descriptions and photographs (Pillai & Scheer, 1976; Plate 4, Fig. 1-3) and the growth form of the species suggest that it is similar to *A. danai* (Veron & Wallace, 1984; Fig. 486-491). Similarly, *A. abrotanoides* described and illustrated (Pillai & Jasmine, 1989; Fig. 4) has a very close resemblance to *A. danai*. In the present work, *A. irregularis* and *A. abrotanoides* are considered to be synonyms of *A. danai*, an opinion also expressed by some authors (Veron & Wallace, 1984; Sheppard, 1987). Synonymies are further discussed in Chapter 3.

Thus, after considering synonymies, the present study raises the tally of coral species reported so far from Lakshadweep to 133.

Plate 2.1

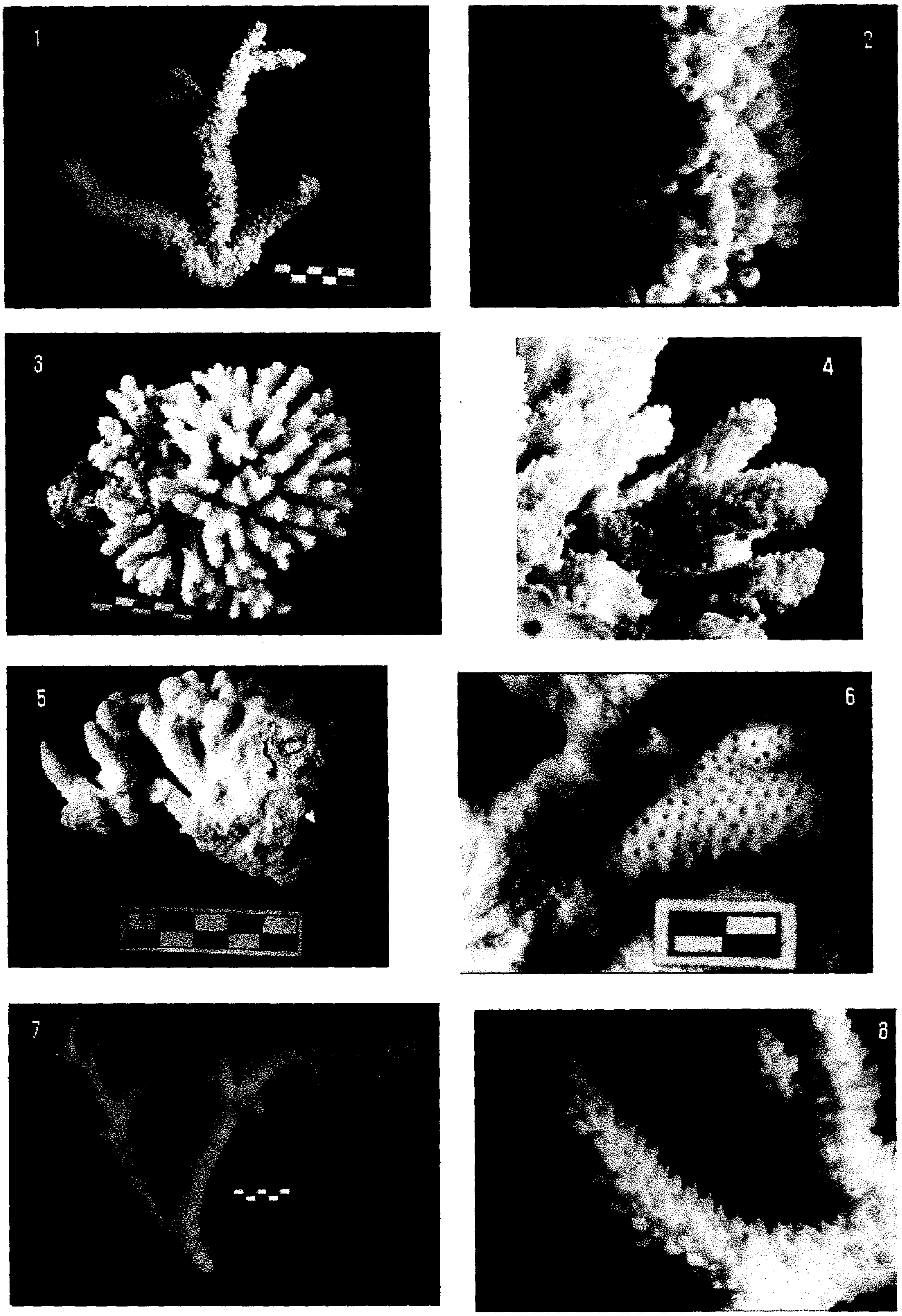

Photo 1-2 *Acropora austera* Photo 3-4 *Acropora cerealis.* Photo 5-6 *Acropora ?millepora*, Photo 7-8 *Acropora pulchra* (each subdivision of scale bar = 10 mm)

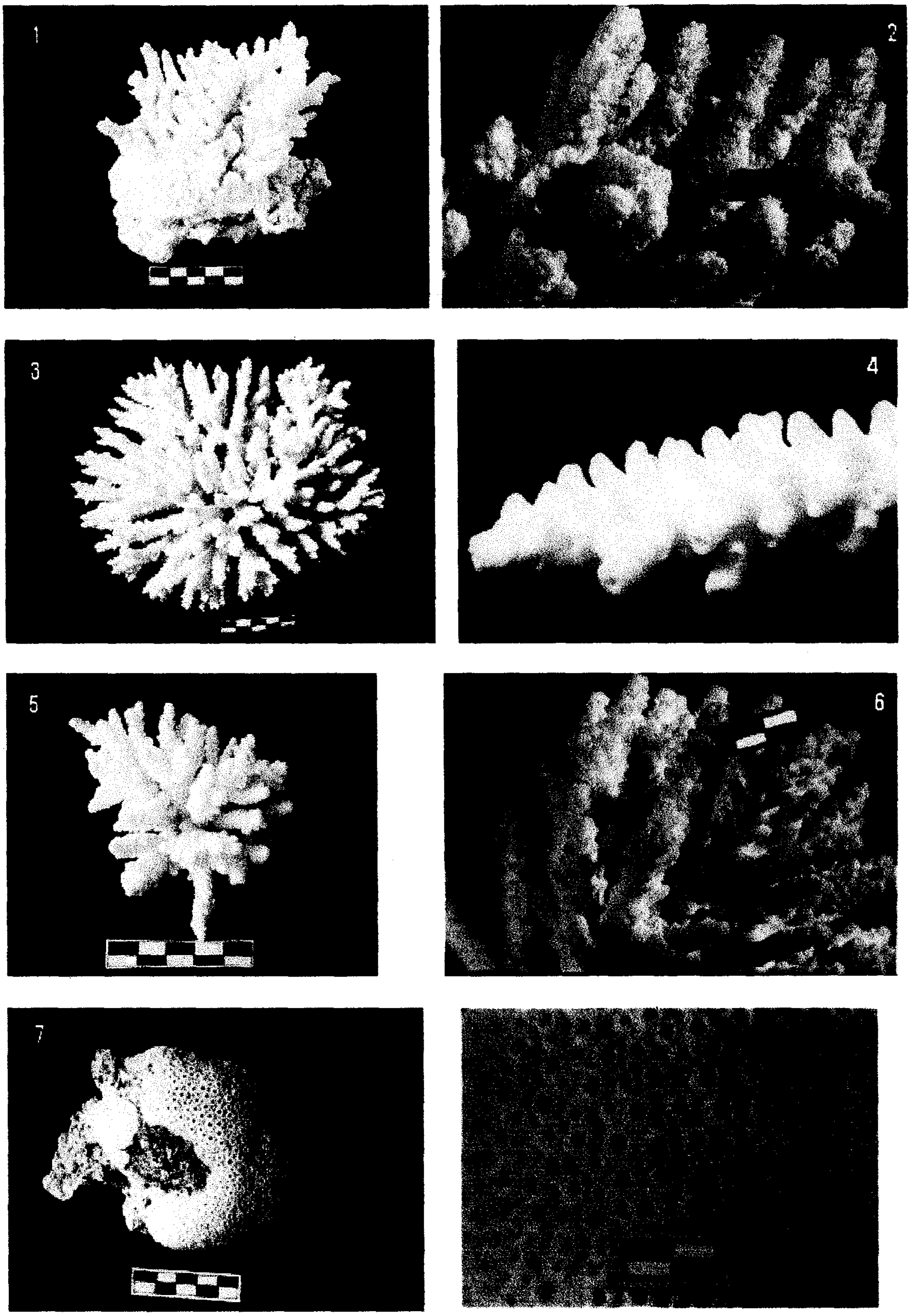

Photo 1-2 *Acropora selago* Photo 3-4 *Acropora tenuis* Photo 5-6 *Acropora valida* Photo 7-8 *Astreopora ocellata* (each subdivision of scale bar = 10mm)

Plate 2.3

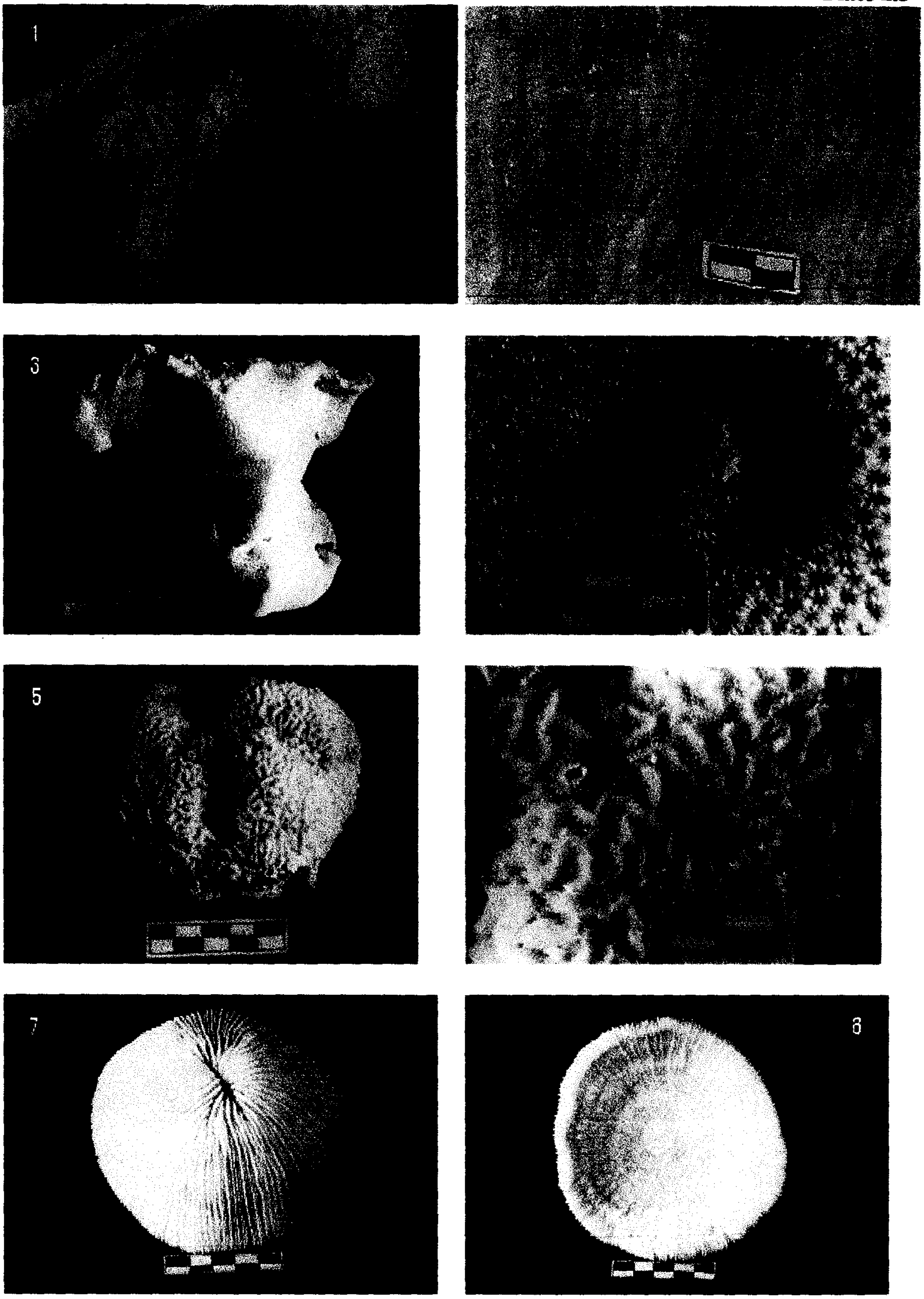

Photo 1 *Montipora foveolata* Photo 2 *Pachyseris speciosa* Photo 3-4 *Pavona decussata* Photo 5-6 *Pavona venosa* Photo 7-8 *Fungia (Verrillofungia) concinna* (each subdivision of scale bar = 10mm)

Plate 2.4

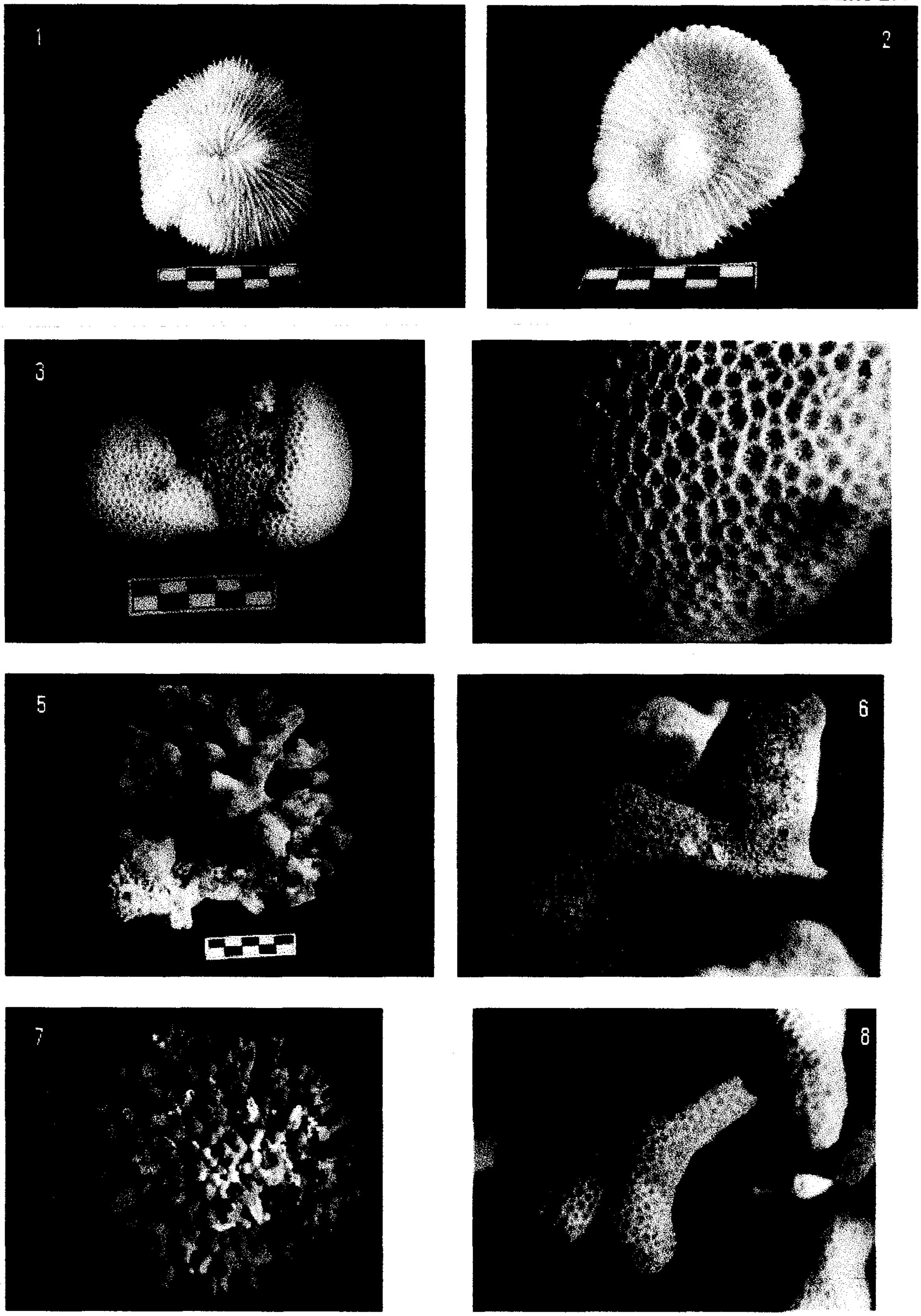

Photo 1-2 *Fungia (Danafungia) scruposa* Photo 3-4 *Goniopora lobata* Photo 5-6 *Porites compressa* Photo 7-8 *Porites nigrescens* (each subdivision of scale bar = 10mm)

Plate 2.5

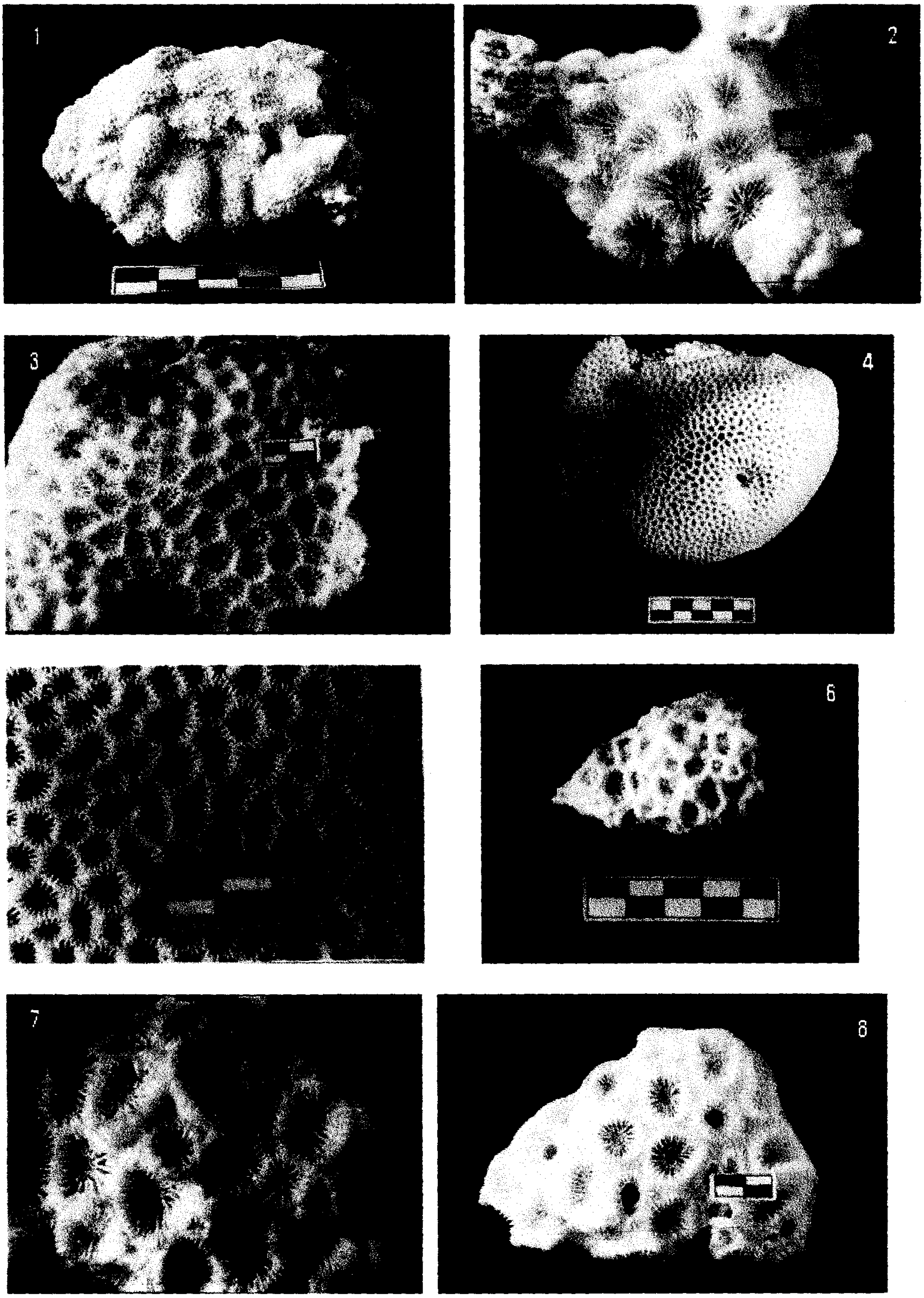

Photo 1 *Porites lichen* Photo 2 *Favites russelli* Photo 3 *Goniastrea aspera* Photo 4-5 *Goniastrea edwardsi* Photo 6-7 *Montastrea curta* Photo 8 *Montastrea magnistellata* (each subdivision of scale bar = 10mm)

Plate 2.6

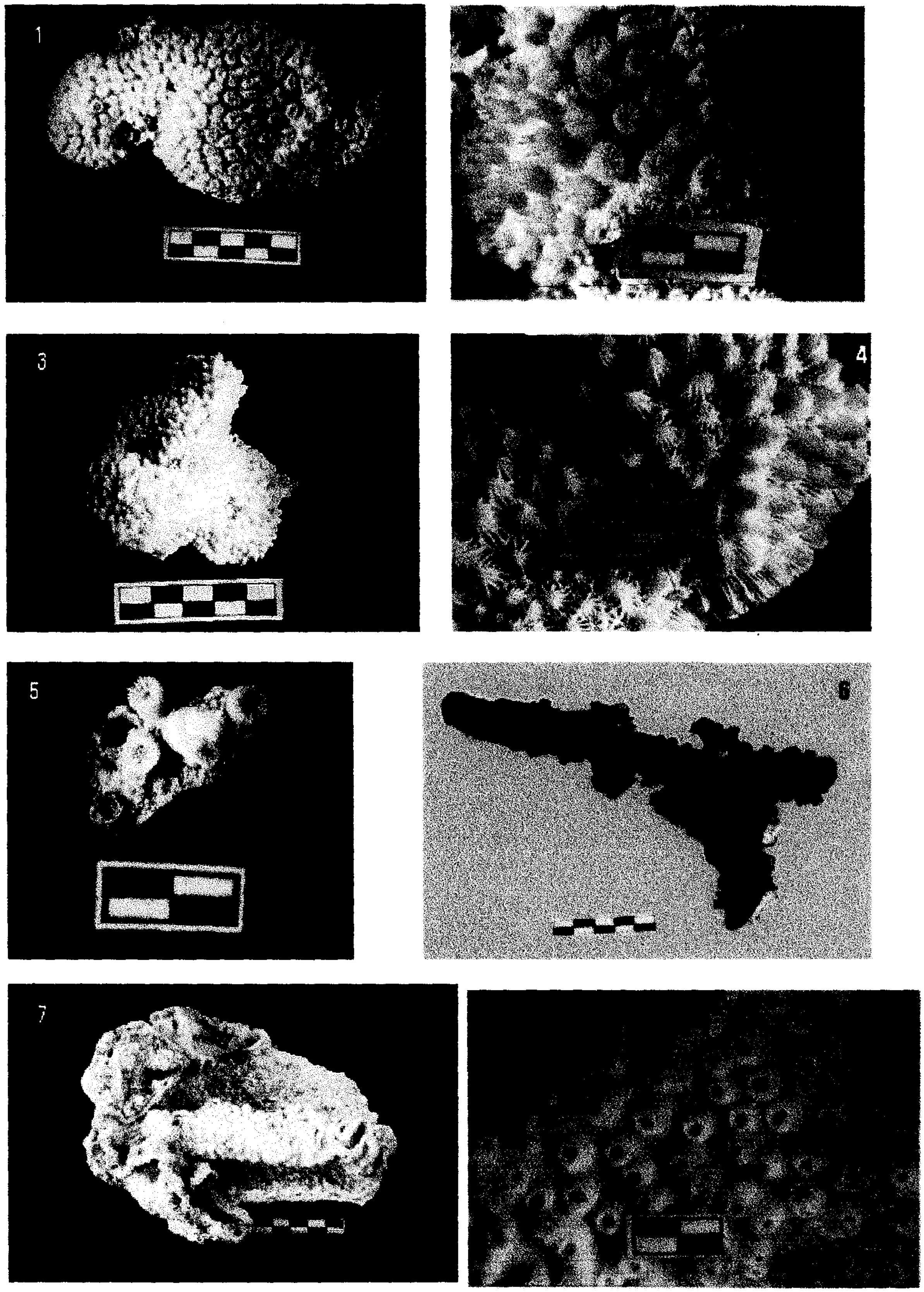

Photo 1-2 *Galaxea astreata* Photo 3-4 *Hydnophora exesa* Photo 5 *Paracyathus* sp. Photo 6 *Tubastrea micranthus* Photo 7-8 *Turbinaria frondens* (each subdivision of scale bar = 10mm)

CHAPTER THREE

BIOGEOGRAPHICAL DISTRIBUTION OF CORALS IN SOUTH ASIA

3.1 INTRODUCTION

Extensive coral reefs are present along the western regions of the world's tropical oceans, in the Indo-West Pacific as well as in the western Atlantic ocean such as the Carribean (Vaughan & Wells, 1943; Wells, 1954; Stehli, 1968; Vermeij, 1978; Rosen, 1981; Sheppard, 1983, 1987; Scheer, 1984; Veron, 1985a; Jackson, 1991). Scheer (1984) attributed this to the presence of many islands along western regions and to the favourable conditions for coral spat settlement and reef formation in these localities. The establishment and diversity of coral species in any particular locality is an interplay of a magnitude of factors that involve the prevailing climatic conditions, bathymetry, suitability of substrate for larval settlement, sedimentation, currents, biological interaction as well as the changes the reefs were subject to during the past geological ages.

The biogeographical distribution of reef-building corals has been reviewed by Wells (1966), Porter (1972) and Veron (1985a, 1986, 1993). During the Tertiary period (70 Ma), when most of the present coral genera and species probably evolved, the continents of the southern hemisphere (Australia, India, Africa and south America) were well south of the present position, leaving a tropical/ subtropical circum-global seaway (the Tethys Sea) linking the world's greatest oceans. This allowed many groups of tropical organisms to range from the Atlantic to the central Pacific. Continental drift during the Cainozoic resulted in the closure of the Tethys Sea leading to the independent development of coral fauna in two regions *viz.* in the Atlantic and far-eastern Pacific and in the Indian and western Pacific oceans. The subsequent closure of the Isthmus of Panama and extinction of corals on both sides of the Isthmus during the Ice Ages resulted in distinct Atlantic and Indo-Pacific corals. As a result, only seven genera are now found both in the Atlantic and the Indian/ Pacific oceans. A general similarity of scleractinian fauna is observed in various parts of the Indo-Pacific (Vaughan & Wells, 1943), with the highest number of genera reported from the central Indo-Pacific.

Coral reefs of the Indian Ocean were almost neglected until the International Indian Ocean Expedition (IIOE). Indian Ocean coral reefs include sea-level atolls, fringing and barrier reefs, elevated reefs and reef platforms now submerged. From geological and paleomagnetic data, it can be inferred that reefs in the Indian ocean have originated almost entirely during Mesozoic times, attaining their present approximate distribution and shape by the end of the Tertiary period. Along the Indian subcontinent, the major part of the Arabian Sea and the Bay of Bengal coast is devoid of reefs. Sewell (1932) attributed the paucity of corals in these regions to the large quantity of freshwater and silt drained from adjacent coastal areas. The coral formations of the southeastern coast of India extend southwards, fringing the coast of Sri Lanka. Reefs of continental coasts are mostly fringing reefs and include the Andaman and Nicobar islands, the Palk Bay as well as the Gulf of Mannar on the southeastern coast in the Bay of Bengal, and the Gulf of Kachchh along the northwestern coast in the Arabian sea. Next to fringing reefs, atolls are the dominant types of reefs exemplified by the Lakshadweep and Maldive archipelagoes.

The biogeographical distribution of corals in the Indian ocean has been analyzed by several coral taxonomists/ecologists (Wells, 1954, 1966; Stehli & Wells, 1971; Rosen, 1971a; Vermeij, 1978; Rosen, 1981; Scheer, 1984; Sheppard, 1987). The distribution of 77 genera and subgenera of hermatypic corals at 39 locations in the Indo-Pacific, including 10 locations in the Indian Ocean, was compiled by Wells (1954) and presented on a map of the Indo-Pacific along with pangeneric lines (lines of equal number of genera). It revealed that

Indonesia in the western Pacific lay at the centre of coral development. He was aware that data for some regions were unavailable. Subsequently, Rosen (1971a) re-analyzed the biogeographical pattern by including data from additional localities and remarked that coral records were extremely variable over relatively short distances. He mapped the distribution of 80 genera at 57 localities in the Indian Ocean and observed maximum diversity in the Seychelles-Maldives region but could not conclusively establish whether it was continuous with the main Indonesian focal region since many coral reef areas remained to be explored.

Scheer (1984) compiled available information on the distribution of 88 genera and subgenera of corals in the Indian Ocean and adjacent seas. He reappraised the localities cited in Rosen (1971a) and reduced their number from 57 to 53. In his ultimate analysis, the genera-rich belt of locations extended from south Mozambique to the Maldives, with additional focal points in the Red Sea and near Phuket (Thailand). He also listed eleven coral genera endemic to the Indian Ocean. Sheppard (1983) provided diversity contours for various localities in the Indian Ocean and inferred that Indian Ocean fauna is quite uniform when compared to the Pacific region. Veron (1985a) arrived at similar conclusions.

In the present chapter, the biogeographical distribution of hermatypic and ahermatypic coral genera/species of the South Asia region is presented and discussed. The South Asia Region is located in the northern Indian Ocean, divided by the Indian land mass into the Arabian Sea and the Bay of Bengal. This region is one of the six International Coral Reef Initiative (ICRI) regions identified for monitoring by the United Nations Global Conference on the Sustainable Development of Small Developing States held at Barbados in 1994 and subsequently adopted by the Global Coral Reef Monitoring Network (GCRMN). It is supported by the Intergovernmental Oceanographic Commission (IOC), United Nations Environment Programme (UNEP) and IUCN (The World Conservation Union) (UNESCO, 1997). This region includes three major countries: India, Sri Lanka and the Maldives. As for other countries in the region, no reefs have been reported in Pakistan and Bangladesh due to the prevalance of turbid waters, though living corals have been reported between Cape Monze and Chuma Island in Pakistan (see Kazmi & Kazmi, 1997) and Narikel Jinjira (St. Martin's Island) in Bangladesh (see Mollah, 1997).

3.2 METHODOLOGY

3.2.1 Distribution of coral species in South Asia

The areas considered for this study lie approximately between 0°4' - 23°40'N and 68°20' - 93°56'E. Information on the distribution of coral species was compiled from available published literature (Mosely, 1881; Pillai, 1967a-g, 1971a,b,c, 1972, 1983a,b, 1986b; Scheer & Pillai, 1974; Pillai & Scheer, 1976; Qasim & Wafar, 1979; Pillai & Patel, 1988; Pillai & Jasmine, 1989, 1995; Rajasuriya & Silva, 1988; Rajasuriya, 1994; Mukherjee, 1994; Zahir & Naeem, 1996; Rodrigues *et al.*, 1998), supplemented with data from Lakshadweep collected during the present study. A species list was prepared after a major attempt in excluding synonymies as suggested by recent taxonomic workers (Veron & Pichon, 1976, 1980, 1982; Veron *et al.* 1977; Veron & Wallace, 1984; Scheer & Pillai, 1974; Pillai, 1986b; Sheppard, 1987). Wherever a disagreement on the synonymy of a coral species existed among coral taxonomists – an inevitable situation – the views of Dr. Pillai were given added weightage due to his extensive experience in the taxonomy of corals of south Asia, unless a personal opinion can be offered. This compromise was arrived at as holotypes of coral species (except for photographs published in the literature) scattered in different international museums, were not available/accessible for detailed scrutiny.

3.2.2 Cluster analysis

In an attempt to unravel coral fauna similarities between localities in the South Asia region, the synonymised presence-absence species data matrix of coral species was subjected to cluster analysis (Clifford & Stephenson, 1977) using the Czekanowski index (S). Corals that were not identified up to the species level were excluded in the analysis.

$$S = \frac{2 \cdot a}{a + b + c}$$

where,

a = Number of co-occurrences of species at sites 1 and 2

b = Number of occurrences of species only at site 1

c = Number of occurrences of species only at site 2

This index is similar to the Dice or Sorenson coefficient used by Sheppard (1987), which doubly weigh joint presences and ignores joint absences. The Czekanowski dissimilarity index (1 - S) among pairs of sites was computed to obtain the dissimilarity matrix and sites clustered using the group average linkage method (Clifford & Stephenson, 1977). In the resulting dendrogram, sites harbouring similar coral species formed clusters.

3.3 RESULTS

3.3.1 Distribution of coral species

A brief description of the localities in the South Asia region considered for the biogeographical analysis and a historical review of coral systematics studies carried out are presented below. A descriptive account of Lakshadweep has been omitted here since it has been presented in Chapter 1. The distribution of the synonymised scleractinian coral species from seven localities in South Asia (Fig. 3.1) is presented in Table 3.1. The major source for information in the table (except Sri Lanka) is Dr. Pillai's publications. Other sources are indicated in the table. In the case of Sri Lanka, the information was extracted from Rajasuriya and De Silva (1988) and Rajasuriya (1994). A synopsis of the number of hermatypic/ ahermatypic genera/ species is presented in Table 3.2 while the distribution of coral genera is presented in Table 3.3.

3.3.1.1 Gulf of Kachchh

Located between 22°15' - 23°40'N and 68°20' - 70°40'E along the Gujarat coast, the Gulf covers an area of 7,350 km². There are about 40 islands with patchy coral formations, the largest being Pirotan island. Coral formations are present on wave cut and shallow eroded banks covered by loose dead coral boulders and pebbles. The majority of reefs are narrow with living corals usually present at the edges of the seaward slope of reefs. The Gulf of Kachchh coral formations roughly demarcate the northern limit of coral reef growth in the Indian Ocean, but for the northern Red Sea.

The first record on corals in the Gulf of Kachchh is that of Gideon *et al.* (1957). Subsequently, Patel (1976, 1978) described the generic diversity of the coral fauna in the region. Live ramose coral colonies have not been encountered although huge debris of dead *Acropora* species were recorded in this area (Patel, 1978; Pillai *et al.*, 1980). A consolidated checklist was prepared and published by Pillai & Patel (1988).

Very few corals have been reported from this region. Earlier workers have attributed the paucity of corals in this region to geographical isolation, prolonged exposure to air and high degree of siltation from neighbouring coastal areas (Sewell,

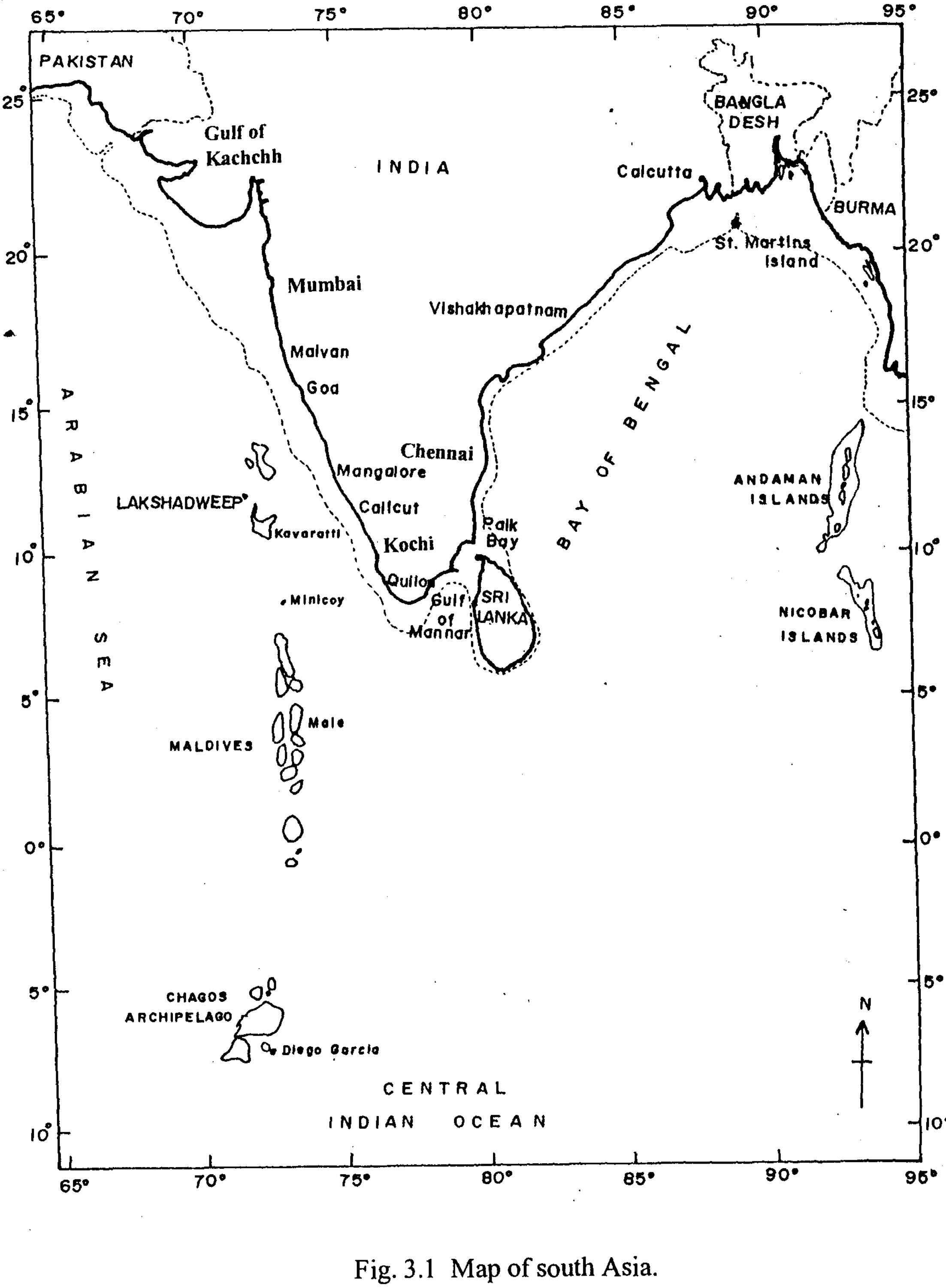

Fig. 3.1 Map of south Asia.

Table 3.1 Distribution of coral species in south Asia.

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldi
ORDER: Scleractinia Bourne (1900)							
SUBORDER: Astrocoeniina Vaughan & Wells (1943)							
FAMILY: Pocilloporidae Gray (1842)							
Pocillopora acuta Lamarck (1816)	-	-	-	-	-	-	+
Pocillopora ankeli Scheer & Pillai (1974)	-	-	-	+	-	-	-
Pocillopora brevicornis (Linnaeus, 1758)	-	-	-	+	-	-	-
Pocillopora damicornis (Linnaeus, 1758)	-	+	+	+	P	+R&S	+
Pocillopora elegans (Dana, 1846)	-	-	-	-	-	+R&S	-
Pocillopora eydouxi Edwards & Haime (1860)	-	+	+	+	P	+R&S	+
Pocillopora cf informis (Dana, 1846)	-	-	-	-	-	+R&S	-
Pocillopora ligulata Dana (1846)	-	+	-	-	+	-	+
Pocillopora meandrina var nobilis Dana (1846)	-	+	-	+	+	-	+
Pocillopora molokensis Vaughan (1907)	-	-	-	-	-	+R&S	+
Pocillopora verrucosa Ellis & Solander (1786)	-	+	+	+	P	+R&S	+
Seriatopora caliendrum Ehrenberg (1834)	-	-	-	-	-	-	+SC
Seriatopora crassa Quelch (1886)	-	-	-	+	-	-	-
Seriatopora hystrix (Dana, 1846)	-	-	-	+	-	-	+
Seriatopora stellata Quelch (1886)	-	-	-	+	-	-	-
Stylophora pistillata Esper (1797)	-	-	-	+	P	+R	+
Madracis sp.	-	-	+	+	-	-	-
FAMILY: Astrocoeniidae Koby (1890)							
Stylocoeniella armata (Ehrenberg, 1834)	-	+	-	-	-	-	+SC
Stylocoeniella guentheri Bassett-Smith (1890)	-	-	-	-	-	+R&S	+
FAMILY: Acroporidae Verrill (1902)							
Acropora aculeus (Dana, 1846)	-	-	-	-	-	+R&S	-
Acropora anthocercis (Brook, 1893)	-	-	-	-	-	+R&S	-
Acropora aspera (Dana, 1846)	-	-	-	+M	P	-	+SC
Acropora austera (Dana, 1846)	-	-	-	-	P*	-	+SC
Acropora brevicollis (Brook, 1893)	-	-	+	-	-	-	-
Acropora cerealis (Dana, 1846)	-	-	-	-	P*	-	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
Acropora clathrata (Brook, 1891)	-	-	-	-	-	+R&S	+
Acropora concinna (Brook, 1893)	-	-	-	-	-	-	+SC
Acropora corymbosa (Lamarck, 1816)	-	-	+	-	P	-	+
Acropora danai (Edwards & Haime, 1860)	-	-	-	-	P	+R&S	+
Acropora divaricata (Dana, 1846)	-	-	-	-	-	+R&S	+
Acropora diversa (Brook, 1893)	-	-	+	+	-	-	+
Acropora dumosa (Brook, 1893)	-	-	-	+	-	-	-
Acropora echinata (Dana, 1846)	-	-	-	+	+	-	+
Acropora efflorescens (Dana, 1846)	-	+	-	+	P	-	+
Acropora elseyi (Brook, 1892)	-	-	-	-	-	-	+
Acropora eurystoma (Klunzinger, 1879)	-	-	-	-	-	-	+
Acropora florida (Dana, 1846)	-	-	-	-	-	-	+SC
Acropora (Anacropora) forbesi Ridley (1884)	-	-	-	-	-	+R	-
Acropora formosa (Dana, 1846)	-	-	+	+	P	+R&S	+
Acropora forskali (Ehrenberg, 1834)	-	-	-	-	P	-	+
Acropora gemmifera (Brook, 1892)	-	-	-	-	-	-	+SC
Acropora granulosa (Edwards & Haime, 1860)	-	-	-	+	P	-	+
Acropora gravida (Dana, 1846)	-	-	-	+	-	-	-
Acropora haimei (Edwards & Haime, 1860)	-	-	-	-	-	+R&S	+
Acropora hemprichi (Ehrenberg, 1834)	-	-	-	-	+	+R&S	+
Acropora horrida (Dana, 1846)	-	-	-	-	-	-	+SC
Acropora humilis (Dana, 1846)	+	-	+	+	P	+R&S	+
Acropora hyacinthus (Dana, 1846)	-	+	+	+	P	+R&S	+
Acropora indica (Brook, 1893)	-	-	+	-	+	-	-
Acropora latistella (Brook, 1891)	-	-	-	-	-	-	+SC
Acropora loripes (Brook, 1892)	-	-	-	-	-	-	+SC
Acropora microphthalma (Dana, 1846)	-	-	-	-	-	+R&S	+SC
Acropora millepora (Ehrenberg, 1834)	-	-	+	+	P*?	+R&S	+
Acropora monticulosa (Brueggemann, 1879)	-	-	-	-	P?	-	-
Acropora multiacuta Nemenzo (1967)	-	-	-	+	-	-	-
Acropora nasuta (Dana, 1846)	-	-	-	-	P	+R&S	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
Acropora nobilis (Dana, 1846)	-	-	+	+	P	+R&S	+
Acropora (Isopora) palifera (Lamarck, 1816)	-	-	-	+	P	-	+
Acropora pharaonis (Edwards & Haime, 1860)	-	-	-	-	-	-	+
Acropora pulchra (Brook, 1891)	-	-	-	-	P*	-	+SC
Acropora rambleri (Bassett-Smith, 1880)	-	-	-	+	-	-	-
Acropora robusta (Dana, 1846)	-	-	-	+	P	+R&S	+
Acropora samoensis (Brook, 1891)	-	-	-	-	-	+R&S	-
Acropora secale (Studer, 1878)	-	-	-	+	-	+R&S	-
Acropora selago (Studer, 1878)	-	-	-	-	P*	+R&S	+SC
Acropora solitaryensis (Veron & Wallace, 1984)	-	-	-	-	-	+R&S	-
Acropora squarrosa (Ehrenberg, 1834)	+	-	-	-	+	-	+
Acropora stoddarti Pillai & Scheer (1976)	-	-	-	-	-	-	+
Acropora syringodes (Brook, 1892)	-	-	-	+	-	-	+
Acropora tenuis (Dana, 1846)	-	-	-	-	P*	+R&S	+SC
Acropora teres (Verrill, 1866)	-	-	-	-	P	-	+
Acropora valenciennesi (Edwards & Haime, 1860)	-	-	+	-	-	+R&S	+SC
Acropora valida (Dana, 1846)	-	+	+	+	P*	+R&S	+
Acropora vaughani Wells (1954)	-	-	-	-	-	-	+SC
Astreopora gracilis Bernard (1896)	-	-	-	-	-	+R&S	+
Astreopora listeri Bernard (1896)	-	-	-	+	P	-	+
Astreopora myriophthalma (Lamarck, 1816)	-	-	+	-	P	-	+
Astreopora ocellata Bernard (1896)	-	-	-	-	P*	-	+
Montipora aequituberculata Bernard (1891)	-	-	-	-	-	+R&S	-
Montipora cocosensis Vaugham (1918)	-	-	-	+	-	-	-
Montipora composita Crossland (1952)	-	-	-	+	-	-	-
Montipora danae (Edwards & Haime, 1851)	-	-	-	-	-	+R&S	+
Montipora digitata (Dana, 1846)	-	-	+	+	-	+R	-
Montipora divaricata Brueggeman (1879)	-	-	+	+	-	-	-

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
Montipora explanata Brueggemann (1875)	+	-	+	-	+	-	-
Montipora exserta Quelch (1886)	-	-	+	-	-	+R&S	-
Montipora floweri Wells (1854)	-	-	-	-	-	-	+
Montipora foliosa (Pallas, 1766)	+	+	+	+	P	+R&S	+
Montipora foveolata (Dana, 1846)	-	-	-	-	P*	-	-
Montipora granulosa Bernard (1897)	-	-	+	-	-	-	-
Montipora hispida (Dana, 1846)	+	-	+	+	-	+R&S	+
Montipora jonesi Pillai (1986)	-	-	+	-	-	-	-
Montipora maldivensis Pillai & Scheer (1976)	-	-	-	-	-	-	+
Montipora manauliensis Pillai (1969)	-	-	+	-	-	-	-
Montipora millepora Crossland (1952)	-	-	-	-	-	+R&S	-
Montipora monasteriata (Forsskal, 1775)	+	-	+	-	-	+R&S	+SC
Montipora peltiformis Bernard (1896)	-	-	-	+	-	-	-
Montipora sinensis Bernard (1897)	-	-	-	-	-	-	+SC
Montipora sinuosa Pillai & Scheer (1976)	-	-	-	-	-	-	+
Montipora spumosa (Lamarck, 1816)	-	-	+	-	-	-	-
Montipora subtilis Bernard (1897)	-	-	+	-	-	-	-
Montipora suvadivae Pillai & Scheer (1976)	-	-	-	-	-	-	+
Montipora tuberculosa (Lamarck, 1816)	-	-	+	-	P	-	+
Montipora turgescens Bernard (1897)	+	+	+	+	P	-	-
Montipora undata (Bernard, 1897)	-	-	-	-	-	+R&S	-
Montipora venosa (Ehrenberg, 1834)	+	-	+	+S	P	-	+SC
Montipora verrilli Vaughan (1907)	-	-	+	-	-	-	-
Montipora verrucosa (Lamarck, 1816)	-	-	+	+M	-	+R&S	+SC
Montipora n. sp. 1 Pillai & Jasmine (1989)	-	-	-	-	+	-	-
Montipora n. sp. 2 Pillai & Jasmine (1989)	-	-	-	-	+	-	-
SUBORDER: Fungiina Verrill (1865)							
FAMILY: Agariciidae Gray (1847)							
Coeloseris mayeri Vaughan (1918)	-	-	-	+	-	-	-
Gardineroseris planulata (Dana, 1846)	-	-	-	+	P	+R&S	+
Leptoseris explanata Yabe & Sugiyama (1941)	-	-	-	-	-	+R	+SC

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
Leptoseris fragilis Edwards & Haime (1849)	-	-	-	+	-	-	+
Leptoseris gardineri Horst (1921)	-	-	-	-	-	-	+
Leptoseris hawaiiensis Vaughan (1907)	-	-	-	+S	-	-	+SC
Leptoseris incrustans (Quelch, 1886)	-	-	-	-	-	-	+
Leptoseris mycetoseroides Wells (1954)	-	-	-	-	-	+R&S	+SC
Leptoseris papyracea (Dana, 1846)	-	-	-	+	-	+R&S	-
Leptoseris scabra Vaughan (1907)	-	-	-	-	-	+R&S	+
Leptoseris solida (Quelch, 1886)	-	-	-	-	-	-	+SC
Pachyseris rugosa (Lamarck, 1801)	-	-	+	+	-	+R&S	+
Pachyseris speciosa (Dana, 1846)	-	-	-	+	P*	+R	+
Pavona acuticarinata (Umbgrove)	-	-	-	-	-	-	+
Pavona cactus (Forsskal, 1775)	-	-	+	+	-	-	+SC
Pavona clavus (Dana, 1846)	-	-	-	+	-	+R&S	+
Pavona decussata (Dana, 1846)	-	-	+	+	P*	+R&S	-
Pavona divaricata (Lamarck, 1816)	-	-	+	-	-	+R&S	-
Pavona duerdeni Vaughan (1907)	-	-	+	+	+	+R&S	+
Pavona explanulata (Lamarck, 1816)	-	-	-	+	-	+R&S	+
Pavona maldivensis (Gardiner, 1905)	-	-	-	-	+	+R	+
Pavona minuta Wells (1954)	-	-	-	-	-	+R&S	+SC
Pavona varians Verrill (1864)	-	-	+	+	P	+R&S	+
Pavona venosa (Ehrenberg, 1834)	-	-	-	-	P*	+R&S	+SC
Pavona xarifae Scheer & Pillai (1974)	-	-	-	+	-	-	-
Pavona yabei Pillai & Scheer (1976)	-	-	-	-	-	-	+
FAMILY: Siderastreidae Vaughan & Wells (1943)							
Coscinaraea columna (Dana, 1846)	-	-	-	-	-	+R&S	-
Coscinaraea monile (Forsskal, 1775)	+	-	+	-	-	-	+
Coscinaraea sp.	-	+ Q&W	-	-	-	-	-
Psammocora contigua (Esper, 1797)	-	-	+	+	P	+R&S	+
Psammocora digitata Edwards & Haime (1851)	+	-	-	-	+	+R&S	+
Psammocora explanulata Horst (1922)	-	-	-	-	-	-	+SC
Psammocora folium Umbgrove (1939)	-	-	-	-	-	-	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
Fungia (Verrillofungia) concinna Verrill (1864)	-	-	-	+M	P*	-	-
Fungia (Verrillofungia) repanda Dana (1846)	-	-	-	+	-	+R&S	+
Fungiacyathus sarsi Gardiner & Waugh	-	-	-	-	-	-	+
Fungiacyathus stephana (Alcock, 1893)	-	-	-	-	-	+R&S	-
Fungiacyathus symmetrica (Pourtales, 1879)	-	-	-	+	-	-	-
Halomitra pileus (Linnaeus, 1758)	-	-	-	-	-	-	+
Herpolitha limax (Houttuyn, 1772)	-	-	-	+	-	+R&S	+
Herpolitha weberi (Horst, 1921)	-	-	-	-	-	-	+
Podabacia crustacea (Pallas, 1766)	-	-	-	-	-	+R&S	+
Polyphyllia talpina (Lamarck, 1909)	-	-	-	+	+	+R	+
Polyphyllia sp.	-	-	-	-	-	+R&S	-
Sandalolitha dentata Quelch (1884)	-	-	-	-	-	-	+
Sandalolitha robusta (Quelch, 1886)	-	-	-	-	+	+R&S	+
Zoopilus echinatus (Dana, 1846)	-	-	-	-	-	+R&S	+SC
FAMILY: Micrabaciidae Vaughan (1905)							
Stephanophyllia complicata Mosely (1876)	-	-	-	-	-	-	+
Stephanophyllia fungulus Alcock (1902)	-	-	-	-	-	-	+
FAMILY: Poritidae Gray (1842)							
Alveopora allingi Hoffmeister (1925)	-	-	-	-	-	-	+
Alveopora daedalea (Forsskal, 1775)	-	-	-	+	-	-	+
Alveopora fenestrata (Lamarck, 1816)	-	-	-	-	-	+R&S	-
Alveopora superficialis Pillai & Scheer (1976)	-	-	-	-	+	-	+
Alveopora viridis Quoy & Gaimard (1833)	-	-	-	-	-	+R&S	+
Alveopora verrilliana (Dana, 1872)	-	-	-	-	-	+R&S	-
Goniopora bernardi (Faustino, 1921)	-	-	-	-	-	+R&S	-
Goniopora fruticosa (Kent, 1891)	-	-	-	-	-	+R&S	-
Goniopora granulosa Pillai & Scheer (1976)	-	-	-	-	-	-	+
Goniopora lobata Edwards & Haime (1860)	-	-	+	-	P*	-	+
Goniopora minor Crossland (1952)	+	-	-	-	+	-	+
Goniopora nigra Pillai (1967)	+	-	+	-	-	-	-

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
Psammocora haimeana Edwards & Haime (1851)	-	-	-	-	+	-	+
Psammocora nierstraszi Horst (1921)	-	-	-	-	-	-	+
Psammocora profundacella Gardiner (1898)	-	-	-	+	P	-	+SC
Pseudosiderastrea tayamai Yabe & Sugiyama (1935)	+	+ Q&W	+	+	-	+R&S	-
Siderastrea savignyana Edwards & Haime (1850)	+	-	+	-	-	-	-
FAMILY: Fungiidae Dana (1846)							
Cycloseris cooperi (Gardiner, 1909)	-	-	-	-	-	-	+
Cycloseris costulata (Ortmann, 1889)	-	-	-	+	-	+R&S	+
Cycloseris cyclolites (Lamarck, 1801)	-	-	+	+	-	+R&S	-
Cycloseris hexagonalis Edwards & Haime (1849)	-	-	-	+	-	+R&S	-
Cycloseris mycoides Alcock (1893)	-	-	-	+S	-	-	-
Cycloseris patelliformis (Boschma, 1923)	-	-	-	+	-	+R&S	-
Cycloseris somervillei (Gardiner, 1909)	-	-	-	-	+	-	+S
Cycloseris sp.	-	-	-	-	+	-	-
Diaseris distorta (Michelin, 1843)	-	-	-	+	-	+R&S	+
Diaseris fragilis Alcock (1893)	-	-	-	+S	-	+R&S	-
Fungia (Ctenactis) echinata (Pallas, 1766)	-	-	-	+	-	+R&S	+
Fungia (Danafungia) corona Doderlein (1901)	-	-	-	+S	-	-	-
Fungia (Danafungia) danai Edwards & Haime (1851)	-	-	-	+	+	+R&S	+
Fungia (Danafungia) horrida Dana (1846)	-	-	-	+	-	-	-
Fungia (Danafungia) scruposa Klunzinger (1879)	-	-	-	-	P*	-	-
Fungia (Danafungia) subrepanda Doderlein (1901)	-	-	-	+S	-	-	-
Fungia (Fungia) fungites (Linnaeus, 1758)	-	-	-	+	P	+R	+
Fungia (Pleuractis) moluccensis Horst (1919)	-	-	-	+	-	+R	-
Fungia (Pleuractis) paumotensis Stutchbury (1833)	-	-	-	+	-	+R	+SC
Fungia (Pleuractis) scutaria Lamarck (1801)	-	-	-	+	P	+R&S	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
Goniopora planulata Ehrenberg (1834)	+	-	+	+	-	-	+
Goniopora stokesi Edwards & Haime (1851)	-	-	+	+	P	+R&S	+
Goniopora tenella Quelch (1886)	-	-	-	-	-	-	+SC
Goniopora tenuidens Quelch (1886)	-	-	-	+	-	-	+SC
Goniopora spec *cf* Red Sea 4 Bernard (1903)	-	-	-	-	-	+R&S	-
Goniopora n. sp. Pillai & Jasmine (1989)	-	-	-	-	+	-	-
Porites compressa Dana (1846)	+	-	+	-	P*	-	-
Porites cribripora (Dana, 1846)	-	-	-	-	-	+R&S	-
Porites cylindrica Dana (1846)	-	-	-	+	+	-	+
Porites echinulata (Klunzinger, 1879)	-	-	-	-	-	+R&S	-
Porites exserta Pillai (1967)	-	-	+	-	-	-	-
Porites gaimardi Edwards & Haime	-	-	-	-	-	+R&S	+SC
Porites lichen Dana (1846)	+	+ Q&W	+	-	P*	-	+
Porites lobata Dana (1846)	-	-	-	+	+	-	-
Porites lutea Edwards & Haime (1860)	+	+ Q&W	+	+	P	-	+
Porites mannarensis Pillai (1967)	-	-	+	-	-	-	-
Porites mauritiensis Bernard	-	-	-	-	-	-	+S
Porites mayeri Vaughan (1918)	-	-	-	-	-	-	+SC
Porites minicoiensis Pillai (1967)	-	-	-	-	P	-	-
Porites nigrescens Dana (1848)	-	-	-	-	P*	-	+SC
Porites profundus Rehberg (1892)	-	-	-	-	-	-	+
Porites solida (Forsskal, 1775)	-	-	+	+	P	+R&S	+
Porites vaughani Crossland (1952)	-	-	-	-	-	-	+SC
Porites species 1	-	-	-	-	-	+R&S	-
Porites species 2	-	-	-	-	-	+R&S	-
Porites (Synarea) convexa Verrill (1864)	-	-	+	-	P	-	+
Porites (Synarea) horizontalata Hoffmeister (1925)	-	-	-	-	-	-	+
Porites (Synarea) rus (Forsskal, 1775)	-	-	-	-	-	+R&S	+S
Porites (Synarea) sp.	-	+ Q&W	-	-	-	-	-
Stylaraea punctata (Linnaeus, 1758)	-	-	-	-	-	+R&S	-

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
SUBORDER: Faviina Vaughan & Wells (1943)							
FAMILY: Faviidae Gregory (1900)							
Caulastrea furcata Dana (1846)	-	-	-	-	-	-	+
Caulastrea tumida Matthai (1928)	-	-	-	-	-	-	+
Cyphastrea chalcidicum (Forsskal, 1775)	-	-	-	-	-	+R&S	+
Cyphastrea microphthalma (Lamarck, 1816)	-	-	+	+	P	-	+
Cyphastrea serailia (Forsskal, 1775)	+	-	+	-	P	+R&S	+
Cyphastrea sp.	-	+ Q&W	-	-	-	-	-
Diploastrea heliopora (Lamarck, 1816)	-	-	-	+	P	+R&S	+
Echinopora hirsutissima Edwards & Haime (1850)	-	-	-	-	-	-	+
Echinopora horrida (Dana, 1846)	-	-	-	+	-	-	+SC
Echinopora gemmacea Lamarck (1816)	-	-	-	-	-	-	+SC
Echinopora lamellosa (Esper, 1795)	-	-	+	+	P	+R&S	+
Favia amicorum (Edwards & Haime)	-	-	-	-	-	-	+SC
Favia favus (Forsskal, 1775)	+	-	+	+	P?	+R&S	+
Favia matthaii (Vaughan, 1918)	-	-	-	-	-	+R&S	+SC
Favia maxima (Veron *et al.*, 1977)	-	-	-	-	-	+R&S	-
Favia pallida (Dana, 1846)	-	-	+	+	P	+R&S	+
Favia rotumana (Gardiner, 1899)	-	-	-	+	-	-	+
Favia rotundata (Veron *et al.*, 1977)	-	-	-	-	-	+R&S	+
Favia speciosa (Dana, 1846)	+	-	+	+	+	+R&S	+
Favia stelligera (Dana, 1846)	-	-	+	+	+	-	+
Favia veroni (Moll & Borel Best, 1984)	-	-	-	-	-	+R&S	-
Favites abdita (Ellis & Solander, 1786)	-	+	+	+	P	+R&S	+
Favites complanata (Ehrenberg, 1834)	+	-	+	+	P	+R&S	+
Favites flexuosa (Dana, 1846)	-	-	-	+	P	+R&S	+
Favites melicerum (Ehrenberg, 1834)	+	-	+	-	+	+R&S	+
Favites pentagona (Esper, 1794)	-	+CR	+	-	+	+R&S	+
Favites russelli (Wells, 1954)	-	-	-	-	P*	-	-
Favites sp.	-	+ Q&W	-	-	-	-	-
Goniastrea aspera Verrill (1865)	-	-	-	-	P*	+R&S	-

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
Goniastrea australensis (Edwards & Haime, 1857)	-	-	-	-	+	+R&S	-
Goniastrea edwardsi Chevalier (1971)	-	-	-	-	P*	+R&S	-
Goniastrea pectinata (Ehrenberg, 1834)	+	-	+	+	P	+R&S	+
Goniastrea retiformis (Lamarck, 1816)	-	-	+	+	P	+R&S	+
Goniastrea sp.	-	+ Q&W	-	-	-	-	-
Leptastrea bottae (Edwards & Haime, 1849)	-	-	-	-	+	-	+
Leptastrea purpurea (Dana, 1846)	+	-	+	+	P	+R&S	+
Leptastrea transversa Klunzinger (1879)	-	-	+	+	P	+R&S	+
Leptoria phrygia (Ellis & Solander, 1786)	-	-	+	+	P	+R&S	+
Montastrea annuligera (Edwards & Haime, 1849)	-	-	-	-	-	-	+SC
Montastrea curta (Dana, 1846)	-	-	-	-	P*	+R&S	+SC
Montastrea magnistellata Chevalier (1971)	-	-	-	-	P*	-	-
Montastrea valenciennesi (Edwards & Haime, 1848)	-	-	+	+	P	+R&S	+
Oulastrea crispata (Lamarck, 1816)	-	-	-	+	-	-	-
Oulophyllia benettae (Veron *et al.*, 1977)	-	-	-	-	-	-	+SC
Oulophyllia crispa (Lamarck, 1816)	-	-	-	+	-	+R&S	+
Platygyra daedalea (Ellis & Solander, 1786)	-	-	+	+	P	+R&S	-
Platygyra lamellina (Ehrenberg, 1834)	-	-	+	+	P	+R&S	+
Platygyra sinensis (Edwards & Haime, 1849)	+	-	+	+	P	+R&S	+SC
Plesiastrea versipora (Lamarck, 1816)	+	-	+	+	+	+R&S	+
FAMILY: Trachyphyliidae Verrill (1901)							
Trachyphyllia geoffroyi Audouin (1826)	-	-	-	+	-	-	+
FAMILY: Rhizangiidae d'Orbigny (1851)							
Astrangia sp.	-	+CR	-	-	-	-	-
Cladangia exusta Lutken (1873)	-	+	-	-	-	-	-
Culicia rubeola (Quoy & Gaimard, 1833)	-	+	+	+	-	-	+
FAMILY: Oculinidae Gray (1847)							
Galaxea astreata (Lamarck, 1816)	-	-	+	+	P*	+R&S	+
Galaxea fascicularis (Linnaeus, 1767)	-	-	+	+	P	+R&S	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
FAMILY: Merulinidae Verrill (1866)							
Hydnophora exesa (Pallas, 1766)	+	-	+	+	P*	+R&S	+
Hydnophora microconos (Lamarck, 1816)	-	-	+	+	P	+R&S	+
Hydnophora rigida (Dana,1846)	-	-	-	+	-	-	-
Merulina ampliata (Ellis & Solander, 1786)	-	-	+	+	+	-	+
Merulina sp.	-	-	-	-	-	+R&S	-
Scapophyllia cylindrica (Edwards & Haime, 1848)	-	-	-	+	-	-	-
FAMILY: Pectiniidae Vaughan & Wells (1943)							
Echinophyllia aspera (Ellis & Solander, 1786)	-	-	-	-	-	+R&S	+
Mycedium elephantotus (Pallas, 1766)	+	-	+	+	-	+R&S	+
Oxypora lacera (Verrill, 1864)	-	-	-	-	-	-	+
Pectinia alcicornis (Saville-Kent, 1871)	-	-	-	-	-	-	+
Pectinia lactuca (Pallas, 1766)	-	-	-	+	-	-	+
Pectinia paeonia (Dana, 1846)	-	-	-	-	-	-	+SC
Pectinia sp.	-	-	-	-	-	+R&S	-
Physophyllia ayleni (Wells, 1935)	-	-	-	-	-	-	+
FAMILY: Mussidae Ortmann (1890)							
Acanthastrea echinata (Dana, 1846)	-	-	-	-	P	+R&S	+
Acanthastrea simplex Crossland (1948)	+	-	-	-	-	-	-
Acanthastrea sp.	-	-	-	-	-	+R&S	-
Australomussa rowleyensis (Veron, 1985)	-	-	-	-	-	+R&S	-
Blastomussa merleti (Wells, 1961)	-	-	-	-	-	+R	-
Cynarina lacrymalis (Edwards & Haime, 1848)	-	-	-	-	-	+R&S	+
Lobophyllia corymbosa (Forsskal, 1775)	-	-	-	+	P	+R&S	+
Lobophyllia hemprichii (Ehrenberg, 1834)	-	-	-	-	-	+R&S	+
Scolymia vitiensis Brueggemann, 1877	-	-	-	-	-	-	+
Symphyllia agaricia (Edwards & Haime, 1849)	-	-	-	+	-	+R&S	-
Symphyllia nobilis (Dana, 1846)	-	-	+	+	P	+R&S	+
Symphyllia radians Edwards & Haime, 1849	+	-	+	+	P	+R&S	+
Symphyllia valenciennessi (Edwards & Haime, 1849)	-	-	-	-	-	+R&S	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
SUBORDER: Caryophylliina Vaughan & Wells (1943)							
FAMILY: Caryophylliidae Gray (1847)							
Caryophyllia arcuata Edwards & Haime (1848)	-	+	-	+	+	-	-
Caryophyllia cinticulatus (Alcock, 1902)	-	-	-	-	-	-	+
Caryophyllia clavus Sacchi (1835)	-	+	+	+	+	-	+
Caryophyllia grandis Gardiner & Waugh (1938)	-	-	-	-	-	-	+
Caryophyllia grayi Edwards & Haime (1848)	-	-	-	+	-	-	-
Caryophyllia mabahithi Gardiner & Waugh (1938)	-	-	-	-	-	-	+
Caryophyllia paradoxus Alcock (1893)	-	+	-	-	-	-	-
Catalaphyllia jardinei (Saville-Kent, 1893)	-	-	-	-	-	+R&S	+
Conotrochus brunneus (Moseley, 1881)	-	-	-	-	-	-	+
Deltocyathus andamanicus Alcock (1902)	-	-	-	+	-	-	+
Deltocyathus rotulus (Alcock, 1898)	-	-	-	-	-	+R&S	-
Discotrochus dentatus (Alcock, 1902)	-	-	-	-	-	-	+
Euphyllia ancora (Veron & Pichon, 1980)	-	-	-	-	-	+R&S	-
Euphyllia cristata Chevalier (1971)	-	-	-	-	-	-	+SC
Euphyllia divisa (Veron & Pichon, 1980)	-	-	-	-	-	+R&S	-
Euphyllia fimbriata (Spengler, 1799)	-	-	-	-	-	-	+
Euphyllia glabrescens (Chamisso & Eysenhadt, 1821)	-	-	-	+	P	+R&S	+
Heterocyathus aequicostatus Edwards & Haime (1848)	-	+	+	+	-	+R&S	+
Paracyathus indicus Duncan (1889)	-	-	-	+	-	-	-
Paracyathus gardineri Vaughan	-	-	-	-	-	-	+
Paracyathus lifuensis Gardiner (1899)	-	-	-	-	-	-	+
Paracyathus profundus Duncan (1889)	-	+	+	-	-	-	-
Paracyathus stokesi Edwards & Haime (1848)	+	+	+	-	-	+R&S	-
Paracyathus striatus (Philippi, 1842)	-	-	-	-	-	+R&S	-
Paracyathus sp.	-	-	-	-	P*	-	-
Physogyra lichtensteini (Edwards & Haime, 1851)	-	-	-	+	-	-	+

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
Plerogyra sinuosa (Dana, 1846)	-	-	-	+	-	+R&S	+
Polycyathus andamanensis Alcock (1893)	-	-	-	+	-	-	-
Polycyathus conceptus Gardiner & Waugh (1938)	-	-	-	-	-	-	+
Polycyathus verrilli Duncan (1889)	+	-	+	+	-	-	+
Solenosmilia variabilis Duncan (1873)	-	+	-	-	-	-	-
Stephanocyathus nobilis (Moseley, 1881)	-	+MH	-	-	+	-	+
Trochocyathus rotulus Alcock (1902)	-	-	-	-	-	-	+
Tropidocyathus cooperi Gardiner (1905)	-	-	-	-	-	-	+
Tropidocyathus herdmani (Bourne, 1905)	-	-	-	-	-	+R&S	-
FAMILY: Flabellidae Bourne (1905)							
Flabellum multifore Gardiner (1904)	-	-	-	-	-	-	+
Flabellum pavoninum Lesson (1831)	-	-	-	-	+	-	+
Flabellum stokesi (Edwards & Haime, 1848)	-	+	+	+	-	+R&S	+
Placotrochus laevis Edwards & Haime (1848)	-	-	-	+	-	+R&S	-
SUBORDER: Dendrophylliina Vaughan & Wells (1934)							
FAMILY: Dendrophylliidae Gray (1847)							
Balanophyllia affinis (Semper, 1872)	-	-	+	-	-	+R&S	+
Balanophyllia cornu Moseley (1881)	-	-	-	-	-	-	+
Balanophyllia cumingii (Edwards & Haime, 1848)	-	+	+	-	-	+R&S	-
Balanophyllia diffusa Harrison & Poole (1909)	-	-	-	-	-	-	+
Balanophyllia diomedeae Vaughan	-	-	-	-	-	-	+
Balanophyllia imperialis (Kent, 1871)	-	-	-	+	-	+R&S	-
Balanophyllia italica (Michelin, 1841)	-	-	-	-	-	-	+
Balanophyllia parallela (Semper, 1872)	-	-	-	-	-	+R&S	-
Balanophyllia ponderosa Horst (1926)	-	-	-	-	-	-	+
Balanophyllia scabra Alcock (1893)	-	-	-	+	-	-	-
Balanophyllia taprobanae (Bourne, 1905)	-	-	-	-	-	+R&S	-
Dendrophyllia arbuscula Horst (1922)	-	-	-	+	-	-	+
Dendrophyllia coarctata Duncan (1889)	-	-	+	-	-	-	-

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
Dendrophyllia cf cornigera (Lamarck, 1816)	-	+	-	-	-	-	+
Dendrophyllia fistula (Alcock, 1902)	-	-	-	-	-	-	+
Dendrophyllia gracilis (Edwards & Haime, 1848)	-	-	-	-	-	+R&S	-
Dendrophyllia horsti Gardiner & Waugh (1939)	-	-	-	-	-	-	+
Dendrophyllia indica Pillai (1967)	-	+	+	+	-	-	-
Dendrophyllia miniscula Bourne (1905)	+	+	+	+	-	+R&S	+
Dendrophyllia robusta (Bourne, 1905)	-	-	-	-	-	+R&S	+
Dendrophyllia serpentina (Vaughan, 1907)	-	-	-	-	-	-	+
Enallopsammia amphelioides (Alcock, 1902)	-	-	-	+	-	-	+
Enallopsammia marenzelleri Zibrowius (1973)	-	-	-	+	-	-	-
Endopachys grayi Edwards & Haime (1848)	-	+	-	-	-	-	-
Endopsammia phillippensis Edwards & Haime (1848)	-	-	+	-	-	-	+
Heteropsammia cochlea (Spengler, 1781)	-	+	-	-	-	+R&S	-
Heteropsammia michelini Edwards & Haime (1848)	-	-	+	+	-	-	+
Psammoseris rousseaui Edwards & Haime	-	-	-	-	-	-	+
?*Psammoseris sulcata* (Verrill, 1866)	-	-	-	-	-	+R&S	-
Tubastrea aurea (Quoy & Gaimard, 1833)	+	+	+	+	P	+R&S	+
Tubastrea coccinea (Ehrenberg, 1834)	-	-	-	-	-	-	+
Tubastrea micranthus (Ehrenberg, 1834)	-	-	-	+	P*	+R&S	+
Turbinaria crater (Pallas, 1766)	+	-	+	+	+	-	-
Turbinaria frondens (Dana, 1846)	-	-	-	-	P*	-	-
Turbinaria marmorea Rehberg, 1892	-	-	-	-	-	-	+
Turbinaria mesenterina (Lamarck, 1816)	-	+CR	-	-	P	-	+
Turbinaria peltata (Esper, 1779)	+	-	+	+	-	+R&S	+
Turbinaria quincuncialis (Ortmann, 1889)	-	-	-	-	-	+R&S	-
Turbinaria stellulata (Lamarck, 1816)	-	-	-	-	-	-	+SC
Turbinaria undata Bernard (1896)	-	-	+	-	-	-	-
Turbinaria veluta Bernard, 1896	-	-	-	+	-	-	-

Coral species	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Lakshadweep	Sri Lanka	Maldives
Turbinaria n. sp. Pillai & Jasmine (1989)	-	-	-	-	+	-	-
Turbinaria sp.	-	+	-	-	-	-	-
ORDER: Stolonifera Hickson (1833)							
FAMILY: Tubiporidae Ehrenberg (1828)							
Tubipora musica Linnaeus (1758)	-	-	-	+M	P	-	-
ORDER: Coenothecalia Bourne (1895)							
FAMILY: Helioporidae Mosely (1876)							
Heliopora coerulea (Pallas, 1766)	-	-	-	+M	P	-	-
CLASS: Hydrozoa Owen (1843)							
ORDER: Milleporina Hickson (1901)							
FAMILY: Milleporidae Fleming (1828)							
Millepora dichotoma (Forsskal, 1775)	-	-	-	-	P	-	-
Millepora exesa (Forsskal, 1775)	-	-	-	-	P	+R&S	-
Millepora platyphylla Hemprich & Ehrenberg (1834)	-	-	-	+M	P	+R&S	-
Millepora tenella (Ortmann, 1892)	-	-	-	-	-	+R&S	-
Millepora tenera Boschma (1949)	-	-	-	-	+	-	-
ORDER: Stylasterina Hickson & England (1905)							
FAMILY: Stylasteridae Gray (1847)							
Distichopora violacea (Pallas, 1766)	-	-	-	-	-	+R&S	-

+: recorded -: not yet recorded P: recorded in the present study *: new record

Sources: CR - Rodrigues *et al.* (1998); M - Mukherjee (1994); MH - Mosely (1881); Q&M - Qasim & Wafar (1979); R - Rajasuriya (1994); R&S - Rajasuriya & Silva (1988); S - Sheppard (1987); SC - Susan Clark as cited in Zahir & Naeem (1996); others, not specifically cited in the table (Pillai, 1967a-g, 1971a,b,c, 1972, 1983a, 1986b; Scheer & Pillai, 1974; Pillai & Scheer, 1976; Pillai & Patel, 1988; Pillai & Jasmine, 1989, 1995).

Table 3.2 Synopsis of coral species recorded in south Asia.

	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives	India	South Asia
Number of species identified up to genus only	-	7	1	1	2	4	-	10	14
Number of unnamed new species	-	-	-	-	4	3	-	4	7
Number of hermatypic genera	20	13	32	52	37	56	60	57	71
Number of ahermatypic genera	4	12	9	13	6	10	18	19	25
Total number of genera	24	25	41	65	43	66	78	76	96
Number of hermatypic species	33	25	89	134	125	159	212	216	330
Number of ahermatypic species	4	17	13	21	8	18	39	36	68
Total number of species	**37**	**42**	**102**	**155**	**133**	**177**	**251**	**252**	**398**

Table 3.3 Distribution of coral genera in south Asia (in alphabetical order).

Genus	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
1. *Acanthastrea*	+	-	-	-	+	+	+
2. *Acropora*	+#	+	+	+	+	+	+
3. *Alveopora*	-	-	-	+	+	+	+
4. *Astrangia**	-	+	-	-	-	-	-
5. *Astreopora*	-	-	+	+	+	+	+
6. *Australomussa*	-	-	-	-	-	+	-
7. *Balanophyllia**	-	+	+	+	-	+	+
8. *Blastomussa*	-	-	-	-	-	+	-
9. *Caryophyllia**	-	+	+	+	+	-	+
10. *Catalaphyllia*	-	-	-	-	-	+	+
11. *Caulastrea*	-	-	-	-	-	-	+
12. *Cladangia**	-	+	-	-	-	-	-
13. *Coeloseris*	-	-	-	+	-	-	-
14. *Conotrochus**	-	-	-	-	-	-	+
15. *Coscinaraea*	+	+	+	-	-	+	+
16. *Culicia**	-	+	+	+	-	-	+
17. *Cycloseris*	-	-	+	+	+	+	+
18. *Cynarina*	-	-	-	-	-	+	+
19. *Cyphastrea*	+	+	+	+	+	+	+
20. *Deltocyathus**	-	-	-	+	-	+	+
21. *Dendrophyllia**	+	+	+	+	-	+	+
22. *Diaseris*	-	-	-	+	-	+	+
23. *Diploastrea*	-	-	-	+	+	+	+
24. *Discotrochus**	-	-	-	-	-	-	+
25. *Distichopora**	-	-	-	-	-	+	-
26. *Echinophyllia*	-	-	-	-	-	+	+
27. *Echinopora*	-	-	+	+	+	+	+
28. *Enallopsammia**	-	-	-	+	-	-	+
29. *Endopachys**	-	+	-	-	-	-	-
30. *Endopsammia**	-	-	+	-	-	-	+
31. *Euphyllia*	-	-	-	+	+	+	+
32. *Favia*	+	-	+	+	+	+	+

Genus	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
33. *Favites*	+	+	+	+	+	+	+
34. *Flabellum**	-	+	+	+	+	+	+
35. *Fungia*	-	-	-	+	+	+	+
36. *Fungiacyathus**	-	-	-	+	-	+	+
37. *Galaxea*	-	-	+	+	+	+	+
38. *Gardineroseris*	-	-	-	+	+	+	+
39. *Goniastrea*	+	+	+	+	+	+	+
40. *Goniopora*	+	-	+	+	+	+	+
41. *Halomitra*	-	-	-	-	-	-	+
42. *Heliopora*	-	-	-	+	+	-	-
43. *Herpolitha*	-	-	-	+	-	+	+
44. *Heterocyathus*	-	+	+	+	-	+	+
45. *Heteropsammia*	-	+	+	+	-	+	+
46. *Hydnophora*	+	-	+	+	+	+	+
47. *Leptastrea*	+	-	+	+	+	+	+
48. *Leptoria*	-	-	+	+	+	+	+
49. *Leptoseris*	-	-	-	+	-	+	+
50. *Lobophyllia*	-	-	-	+	+	+	+
51. *Madracis*	-	-	+	+	-	-	-
52. *Merulina*	-	-	+	+	+	+	+
53. *Millepora*	-	-	-	+	+	+	-
54. *Montastrea*	-	-	+	+	+	+	+
55. *Montipora*	+	+	+	+	+	+	+
56. *Mycedium*	+	-	+	+	-	+	+
57. *Oulastrea*	-	-	-	+	-	-	-
58. *Oulophyllia*	-	-	-	+	-	+	+
59. *Oxypora*	-	-	-	-	-	-	+
60. *Pachyseris*	-	-	+	+	+#	+	+
61. *Paracyathus**	+	+	+	+	+	+	+
62. *Pavona*	-	-	+	+	+	+	+
63. *Pectinia*	-	-	-	+	-	+	+
64. *Physogyra*	-	-	-	+	-	-	+
65. *Physophyllia*	-	-	-	-	-	-	+
66. *Placotrochus**	-	-	-	+	-	+	-
67. *Platygyra*	+	-	+	+	+	+	+
68. *Plerogyra*	-	-	-	+	-	+	+

Genus	Gulf of Kachchh	West coast of India	Gulf of Mannar & Palk Bay	Andaman & Nicobar	Laksha-dweep	Sri Lanka	Maldives
69. *Plesiastrea*	+	-	+	+	+	+	+
70. *Pocillopora*	-	+	+	+	+	+	+
71. *Podabacia*	-	-	-	-	-	+	+
72. *Polycyathus**	+	-	+	+	-	-	+
73. *Polyphyllia*	-	-	-	+	+	+	+
74. *Porites*	+	+	+	+	+	+	+
75. *Psammocora*	+	-	+	+	+	+	+
76. *Psammoseris*	-	-	-	-	-	+	+
77. *Pseudosiderastrea*	+	+	+	+	-	+	-
78. *Sandalolitha*	-	-	-	-	+	+	+
79. *Scapophyllia*	-	-	-	+	-	-	-
80. *Scolymia*	-	-	-	-	-	-	+
81. *Seriatopora*	-	-	-	+	-	-	+
82. *Siderastrea*	+	-	+	-	-	-	-
83. *Solenosmilia**	-	+	-	-	-	-	-
84. *Stephanocyathus**	-	+	-	-	+	-	+
85. *Stephanophyllia**	-	-	-	-	-	-	+
86. *Stylaraea*	-	-	-	-	-	+	-
87. *Stylocoeniella*	-	+	-	-	-	-	+
88. *Stylophora*	-	-	-	+	+	+	+
89. *Symphyllia*	+	-	+	+	+	+	+
90. *Trachyphyllia*	-	-	-	+	-	-	+
91. *Trochocyathus**	-	-	-	-	-	-	+
92. *Tropidocyathus**	-	-	-	-	-	+	+
93. *Tubastrea**	+	+	+	+	+	+	+
94. *Tubipora**	-	-	-	+	+	-	-
95. *Turbinaria*	+	+	+	+	+	+	+
96. *Zoopilus*	-	-	-	-	-	+	+

+ recorded - not yet recorded * ahermatypic # not recorded live

1932). Severe siltation, dredging of sand for the cement industry, quarrying of large quantities of corals, especially at Pirotan island, and the destruction of mangroves have posed threats to these reefs (Pillai, 1996).

From the list of species in Table 3.1 it is observed that only 37 species have been so far reported from the Gulf of Kachchh, 33 species being hermatypic while the rest are ahermatypes (Table 3.2). Fourteen of the species reported have not been recorded in Lakshadweep.

3.3.1.2 West coast of India

Very few coral formations are present along the west coast of India. Among the earliest reports are those of Mosely (1881) on the occurence of *Stephanocyathus nobilis* along the west coast of India and those of Alcock (1893, 1898) from deep waters off the Travancore coast. Isolated coral growths have been reported from Malvan, Malpe, Ratnagiri and Goa (Qasim & Wafar, 1979; Rodrigues *et al.*, 1998). A few species are also cited in Scheer & Pillai (1983). Qasim and Wafar (1979) reported *Pseudosiderastrea* sp. from the west coast. As this genus is monospecific, it is cited as *Pseudosiderastrea tayamai* in the distribution table (Table 3.1). The ahermatypic coral, *Astrangia* sp., has also been reported to settle on artificial substrates at localities along the Goa coast (Anil & Wagh, 1984). A recent report on the corals from the Travancore coast has been published by Pillai and Jasmine (1995).

A total of 42 species are consolidated from the west coast of India of which 25 are hermatypes and 17 ahermatypes (Table 3.2). Seventeen of these coral species have not been reported in Lakshadweep.

3.3.1.3 Gulf of Mannar and Palk Bay

The Gulf of Mannar lies between 8°47' - 9°15'N and 78°12' - 79°14'E. Situated between India and Sri Lanka, it has been considered as a partly drowned barrier reef (Stoddart, 1973). It comprises several fringing reefs and patchy reefs distributed along the shelf of 21 islands stretching between Tuticorin and Rameshwaram. Foliaceous forms such as *Echinopora lamellosa* and *Montipora foliosa* are now scarce due to quarrying while fungiids are poorly represented (Pillai, 1996).

The reefs of the Palk Bay are confined to the northern and eastern coast of Rameshwaram Islands and the northern side of Mandapam between 9°10' - 9°18'N and 79°4' - 79°15'E. The Gulf of Mannar and Palk Bay at Mandapam are separated by a narrow strip of land having permanent connection through the Pamban pass where waters of the two regions mix freely. The Palk Bay is a rather shallow basin with mostly muddy inshore region, while the Gulf of Mannar is more open, deep and with rocky patches in the inshore region (Jayaram, 1954). There is an enormous literature on the distribution of corals in the area (Foote, 1888; Brook, 1893; Thurston, 1895; Bernard, 1897, 1905; Mathai, 1924; Gravely, 1927; Sewell, 1932, 1935). Among the more recent publications are those of Pillai (1971b,c, 1977, 1983a) and Mergner & Scheer (1974).

The status of present day reefs is very poor and reefs are not in pristine conditions since they were quarried in the early sixties (Pillai, 1996). Anthropogenic activities have resulted in large scale destruction of corals in the Gulf of Mannar and Palk Bay, epitomized by the disappearance of the fringing reef at Manauli (Pillai, 1996).

The synonymised list resulted in a total of 102 species for the area of which 89 are hermatypes and 13 ahermatypic (Table 3.2). Forty three species present in the Gulf of Mannar have not been reported in Lakshadweep.

3.3.1.4 Andaman and Nicobar Islands

The Andaman and Nicobar islands are situated between 6°45' - 13°13'N and 90°20' - 93°56'E. The Andaman occupies an area of 11,000 km² while the Nicobar is 2,700 km² in area.

This island-arc system is associated with the Himalayan ranges, formed along a converging plate boundary. These islands are summits of a submarine mountain range, basically volcano-sedimentary in nature, and continue with the Arakan Yomas mountain range of Burma in the north and the islands of Sumatra in the south. The northward movement and anticlockwise rotation of the Indian plate during the Tertiary has resulted in its subduction beneath the Asian plate. The chain of mountains were uplifted and attained maximum elevation of 2,700m above Mean Sea Level during the Tertiary and submerged again by the end of the same period.

The major reefs in the area are of the fringing type, comprising 350 islands. Along the west coast of Andaman, Sewell (1935) has reported the existence of a chain of uninterrupted banks considered as barrier reefs. Quarrying of sand resulting in sea erosion and subsequent siltation, besides quarrying of corals and effluent discharge from timber factories are reported to cause damage to coral reefs in the area (Dorairaj *et al.*, 1987). Mass mortality of corals has been observed in and around Port Blair, Labrynthene island, Chester island and Wandoor Marine Park while the outer reefs at Jolly Buoy are dead (Pillai, 1996).

Alcock (1893) had described coral specimens, including deep sea species, collected during his visit to Port Blair aboard the research vessel *R.M.S. Investigator*. Sewell (1922) visited Nicobar and described the ecology of formation of reefs in the area. He also reported a 320km barrier reef on the west of the Andamans (Sewell, 1935). Mathai (1924) studied and described material from Andamans collected in the Indian museum, Calcutta. Coral species from the Andaman and Nicobar were reported by Pillai (1967g) and Scheer (1971). Subsequently, Pillai (1972), Scheer and Pillai (1974) and Reddiah (1977) provided additional information on the coral fauna of the region. Pillai (1983a,b) presented a consolidated checklist of the coral fauna from Andaman and Nicobar. The coral reef ecosystem at Chiriatapu in south Andaman has recenty been described by Mukherjee (1994).

The present updated list has resulted in 155 species of which 134 are hermatypes and 21 are ahermatypes (Table 3.2). Eighty of these coral species have not been reported in Lakshadweep.

3.3.1.5 Sri Lanka

Located between 6° - 10°N and 80° - 82°E, the coral reefs of Sri Lanka are mainly of the fringing type, developed over sandstone and granite/ granulite, with the former being the most dominant type. Islands of Sri Lanka are located only 35km from India at its northeastern end and were a part of the Tamilnadu mainland believed to have severed from it only in recent times. They remained separated from the mainland by a submerged platform barely 9m deep. Eighty per cent of the island consists of Precambrian crystalline rocks (Cooray, 1984). Coral reefs and limestone shores are generally restricted to small sectors of the middle east coast, the southwestern coast and the northern coast. Outside the Indo-Sri Lankan strait the coastal shelf deepens to 1,800 - 2,880m. This coast has been submerged repeatedly from Jurassic to mid-Pleistocene times, with broad outlines of the coast emerging only during the Cretaceous.

The earliest reports on corals in the area are those of Ridley (1883), Ortmann

(1889) and Bourne (1905). Pillai (1971b,c, 1972) recorded a total of 90 species divided among 39 genera. Reefs in Sri Lanka were investigated by Mergner and Scheer (1974). Scheer (1984) reported 40 hermatypic genera based on studies by earlier workers as well as his own. Rajasuriya and De Silva (1988) published a list comprising of 171 species divided among 65 genera. Subsequently, an additional 12 species belonging to 3 genera were added to the list (Rajasuriya, 1994).

In Table 3.1 a total of 177 coral species have been listed from Sri Lanka, 159 of them being hermatypic (Table 3.2). Ninety nine of these coral species have not been reported in Lakshadweep.

3.3.1.6 Maldives

The Maldive archipelago is situated between 7°5'N - 0°40'S and 72°55' - 73°10'E, about 480 km southwest of Cape Comorin, and 650 km southwest of Sri Lanka. The archipelago consists of 22 atolls and nearly 2000 small islands. Among these, Suvadiva atoll is one of the largest atolls in the world. Northern and central Maldivian atolls contain ring shaped reefs known as *faros*, relatively rare elsewhere. Maldivian atolls form the central and southern part of the Chagos-Laccadives Ridge, which is part of a larger feature that stretches from the late Cretaceous to early Tertiary Deccan Traps of India (66-68Ma) to the volcanically active island of Reunion located 21°S (Morgan, 1981). It comprises an early to mid-Tertiary volcanic basement (50-60 Ma) overlain by about 2000m of carbonate sediments (Purdy & Bertram, 1993).

Among the first to study Maldivian reefs was Commander Moresby who surveyed these reefs in 1834-1836 but published only a brief account of the northern atolls (Moresby, 1835). The first comprehensive report was provided by Gardiner, based on his visit spanning several weeks during 1899-1900, aboard the *R.M.S.*

Investigator. The results obtained were consolidated in 2 classical volumes on the fauna and reef development in Maldives and Lakshadweep (Gardiner, 1903-1906). Subsequently, Agassiz (1903) augmented information on Maldivian corals. Thereafter, there was a break until Deraniyagala collected and described materials for the Colombo museum (Deraniyagala, 1956) followed by Sewell during the John Murray expedition. Sewell's investigations resulted in a few literary works (Sewell, 1936, Gardiner & Waugh, 1939). Pillai and Scheer (1976) documented coral specimens collected during a German survey, the Xarifa expedition in 1957-1958, under the leadership of Dr. Hans Hass. Another major expedition to the Maldives was conducted by a team of British scientists, under the surveillance of Stoddart in 1964. Very recently, Dr. Susan Clark has reviewed the Maldivian coral fauna and finalized a list as cited in Zahir & Naeem (1996).

The present consolidated list indicates the existence of 251 species of corals in the Maldives, the maximum number of coral species among all the localities considered (Table 3.2). Of these, 212 species are hermatypic while the rest are ahermatypes. One hundred and forty nine these coral species have not been reported in Lakshadweep.

3.3.2 Cluster analysis

Results of the cluster analysis revealed two major clusters (Fig. 3.2). Lakshadweep and Maldives formed one cluster while Andaman and Nicobar Islands paired with the Gulf of Mannar/ Palk Bay. Sri Lankan coral fauna exhibited closer affinities with the atoll fauna rather than the coral fauna of the Gulf of Mannar/ Palk Bay. The Gulf of Kachchh and Indian west coast coral fauna did not exhibit any affinities towards other localities.

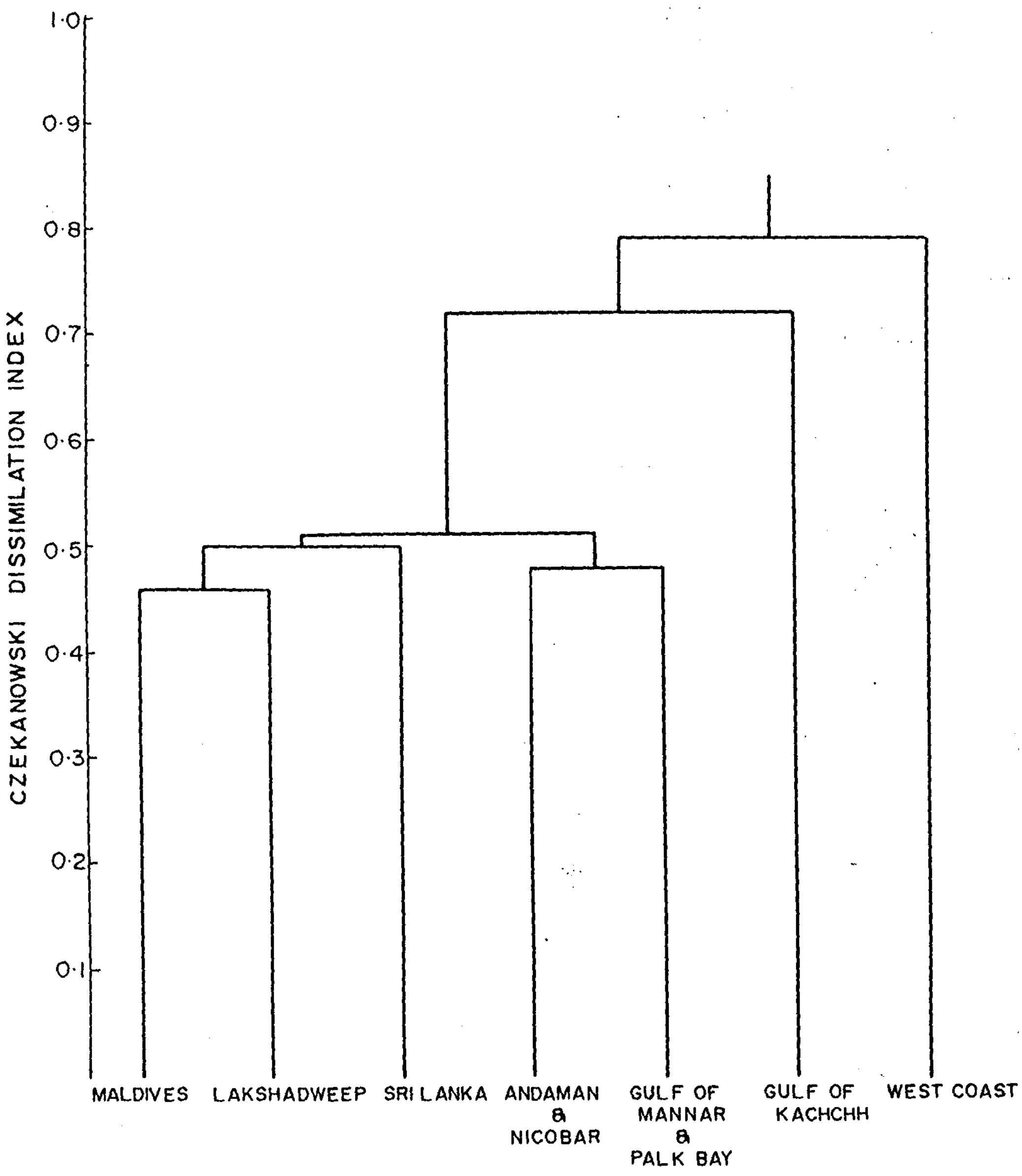

Fig. 3.2 Dendrogram illustrating similarities between coral reef localities in south Asia.

3.4 DISCUSSION

Although comparative accounts on the distribution of corals are available for the Indian Ocean, barring recent publications by Sheppard (1983, 1987), all these reports are at the generic level. Since species rather than genera are the basic biological units, species distribution patterns are likely to give a better insight into coral biogeography. Many workers have stressed that distribution data that are compiled based only on genera may not present a proper picture of the biogeographical pattern since a genus may be monospecific or have many species as in *Acropora* (Veron, 1985a; Sheppard, 1987). The reason for considering only genera by early biogeographers has been the simplicity, as they can be easily identified with a certain degree of accuracy. Veron (1985a) pointed out that, except for Australia, corals are little understood at the species level in the Indo-Pacific. Further, synonyms are being used by different authors rendering comparisons difficult.

In a recent attempt to delete junior/ redundant synonyms, Sheppard (1987) provided a synonymised list of coral species in 24 localities in the Indian ocean and adjacent seas. In his study, he has pooled data on coral distribution in southeast India with those of Sri Lanka. In the present study, these two localities are treated separately. It is not known how far the synonymized list prepared by Sheppard (1987) is acceptable to coral taxonomists, as it requires revision. For example, *Acropora ceylonica* is listed as a valid species. This is a junior synonym of *A. variabilis* which in turn is a synonym of *A. valida* (Dr. Pillai, personal communication). Although Sheppard (1987) considers *Acropora plantaginea* synonymous to *A. secale*, Pillai (1983a) regards it a synonym of *A. humilis*. *Pavona yabei* reported from the Maldives by Pillai and Scheer (1976) though renamed as *Leptoseris yabei* by other authors, has been retained as such in the present study. As indicated earlier, much weightage has been given to Dr Pillai's views on the synonymy of coral species. Thus, though Veron and Wallace (1984) regard *Acropora cythera* as a distinct species, Scheer and Pillai (1983) consider it a synonym of *A. hyacinthus* and the latter's views are incorporated in the present work. A few other controversial species are discussed below.

Veron and Pichon (1976) have merged *P. acuta* (Lamarck, 1816) and *P. brevicornis* in the synonymy list of *P. damicornis*. However, Scheer and Pillai (1983) consider *P. acuta* as a valid species, based on the absence of true verrucae. Veron and Pichon (1976) visualize *P. brevicornis* to be part of a continuous series formed by *P. damicornis*, *P. danae*, *P. verrucosa* and *P. meandrina*. Scheer and Pillai (1983) have maintained the validity of *P. brevicornis* and have opined that this species has closer affinities with *P. verrucosa* or *P. meandrina* rather than with *P. damicornis*. Considering Pillai's opinion, both *P. acuta* and *P. brevicornis* are considered as separate species in the present work.

Veron and Wallace (1984) have merged *Acropora intermedia* with the synonymy list of *A. nobilis* expressing the view that Brook's holotype of *A. intermedia* was *A. nobilis*. However, after examining the descriptions and figures of *A. intermedia* (Pillai & Scheer, 1976; Plate 2, Fig. 1) and *A. nobilis* (Scheer & Pillai, 1983; Plate 5, Fig. 9-10; Veron & Wallace, 1984; Fig. 505-512) it is concluded that the two species are not the same. Pillai (1993) also treats *Acropora intermedia* as a valid species.

Galaxea clavus was given a separate status by Pillai (1986b). However, he also opined that the species was similar to *G. astreata* except that the corallites of *G. clavus* project more than in *G. astreata*. In the present study, as variations in the extent of projection by corallites were observed within the same colony, *G. clavus* is treated as a synonym of *G. astreata*. Veron and Pichon (1980) also consider *G. clavus* as a synonym of *G. astreata*.

In the case of coral species of Sri Lanka, an attempt was made to synonymize the checklist of Rajasuriya and De Silva (1988). Many of the synonyms cited in their checklist are erroneously attributed to species recorded by Pillai (1972) though they were actually reported by Ridley (1883), Ortmann (1889) and Bourne (1905). *Turbinaria quincuncialis* reported by Ortmamn (1889) could be *T. crater* (Pillai, 1972). As these coral species have not been examined, their identities have been retained. In the checklist of Maldivian corals (Zahir & Naeem, 1996), Dr. Susan Clark reported *Favites amicorum* and *Favites bennettae* which are synonyms of *Favia amicorum* and *Oulophyllia bennettae*, respectively (Veron *et al.*, 1977). It may be appropriate to add that the exercise of synonymizing the coral species in the present work could be incomplete and holotypes housed in the different international museums need to be examined to arrive at a definitive conclusion.

A total of 398 coral species are reported in the present compilation for south Asia. The highest number of species (251) is reported in the Maldives while the lowest (37) has been recorded from the Gulf of Kachchh. The present study has indicated that Lakshadweep coral fauna has closer affinities with the Maldivian fauna, as indicated by the results of the cluster analysis. Moreover Maldives and Lakshadweep have a common geological history. These results are in accordance with observations made by Pillai (1971a,b) and refined inferences obtained by Sheppard (1987). The present analysis revealed that the coral fauna of the Andaman and Nicobar islands were similar to that of the Palk Bay and Gulf of Mannar. The tiny islands of the Gulf of Mannar are believed to have a continental origin similar to the Andaman and Nicobar islands (Pillai, 1977). The east coast has been submerged repeatedly from the Jurassic to the mid-Pleistocene eras, though the coast might have been determined during the Cretaceous. Vast stretches of land underwent subsidence many times until the Pleistocene, resulting in the relative change in sea levels and a recent tectonic uplift within 5000 yr. B.P.

caused the emergence of these islands (Wadia, 1966). A similar phenomenon of sinking has been recorded in Madagascar, Mergui, east India and along the east coast of Australia (see Pillai, 1977).

Result obtained in the present study indicated that the coral fauna of the Gulf of Mannar / Palk Bay was similar with that of the Andaman & Nicobar islands. In contrast, Sheppard's cluster analysis indicated that the Andaman and Nicobar coral fauna had no affinities with other localities considered in the present study. Further, his analysis suggested that the coral fauna of the Gulf of Kachchh was similar to that of the Palk Bay, Gulf of Mannar and Sri Lanka. This is probably because Sheppard (1987) pooled data from the last 3 localities. The present analysis appear to present a more realistic picture of affinities of the coral fauna in south Asia.

No coral genus endemic to India has been reported so far (Pillai, 1983a). In the south Asia region, some genera have been reported from single localities (Table 3.3). *Coeloseris*, *Oulastrea*, *Astrangia*, *Cladangia*, *Scapophyllia*, *Solenosmilia* and *Endopachys* have been reported only from Indian localities. *Halomitra*, *Stephanophyllia*, *Caulastra*, *Oxypora*, *Physophyllia*, *Scolymia*, *Conotrochus*, *Discotrochus* and *Trochocyathus* have been reported only in the Maldives while *Stylaraea*, *Australomussa*, *Blastomussa* and *Distichopora* have been recorded only in Sri Lanka. These genera have however been reported elsewhere in the Indo-Pacific (see Veron, 1993). Such localization of genera could thus be due to insufficient surveys conducted in the region.

Many genera recorded in Maldives have not yet been recorded in Lakshadweep. This observation is significant since many of the genera are present in other localities of south Asia. One reason for the discrepancy could be because many islands in Lakshadweep still remain unexplored, especially when it comes to deep water corals.

Notable among coral species not reported so far from Lakshadweep are members of the families Fungiidae and Dendrophyllidae. Except for the genus *Fungia*, most other genera belonging to family Fungiidae are not represented in Lakshadweep. Similarly, species belonging to the family Dendrophyllidae, *viz. Balanophyllia* and *Dendrophyllia* have not so far been reported in Lakshadweep. Pillai (1971b) compared the coral fauna of Minicoy with that of the southeast Indian reefs and observed that a few genera such as *Diploastrea*, *Fungia*, *Euphyllia*, *Lobophyllia* and *Symphyllia* are missing from the faunal list of southeast India. Thus, while there are no major shifts in observations and inferences, these have been reinforced.

The absence of ramose corals in the Gulf of Kachchh has been attributed to prolonged and wide tidal fluctuations as well as siltation (Pillai, 1983a). Further, agariciids and fungiids have also not been recorded in this region. Along the west coast of India, the absence of ramose corals has been attributed to siltation and low salinities (Bakus *et al.*, 1994). Siltation during the northeast monsoon has also a major impact on the distribution of corals along the southeast coast of India (Pillai, 1971b). While Pillai (1983a) reported a total of 199 species of scleractinian corals belonging to 71 genera from reefs around India, the present study has updated the total number of species to 252. These include 216 species of hermatypic corals, belonging to 57 genera and 36 ahermatypic species belonging to 19 genera, and raises the tally of coral genera in Indian waters to 76.

Rosen (1971a) has tabled the presence of coral genera for 57 localities in the Indian Ocean. Accordingly, 27 genera were found to be present in Lakshadweep. The present work, after considering earlier publications, raises the tally to 42 genera. Rosen grouped coral genera according to their frequency of distribution into 3 major groups, with group I, II and III genera occurring in more than 50%, between 25% and 50% and less than 25% of the localities under consideration, repectively. All the group I coral genera are represented in Lakshadweep while from group II only 3 genera *viz.*, *Coscinaraea*, *Herpolitha* and *Seriatopora* have not yet been recorded in Lakshadweep. The group III generic corals are however poorly represented in Lakshadweep.

It may be apt to point out at this juncture that, globally, corals are being threatened due to natural and anthropogenic activities (UNESCO, 1997). Coral reefs in India, particularly in the Gulf of Kachchh, Gulf of Mannar and Palk Bay have been damaged and in some cases destroyed (Pillai, 1996). Surveys of coral species in these areas were carried out decades ago and it is not known whether the distribution lists published in the literature remain valid.

CHAPTER FOUR

COMMUNITY STRUCTURE AND DIVERSITY OF CORALS ON THE REEF FLAT AT AGATTI

4.1 INTRODUCTION

Coral reefs are perhaps the most complex among marine ecosystems. They are formed primarily by hermatypic corals which have the remarkable ability to construct massive calcium carbonate skeletal structures forming the basic framework and substrate. They are colonised by a diverse group of organisms belonging to almost all phyla. While earlier studies on reefs concentrated on taxonomical aspects, recent studies have attempted to obtain quantitative data on their abundance and distribution to understand their community structure and diversity. Species diversity on coral reefs is very high and is comparable to the high diversity prevailing in tropical rain forests (Connell, 1978; Jackson, 1991). During the past few decades, coral reef ecologists have been attempting to document the distribution, abundance, diversity and zonation of coral species globally to formulate general patterns and to test ecological hypotheses. For a long time, it was widely believed that coral diversity is maintained by the specialization of species for different types of reef habitats (niche diversification). However, this view has been questioned when reef communities were observed to change due to disturbance and fluctuations in recruitment (Connell, 1978; Huston, 1985; Sale, 1988). Pickett and White (1985) define disturbance as "any relatively discrete event in time that disrupts ecosystems, community, or population structure and changes resources, substrate availability, or the physical environment". Although the complexity of coral reefs is being gradually unravelled through the collection and analyses of quantitative data as well as testing of hypotheses, many questions still remain unresolved. The diversity and distribution of reef organisms has recently been reviewed by Paulay (1997).

The coral fauna of Lakshadweep has been studied by several investigators (Gardiner 1904, 1905; Pillai 1971a, 1986a,b; Pillai & Jasmine, 1989). While these accounts mainly deal with the taxonomy of corals and general aspects of coral reefs, there is hardly any quantitative information on the distribution, abundance or diversity of coral communities not only in Lakshadweep but also in other coral reefs located in Indian territorial waters. Such information is vital for unravelling the complexity and understanding coral reef organization and community structure which may ultimately help in the monitoring and management of these reefs. Many factors play a role in the distribution of corals on the reefs, especially along the reef flat which is subject to the influence of tides, temperature fluctuations, degree of wave exposure, mechanical destruction during storms and biological factors. In the present study, quantitative information on the distribution, abundance and diversity of corals on the shallow reef flat of Agatti, one of the Lakshadweep atolls, was collected and analyzed.

4.2 METHODOLOGY

4.2.1 Sampling

The distribution, abundance and other coral community characteristics were studied at Agatti atoll during October-November 1993 and March-April 1994. Quantitative treatment of data requires numerical measurements of coral species abundance collected either by the conventional quadrat sampling method or by the line intercept transect method. Quadrat sampling has been considered appropriate for reef flats (Stoddart, 1969). Although the line intercept transect method (Loya & Slobodkin, 1971) is efficient in terms of information recorded per time spent underwater, it has drawbacks, particularly when the distribution of corals is very heterogenous (Ditlev, 1978). A preliminary survey conducted had suggested that the distribution of corals was heterogenous and hence quadrat sampling was selected. The quadrat used was a 1x1m aluminium frame with a nylon string grid of 100 squares.

Sixteen transects were fixed on the reef flat, on the eastern side of the atoll at intervals of 500m, from the northern to the southern end (Fig. 4.1). At each transect a nylon line, marked at 5m intervals to denote stations was laid, running from the average high tide mark towards the low tide mark and perpendicular to the shore. The 0m station mark on the line was made to coincide with the average high tide mark. Starting from the 0 m station, the percentage cover of live corals was estimated at 5m intervals in duplicate quadrats, on either side of the transect line. Whenever a species could not be identified in the field, a small piece was collected and labelled for later identification in the laboratory. General features prevailing at each transect were noted. Sampling along transects extended seawards to as far as the low tide permitted. In case sampling could not be completed on the same day, it was continued on the following day. The extent of exposure at each station varied from station to station due to variation in the tidal height and difference in the topographical features at each station. In all, 850 quadrats were enumerated in October-November 1993. Their percentage cover was again estimated in March-April 1994 at alternate transects (II, IV, VI, VIII, IX, X, XII and XIV). During this period, 384 quadrats were enumerated.

4.2.2 Statistical analyses

The coral percentage cover data collected during October-November 1993 and March-April 1994 along the transects were pooled and statistically analysed. Most statistical analyses were adapted from Sokal & Rohlf (1981).

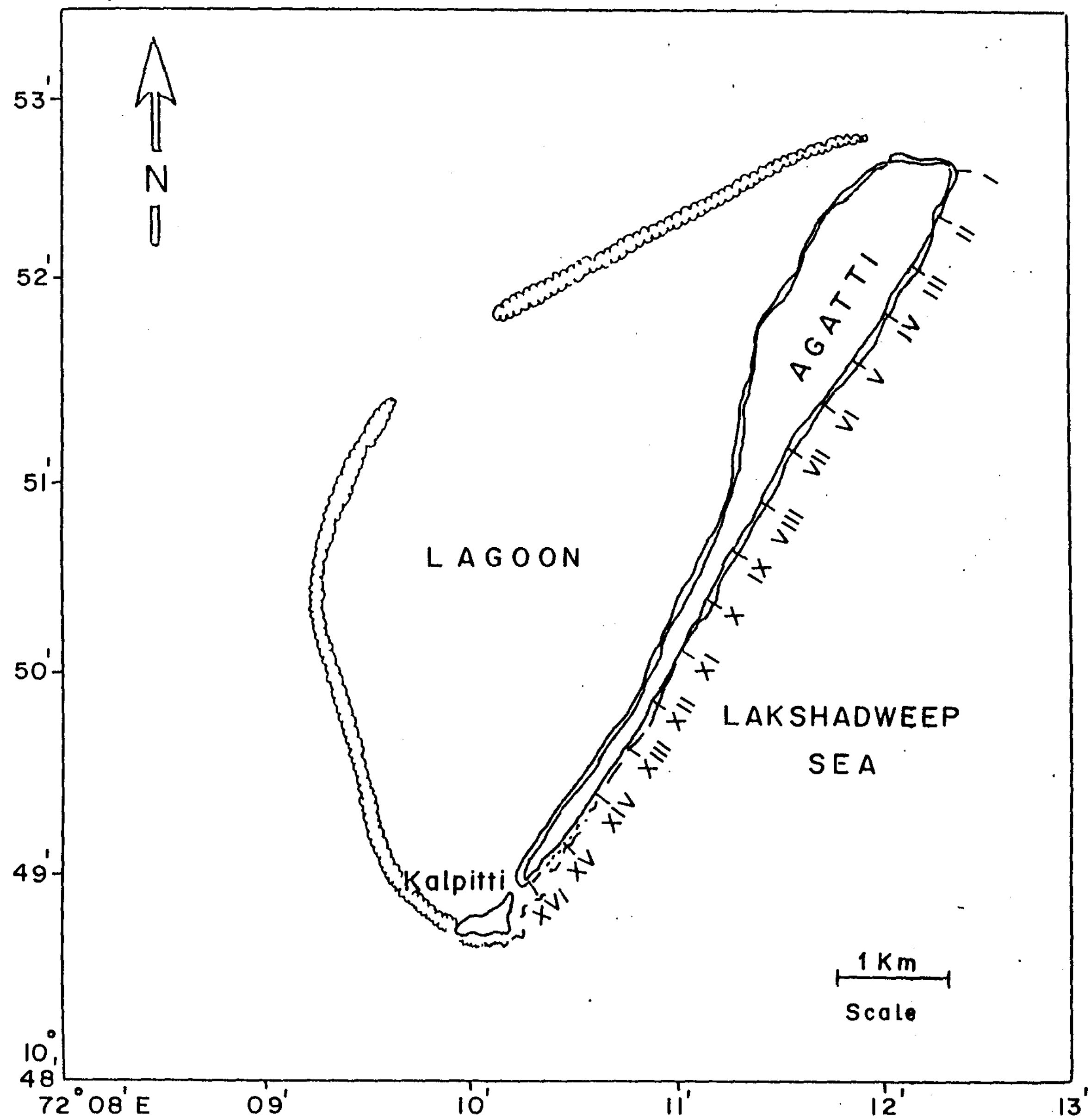

Fig. 4.1 Map of Agatti atoll indicating the location of transects.

4.2.2.1 Standard deviation: The standard deviation (σ) of percentage cover values was computed as follows:

$$\sigma = \sqrt{\frac{\Sigma (X_i - \overline{X})^2}{(N - 1)}}$$

where,

X_i is the individual percentage cover observation

$\overline{X}$ is the mean percentage cover

N is the sample size (number of quadrats)

4.2.2.2 Standard error: The standard error (S.E.) of the mean percentage cover values obtained with 95% confidence limits was calculated as follows:

$$S.E. = \overline{X} \pm t_{0.5[N-1]} \cdot \frac{\sigma}{\sqrt{N}}$$

where,

$\overline{X}$ is the mean percentage cover of the sample

$t_{0.5[N-1]}$ is the tabulated t statistics with N-1 degrees of freedom

σ is the standard deviation of percentage cover obtained

N is the sample size (number of quadrats)

4.2.2.3 Principal component analysis: Stations were ordinated by Principal Component Analysis (Pielou, 1984) using the pooled station data. This method involved an eigen analysis of the species covariance matrix to determine eigen vectors. The principal components with the largest eigen values and the scatter diagram of component scores were examined. The eigen vector coefficients were scrutinized to determine which species combine to form the axes. Ordination resulted in the subdivision of the reef flat into zones.

4.2.2.4 *t* - test: A *t* - test (Sokal & Rohlf, 1981) was applied to coral cover values of each species as well as totals to analyze differences between the zones on the reef flat.

$$t = \frac{|\overline{X}_1 - \overline{X}_2|}{\sqrt{\dfrac{(N_1 - 1) \cdot \sigma_1^2 + (N_2 - 1) \cdot \sigma_2^2}{N_1 + N_2 - 2} \cdot \dfrac{N_1 + N_2}{N_1 \cdot N_2}}}$$

where,

$\overline{X}_1$ is the mean of sample 1

σ_1^2 is the variance of sample 1

N_1 is the size of sample 1

$\overline{X}_2$ is the mean of sample 2

σ_2^2 is the variance of sample 2

N_2 is the size of sample 2

4.2.2.5 Cluster analysis: The coral community structure was analyzed by subjecting the pooled transect data to cluster analysis (Clifford & Stephenson, 1977). The percentage cover data was normalized using arcsine transformation ($\sin^{-1}\sqrt{\text{proportion}}$, Sokal & Rohlf, 1981).

The Bray-Curtis dissimilarity index between pairs of species (*j* and *j*+1) was computed using normalized percentage cover data to obtain the dissimilarity matrix and species clustered using the group average linkage method (Clifford & Stephenson, 1977). In the resulting dendrograms, species inhabiting similar stations formed clusters, enabling the delineation of coral assemblages on the reef flat. The index fluctuates between 0-1, unity indicating complete similarity of stations occupied by species.

$$\text{Bray-Curtis dissimilarity index} = \frac{\sum | X_{i,j} - X_{i,j+1} |}{\sum | X_{i,j} + X_{i,j+1} |}$$

where,

$\sum X_{i,j}$ is the percentage cover of species i at station j

$\sum X_{i,j+1}$ is the percentage cover of species i at station $j + 1$

4.2.3 Community characteristics

Several community indices indicating the diversity and dominance of species in the coral reef community on the reef flat at Agatti were computed.

The number of species was taken as an index of species richness. The Shannon-Wiener species diversity index (H'), expressed in bits, and evenness (J) were calculated (Pielou, 1975). This index incorporates species richness and evenness of occurrence and has been widely used in community ecology. The diversity index is zero when only one species is present and increases with species richness and evenness. The evenness index ranges from 0-1, representing maximum and minimum dominance respectively.

$$H' = -\sum p_i \cdot \log_2 p_i$$

$$J = \frac{H'}{\log_2 s}$$

where,

p_i is the proportion of % cover of species i

s is the total number of species in the sample

The diversity of the coral reef flat community with 95% confidence limits was estimated using the Brillouin's index (H) as given in Pielou (1974).

$$H = \frac{1}{N} \cdot \log_2 \cdot \frac{N!}{\Pi N_i!}$$

Quadrats were successively randomnly pooled and the Brillouin's diversity index calculated each time. A plot of the Brillouin's index *versus* pooled quadrat size levels off after sufficient quadrats (t) have been pooled to yield a representative value of the community diversity. The point at which the curve levels off (t) along with the corresponding pooled quadrat number (k) was noted and for all values where $k > t$, h_k was calculated. Every estimate of diversity after t is treated as a separate estimate of the community diversity, enabling the estimation of its variance.

$$h_k = \frac{M_k \cdot H_k - M_{k-1} \cdot H_{k-1}}{M_k - M_{k-1}}$$

where, M_k is the total number of individuals in the accumulated pool of k samples and h_k is the Brillouin's index.

These successive diversity values were checked to ascertain that they do not exhibit serial correlation (r_s). As suggested by Lloyd *et al.* (1968), replicate estimates were calculated, each based on a different permutation of quadrats, and the median values selected.

The estimate of the diversity of the whole community (H') is given by:

$$\bar{H}' = \bar{h} = \frac{1}{n - t} \cdot \Sigma \; h_k$$

where,

n is the number of h's calculated

k ranges from $t + 1$ to n

The sampling variance of the estimate is given by:

$$\mathrm{var}\,(\bar{H}') = \mathrm{var}\,(\bar{h}) = \frac{1}{n \cdot (n - 1)} \cdot (\Sigma\, h_k^2 - n \cdot \bar{h}^2)$$

The 95% confidence limits for the diversity of the community is given by:

$$\bar{h} \pm 1.96 \sqrt{\mathrm{var}\,(\bar{h})}$$

As the base of the logarithm used in all calculations was 2, results are expressed in bits.

4.3 RESULTS

4.3.1 Physical and general characteristics

Agatti (10° 51'N, 72°11'E) is the most westerly among the Lakshadweep group of islands. The reef forms an ellipse 6km in length and 1km wide at its broadest point and has an area of 2.7km². Unlike other islands, the eastern side is not characterized as a storm beach and has a narrow coralline sandy beach. To the south, separated from the main island by a narrow channel, is the small unihabitated island of Kalpitti (Fig. 4.1). Sandwiched between the island and the reef on the western side is a lagoon.

The intertidal reef flat at Agatti is approximately 170m in width, narrow towards the northern end. The reef flat is bordered by a sloping coralline sandy stretch, 5-10m in width, extending above the average high tide mark. Wave action, intense towards the northern end of the reef flat, progressively decreases towards the southern end. The reef flat is characterized by a number of rock pools of varied sizes, which retain water during low tide. Besides corals, the reef flat is colonized by diverse organisms such as sponges, polychaetes, crabs, molluscs, echinoderms, ascidians and fishes. In the following account only a few dominant organisms are mentioned. General characteristics of the transects studied are briefly described below:

Transect I: This transect was located at the northern tip of Agatti and subject to strong wave action. On account of strong wave action, sampling was difficult, enabling observations to be recorded only up to 35m of the transect.

Transect II: The coralline sandy shore extended to 13.5m above the high tide mark. This sandy stretch extended seawards resulting in a fairly large sand flat close to the shore. Sea grapes, *Boergesenia forbesii* (Harvey) Feldmann, were abundant for up to

10m of the transect. Along this transect, approximately between 50-60m, dead coralline rubble was encountered amidst live corals. During the low tide, a vast expanse is exposed.

Transect III: At this transect, the sandy stretch was 13.5m wide. This transect was primarily on a sand flat covered with sparse growth of seagrasses, *Thalassia hemprichii* (Ehrenberg) Ascherson. Dead coral rubble was observed beyond 55m.

Transect IV: The upper sandy stretch was 11.5m wide along this transect. The physical characteristics were similar to transect III with a sand flat bearing sparse growth of seagrasses, *T. hemprichii*. At about 30m from the high tide mark was a rock pool. Beyond 90m and up to 120m many live coral colonies were present. Sea urchins and sea cucumbers were abundant at this transect.

Transect V: The upper sandy shore stretched to about 12m. This transect was characterized by sand flats and rock pools. In some rock pools, the seagrass *T. hemprichii* grew luxuriously. Sea urchins (*Diadema* sp., *Tripneustes* sp., *Echinometra* sp.) and sea cucumbers (*Holothuria* sp., *Synapta* sp.) were also abundant at this transect. Beach rock was prominent along the shore, below the sandy stretch.

Transect VI: The upper sandy shore was about 15m in width. This transect mainly traversed sand flats. Sparse to lush growth of *T. hemprichii* was observed. Sea cucumbers (*e.g. Holothuria leucospilota* Brandt) and sea urchins (*Tripneustes gratilla* (Linnaeus)) were observed at this transect. Coral colonies were abundant beyond 95m. Sampling could be carried out for about 150m. Tetrapods, arranged on the shore to prevent erosion, constituted a landmark for this transect.

Transect VII: The upper sandy shore extended up to 11m. Lush to moderate growth of

T. hemprichii was observed at this transect. Arborescent colonies of corals were found at this location. Sampling could be conducted for up to 150m. A single individual of the crown of thorns, *Acanthaster planci* Linnaeus, was encountered at this transect. Dead, compacted coral rocks characterized the upper shore. A few coral colonies were present beyond 105m.

Transect VIII: The upper sandy stretch was 15m wide. This region was dominated by sand flats with a few pools in between. Moderate to good growth of seagrasses was observed. Between 25-30m coralline sand harbouring rich growth of the seagrass *T. hemprichii* was observed. Coral colonies were abundant at this transect. So were holothurians (*Holothuria* sp., *Stichopus* sp.). Sampling could be carried out for up to 165m since a large area of the flat was exposed during the low tide.

Transect IX: The 13.5m upper sandy stretch was characterized by burrows of the crab, *Ocypode* spp. Rich to moderate meadows of *T. hemprichii* could be observed. The brown alga, *Padina* sp., was abundant on the sand flat. Sea cucumbers were present in significant numbers while a few sea urchins, *Tripneustes gratilla* and dead corals were also encountered. There were extensive sandy flats and rock pools.

Transect X: The upper sandy shore was 12m in width and as in the previous transect, characterized by *Ocypode* burrows. About 30m from the shore was an extensive waist deep rock pool with a luxuriant growth of seagrasses, *T. hemprichii*, extending up to 80m. The alga, *Turbinaria ornata* (Turner) J. Agardh, was abundant along this transect. Live coral cover was low.

Transect XI: The sandy stretch at this transect was 12m wide. This transect was similar to transect X, with rock pools and sand flats with meadows of *T. hemprichii*. Coral cover was moderate. A few cushion stars, *Culcita* sp., were encountered at this transect. Piles of seagrasses and algal debris could be seen strewn ashore.

Transect XII: After a narrow sandy belt of about 1.5m, the substratum is made up of compacted dead coralline rocks inhabited by crabs, gastropods and sessile organisms. These rocks extended for about 8m. A large area was exposed and sampling could be conducted for about 150m. Many coral colonies were observed along this transect. A few cushion stars were also recorded.

Transect XIII: At this transect, the upper sandy stretch was 13.5m wide. There was an extensive shoulder deep rock pool near the shore which extended to about 25m. Beyond was a very shallow sand flat with lush growth of seagrasses, *T. hemprichii*, as well as the green alga, *Ulva lactuca* Linnaeus. Sampling could be carried out along the transect for a distance of 150m. One of the landmarks of this transect was the presence of tetrapods along the shore, to prevent erosion.

Transect XIV: This area was covered with sand flats and pools colonised by seagrasses, *T. hemprichii*. Beyond 70m, rubble of dead corals were observed. Sampling could be conducted for up to 150m of the transect length. Very few corals could be recorded along this transect. Piles of seagrasses and algal debris were strewn ashore.

Transect XV: The width of the upper sandy stretch extended to 18.5m. This transect was dominated by algae and only a few coral colonies could be recorded. Sampling was carried out up to 150m. As in transect XIV, algae and seagrasses were piled ashore.

Transect XVI: The upper sandy stretch extended for about 12.2m. Along this transect no corals could be recorded. The substratum along this transect was primarily sandy harbouring algae such as *Boergesenia forbesii* and *Enteromorpha clathrata* (Roth) Greville. Sea urchins (*Tripnuestes gratilla*) were also abundant along this transect.

4.3.2 Coral reef flat community characteristics

Corals were abundant along transects II, VI to IX and XII. No corals were recorded in quadrats along transects III, XV and XVI. The growth form of corals was dominated by branching types with a few encrusting and massive/ submassive forms. Branching/ digitate corals were generally distributed seawards while encrusting and massive/ submassive forms were dominant in calmer waters, in tide pools and in the nearshore areas of the reef flat. Corals were absent at the 0m and 5m stations. At the 10m and 15m stations, corals were recorded in a total of only 4 quadrats.

The maximum number of coral species (27) was recorded at transects VI and XII. Considering individual quadrats, the maximum number of coral species recorded was 9 at the 120m station along transect VI and diversity values ranged from 0 to 3.02 bits. Coral percentage cover, species richness and species diversity increased, while evenness values slightly decreased seawards (Fig. 4.2). The erratic values recorded at the 155m-165m stations are probably due to the small number of quadrats enumerated at these stations. The total number of quadrats sampled on the reef flat was adequate to estimate community diversity as evidenced by the levelling of the curve (Fig. 4.3). The median value of the Brillouin's index, based on 11 replicate analyses (Table 4.1), yielded a coral reef flat community diversity value of 3.65 ± 0.24 bits (t=134, r_s=0.024).

The most abundant coral species on the reef flat were *Pocillopora damicornis*, *Porites lutea*, *Acropora humilis*, *A. corymbosa* and *A. robusta* (Fig. 4.4). Several coral species exhibited restricted distributions. *Porites compressa* was recorded in quadrats only at transect XI. Colonies of *Acropora aspera* were recorded in quadrats only at transects VI and VII. *Goniastrea retiformis* was dominant at transect VI and a small colony was recorded at transect XIV. The mushroom coral, *Fungia scutaria*, was recorded in quadrats at transects X and XII only.

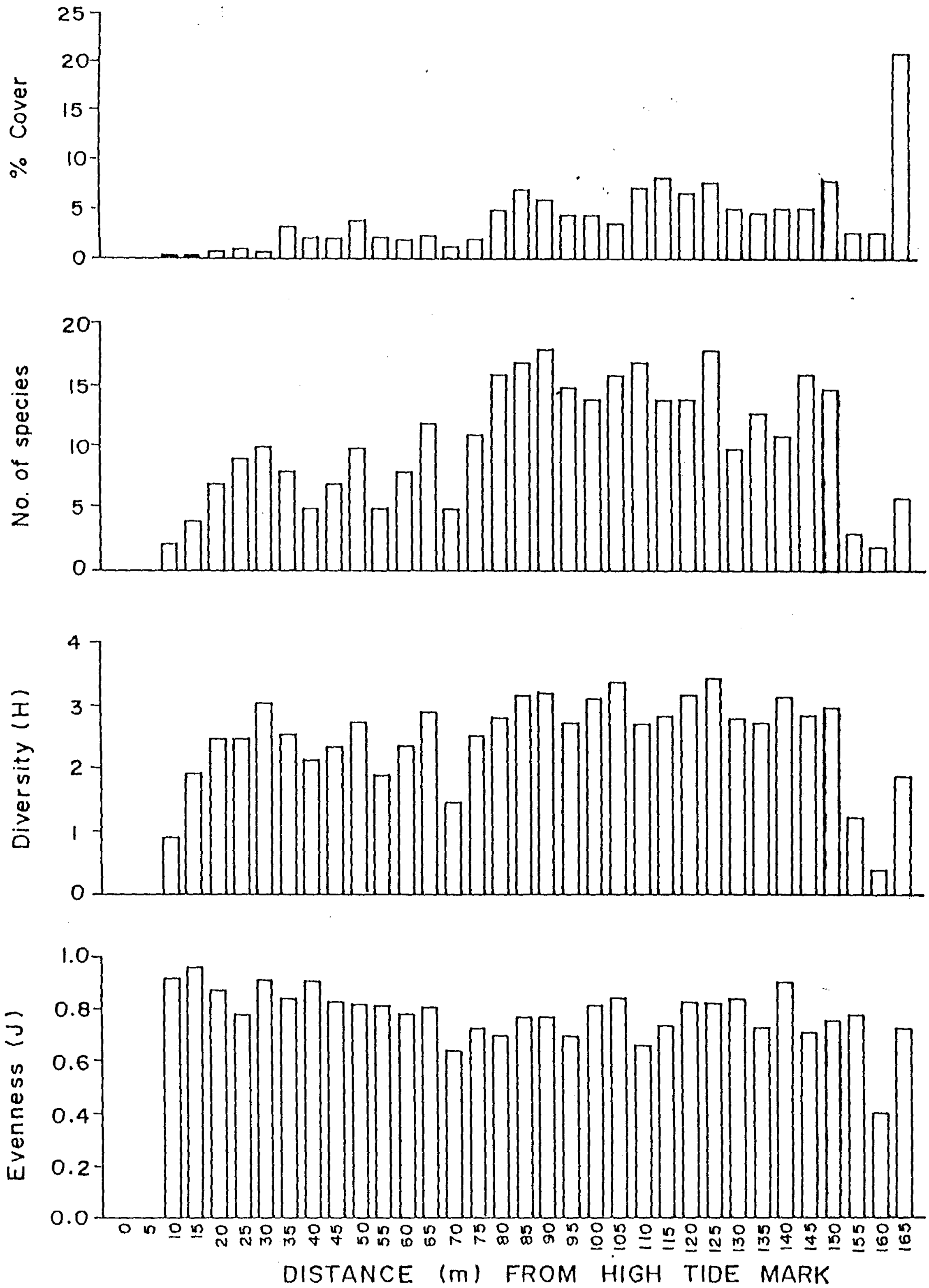

Fig. 4.2 Coral community characteristics of the reef flat at Agatti.

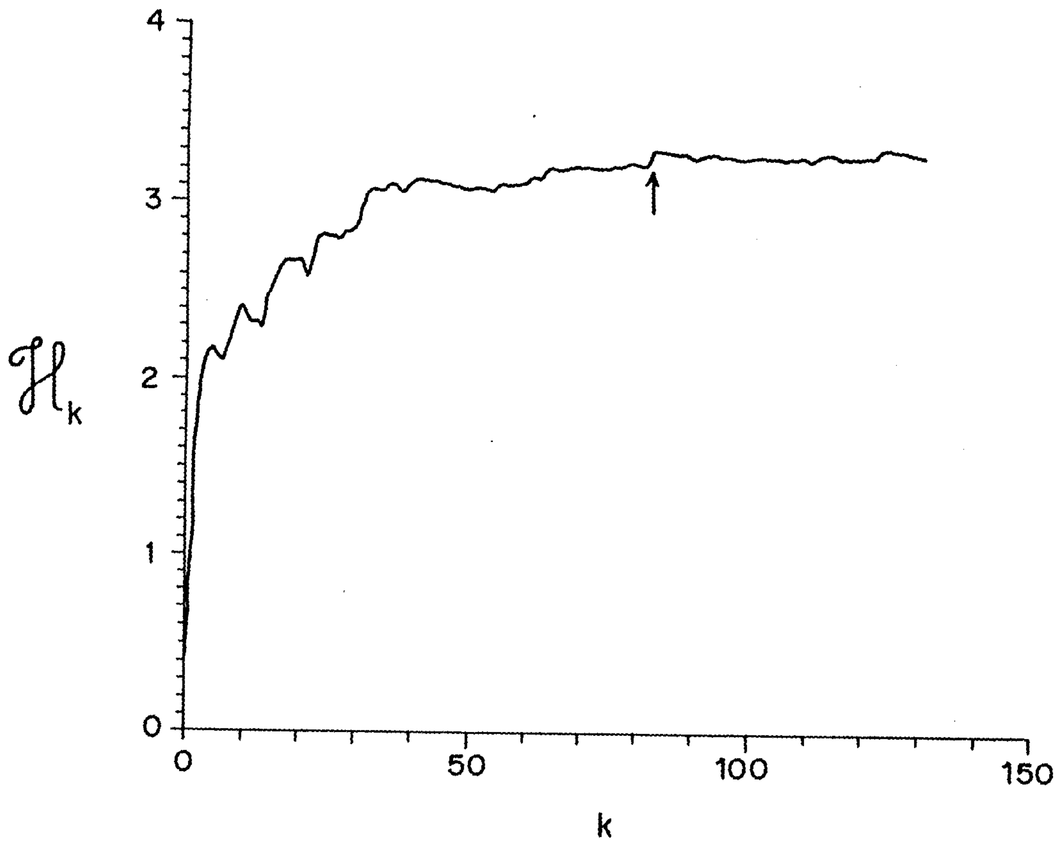

Fig. 4.3 Plot of the Brillouin's index *versus* k for the coral reef community on the reef flat at Agatti. The arrow indicates the position of *t*.

Table 4.1 Summary of results of replicated Brillouin index diversity analyses.

1. 3.35 ± 0.31 bits (t- value = 190, r_s= 0.099)
2. 3.41 ± 0.45 bits (t- value = 235, r_s= 0.058)
3. 3.42 ± 0.31 bits (t- value = 187, r_s= 0.046)
4. 3.64 ± 0.35 bits (t- value = 185, r_s= 0.080)
5. 3.64 ± 0.37 bits (t- value = 186, r_s= 0.051)
6. 3.65 ± 0.24 bits (t- value = 134, r_s= 0.024)
7. 3.65 ± 0.28 bits (t- value = 191, r_s= 0.091)
8. 3.66 ± 0.20 bits (t- value = 61, r_s= 0.099)
9. 3.72 ± 0.28 bits (t- value = 162, r_s= 0.097)
10. 3.76 ± 0.29 bits (t- value = 150, r_s= 0.022)
11. 3.77 ± 0.36 bits (t- value = 190, r_s= 0.004)

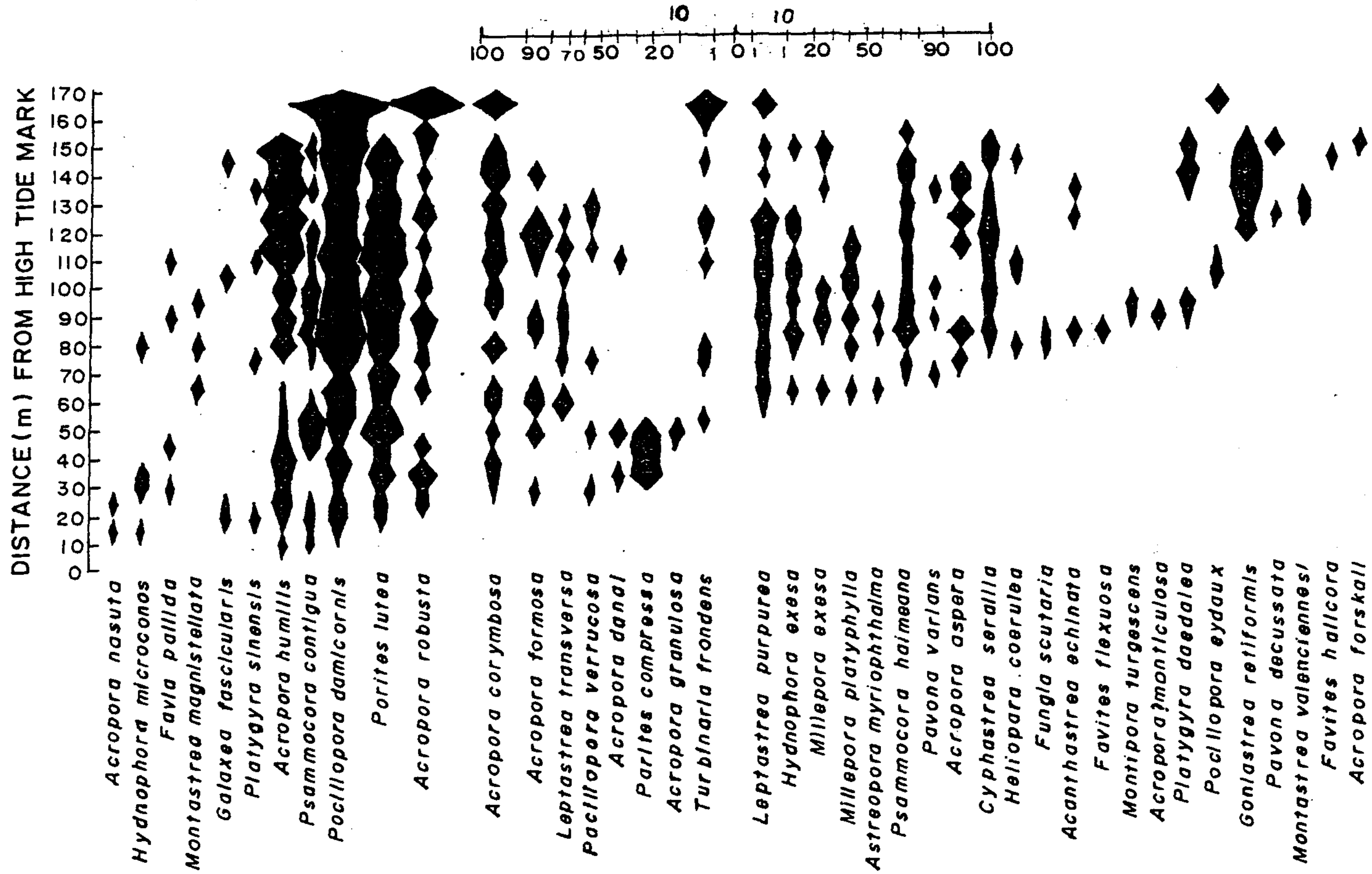

Fig. 4.4 Kite diagrams illustrating the abundance (percentage cover) and distribution of coral species on the Agatti reef flat in 1993-94.

A zonation pattern could be discerned on the reef flat along the intertidal gradient (Fig. 4.4). Starting from the average high tide mark up to a distance of 20m, the area was generally devoid of corals and colonized by algae and/or seagrasses. A few dead massive, sometimes branching, coral colonies were observed in seagrass beds. The number of coral species and their abundance increased seawards. Among the first coral species to be encountered along the intertidal gradient were *Porites lutea*, *Pocillopora damicornis* and *Acropora humilis*. Corals recorded in the surf zone of the reef flat, towards the seaward end of the reef flat, were *Pocillopora damicornis*, *Acropora robusta*, *A. corymbosa*, *A. humilis*, *A. aspera*, *Heliopora coerulea*, *Millepora* spp., *Montipora turgescens* and *Leptastrea* spp.. Among these species, *Pocillopora damicornis*, *Acropora robusta*, *A. corymbosa*, *Heliopora coerulea* and *Millepora* spp. were dominant. At transect I, where wave action was intense, only 35m of the transect could be sampled and it was colonized by *Acropora robusta* (89%), *Pocillopora* spp. (7%) and *Porites lutea* (4%). Colonies of *Heliopora coerulea* and *Millepora* spp., although not recorded in quadrats, were also observed at this transect.

Principal component analysis of the data revealed that the first two principal components together accounted for 85.6% of the total variance in the data (Table 4.2). The first principal component was weighed by *Pocillopora damicornis* and *Acropora robusta* while the second principal component was weighed by *Acropora humilis* and *Porites lutea* (Table 4.2). *Pocillopora damicornis* and *Acropora robusta* were dominant on the outer reef flat (Fig. 4.4, Table 4.3) while *Acropora humilis* and *Porites lutea*, although dominant on the outer reef flat, was also abundant on the inner reef flat (Table 4.3). The scatter plot of component scores revealed that the reef flat could be divided into two zones on the basis of distance from the average high tide mark: an inner reef flat and an outer reef flat demarcated by Axis I (Fig. 4.5).

Table 4.2 Results of PCA analysis: eigen vectors of the covariance matrix.

	Principal components			
	1	2	3	4
1. *Pocillopora damicornis*	0.79661	0.18535	0.20239	-0.46985
2. *Pocillopora verrucosa*	-0.00131	0.01364	-0.00476	0.01607
3. *Pocillopora eydouxi*	0.04084	-0.01367	-0.00164	0.03309
4. *Montipora turgescens*	0.00005	0.00083	0.00625	0.00104
5. *Acropora humilis*	-0.00996	0.75559	-0.57566	0.03717
6. *Acropora ?monticulosa*	0.00060	0.00309	0.00715	0.00930
7. *Acropora robusta*	0.56581	-0.23816	-0.27391	0.63522
8. *Acropora danai*	-0.00213	-0.00076	0.02410	0.05399
9. *Acropora formosa*	-0.00942	0.08283	0.09910	0.13501
10. *Acropora aspera*	0.00079	0.08886	-0.09636	-0.06916
11. *Acropora corymbosa*	0.15997	0.07757	0.05958	0.14881
12. *Acropora nasuta*	-0.00074	-0.00275	-0.00285	-0.00024
13. *Acropora granulosa*	-0.00118	-0.00033	0.01251	0.01969
14. *Acropora forskali*	0.00056	0.01370	-0.02022	-0.01677
15. *Astreopora myriophthalma*	0.00003	-0.00079	0.01195	-0.00785
16. *Pavona decussata*	0.00128	0.03650	-0.05579	-0.03646
17. *Pavona varians*	-0.00052	0.01662	-0.01900	-0.01085
18. *Psammocora contigua*	-0.00545	0.04384	0.13018	-0.03901
19. *Psammocora profundacella*	0.00338	0.02932	0.07139	-0.07421
20. *Fungia scutaria*	0.00019	0.00064	0.00233	-0.00452
21. *Porites lutea*	-0.02667	0.51785	0.66992	0.42954
22. *Porites compressa*	-0.02011	-0.07443	-0.04804	0.34254
23. *Favia pallida*	-0.00022	0.00261	0.01138	0.00664
24. *Favites halicora*	-0.00001	0.00367	0.00141	-0.00266
25. *Favites flexuosa*	0.00098	0.00111	0.01164	-0.02334
26. *Goniastrea retiformis*	-0.00789	0.15643	-0.20975	0.00797
27. *Platygyra daedalea*	0.00003	0.02788	-0.02761	-0.02595
28. *Platygyra sinensis*	-0.00169	-0.00138	0.00351	0.00120
29. *Hydnophora exesa*	0.00120	0.02456	0.05019	-0.03101
30. *Hydnophora microconos*	-0.00097	-0.00395	-0.00335	0.01937
31. *Montastrea magnistellata*	-0.00042	-0.00080	0.01453	-0.00807
32. *Montastrea valenciennesi*	-0.00025	0.00823	-0.01047	0.00762
33. *Leptastrea purpurea*	0.03895	0.04544	0.00960	0.07950
34. *Leptastrea transversa*	-0.00182	0.00873	0.00218	-0.01323
35. *Cyphastrea serailia*	-0.00024	0.08336	0.02144	0.01754
36. *Galaxea fascicularis*	-0.00126	-0.00196	0.00590	-0.00360
37. *Acanthastrea echinata*	-0.00013	0.01161	-0.01586	-0.01373
38. *Turbinaria frondens*	0.12277	-0.03799	-0.04091	0.05728
39. *Heliopora coerulea*	0.00053	0.00995	0.02191	-0.00397
40. *Millepora platyphylla*	0.00033	0.03528	0.03115	0.02020
41. *Millepora exesa*	0.00069	0.02416	-0.00886	-0.01669
Eigen value	4.27674	0.78145	0.33560	0.18788
Proportion	0.72409	0.13231	0.05682	0.03181
Cumulative proportion	0.72409	0.85640	0.91322	0.94503

Table 4.3 Mean percentage cover (± S.E.) of dominant coral species at Agatti in 1993-94

	Inner Reef Flat		Outer Reef Flat		
	% cover	Max %cover	% cover	Max %cover	*t*-value (df=1232)
No. of quadrats	636		598		
Acropora aspera	@	6	0.1 ±0.1	20	2.42*
Acropora corymbosa	@	5	0.3 ±0.1	28	4.29***
Acropora formosa	0.1 ±0.1	18	0.2 ±0.1	25	1.71n.s.
Acropora humilis	0.1 ±0.1	8	0.9 ±0.3	38	6.33***
Acropora robusta	@	9	0.3 ±0.1	21	3.31***
Cyphastrea serailia	-	-	0.1 ±0.1	7	4.66***
Goniastrea retiformis	-	-	0.2 ±0.2	30	2.43*
Hydnophora exesa	-	-	0.1 ±0.1	8	3.46***
Leptastrea purpurea	@	6	0.1 ±0.1	7	3.48***
Leptastrea transversa	@	4	0.1 ±0.1	14	1.97*
Millepora exesa	-	-	0.1 ±0.1	6	3.09**
Millepora platyphylla	@	7	0.1 ±0.1	14	1.61n.s.
Pocillopora damicornis	0.4 ±0.2	23	1.3 ±0.3	33	6.11***
Porites compressa	0.2 ±0.2	25	-	-	2.67**
Porites lutea	0.3 ±0.1	27	1.1 ±0.3	35	5.68***
Psammocora contigua	0.1 ±0.1	10	0.2 ±0.1	14	2.14*
Psammocora profundacella	@	2	0.1 ±0.1	8	4.96***
Total coral cover	1.2 ±0.4	46	5.5 ±0.7	58	10.36***
Number of species	23			38	
H' (bits)	3.05			3.63	
J	0.67			0.69	
No. of quadrats with no corals	555 (87%)			280 (47%)	

@ mean cover <0.1%   *** P <0.001   ** P<0.01   * P<0.05   n.s. not significant

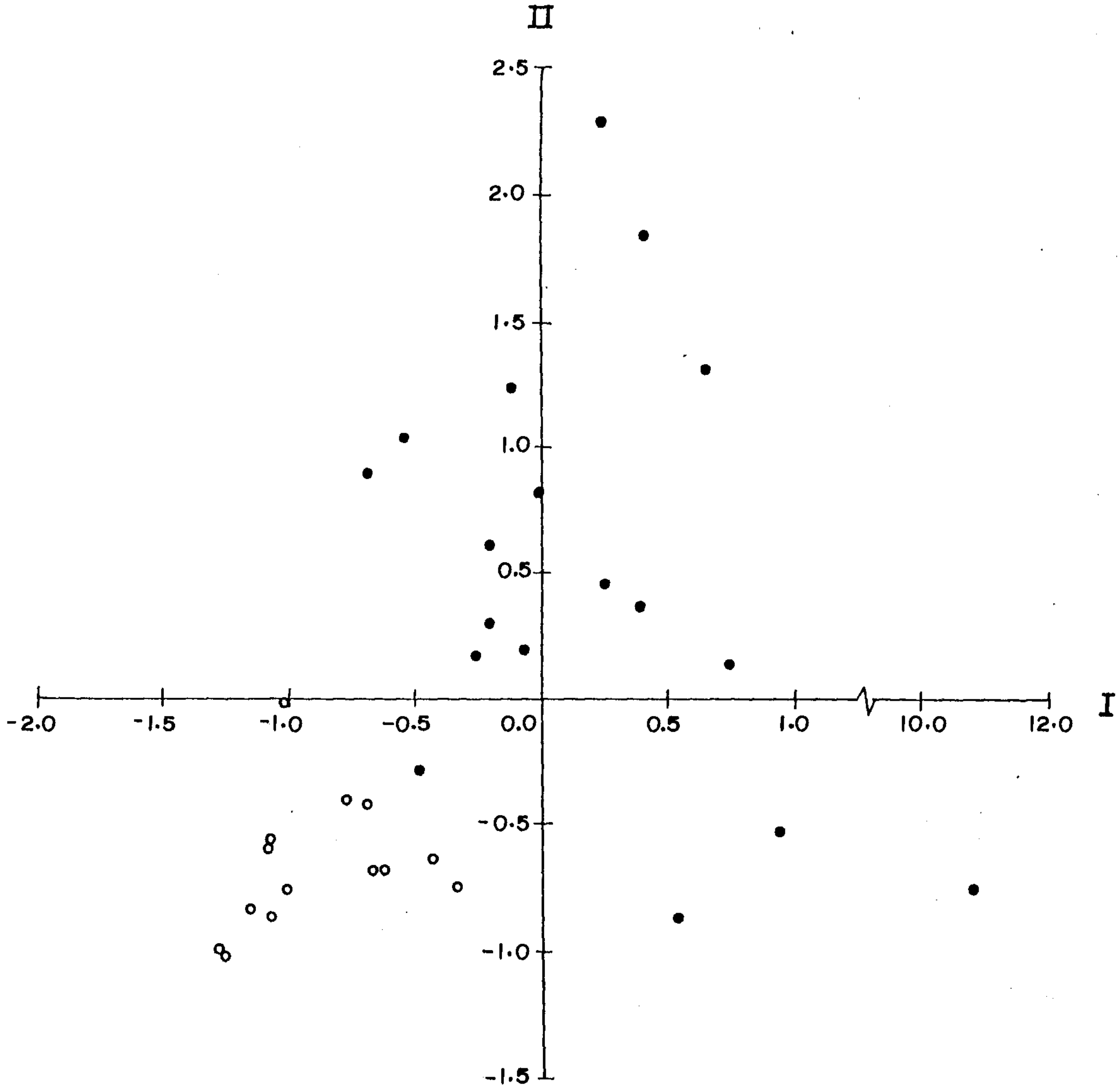

Fig. 4.5 A two dimensional ordination by PCA of the correlation matrix of the 32 stations (0m-155m). Open circles indicate inner reef flat stations while filled circles indicate outer reef flat stations.

The percentage coral cover on the outer reef flat was significantly higher than that of the inner reef flat (Table 4.3). *Acropora formosa* occurred on the inner as well as outer reef flat (Table 4.3). *A. humilis*, although significantly abundant on the outer reef flat (Table 4.3), was also recorded in the inner reef flat. The number and percentage of quadrats with no coral species in the inner reef flat was almost double that of the outer reef flat (Table 4.3). The high percentage of such quadrats indicated that the distribution of corals was heterogenous. There were also differences in species richness and species diversity. Dominance of coral species, as indicated by the evenness index, was equally observed in both zones. The inner reef flat was characterized by *Porites lutea*, *Psammocora contigua*, *Acropora humilis* and *A. formosa* with very low cover. The outer reef flat was dominated by *Pocillopora damicornis*, *Acropora humilis*, *A. robusta* and *Porites lutea*. Another massive coral, *Goniastrea retiformis* also colonised the outer reef flat (Table 4.3).

Analysis of station fauna similarities revealed the presence of one minor and two major clusters (Fig. 4.6). The first major cluster comprised species that were abundant on the entire reef flat and predominant on the outer reef flat. It characterized the dominant coral species assemblage on the reef flat and consisted of *Pocillopora damicornis*, *Porites lutea*, *Acropora humilis*, *A. corymbosa* and *A. robusta* (Fig. 4.6). The second major cluster grouped *Acropora formosa*, *Psammocora profundacella*, *Cyphastrea serailia*, *Hydnophora exesa*, *Leptastrea purpurea*, *L. transversa*, *Millepora platyphylla*, *Psammocora contigua* and *Millepora exesa*. These species represented another major coral assemblage predominant on the outer reef flat. The cluster of *Acropora aspera* and *Goniastrea retiformis* represented a minor assemblage on the reef flat. *Porites compressa*, whose distribution was restricted only to the inner reef flat at transect XI, was isolated from the clusters.

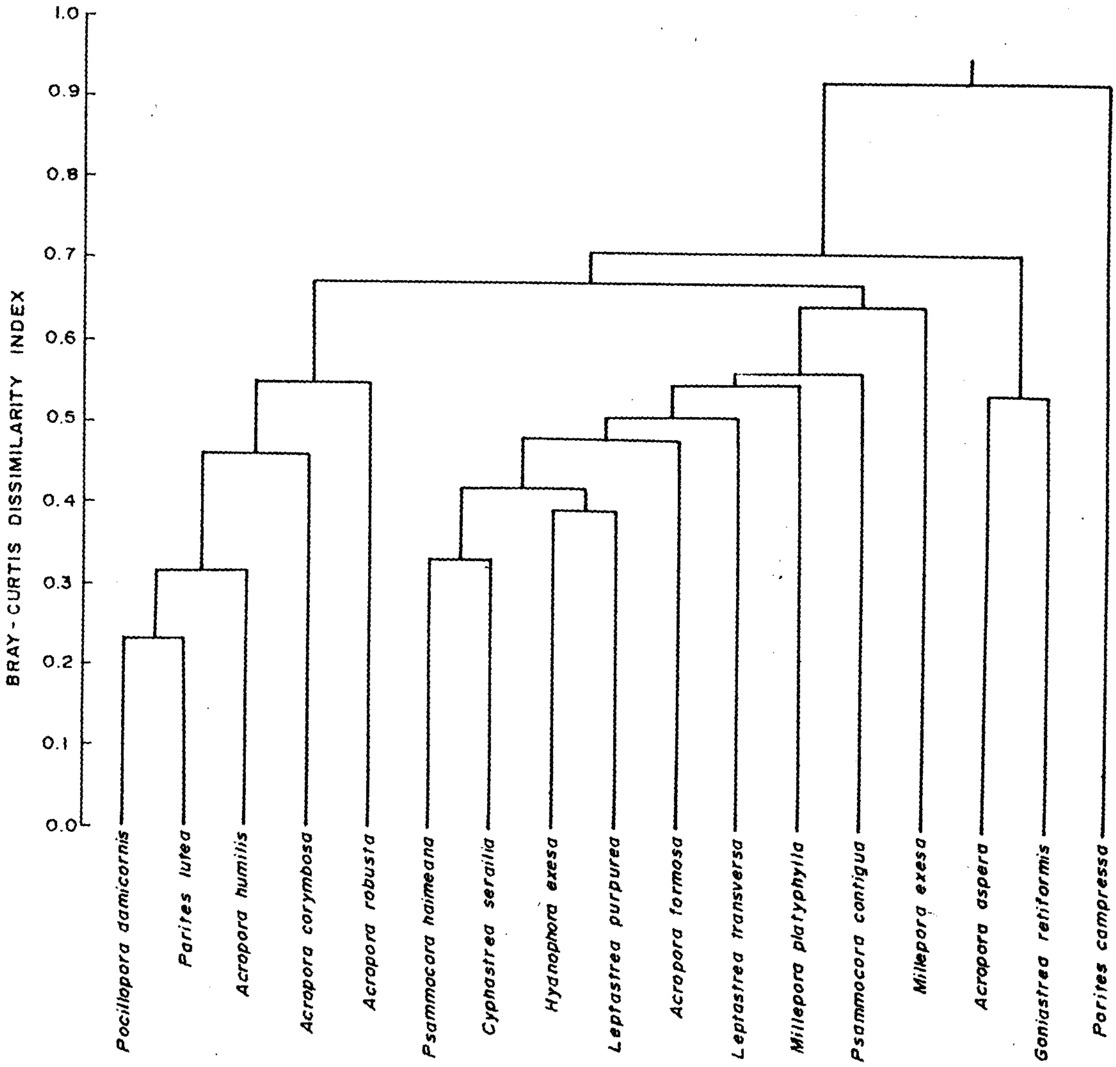

Fig. 4.6 Dendrogram delineating coral species assemblages based on station faunal similarities on the reef flat at Agatti.

Predators of corals were not observed in significant numbers on the reef flat. Only two individuals of the crown of thorns, *Acanthaster planci* (Linnaeus), were recorded on the reef flat in 1993-94. As indicated above, the cushion star, *Culcita novaeguinea* Muller & Troschel, was recorded at transect XI in low densities. While *Acanthaster planci* feeds on *Acropora*, *Montipora*, *Pavona* and some other genera, *Culcita novaeguinea* has been reported to feed on juvenile *Acropora* and *Pocillopora* (Goreau *et al.*, 1972). The major bioeroders of corals were the sea urchins *e.g. Eucidaris*, *Diadema* and *Echinometra*. Corallivorous gastropods *e.g. Coralliophylia* recorded in lagoons were rare on the Agatti reef flat. Except for *Canthigaster* and *Chaetodon*, corallivorous fish genera on the reef flat *viz. Heniochus*, *Rhinecanthus*, *Tetraodon*, *Oxymonacanthus*, *etc.* were not abundant in the study area due to the shallowness of the reef flat.

4.4 DISCUSSION

One of the frequent sources of bias while estimating the abundance of organisms is the positioning of quadrats/ transects. There is a tendency to locate transects or place quadrats in sites deemed favourable because the study organism is abundant and this results in high abundance values (Hughes, 1993; Connell, 1997). In the present study, this bias was eliminated by fixing transects and placing quadrats at specific distance intervals. Although this resulted in analyzing a large number of quadrats that did not contain any coral species, the mean abundance values obtained are representative of the reef flat.

The mean percentage cover of live corals on the reef flat at Agatti was low, 1.2 ± 0.4% and 5.5 ± 0.7% on the inner and outer reef flat, respectively. The maximum percentage cover of live corals recorded in an individual quadrat was 58%, on the outer reef flat. The high standard error values obtained in the present study are indicative of the high degree of patchiness exhibited by the coral species, which were abundant only at selected transects. No published quantitative data on the coral cover in Lakshadweep or elsewhere in Indian reefs are available for comparison. On reef flats in the northern Gulf of Eilat (Red Sea), live coral cover was highly variable ranging from 5.50 to 31.66%, with a mean value of 19.3% (Benayahu & Loya, 1977). Ditlev (1978) reported coral cover values varying from 1 to 10% on the intertidal reef flat at Phuket (Thailand). Hong and Sasekumar (1981) recorded 26.5% live coral cover on the reef flat at Cape Rachado (Malaya). Brown *et al.* (1983) recorded values of up to around 80% live coral cover in Indonesian reef flats. These studies, except that of Benayahu and Loya (1977), do not however report confidence limits of estimates. Morrissey (1980) reported a mean total line cover value of 7.1% for live corals on the reef flat at Magnetic Island, Australia. Although coral cover on the reef flat at Agatti appears low, it is comparable with that on the reef flat at Phuket and at Magnetic Island. In general, reef flats are known to support low cover of live corals (Stephenson *et al.*, 1931; Wells 1954, 1957; Spencer-Davies *et al.*, 1971; Done, 1983).

The abundance and number of species of corals on the Agatti reef flat progressively increased seawards along the intertidal gradient. Species diversity also exhibited the same trend. Similar observations have been recorded on reef flats at other geographical locations (Ditlev, 1978; Morrissey, 1980; Brown *et al.*, 1983). The range of coral diversity values (equivalent to 0-2.09 nats) recorded at Agatti is comparable with values obtained on other reef flats. The coral diversity values on the reef flat at Magnetic island ranges from 0 to 2.34 nats (Morrissey, 1980) while at Cape Rachado it ranges from 0 to 2.1 nats (Hong & Sasekumar, 1981). On the fringing reef of Reunion island, a low value of 2.0 bits has been recorded on a compact reef flat and attributed to the dominance of 2 species of corals (Bouchon, 1981). The Brillouin's index of the Agatti coral reef flat community diversity obtained in the present study could not be compared due to unavailability of published values. Ecologists have generally avoided this index which, although requiring data from a large number of quadrats and cumbersome to compute, remains the only method to estimate the mean diversity of a biological community with confidence limits (Pielou, 1974).

An intriguing community characteristic of a coral reef is its high species diversity and several hypotheses have been formulated to explain it. Connell (1978) evaluated the available six major hypotheses propounded to explain how local diversity is produced and maintained: the intermediate disturbance, equal chance, gradual change, niche diversification, circular network and compensatory mortality hypotheses. Among these, he favoured the intermediate disturbance hypothesis to account for the high species diversity in coral reefs and tropical rain forests. This hypothesis centers on a convex relationship between the levels of disturbance and species richness (number of species), resulting in the highest number of species at intermediate levels of disturbance. The hypothesis also considers the frequency of disturbance and the period elapsed after the disturbance. It assumes that species richness is the result of a historical balance between competitive exclusion and the processes of disturbance (physical, biological/pathogenic and anthropogenic) that prevent exclusion. When disturbance is low, competitive exclusion occurs whereas when disturbance is high, the high levels of mortality result in low diversities. Thus, low levels of diversity are manifest at extreme levels of disturbances. Evidence for this hypothesis emanated from studies of ecological succession. A corollary to this hypothesis is that coral species richness and abundance (coral cover) should exhibit a similar convex relationship. Grigg (1983) observed a convex relationship between the Shannon-Wiener species diversity index and coral cover in Hawaiian reefs sheltered from wave disturbance. It may be noted that species richness is not always correlated with species diversity (an index based on species richness weighed by their relative abundance).

On the Agatti reef flat, species richness and diversity of coral species increased seawards owing to the decreased intensity of physical characteristics such as temperature and desiccation, which can be termed as a form of disturbance. Storms such as cyclones/hurricanes are not prevalent. However, when the mean number of coral species was plotted as a function of coral percentage cover, their convex relationship was not evident (Fig. 4.7). Similar observations have been obtained by other workers (Porter, 1974; Liddell & Ohlhorst, 1987; Hughes, 1989). Connell (1978) invoked the compensatory mortality hypothesis to account for such observations. Nevertheless, several other studies have shown that while disturbances such as storms cause significant effects on coral cover, effects on diversity are not consistent (Rogers, 1993). Jackson (1991) questioned the applicability of the intermediate disturbance hypothesis to coral reefs as (1) Connell's long term coral cover data exhibited a positive linear relationship with species richness and (2) high coral cover and low diversity are generally observed at the shallowest depths where disturbance is greatest. These two observations contradicted the predictions/corollary predictions of the intermediate disturbance hypothesis. Long term studies on coral reefs are very few in number and hence it is difficult to evaluate the intermediate disturbance hypothesis. It is most likely that, while not being discounted by Connell (1978), other hypotheses may also be applicable for coral reefs. As indicated above, the core of the intermediate disturbance hypothesis is the competitiveness of coral species, a subject presented and discussed in the next chapter (Chapter 5).

The major abiotic factors influencing the distribution and abundance of corals are light penetration (sedimentation, depth), water movement (tides, waves and

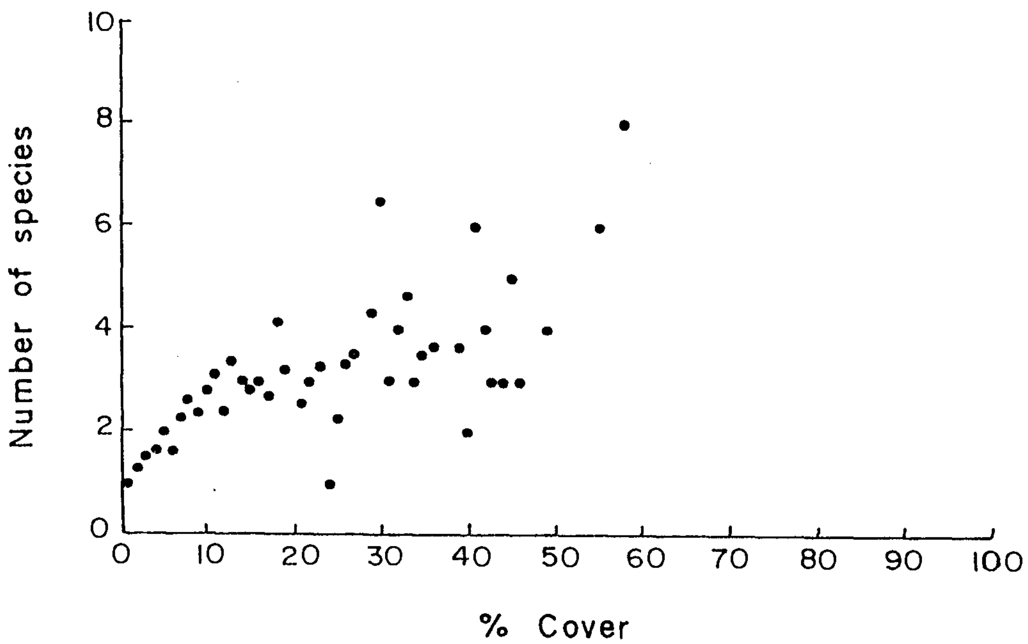

Fig. 4.7 The relationship between coral abundance (percentage cover) and the number of species on the Agatti reef flat.

currents), duration of emersion and nutrient levels (Morrissey, 1980; Done, 1983). Nutrient levels, suspectedly high due to anthropogenic activities such as defecation on the reef flat, have not been quantified in this study and are hence not discussed. On shallow reef flats, such as at Agatti, light levels do not constitute an important factor as the reef flat is uniformly exposed to high levels of illumination. Variations in distribution can be attributed to other factors such as elevation resulting in exposure to high temperature, water movements and nutrient levels. Emersion due to tidal ebb and flow determines the upper limits of distribution of corals as they are not able to withstand long periods of exposure (Stoddart, 1969). Tidal amplitude in Lakshadweep is less than 2m and lowest low waters occur in November-December around 18.00 hrs (Admiralty Tide Tables). These tides have a range at springs of 0.3-1.0m and are classified as microtidal (Stoddart, 1971). Tidal amplitude is small when compared to 4m tidal amplitude on the reef flats of Hainan Island in the China seas (Ren-Lin *et al.*, 1966) and 3.4m tidal amplitude on reef flats at Phuket, along the west coast of Thailand (Ditlev, 1978). However the timing of the lowest low waters in these reef flats is the same, occurring when insolation is comparatively low thereby helping in minimizing desiccation.

Wave action progressively decreases southwards at Agatti as the reef flat widens. Wave action is known to decrease with distance from the reef flat margin (Rosen, 1971b; Pichon, 1972, 1978). Hydrodynamic gradients have been recognized as a major factor determining the zonation pattern on reef flats (Ditlev, 1978; Done, 1983). Growth forms have been demonstrated to exhibit a clearer zonation pattern than coral species (Marshall, 1931; Vaughan & Wells, 1943; Pichon, 1978). Worldwide zonation schemes for coral taxa and growth forms have been formulated on the basis of broadly defined growth form alliances and wave related aspects (Rosen, 1975; Pichon, 1978). In the Indo-Pacific, Rosen (1975) recognized a *Pocillopora* association followed by

Acropora, Faviid and *Porites* associations in order of decreasing wave energy. According to the Pichon (1978) coral zonation scheme, reef flats are dominated by massive growth forms followed by branching growth forms towards the reef front. Studies have however shown that biotic interactions and recruitment are also important in determining coral distributions (Connell, 1973; Glynn, 1988; Sale, 1988). The importance of predation in influencing coral distribution depends on the abundance of predator populations (Endean, 1976). Furthermore, coral predators have also been reported to respond to physical factors such as wave action (Goreau *et al.*, 1972). On the reef flat at Agatti, the density of coral predators was low and hence its impact minimal.

Using cluster analysis, three assemblages of corals could be discerned on the reef flat. The first assemblage represented the dominant coral species on the Agatti reef flat which comprised branching corals (*Pocillopora damicornis*, *Acropora humilis*, *A. corymbosa*, *A. robusta*) and a massive coral (*Porites lutea*). The second assemblage was dominated by massive coral growth forms (*Psammocora profundacella*, *Cyphastrea serailia*, *Hydnophora exesa* and *Leptastrea purpurea*). The third assemblage comprising of *Acropora aspera* and *Goniastrea retiformis* represented the minor assemblage at transect VI.

The Agatti reef flat was dominated by branching coral growth forms. The growth forms of corals on the inner reef flat were either massive (*Porites lutea*, *Psammocora contigua*) or branching (*Acropora humilis*, *A. formosa*). The outer reef flat was dominated by branching growth forms and a few massive corals (*Porites lutea*, *Goniastrea retiformis*). Coral species that could be considered as typical of wave exposed areas in Lakshadweep were *Pocillopora damicornis*, *Acropora robusta*, *Goniastrea retiformis*, *Millepora* spp. and *Heliopora coerulea*. Faviids were not conspicuous on the reef flat. Zonation of corals on the Agatti reef flat thus roughly corresponds to general reef schemes of Rosen (1975) and Pichon (1978). At Minicoy, one of the Lakshadweep group of islands, the massive coral, *Porites* sp. was reported to be abundant while branching growth forms *e.g. Acropora* sp., *Pocillopora* sp. and other massive forms *e.g. Favia* sp., *Favites* sp., *Leptastrea* sp. and *Platygyra* sp. were common on the reef flat (Pillai, 1971a).

The succession of coral species as proposed by Rosen (1975) has been reported along the Indian coast, on the fringing reef flat at Chiriatapu in south Andamans (Mukherjee, 1994). Variations in the general reef schemes have been reported. On reef flats in the northern Gulf of Eilat, the most abundant corals were mainly of massive (Benayahu & Loya, 1977). The coral community of the reef flat at Magnetic island was also dominated by massive growth forms (Morrissey, 1980). At Cape Rachado, massive corals dominated the fringing reef flat (Hong & Sasekumar, 1981). Around Pulau Pari on the Indonesian coast, branching corals dominated the reef flats, particularly the outer reef flats (Brown *et al.*, 1983). In the Indo-Pacific, encrusting and streamlined morphs of massive species occur along with dominant branching genera in surf areas (Wells, 1954; Rosen, 1971b, 1975). It has been reported that coral branches despite possessing low tensile strength have high compressive strength (Wainwright *et al.*, 1976; Tunnicliffe, 1981).

Massive coral growth forms have generally been reported to be dominant in high sedimentation rate areas such as the turbid Fanning lagoon (Roy & Smith, 1971), protected reef flat at Magnetic island (Morrissey, 1980) and the reef flat at Cape Rachado with high sediment load (Hong & Sasekumar, 1981). Along the southeastern coast of India, field studies have also revealed that a few massive coral species dominated the Palk Bay due to sedimentation while the Gulf of Mannar had luxuriant and diverse growth of corals (Pillai, 1971b). Simulation studies in the Caribbean have suggested that merely altering wave and light energy inputs result in modifications in the zonation pattern of coral reefs (Graus & Macintyre, 1989). Biotic as well as abiotic factors thus seem to play a role in determining zonation patterns. Unfortunately, no simulation studies have been carried out for any Indian reefs. It is therefore pertinent to note that despite decades of research on coral reefs in general and Indian coral reefs in particular, patterns and processes are still far from being clearly understood.

CHAPTER FIVE

SPECIES INTERACTIONS ON THE REEF FLAT AT AGATTI

5.1 INTRODUCTION

Competition for space is a common phenomenon among sedentary organisms in a coral reef ecosystem. Scleractinian coral species have to compete for space with one another as well as with other space utilizers belonging to diverse phyla. Initially, coral larvae (planulae) or coral fragments (propagules) capture space on the substratum. They subsequently grow in three dimensions, laterally and vertically, resulting in the occupation of larger reef areas which sometimes lead to overlapping territories. How different species of corals react to such advancements by conspecific or other coral species was first investigated by Lang (1971, 1973), who reported an inflexible linear hierarchy of dominance among coral species on Jamaican reefs in the Caribbean. This intrigued many other reef ecologists who have tried to determine the prevalence of such a hierarchy in other regions and unveil the significance of these interactions in structuring coral reef communities (Sheppard, 1979, 1980; Wellington, 1980; Bradbury & Young, 1981a,b, 1983; Bak *et al.*, 1982; Logan, 1984; Dai, 1990; Genin *et al.*, 1994; Chadwick-Furman & Rinkevich, 1994; Veghel *et al.*, 1996). The mechanisms and effects of intra and interspecific competition have been recently reviewed by Lang and Chornesky (1990).

Various strategies are employed by corals to establish and retain a place for themselves on the reefs. Some species extrude mesenterial filaments which damage the tissues of neighbouring corals by digesting the tissues in immediate contact (Lan

1971, 1973) while some others develop sweeper tentacles to attack colonies in their proximity (Richardson *et al.*, 1979; Chornesky, 1983, 1989; Bak *et al.*, 1982). These strategies are however considered to be primarily defence mechanisms rather than competitive strategies (Connell, 1976). Histoincompatibility reactions have also been observed particularly in grafting experiments, resulting in bleaching of coral tissues and formation of dead gaps at the graft interface (Rinkevich & Loya, 1983). Still others, the foliaceous or tabular forms indirectly affect corals in their vicinity by overshadowing them and reducing their light requirements (Connell, 1973; Porter, 1974; Hughes & Jackson, 1985; Glynn, 1987). Morphotypes have been recognized in the Caribbean hermatypic coral *Montastrea annularis* on the basis of competitive behaviour (Veghel & Bak, 1993). Nevertheless, whether these interactions greatly affect the community structure on reefs is still being debated and is a question that has not been satisfactorily resolved.

Other major space utilizers on reefs include macrophytes (algae and seagrasses), sponges and alcyonaceans (soft corals). Among these, macrophytes could be considered as important competitors as they compete with scleractinian corals for space in the illuminated habitat, a limiting factor important to both competitors in the coral reef ecosystem. Despite their importance, macrophytes such as seaweeds are rarely studied by coral reef ecologists (Hay, 1997). The role of algae in coral reefs has been reviewed by several workers (Cribb, 1973; Littler & Littler, 1988; Berner, 1990). Coral spat has been reported to be displaced by algae (Pearson, 1974; Sammarco, 1980). Encrusting coralline algae have also been reported to grow over scleractinians (Grigg & Maragos, 1974; Littler & Doty, 1975; Dana, 1979). Algae have been reported to grow quickly, block light, reduce water flow and preempt space required by juvenile corals (Potts, 1977; Lewis, 1986; Steveninck & Bak, 1986; Hughes, 1989, 1994, 1996).

5.2 METHODOLOGY

5.2.1 Coral-coral species interactions

Investigations to study interactions between neighbouring coral species were carried out during October 1993, April 1994, November 1994 and April 1995. The positive outcome of interaction between two coral colonies results in a dead margin on the subordinate species, an observation easily discernible in the field. In the case of a standoff, when neither species wins, both species appear to stop growing along a common margin. The term 'standoff' was proposed by Connell (1976) as it is a temporary state that may result in a 'win' or 'loss' after a period of time ranging from a few weeks to several years. Russ (1982) prefers the term 'delay/tie' for such an interaction. In the present work, only direct interactions between coral species were studied, ignoring indirect interactions such as overtopping by tabular/ foliose corals.

Field observations on naturally occurring coral species interactions were recorded at random sites on the reef flat at Agatti. The mechanism of the interaction was not investigated due to non availability of facilities. Dominant non scleractinian coral species such as *Millepora platyphylla* and *Heliopora coerulea* were also included in this study. As far as possible, replicate field observations of interacting coral species pairs were recorded. Reversals in the competitive outcome, if any, were also noted. Theoretically, the total number of possible interactions between N species is given by:

$$\frac{N \cdot (N - 1)}{2}$$

where N is the number of species

The degree of dominance of one species over the other was determined by the Competitive Index (C.I.) proposed by Dai (1990) and computed as follows:

$$C.I. = \frac{\text{Number of wins - Number of losses}}{\text{Total number of interactions}}$$

The competitive index ranges from +1 (for a species that wins all interactions) to -1 (for a species that loses all interactions). Reversals in the competitive outcome were taken into consideration while standoffs were not included in computations. A positive index denotes an aggressive species while a negative index represents a subordinate one. Species were categorized as in Dai (1990) as:

+1.00 to +0.6 ——> aggressive

+0.59 to +0.2 ——> moderately aggressive

+0.19 to - 0.2 ——> intermediate

- 0.21 to - 0.6 ——> moderately subordinate

- 0.61 to - 1.0 ——> subordinate

Quadrat data collected during October-November 1993 and March-April 1994 along transects, as described in the previous chapter (Chapter 4) were re-analyzed to study species association. The number of occurrences/ absences of any two given coral species (x and y) in the 1234 1m^2 quadrat sampled was computed. The limitation of this analysis was that the proximity of coral species in a quadrat is not taken into consideration. Only those species that exhibited interactions in the field were considered. Of the 1234 quadrats that were sampled, only the 399 quadrats containing coral species were scrutinized for the purpose. The test criterion (X^2) to validate the null hypothesis that species x and y are independent was computed for each pair of species

(Pielou, 1974). In other words, the null hypothesis is that there is no detectable interaction (*i.e.* $X^2=0$). X^2 was calculated as follows:

$$X^2 = \frac{(\,|\,a \cdot d - b \cdot c\,| - N/2\,)^2 \cdot N}{(a+b) \cdot (c+d) \cdot (a+c) \cdot (b+d)}$$

where,

a = Number of quadrats in which species *x* and *y* co-occur

b = Number of quadrats in which species *x* co-occur with all other species except species *y*

c = Number of quadrats in which species *y* co-occur with all other species except species *x*

d = Number of quadrats in which all species except *x* and *y* co-occur

N = Total number of quadrats

The association is positive if the observed number of quadrats with both species and with neither species exceed expectation ($a \cdot d > b \cdot c$) and negative if the observed number of quadrats containing either species without the other exceed expections ($a \cdot d < b \cdot c$). The calculated X^2 value was compared with the table of the Chi^2 distribution with 1 degree of freedom to determine its level of significance. This test was used only when the smallest expected frequency was at least 5. As many 2x2 tables were being tested simultaneously, a "supercritical" Chi^2 value was used to determine its level of significance (Pielou, 1974). The notation X^2 is used instead of Chi^2 as the latter notation should be restricted only to the theoretical Chi^2 distribution (Pielou, 1974).

The contigency coefficient (Toft & Shea, 1983), normalized by the sample size (N), was computed to determine the intensity of the association:

$$C = \sqrt{\frac{X^2}{N + X^2}}$$

The coefficient approaches but never reaches 1 as competition increases and tends to decrease to 0 when competition decreases.

In addition, an alternative measure of species association, the Karl Pearson coefficient of correlation (r) between pairs of coral species (variables X and Y) in the quadrats was estimated using percentage cover data (Sokal & Rohlf, 1981). The percentage cover data were standardized using the arcsine transformation (Sokal & Rohlf, 1981). The statistical level of significance of the r values was determined by comparing the calculated values with tabulated values at N-2 degrees of freedom, where N is the number of paired observations (quadrats). The coefficient of correlation (r) was computed using the following formula:

$$r = \frac{N \cdot \sum X \cdot Y - (\sum X) \cdot (\sum Y)}{\sqrt{[N \cdot \sum X^2 - (\sum X)^2] \cdot [N \cdot \sum Y^2 - (\sum Y)^2]}}$$

where,

$\sum X$ is the sum of observations of variable X

$\sum X^2$ is the sum of squared observations of variable X

$\sum Y$ is the sum of observations of variable Y

$\sum Y^2$ is the sum of squared observations of variable Y

$\sum X \cdot Y$ is the sum of the products of two variables

N is the number of paired observations

5.2.2 Coral-macrophyte interactions

Coral-macrophyte interactions were investigated by simultaneously recording the percentage cover of coral species as well as macrophyte species (seaweeds and seagrasses) in the 1234 quadrats sampled along transects on the reef flat at Agatti in October-November 1993 and March-April 1994. Details of the sampling methodology are the same as those adopted for corals and described in Chapter 4. The type of substrate occupied by macrophytes was also noted.

The relationship between total coral cover and macrophytes (total algal and seagrass cover) was analysed using the methodology outlined above for coral-coral species interaction by computing the X^2, contigency and correlation coefficients. The level of statistical significance of the coefficients obtained was also determined.

In order to obtain a visual synoptic view of the distribution of corals and macrophytes on the Agatti reef flat, their distribution and abundance was graphically depicted. Selected contours of the total percentage cover of corals, algae and seagrasses in October-November 1993 and March-April 1994 were plotted and superimposed on a map of the study area.

5.3 RESULTS

5.3.1 Coral-coral species interactions

Twenty nine pairs of corals species were observed to naturally interact on the reef flat. Theoretically 406 coral species pair combinations are possible but only 77 (18 of them with reversible outcomes) were observed. Taking into account replicates, reversals of outcomes and standoffs, the total number of observations recorded was 291 (=582 interactions, considering reversals and standoffs). In order to determine the dominance hierarchy only those species that interacted with three or more species were considered for further processing. This reduced the total number of species to 16. Of the 120 possible species pair combinations only 62 could be observed on the reef flat and replicates, reversals and standoffs yielded a total of 504 species interactions. The maximum number of interactions (24.4%) involved *Acropora humilis* while the minimum (0.6%) involved *Acropora nobilis*.

Results obtained on *in situ* coral species interactions indicated that most observations between species pairs were replicated (Table 5.1). Observations also revealed that the outcome of the interaction was not always determinate, and thus no definite linear hierarchy could be established. A large number of reversals of outcomes were recorded (Table 5.1). As a result, the outcome of most interactions (65%) was unpredictable. Standoffs constituted about 4% of the total interactions. Only six species *viz. Montipora turgescens*, *Leptastrea purpurea*, *Acropora nobilis*, *Favia pallida* and *Porites lutea* exhibited no reversals in outcome (Table 5.1).

Notwithstanding the unpredictable outcome of interactions, *Acropora humilis*, with the highest C.I. (+0.69) and *Pavona varians* (+0.56), were the most aggressive coral species on the Agatti reef flat while *Porites lutea*, with the least C.I. (-1.0) was the most subordinate species.

Coral species analysis of quadrats in 1993-1994 revealed that coral pair of species exhibited positive as well as negative associations (Table 5.2). Some trends could be observed in the distribution of coral species. For instance, *P. lutea* occurred as a neighbour of its aggressors in many quadrats. However, no statistically significant associations or correlation coefficients were obtained (Table 5.2). Furthermore, values of contigency coefficients obtained for coral species were very low (Table 5.2).

Table 5.1 Summary of *in situ* coral species interactions on the reef flat at Agatti. (+ indicates that the species in the left hand column kills the species in the top column and the reverse is indicated by '-', standoff is indicated by '±', the number indicates the frequency of events)

	Acropora humilis	*Pavona varians*	*Millepora platyphylla*	*Hydnophora exesa*	*Montipora turgescens*	*Acropora robusta*	*Acropora corymbosa*	*Pocillopora damicornis*	*Leptastrea purpurea*	*Psammocora contigua*	*Acropora nasuta*	*Acropora nobilis*	*Acropora formosa*	*Favia pallida*	*Acropora aspera*	*Porites lutea*	Total	%	C.I.
Acropora humilis		+0 - 1	+2 - 4		+2 - 0	+10 - 2	+21 - 6	+7 - 2	+2 - 0	+1 - 1	+5 - 1	+1 - 0	+5 - 1		+28 - 1	+20 - 0	+104 - 19	24.4	+0.69
Pavona varians	+1 - 0							+2 - 0		± 1			+1 - 0	+2 - 0	+1 - 2		+7 - 2	2.0	+0.56
Millepora platyphylla	+4 - 2			+1 - 0				+0 - 1		+1 - 2			+2 - 0	+1 - 0	+2 - 0	+2 - 0	+13 - 5	3.6	+0.44
Hydnophora exesa			+0 - 1								+1 - 0				+4 - 1		+5 - 2	1.4	+0.43
Montipora turgescens	+2 - 0						+0 - 2								+1 - 0	+1 - 0	+4 - 2	1.2	+0.33
Acropora robusta	+2 - 10						+6 ± 2 - 1	+1 - 0		+2 - 0	+0 - 2		+2 - 0			+4 - 0	+17 - 13	6.3	+0.13
Acropora corymbosa	+6 - 21				+2 - 0	+1 ± 2 - 6		+6 - 1		+1 ± 1 - 0	+1 - 1	+1 - 0	+7 ± 1 - 1		+6 ± 2 - 2	+4 - 0	+35 - 32	14.5	+0.04
Pocillopora damicornis	+2 - 7	+0 - 2	+1 - 0			+0 - 1	+1 - 6				+1 - 1		+1 - 0		+8 - 2	+6 - 0	+20 - 19	7.7	+0.03
Leptastrea purpurea	+0 - 2									+1 - 0			+1 - 0			± 1	+2 - 2	1.0	+0.00
Psammocora contigua	+1 - 1	± 1	+2 - 1			+0 - 2	+0 - 1		+0 - 1						+1 - 0		+4 - 6	2.2	- 0.20
Acropora nasuta	+1 - 5			+0 - 1		+2 - 0	+1 ± 1 - 1	+1 - 1					± 1				+5 - 8	3.0	- 0.23
Acropora nobilis	+0 - 1						+0 - 1									+1 - 0	+1 - 2	0.6	- 0.33
Acropora formosa	+1 - 5	+0 - 1	+0 - 2			+0 - 2	+1 - 7	+0 - 1	+0 - 1		± 1				+3 - 2	+4 - 0	+9 - 21	6.3	- 0.40
Favia pallida		+0 - 2	+0 - 1												+1 - 0		+1 - 3	0.8	- 0.50
Acropora aspera	+1 - 28	+2 - 1	+0 - 2	+1 - 4	+0 - 1		+2 ± 2 - 6	+2 - 8		+0 - 1			+2 - 3	+0 - 1		+8 - 0	+18 - 55	14.9	- 0.51
Porites lutea	+0 - 20		+0 - 2		+0 - 1	+0 - 4	+0 - 4	+0 - 6	± 1			+0 - 1	+0 - 4		+0 - 8		+0 - 50	10.1	- 1.00

Table 5.2 Coral species association (X^2), contigency (**bold**) and correlation (in brackets) coefficients on the reef flat at Agatti. ~~(N=368)~~

	Acropora humilis	*Pavona varians*	*Millepora platyphylla*	*Hydnophora exesa*	*Acropora robusta*	*Acropora corymbosa*	*Pocillopora damicornis*	*Leptastrea purpurea*	*Psammocora contigua*	*Acropora formosa*	*Favia pallida*	*Acropora aspera*	*Porites lutea*
Acropora humilis		**0.05** (0.06)	**0.02** (-0.04)	**0.01** (-0.04)	**0.01** (0.06)	**0.00** (-0.04)	**0.04** (0.08)	**0.04** (-0.05)	**0.00** (0.02)	**0.00** (-0.06)	**0.02** (-0.01)	**0.01** (0.05)	**0.02** (-0.02)
Pavona varians	0.96 +		**0.04** (-0.02)	**0.01** (-0.02)	**0.00** (-0.03)	**0.02** (0.01)	**0.01** (-0.03)	**0.01** (-0.04)	**0.03** (0.05)	**0.02** (0.02)	**0.06** (-0.02)	**0.05** (-0.02)	**0.01** (0.03)
Millepora platyphylla	0.11 +	0.63 -		**0.00** (-0.02)	**0.01** (-0.03)	**0.02** (-0.02)	**0.10** (0.07)	**0.03** (-0.03)	**0.05** (0.03)	**0.01** (-0.01)	**0.05** (-0.02)	**0.03** (-0.02)	**0.05** (0.09)
Hydnophora exesa	0.07 -	0.09 -	0.00 -		**0.05** (-0.01)	**0.05** (-0.01)	**0.01** (0.03)	**0.06** (0.06)	**0.04** (-0.05)	**0.04** (0.08)	**0.02** (-0.02)	**0.01** (0.12)	**0.01** (-0.01)
Acropora robusta	0.02 +	0.00 -	0.06 -	1.15 +		**0.02** (-0.02)	**0.03** (-0.03)	**0.07** (-0.06)	**0.10** (-0.07)	**0.01** (-0.01)	**0.01** (0.03)	**0.01** (0.09)	**0.10** (-0.08)
Acropora corymbosa	0.00 +	0.12 +	0.14 -	1.02 +	0.17 -		**0.04** (0.10)	**0.03** (-0.01)	**0.09** (-0.04)	**0.06** (0.02)	**0.01** (-0.03)	**0.02** (0.06)	**0.01** (0.01)
Pocillopora damicornis	0.54 +	0.04 +	4.06 +	0.02 +	0.36 -	0.56 +		**0.10** (0.16)	**0.10** (0.06)	**0.01** (0.04)	**0.10** (0.12)	**0.10** (0.14)	**0.14** (-0.01)
Leptastrea purpurea	0.80 +	0.07 -	0.28 +	1.56 +	2.27 -	0.27 +	1.83 +		**0.02** (-0.02)	**0.01** (-0.01)	**0.01** (-0.03)	**0.04** (0.08)	**0.05** (-0.02)
Psammocora contigua	0.00 +	0.32 +	1.02 +	0.62 -	3.74 -	3.02 -	1.72 -	0.18 +		**0.01** (-0.02)	**0.02** (-0.04)	**0.03** (-0.04)	**0.01** (0.07)
Acropora formosa	0.00 +	0.15 +	0.01 +	0.65 +	0.09 -	1.54 +	0.04 -	0.03 +	0.01 -		**0.03** (-0.02)	**0.01** (0.04)	**0.01** (-0.02)
Favia pallida	0.10 -	1.53 -	0.85 -	0.17 -	0.02 +	0.05 -	1.12 +	0.02 -	0.16 -	0.25 -		**0.06** (-0.02)	**0.04** (-0.05)
Acropora aspera	0.02 +	0.96 -	0.47 -	0.04 +	0.01 +	0.21 +	2.50 +	0.69 +	0.41 -	0.08 +	1.24 -		**0.01** (-0.02)
Porites lutea	0.20 +	0.07 -	0.88 +	0.01 +	2.38 -	0.06 -	7.49 -	0.87 -	0.05 +	0.04 +	0.62 -	0.03 -	

5.3.2 Coral-macrophyte interactions

Results obtained on the distribution of macrophytes on the Agatti reef flat have been reported elsewhere (Rodrigues *et al.*, 1997) and are briefly reproduced below. While seaweeds included several species, seagrasses were represented by only one species, *viz. Thalassia hemprichii* (Ehrenberg) Ascherson. Total mean macrophyte percentage cover recorded on the reef flat was 46.5 ± 3.3 and 39.6 ± 4.2 in October-November 1993 and March-April 1994 respectively. The dominant macrophyte was the seagrass, *Thalassia hemprichii*, with a mean percentage cover of 26.2 ± 2.9 and 30.3 ± 4.5 in October-November 1993 and March-April 1994, respectively. The dominant alga was the calcareous alga *Halimeda gracilis* Harvey *ex* J. Agardh with a mean percentage cover of 4.6 ± 0.6 and 2.2 ± 0.5 in October-November 1993 and March-April 1994, respectively. Foliose algae such as *Ulva lactuca* Linnaeus were abundant (2.4 ± 0.7) in October-November 1993 while the filamentous turf alga, *Gelidiella acerosa* (Forsskal) Feldmann *et* Hamel, was dominant (3.3 ± 1.0) in March-April 1994.

Algae were observed to grow on dead corals as well as on the coralline sandy substratum. Although not sampled, epiphytic algae were observed on seagrass blades. Dead coral colonies were observed in the seagrass meadows. The analysis of quadrat for coral-macrophyte interaction revealed that statistically significant negative association (X^2) and correlation coefficient were obtained between corals and the seagrass, *Thalassia hemprichii* (Table 5.3). The contigency coefficient between these two groups was also the highest, suggesting competition. While corals and algae exhibited a statistically positive association, the correlation coefficient was negative although not statistically significant (Table 5.3). Algae and seagrasses were statistically negatively associated and correlated (Table 5.3).

Table 5.3 Coral-macrophyte species association (X^2), contigency (bold) and correlation (in brackets) coefficients on the reef flat at Agatti. (N=1125)

	Corals	Algae	*Thalassia hemprichii*
Corals		**0.17** (- 0.01 n.s.)	**0.40** (- 0.41***)
Algae	37.76*** +		**0.16** (- 0.20*)
Thalassia hemprichii	233.94*** -	33.13*** -	

\+ positive association - negative association

*** P < 0.001 * P < 0.05 n.s.: not significant

The contour plots present a bird's eye view of the distribution of corals, algae and seagrasses on the reef flat at Agatti. These plots delineated limits of the habitats of corals, algae and seagrasses (Fig. 5.1 - 6). They also revealed that the abundance of algae on the Agatti reef flat was seasonal, being abundant in October-November 1993 and scarce in March-April 1994. These differences were reported to be statistically significant (Rodrigues *et al.*, 1997). In sharp contrast, the abundance and distribution of corals and seagrasses did not appear to vary between the two sampling periods (Fig. 5.1-2, 5.5-6). Results obtained on the abundance and distribution of macrophytes also revealed that the percentage cover of macrophytes, particularly the seagrass, *Thalassia hemprichii*, decreased seawards (Fig. 5.7) while that of algae slightly increased seawards (Fig. 5.7).

5.4 DISCUSSION

5.4.1 Coral-coral species interactions

The fewer number of observable coral species pair combinations than the theoretical number seems to suggest that all coral species do not interact with one another in the field. Similar observations have been recorded elsewhere (Lang, 1973; Sheppard, 1979; Cope, 1981; Logan, 1984; Dai, 1990).

Most interactions observed between coral species involved dominant coral species of the reef flat at Agatti. *Acropora humilis* (aggressive species), *Acropora corymbosa*, *Pocillopora damicornis*, *Acropora robusta* (intermediate species), *Acropora aspera*, *Acropora formosa* (moderately subordinate species) and *Porites lutea* (subordinate species) were some of the dominant coral species on the reefs. The dominance of coral species at Agatti could thus not be explained merely on the basis of their competitive abilities. In contrast, Sheppard (1979), in his study of interaction

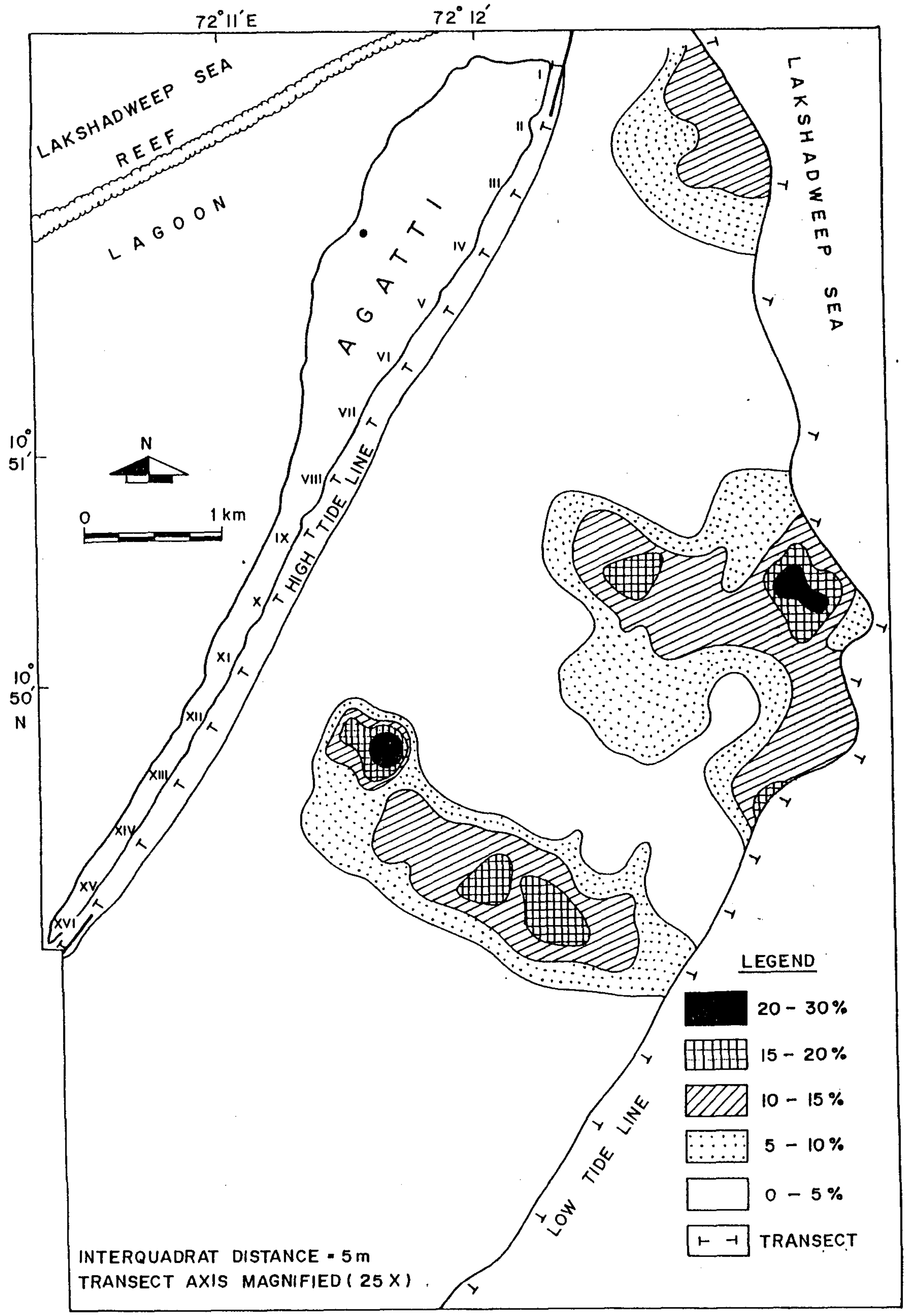

Fig. 5.1 Map of Agatti showing contours of coral abundance in percentage cover of reef flat in October-November 1993.

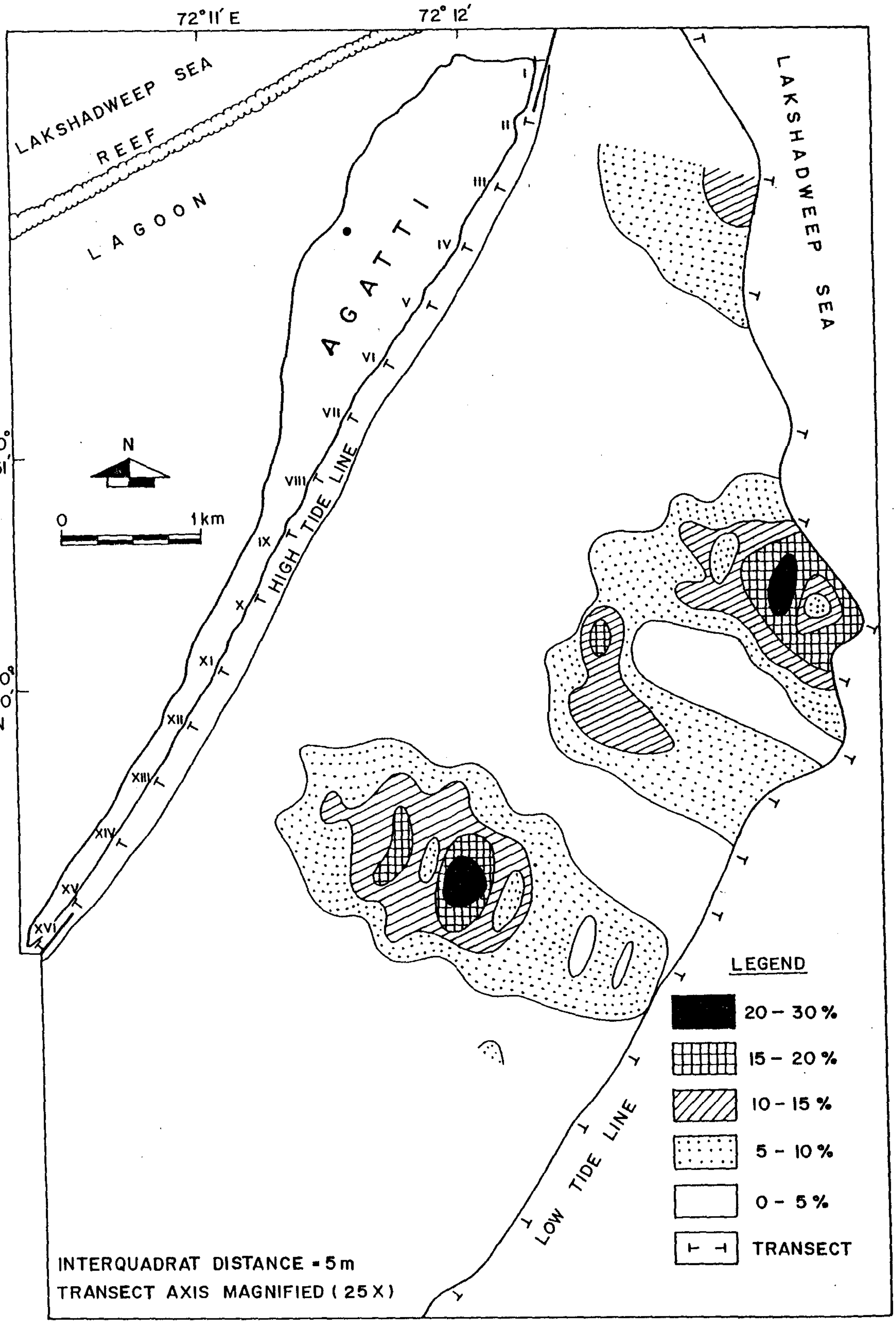

Fig. 5.2 Map of Agatti showing contours of coral abundance in percentage cover of reef flat in March-April 1994.

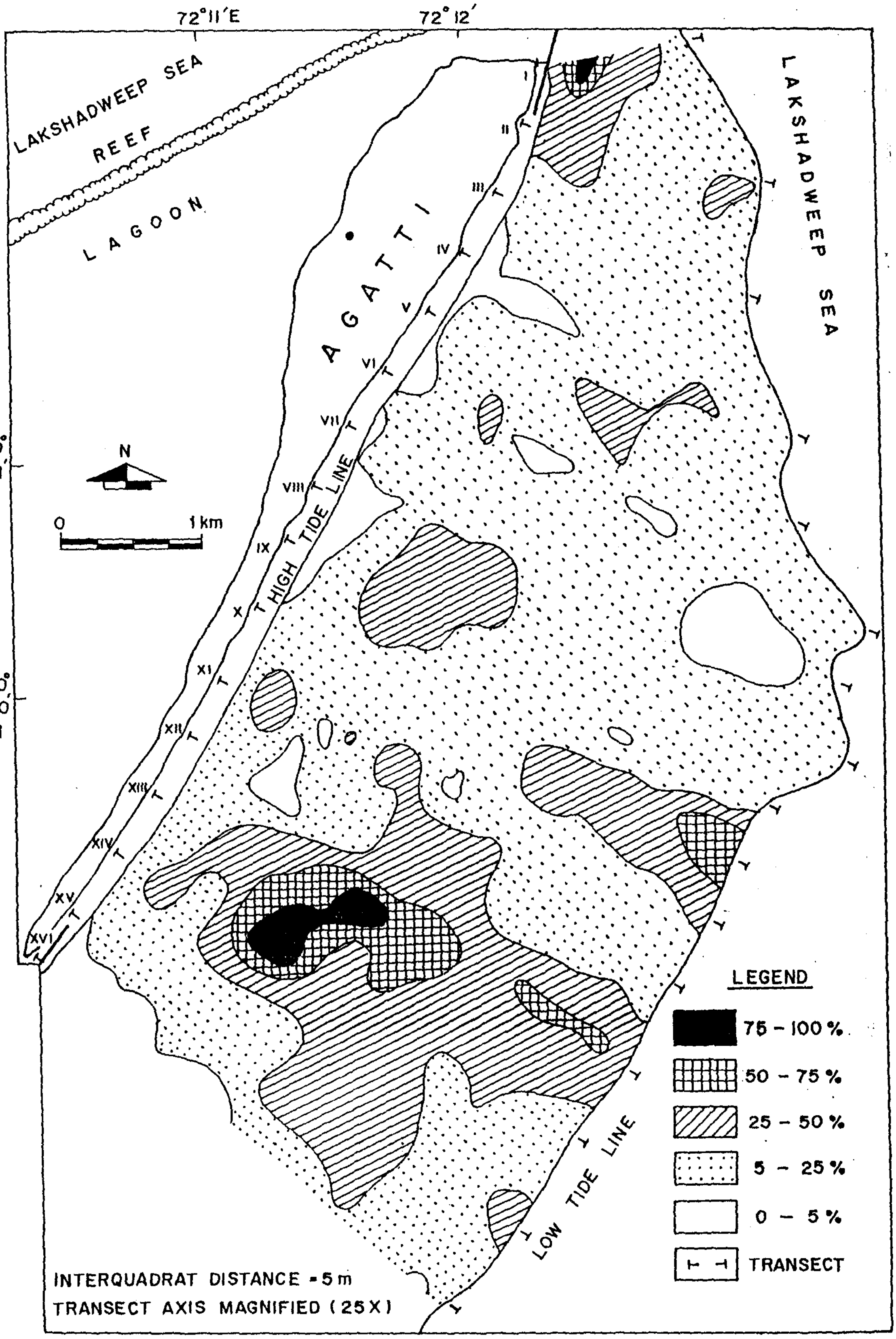

Fig. 5.3 Map of Agatti showing contours of algae abundance in percentage cover of reef flat in October-November 1993.

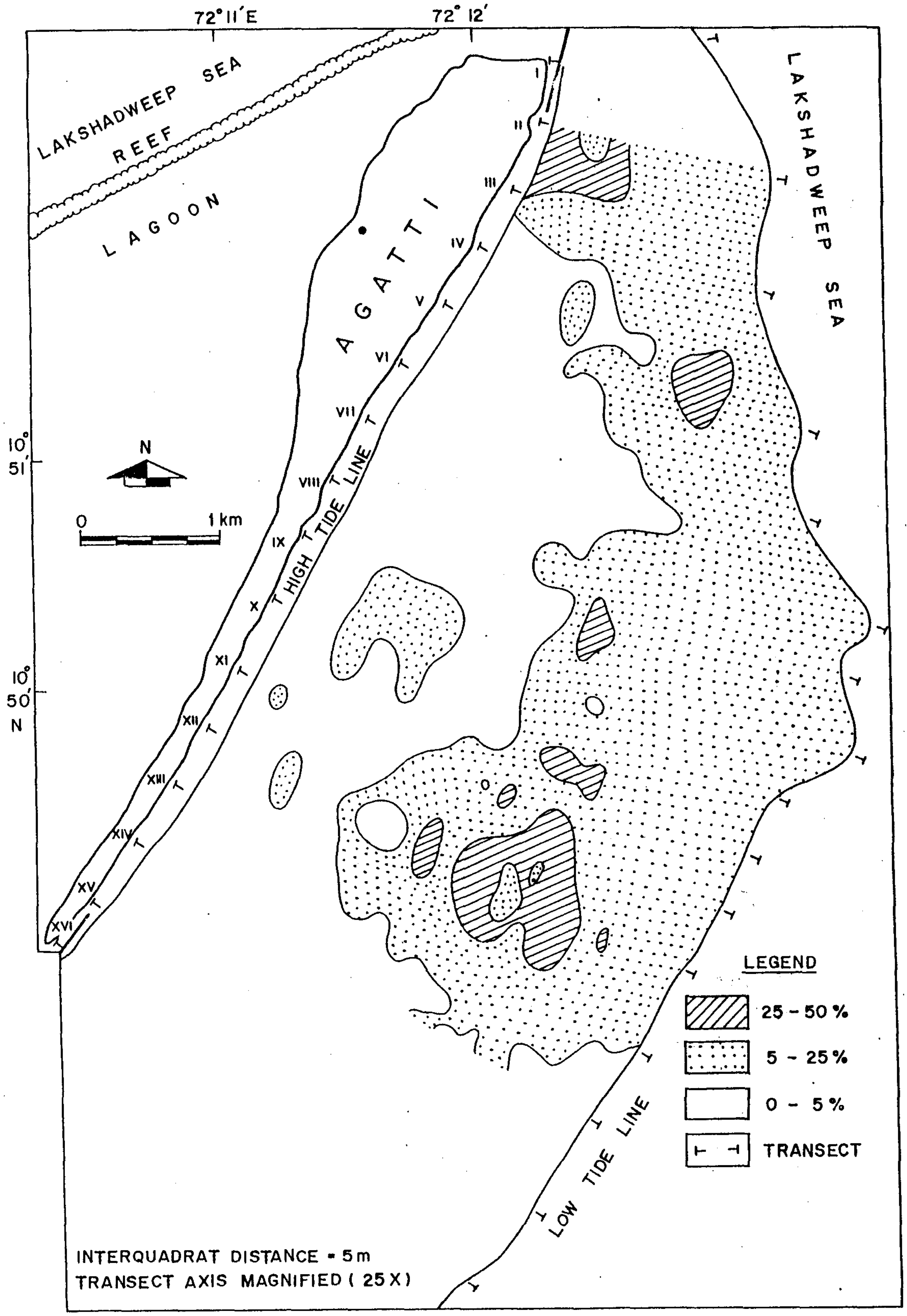

Fig. 5.4 Map of Agatti showing contours of algae abundance in percentage cover of reef flat in March-April 1994.

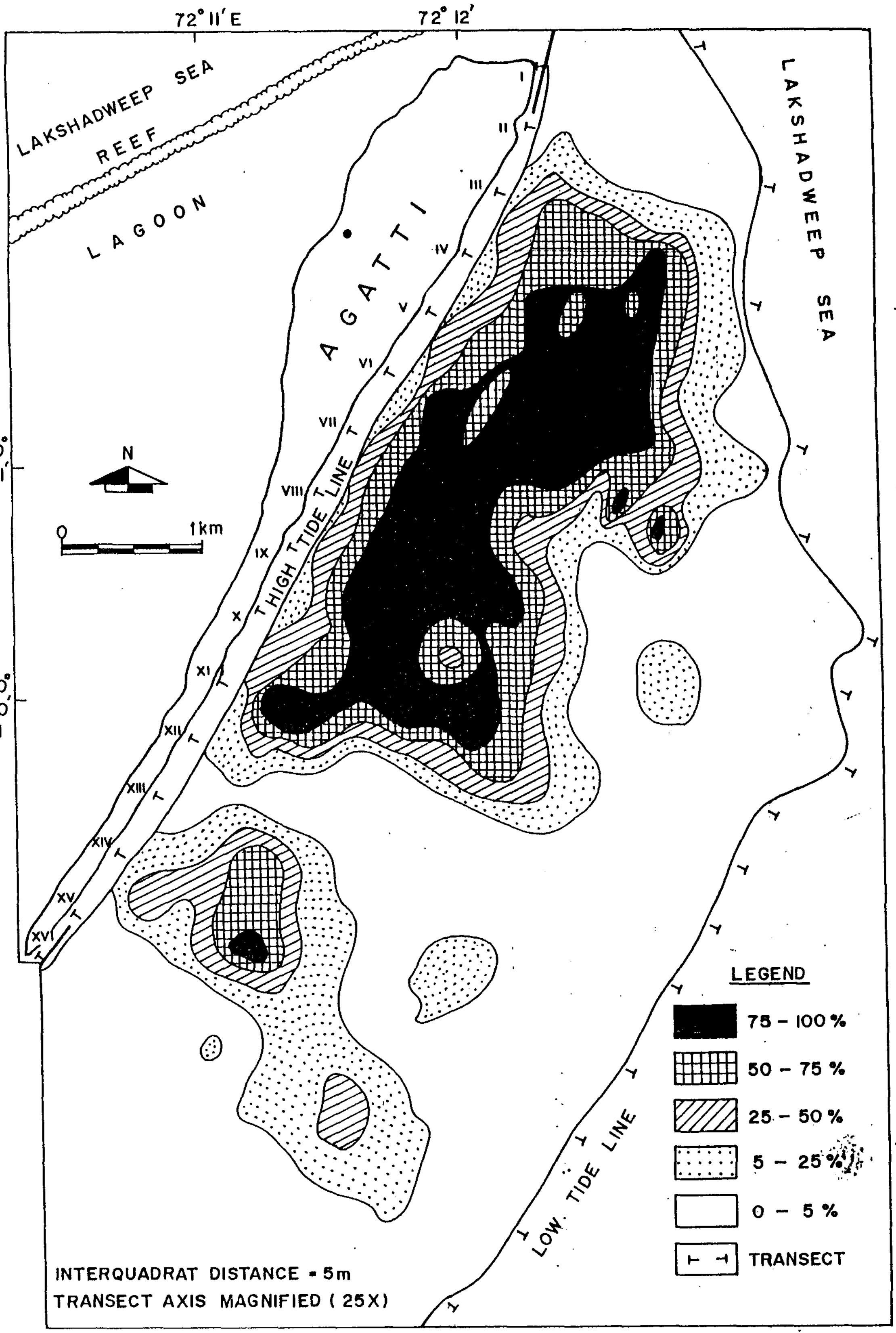

Fig. 5.5 Map of Agatti showing contours of seagrass abundance in percentage cover of reef flat in October-November 1993.

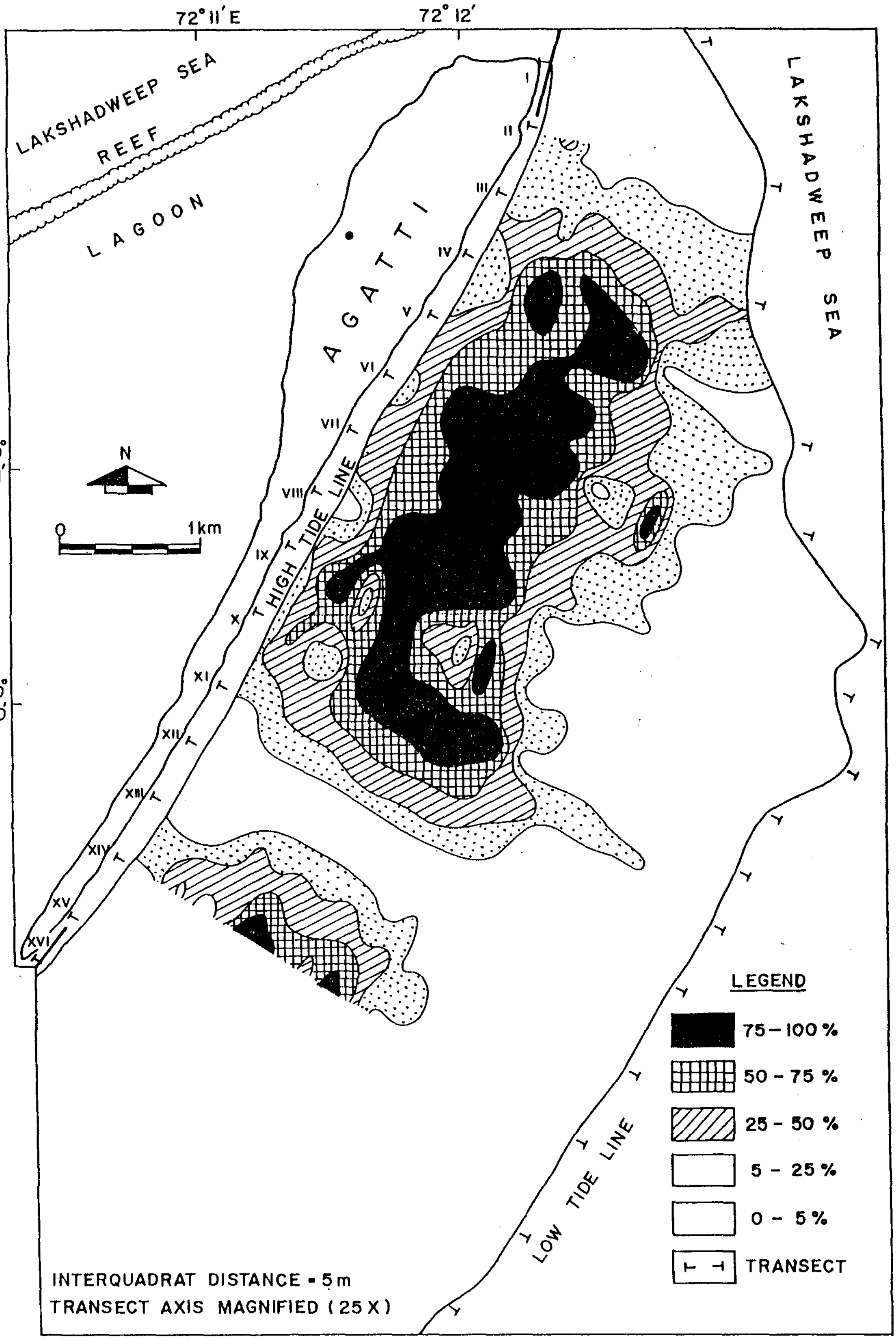

Fig. 5.6 Map of Agatti showing contours of seagrass abundance in percentage cover of reef flat in March-April 1994.

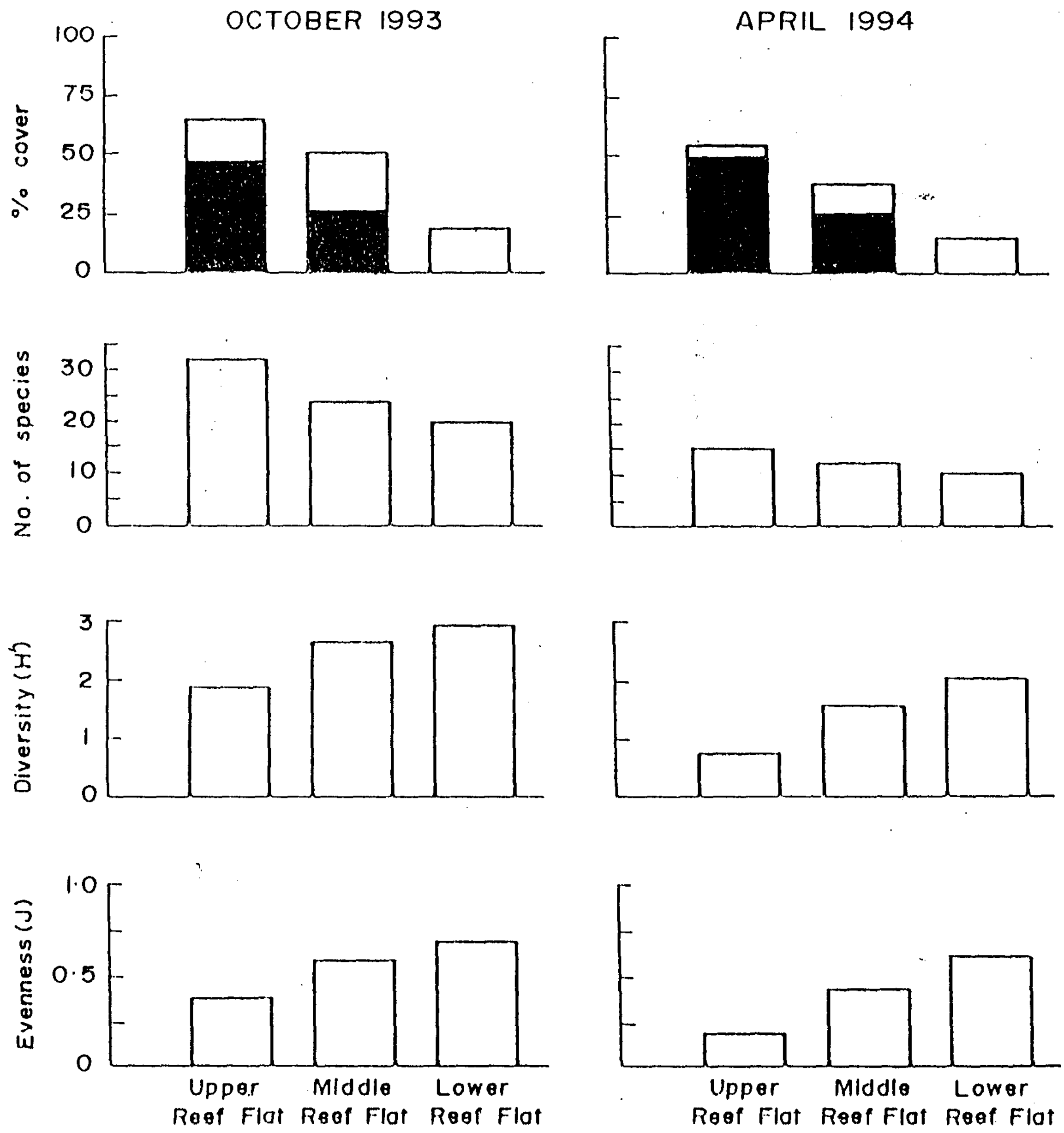

Fig. 5.7 Macrophyte community characteristics of the reef flat at Agatti in October-November 1993 and March-April 1994. The darkened bars denote the percentage cover of *Thalassia hemprichii*. (after Rodrigues *et al.*, 1997)

between coral species on the reefs of Peros Banhos atoll in the Chagos archipelago was able to correlate the abundance of coral species with their order of aggression in some zones of the reefs.

The competitive ability of coral species does not seem to bear any relationship with either their systematic positions or their growth form. For example, the suborder Fungiina comprised aggressive, intermediate and subordinate coral species while the suborder Faviina comprised moderately aggressive, intermediate and moderately subordinate coral species (Table 5.1). Lang (1973) considered species belonging to families Mussidae, Meandrinidae and Faviidae of the suborder Faviina to be the most dominant aggressor species in the Caribbean. She also categorized species of the suborder Faviina as highly aggressive and ramose/ encrusting acroporid as moderate aggressors in the Indo-Pacific. In the present study, however, *Hydnophora exesa* belonging to the suborder Faviina was categorized as moderately aggressive while other species such as *Leptastrea purpurea* and *Favia pallida* were classified as intermediate and moderately subordinate, respectively. It may be noted that species of the families Faviidae and Mussidae constituted minor inhabitants of the reef flat at Agatti (Chapter 4, Fig. 4.4). Moreover, no species belonging to Meandrinidae were encountered during the present surveys. Sheppard (1979) also observed that faviids have representatives at both ends of the hierarchy.

In contrast to Lang's (1973) observations on Indo-Pacific corals, *Acropora aspera*, *A. formosa*, *A. nobilis* at Agatti occupied a moderately subordinate position despite being arborescent. Branching forms are considered to have an advantage due to their faster growth rate and capability to overshadow other corals (Connell, 1973; Porter, 1974) but they are vulnerable to disturbances such as storms and hurricanes (see Connell, 1978; Jackson, 1991). Disturbances such as storms/ cyclones are however rare in Lakshadweep. Moreover, massive or encrusting forms, although growing at a slower rate can outcompete other forms by extruding mesenterial filaments, deploying sweeper tentacles and through immunological reactions (Lang & Chornesky, 1990).

Species interactions have been investigated in the Caribbean (Lang, 1971, 1973; Bak *et al.*, 1982; Logan, 1984; Veghel *et al.*, 1996) and in the Indo-Pacific (Sheppard, 1979; Cope, 1981; Bradbury & Young, 1981a,b, 1983; Sakai, 1985; Yamazato & Yeemin, 1986; Dai, 1990; Genin *et al.*, 1994; Chadwick-Furman & Rinkevich, 1994). Sheppard (1979) considered acroporids on Chagos reefs as aggressive species with the exception of *A. humilis*, which he categorized as a 'moderate aggressor' (although categorized as 'intermediate' in his results and on computing the C.I.). Dai (1990) also considered *A. humilis* to be a moderate aggressor on Taiwanese reefs. In contrast, the present findings are not in accordance to these observations. As can be seen in Table 5.1, *A. humilis* was found to be an overall winner, damaging tissues of eleven of the species considered and being killed only on two occassions. *A. corymbosa* was found to be intermediate at Agatti, although Sheppard (1979) found a close variant of this species, *A. hyacinthus* highly aggressive among Chagos corals. Dai (1990) categorized *A. aspera* as the most aggressive among Taiwanese corals. In contrast, in the present study *A. aspera* was placed in the moderately subordinate category. On the reef flat at Agatti, acroporid were categorized as aggressive, moderately aggressive, intermediate and moderately subordinate (Table 5.1). The observation that *Favia pallida* is a moderately subordinate coral species on the Agatti reef flat is however in conformity with observations by Dai (1990). A compilation of the hierarchical dominance of coral species in Indo-Pacific reefs (Table 5.4) suggests that the hierarchy is not rigid and differs in different geographical locations. Even in Caribbean reefs, Lang's hierarchy (Lang, 1973) on Jamaican reefs suggesting *Montastrea cavernosa* and *Meandrina meandrites* to be respectively subordinate and dominant over *Montastrea annularis* was

Table 5.4 Hierarchical categorization of coral species in Indo-Pacific reefs.

	Locality→ Suborder	Lakshadweep (Present study)	Chagos (Sheppard, 1979)	Hong Kong (Cope, 1981)	Thailand (Yamazato & Yeemin, 1986)	Taiwan (Dai, 1990)
Acropora humilis	Astrocoeniina	Aggressive	intermediate	-	-	moderately aggressive
Pavona varians	Fungiina	Aggressive	intermediate	-	-	moderately aggressive
Millepora platyphylla#	Order Milleporina#	Moderately Aggressive	-	-	-	aggressive
Hydnophora exesa	Faviina	Moderately aggressive	-	aggressive	subordinate*	aggressive
Montipora turgescens	Astrocoeniina	moderately aggressive	subordinate?	-	-	-
Acropora robusta	Astrocoeniina	intermediate	-	-	-	-
Acropora corymbosa	Astrocoeniina	intermediate	-	-	-	-
Pocillopora damicornis	Astrocoeniina	intermediate	-	-	aggressive*	subordinate
Leptastrea purpurea	Faviina	intermediate	-	aggressive	aggressive	moderately subordinate
Psammocora contigua	Fungiina	intermediate	-	-	aggressive*	-
Acropora nasuta	Astrocoeniina	intermediate	-	-	-	-
Acropora nobilis	Astrocoeniina	moderately subordinate	-	-	-	-
Acropora formosa	Astrocoeniina	moderately subordinate	-	-	-	-
Favia pallida	Faviina	moderately subordinate	-	-	moderately aggressive	moderately subordinate
Acropora aspera	Astrocoeniina	moderately subordinate	-	-	-	aggressive
Porites lutea	Fungiina	subordinate	subordinate	-	subordinate	subordinate

non-scleractinian coral * based on one observation only

observed to give a reversed outcome on the reefs of Curacao, Netherlands Antilles (Veghel *et al.*, 1996).

The Caribbean and Indo-Pacific seem to have commonality as far as *Porites lutea* is concerned (Sheppard, 1979; Cope, 1981; Sakai, 1985; Yamazato & Yeemin, 1986; Dai, 1990). All studies on coral species interactions, including the present, have shown *P. lutea* to be the most subordinate species, although it is a major component on most reefs. How subordinate species such as *Porites lutea* maintain their prevalance on all reefs is a question that has puzzled most ecologists. Taylor (1968) and Yamazato & Yeemin (1986) postulated that *Porites lutea* maintains its position on the reef due to its tolerance to adverse environmental conditions such as high sedimentation, wide fluctuation in salinity, temperature and other factors. Another mechanism the subordinates can resort to is to maintain themselves on the reefs by opportunistically gaining a foothold by recruiting in areas of the reef wherever space permits and avoid colonizing areas occupied by their aggressors. Lang and Chornesky (1990) pointed out that the dominance of a coral species in a reef community is not solely determined by its aggressiveness but is the net result of a number of factors prevailing on the reef.

An important observation in the present study is the record of a large number of reversals in the outcome of interactions. On other reefs, the outcome of interactions has generally been accepted to be consistent and inflexible. Cope (1981) was among the first to record a two way outcome in naturally occurring coral species interactions involving *Leptastrea purpurea*, *Favia speciosa*, *Platygyra sinensis*, *Cyphastrea serailia* and *Pavona decussata*. She attributed it to environmental factors. Subsequently, temporal reversals have been reported when sweeper tentacles were used to counteract initial attacks by mesenterial filaments (Wellington, 1980; Chornesky, 1983, 1989). Bak *et al.* (1982) recorded 17-35% unpredictable outcomes in *in situ* and experimental coral species interactions in the Caribbean reefs in the Atlantic and attributed it to extracoelenteric digestion, interference by epifauna and sweeper tentacle formation. Results of competing pairs of species reported in the literature and analyzed by Connell and Keough (1985) suggested that when both species belonged to the same phylum, competition was more symmetrical, *i.e.* one species did not win significantly more often than the other. Veghel *et al.* (1996) also reported reversal in outcomes for some interactions on the reefs of Curacao.

Chornesky (1989), in a long term study involving three of the most common Caribbean corals, *viz. Agaricia agaricites*, *Montastrea annularis* and *Porites astreoides*, observed repeated reversals between pairs of species due to development of sweeper tentacles in response to initial mesenterial filaments attack, resulting in both competitors alternatively gaining and losing tissue and space. She also visualized that such reversals could occur due to changeable environmental circumstances. She remarked that the majority of published accounts were inferential and based on short term observations. In the Gulf of Eilat (Red Sea), *in situ* long term water flow manipulations using submerged pumps suggested that the flow regime can modify the outcome of competitive interaction between an aggressive sweeper tentaculate coral species, *Galaxea fascicularis* and a subordinate species *Acropora variabilis* (Genin *et al.*, 1994). On the other hand, a complex allorecognition system in a hermatypic coral, *Stylophora pistillata*, resulting in consistent outcomes in both time scale and type of response has been reported in the Gulf of Eilat (Chadwick-Furman & Rinkevich, 1994). The competitive outcome of a given pair of coral species can vary due to polypal and gross morphology, physiological health, growth rate, development of sweeper tentacles and numerous other factors (Lang & Chornesky, 1990). In the present study, although the mechanisms of coral species interactions were not investigated, observations nevertheless suggested that the outcome of interactions was unpredictable.

The analysis of transect quadrat data revealed that no statistically significant associations could be detected, ruling out the hypothesis that competition between coral species occurs, despite field observations to the contrary. The statistical analyses of coral species distribution in the Indo-Pacific and eastern Atlantic have also generally revealed that coral species were neighbours by chance and hence have few effects at the community level (Bradbury & Young, 1981b, 1983; Reichelt & Bradbury, 1984). Although correlation coefficients and measures of association are often difficult to interpret, such tests may be prerequisites for considering ecological hypotheses (Pielou, 1974). Shcppard (1985) criticized the 'random neighbour' method adopted by Bradbury and Young (1981b) pointing out that the intervals used to indicate neighbour events exceeded distances of the 'interactive reach' over which most corals interact. The 'interactive reach' refers to the distance over which the polyp/ tentacles/ mesenterial filaments/ sweeper tentacles of the coral species can extend. However, overtoppers such as foliaceous or tabular corals adopt a different mechanism of interaction which indirectly affect corals in their vicinity but beyond their 'interactive reach', by overshadowing them (Connell, 1973; Porter, 1974; Hughes & Jackson, 1985; Glynn, 1987). There also exists inferential evidence that some acroporid, pocilloporid and other reef corals perhaps release chemicals into the surrounding water that injure individuals beyond their 'interactive reach' (Sheppard, 1979; Rinkevich & Loya, 1983).

Amidst the heated debate by theorists and field ecologists on the evidence of competition among species in nature and the methodology to study it (*cf* American Naturalist Vol. 122, No. 5), Toft & Shea (1983) suggested the acceptance of the competitive hypothesis and concentration on the quantification of its intensity. The contigency coefficients suggested by Toft and Shea (1983) obtained in the present study suggested that even if competition was taking place, its intensity was negligible (Table 5.2). Toft & Shea (1983) and Lang & Chornesky (1990) stressed the importance of determining the power of the test which is the probability of not committing a Type II error (accepting a null hypothesis when it is false). The general trend in statistical hypothesis testing is to determine the probability of committing a Type I error (rejecting a null hypothesis when it is true). The power of a given test increases with sample size (Sokal & Rohlf, 1981) and as 399 quadrats were considered in the present analysis, statistical inferences are reasonable.

Results obtained in the present study suggest that competition among coral species occurs but the outcome is unpredictable and hence perhaps statistically not detectable. An alternative explanation is that the coral species in all quadrats sampled were not within the 'interactive reach' of their coral neighbours. Furthermore, no linear hierarchy of coral species could be established due to the number of circular (intransitive) interactions recorded on the Agatti reef flat. Such circular interactions have been reported to occur among weakly aggressive species (Cope, 1981; Logan, 1984) but in the present study it involved the most aggressive species on the reef flat, *viz. Acropora humilis*. Lang (1973) also observed such patterns in laboratory experiments. On Heron Island (Queensland, Australia), Connell (1976) could record only one instance of a circular network involving *Acropora digitifera* and *Acropora hyacinthus* in his long term studies. Nevertheless, observations recorded at Agatti in the present study and elsewhere suggest that the inflexibility of competitive outcomes as well as the hierarchical competitive abilities of coral species need to be re-examined. Such doubts have also been raised by other investigators (Bak *et al.*, 1982; Logan, 1984; Lang & Chornesky, 1990).

Chornesky (1989) predicted that repeated reversals may be common among reef corals. Repeated reversals, standoffs, symmetrical competition and competitive networks in sessile marine communities slow down competitive exclusion of subordinate species and allow high diversity to persist despite active competition (Jackson & Buss, 1975; Buss & Jackson, 1979; Connell, 1983; Connell & Keough, 1985; Chornesky, 1989). This should explain why subordinate species are not eliminated on reefs. It should be noted that repeated reversals *sensu* Chornesky (1989) involve continuous combat resulting in no clear cut winner or loser, unlike symmetrical competition and competitive networks. It is thus different from 'reversals' reported by Cope (1981) and others (Wellington, 1980; Bak *et al.*, 1982; Veghel *et al.*, 1996), including the present study. Connell (1978) considered it unlikely that one type of competitive mechanism would result in circular interactions unless the 'equal chance' hypothesis was invoked as observed in the present study. It may be recollected that in the present study, only the competitive outcome was recorded while the competitive mechanism was not at all investigated. The mechanism of coral species interactions on the reef flat at Agatti needs to be investigated by further observations and field experiments. It is possible that the unpredictability of outcomes of coral interactions at Agatti could be attributable to the topography as well as unpredictable physical factors prevailing on the shallow reef flat resulting in the reversal of competitive outcomes. Whether such unpredictability occurs in deeper waters of Agatti reefs or elsewhere in Lakshadweep also needs to be ascertained.

5.4.2 Coral-macrophyte interactions

Coral-seagrass association/ correlation analyses indicated that their interaction was negative, suggesting competition between these two groups of organisms. These organisms however colonize different types of substrates; corals require a firm substrate for settling while seagrasses colonize loose sediments. Extreme conditions such as sedimentation and lengthy emersion periods prevailing in the inner flat do not favour the growth of corals. Such observations have been recorded elsewhere such as on the southeastern fringing reef flat of Magnetic island in Geoffrey Bay, Australia, where seagrasses occupy the inner sedimentary accumulation zone (Morrissey, 1980). Moreover, seagrasses form dense meadows on the reef flat, resulting in blocking light and smoothering corals as evidenced by dead coral colonies in the seagrass beds at Agatti.

Algae and seagrasses exhibited a significantly negative association as evidenced by the X^2 value though the correlation coefficient was not statistically significant at the same level. While seagrasses colonize loose substrates in coral reefs, algae prefer a firm substrate although some algal species do grow on sand or on seagrass blades. In the present study, a few algae were recorded on sand and epiphytic algae on seagrass blades were not taken into consideration. The discrepancy can perhaps be explained as correlation analysis takes into account abundances.

Corals and algae prefer firm substrate and thus compete for space on the reef framework. As noted above, algae can also colonize loose sediments. In the present study, the X^2 analysis suggested a statistically significant positive association although the correlation coefficient was negative and insignificant. The discrepancy in the results is that while the X^2 test relies on merely their co-occurences in quadrats, correlation analysis takes into account their abundances. Results on the abundance of macrophytes on the reef flat at Agatti revealed that though total macrophyte cover (dominated by seagrasses) decreased seawards, algal cover slightly increased seawards (Fig. 5.7). Coral cover also increased seawards (Chapter 4). Although an inverse relationship between the abundance of algae and corals has been recorded on the Agatti reef flat, both increased seawards, resulting in a statistically significant positive association. Algae tolerate longer periods of emergence than corals (Cribb, 1973) which explains their inverse relationship on the Agatti reef flat. Algal and coral abundance on the reef flat at Magnetic island followed similar trends (Morrissey, 1980). Although algal spores do not survive on living coral (Cribb, 1973), algae can colonize areas of dead coral available.

Corals and algae compete for space, nutrients amd light and any one assemblage can predominate under specific conditions (Littler & Doty, 1975; Littler & Littler, 1988). The distribution of algae appears to be related not only to physical factors such as nutrient levels, wave action, irradiance and temperature but also to biological factors such as competition and predation (grazing). The pattern seems to be generated by competition mediated by the interaction of nutrient availability and disturbances caused by herbivory and wave action (Littler & Littler, 1988). Eutrophic waters where herbivory and wave action are low tend to favour a large population of frondose algae that can outcompete corals (Banner, 1974; Littler & Doty, 1975; Birkeland, 1977; Smith *et al.*, 1981; Littler & Littler, 1988). As indicated in the previous chapter (Chapter 4), nutrient levels, although suspectedly high due to anthropogenic activities such as defecation on the reef flat, have not been quantified in this study and hence are not discussed.

Seagrasses, algae and corals coexist on the reef flat at Agatti and there is no complete monopolization of space by any of these organisms, except for seagrasses in loose substrates on the inner reef flat. Partitioning of space by corals, seagrasses and algae can be visualized by superimposing the contour plots (Fig 5.1-6). The distribution and abundance of algae at Agatti is patchy and governed by the monsoons and seasonal fluctuations attributable to wave action and desiccation (Rodrigues *et al.*, 1997). Herbivory has also been reported to be significant at Agatti with sea urchins as the major grazers (Rodrigues *et al.*, 1997). Herbivory is a form of predation that can also be considered as a type of disturbance (Connell, 1978). Physical disturbances such as storms/ cyclones are not common in Lakshadweep.

Monopolization of space by organisms colonizing firm substrates is reported to be prevented by disturbance caused by physical or biological factors (Dayton, 1971; Connell, 1978). Predation, competition and disease are other important processes affecting the structure and dynamics of biological communities (Hughes, 1989). Herbivory has been considered to play a primary role in determining the distribution of algae in coral reefs Stephenson & Searles, 1960; Samarco, 1980; Lubchenco & Gaines, 1981; Hay 1984). It has been reported to be intense on coral reefs, where grazers often consume 50-100% of total plant production (Hatcher & Larkum, 1983; Carpenter, 1986), more so than in any other marine habitat.

The major grazers on reefs are fishes and sea urchins, with fishes predominating in deeper waters (Morrison, 1988). Parrot fish are the dominant grazers on Pacific reefs, particularly on the Great Barrier Reef, while sea urchins have filled this niche on Caribbean reefs (Birkeland & Grosenbaugh, 1985; Sammarco, 1987; Berner, 1990). Turf algae are abundant while fleshy algae are restricted to shallow reef flats due to intense grazing (Borowitzka, 1981). Experimental field manipulations of grazing sea urchins and fishes on coral reefs have demonstrated that herbivores suppress the abundance of fleshy algae (Ogden *et al.*, 1973; Carpenter, 1981; Sammarco, 1982; Morrison, 1988). The epidemic that killed sea urchins in the Caribbean and resulted in algae replacing corals on reefs is well documented (see Hughes, 1994). On shallow intertidal reef flats such as on the reef flat at Agatti, where herbivorous fishes can forage only during high tide, other herbivores are likely to fill this niche.

The grazers observed on the intertidal reef flat at Agatti were the majid crabs (*Criocarcinus* sp., *Cyclax* sp., *Menaethius* sp., *Micippa* sp., *Schizophrys* sp., *Tylocarcinus* sp.); sea urchins, (*Echinometra mathaei* (Blainville), *Tripneustes gratilla*

(Linnaeus), *Diadema setosum* (Leske), *Toxopneustes pileolus* (Lamarck), *Echinothrix* spp.) and herbivorous reef fishes (*Abudefduf* spp., *Dascyllus* spp., *Chromis* spp., *Amphiprion* spp., juveniles of *Acantharus* spp., *Callyodon* sp., *Leptoscarus* sp., *Siganus* spp.). Among these, sea urchins were abundant. Minor grazers included molluscs such as *Aplysia* sp., *Nerita* spp. and *Littorina* spp.. Algal fragments, particularly *Halimeda* sp., were also recorded in the gut of common holothurians, such as *Holothuria* spp. and *Actinopyga* spp. (Rodrigues *et al.*, 1997). The abundance of grazers, notably the sea urchins, and the seasonality of algae governed by the monsoons prevents the monopolization of space by algae on the reef flat at Agatti. These grazers decreased the competition between corals and algae by making available space for settlement for other organisms such as corals.

An analogy of the Agatti reef flat may be drawn with the reefs of the northern Gulf of Eilat (Red Sea) where there is partitioning of space between algae, stony corals and soft corals mediated by sea urchins (Benayahu & Loya, 1977). On these reefs, algae were dominated by the turf algae, *Sphacelaria tribuloides*, and the brown algae, *Turbinaria elatensis*. In contrast to the Agatti reef flat, calcareous algae were insignificant and the total algal cover ranged from 3.0-75.4%. Algal cover particularly of turf algae increased from April to May and subsequently declined due to spring storms. At Agatti, algae exhibit maximum growth from October to December and decline in subsequent months due to desiccation and wave action (Rodrigues *et al.*, 1997). Benayahu & Loya (1977) attributed the partitioning of space to physical factors such as disturbance caused by extreme low tides, wave action, seasonal variations in temperature, salinity and light and biological factors such as grazing by sea urchins. On the Agatti reef flat, partitioning of space can be attributed to desiccation, wave action and grazing. Nutrient levels could also possibly be another factor in the study area.

It has been suggested that a combination of physical and biotic factors determines the outcome of competition between reef-building corals and algal populations (Johannes *et al.*, 1983). In the present study, competition between corals and algae appeared to be more significant than competition among coral species. Further studies such as field experiments and the quantification of nutrient levels are required to ascertain the role of grazers and nutrients in regulating the abundance and distribution of algae and corals on the reef flat at Agatti.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

The thesis presents and discusses results of investigations carried out in Lakshadweep (8°-12°30'N, 71°-74°E) during 1993-1995 to study the coral fauna of the archipelago. Investigations can be broadly divided into two parts. The first part (Chapters 2 & 3) focusses on the taxonomy of hermatypic and ahermatypic corals of the reefs and discusses affinities with other coral reef areas in south Asia. The theme of the second part (Chapters 4 & 5) relates to the coral community structure and biotic (coral-coral and coral-macrophyte) interactions on the reef flat along the eastern side of the Agatti atoll (10°51'N, 72°11'E).

Field surveys conducted at several islands revealed the presence of 96 coral species divided among 34 genera. Of the 34 genera reported, 32 are hermatypes while 2 are ahermatypes. Twenty eight species are being reported for the first time from the Lakshadweep archipelago. This raises the tally of coral genera and species so far reported from Lakshadweep to 43 and 133, respectively. Two genera, *Pachyseris* and *Paracyathus*, are reported from Lakshadweep for the first time.

Among the new records, 5 species *viz. Montipora foveolata*, *Fungia (Danafungia) scruposa*, *Favites russelli*, *Montastrea magnistellata* and *Turbinaria frondens* are reported from south Asia for the first time. Ten species are being reported from Indian waters for the first time (*Acropora austera*, *A. cerealis*, *A. pulchra*, *A. selago*, *A. tenuis*, *Astreopora ocellata*, *Pavona venosa*, *Porites nigrescens*, *Goniastrea edwardsi* and *Montastrea curta*). Thirteen species (*Acropora ?millepora*, *A. valida*, *Pachyseris speciosa*, *Pavona decussata*, *Fungia (Verrillofungia) concinna*, *Goniopora* *lobata*, *Porites compressa*, *P. lichen*, *Goniastrea ?aspera*, *Galaxea astreata*, *Hydnophora exesa*, *Tubastrea micranthus* and *Paracyathus* sp.), although reported elsewhere in India, are being reported from Lakshadweep for the first time. No coral genus endemic to India has been recorded. Keys to the identification of coral species documented to date from Lakshadweep are presented as an Appendix to the thesis.

An attempt was made to synonymize coral species on the basis of available literature. In the present work, *Acropora irregularis* and *A. abrotanoides* are considered synonyms of *A. danai*. *Galaxea clavus* is treated as a synonym of *G. astreata*. *Acropora intermedia* and *A. nobilis* are considered to be distinct species, although some taxonomists consider them to be the same. The present exercise of synonymizing the coral species may be incomplete and holotypes housed in the different international museums need to be examined to sort out the synonymies.

The coral fauna of seven localities in south Asia (Gulf of Kachchh, west coast of India, Gulf of Mannar & Palk Bay, Andaman & Nicobar Islands, Lakshadweep, Sri Lanka and the Maldives) was compiled and analyzed. A total of 398 coral species are reported in the present compilation for south Asia. The highest number of species (251) are recorded in the Maldives while only 37 species are reported from the Gulf of Kachchh. The present study has indicated that the Lakshadweep coral fauna has closer affinities with the Maldivian fauna, as indicated by the results of the cluster analysis. However, many genera reported in the Maldives have not yet been recorded in Lakshadweep. This discrepancy could be because many reefs in Lakshadweep, particularly in deeper waters, remain unexplored. The analysis also revealed that the coral fauna of the Andaman and Nicobar islands was similar to that of the Palk Bay and the Gulf of Mannar. The Gulf of Kachchh and the west coast coral fauna did not exhibit any affinities towards other localities. Results of this analysis concur with the geological history of the south Asia region.

The present study has updated the total number of species reported in Indian waters from 199 to 252. These include 216 species of hermatypic corals belonging to 57 genera and 36 ahermatypic species belonging to 19 genera. The tally of coral genera in Indian waters thus increases from 71 to 76. Surveys of coral species in most Indian localities were carried out decades ago and it is not known whether the distribution lists published in the literature continue to be valid, as reefs have undergone changes due to anthropogenic activities.

The distribution, abundance and other coral community characteristics were studied on the reef flat at Agatti atoll during October-November 1993 and March-April 1994. The percentage cover of corals and macrophytes (algae and seagrasses) was estimated. Such quantitative data was collected from duplicate quadrats at 5m intervals using a $1m^2$ quadrat along sixteen transects fixed on the eastern side of the atoll at intervals of 500m. In all, 850 quadrats were enumerated in October-November 1993 and 384 quadrats in March-April 1994.

The most abundant coral species on the reef flat were *Pocillopora damicornis*, *Porites lutea*, *Acropora humilis*, *A. corymbosa* and *A. robusta.* Faviids were not conspicuous. Several coral species exhibited restricted distributions. A zonation pattern could be discerned along the intertidal gradient. Starting from the average high tide mark up to a distance of 20m, the area is generally devoid of corals and is colonized by algae and/or seagrasses.

The reef flat was dominated by branching coral growth forms. Principal component analysis of the data revealed that the reef flat could be divided into two zones: an inner reef flat and an outer reef flat. The growth forms of corals on the inner reef flat were either massive (*Porites lutea*, *Psammocora contigua*) or branching (*Acropora humilis*, *A. formosa*). The outer reef flat was dominated by branching growth forms and a few massive coral species, *e.g. Porites lutea*, *Goniastrea retiformis*). The percentage coral cover on the outer reef flat was significantly higher than that of the inner reef flat. There were also differences in species richness and species diversity. Typical corals of wave exposed areas were *Pocillopora damicornis*, *Acropora robusta*, *Goniastrea retiformis*, *Millepora* spp. and *Heliopora coerulea*. Zonation of corals on the Agatti reef flat roughly corresponded to general reef schemes. The major abiotic factors influencing the distribution and abundance of corals are discussed. Predators of corals were not observed in significant numbers on the reef flat.

Three assemblages of corals could be discerned on the reef flat using cluster analysis. The first assemblage represented dominant coral species comprising of branching corals (*Pocillopora damicornis*, *Acropora humilis*, *A. corymbosa*, *A. robusta*) and a massive coral (*Porites lutea*). The second assemblage was dominated by massive growth forms (*Psammocora profundacella*, *Cyphastrea serailia*, *Hydnophora exesa* and *Leptastrea purpurea*) predominant on the outer reef flat. The third assemblage comprising of *Acropora aspera* and *Goniastrea retiformis* represented a minor assemblage at transect VI.

The mean percentage cover of live corals on the reef flat at Agatti was low, being 1.2 ± 0.4% and 5.5 ± 0.7% on the inner and outer reef flat, respectively. The maximum percentage cover of live corals recorded in an individual quadrat was 58%. The high standard error values and the high percentage of quadrats with no coral species obtained in the present study are indicative of the high degree of patchiness exhibited by coral species which were abundant only at selected transects. No published quantitative data on the coral cover in Lakshadweep or elsewhere in Indian reefs are available for comparison. Although coral cover on the reef flat at Agatti appears low, it is comparable with reef flats in other geographical localities such as Phuket (Thailand) and Magnetic Island (Australia).

The maximum number of coral species (27) was recorded at transects VI and XII. The number of species and their abundance progressively increased seawards along the intertidal gradient. Species diversity also exhibited the same trend. The range of coral diversity values recorded at Agatti (0 to 3.02 bits) is comparable with values obtained on other reef flats. Coral species richness increased with coral abundance suggesting that the 'intermediate disturbance' hypothesis proposed to account for the high species diversity in coral reefs is not universal. It is most likely that other hypotheses such as the 'equal chance' hypothesis are applicable for coral reefs. The median value of the Brillouin's index yielded a coral reef flat community diversity value of 3.65 ± 0.24 bits. Results obtained on the quantitative analysis of coral in the present study could not be compared with earlier values, either from Lakshadweep or other reefs in India, due to unavailability of published values.

Investigations to study interactions between neighbouring coral species were carried out during October 1993, April 1994, November 1994 and April 1995 by recording naturally occurring coral species interactions at random sites on the reef flat. The degree of dominance of one species over the other was determined by the Competitive Index (C.I.).

Twenty nine species pairs of corals were observed to naturally interact on the reef flat. The maximum number of interactions (24.4%) involved *Acropora humilis* while the minimum (0.6%) involved *A. nobilis*. Most interactions observed involved dominant coral species. The competitive ability of coral species did not seem to bear any relationship with either their systematic positions or their growth forms. *A. humilis*, with the highest C.I. (+0.69) and *Pavona varians* (+0.56), were the most aggressive coral species while *Porites lutea*, with the least C.I. (-1.0) was the most subordinate species. Although the outcome of interactions have been generally accepted to be consistent and inflexible, *in situ* observations revealed that the outcome of the interaction was not always determinate. Most interactions (65%) were unpredictable due to reversal in outcomes. Standoffs constituted about 4% of the total interactions. Only six species *viz. Montipora turgescens*, *Leptastrea purpurea*, *Acropora nobilis*, *Favia pallida* and *Porites lutea* exhibited no reversals. No definite linear hierarchy could thus be established on the reef flat due to the large number of circular (intransitive) interactions recorded on account of reversals. Although circular interactions have been reported to occur elsewhere among weakly aggressive species, at Agatti it involved the most aggressive species on the reef flat, *viz. Acropora humilis*.

Quadrat data collected during October-November 1993 and March-April 1994 along transects were also re-analyzed to study species association. The contigency coefficient was computed to determine the intensity of the association. In addition, the Karl Pearson coefficient of correlation between pairs of coral species was computed as an alternative measure of species association.

The analysis of transect quadrat data revealed that no statistically significant associations/ correlation could be detected, ruling out the statistical hypothesis that competition between coral species occurs, despite field observations to the contrary. The contigency coefficients obtained suggested that even if competition was taking place, its intensity was negligible.

Statistical analyses of coral species distribution in some Indo-Pacific and eastern Atlantic reefs have also revealed that coral species were neighbours by chance and hence have few effects at the community level. A compilation of the hierarchical dominance of coral species in Indo-Pacific reefs suggests that the hierarchy is not rigid and differs depending on the geographical location.

The subordinate coral, *Porites lutea*, occurred as a neighbour of its aggressors in many quadrats. The dominance of coral species at Agatti could thus not be explained merely on the basis of their competitive abilities. Previous studies on coral species interactions in all oceans have shown *P. lutea* to be the most subordinate species, although it is a major component on most reefs. How subordinate species such as *P. lutea* maintain their prevalance on all reefs has puzzled most ecologists.

The results obtained suggest that although competition among coral species occurs, it could not perhaps be statistically detected as the outcome is unpredictable. An alternative explanation is that the coral species in all quadrats sampled were not within the 'interactive reach' of their coral neighbours. Observations recorded at Agatti and elsewhere suggest that the inflexibility of competitive outcomes as well as the hierarchical competitive abilities of coral species need to be re-examined.

Reversals in sessile marine communities slows down competitive exclusion of subordinate species and allows high diversity to persist despite active competition. This could explain why subordinate species are not eliminated on reefs. The mechanism of coral species interactions on the reef flat at Agatti needs to be investigated through further field observations and experiments. It is possible that the unpredictability of outcomes of coral interactions at Agatti could be attributable to the topography as well as unpredictable physical factors prevailing on the shallow reef flat resulting in the reversal of competitive outcomes. Whether such unpredictability occurs in deeper waters of Agatti reefs or elsewhere in Lakshadweep also needs to be ascertained.

Coral-macrophyte interactions were analysed by computing the X^2, contigency and correlation coefficients. The level of statistical significance of the coefficients obtained were also determined.

The analysis of quadrat for coral-macrophyte interaction revealed that a statistically significant negative association (X^2) and correlation coefficient were obtained between coral and the seagrass, *Thalassia hemprichii*. The contigency coefficient between these two groups was also the highest, implying competition. These organisms however colonize different types of substrate; corals require a firm substrate for settling while seagrasses colonize loose sediments.

Algae and seagrasses exhibited a significantly negative association as evidenced by the X^2 value although the correlation coefficient was not statistically significant at the same level. While seagrasses colonize loose substrates in coral reefs, algae prefer a firm substrate, although some algal species do grow on sand or on seagrass blades. The discrepancy can perhaps be explained as correlation analysis takes into account abundances.

Results obtained on the abundance and distribution of macrophytes revealed that the percentage cover of macrophytes, particularly the seagrass, *T. hemprichii*, decreases seawards, although that of algae slightly increases seawards. Contour plots of the distribution and abundance of corals and macrophytes on the Agatti reef flat, superimposed on a map of the study area, delineated their habitats. They also revealed that the abundance of algae on the Agatti reef flat was seasonal, being abundant in October-November 1993 and scarce in March-April 1994. Corals and seagrasses did not exhibit seasonality.

Corals and algae both prefer firm a substrate and thus compete for space on the reef framework. Algae can also colonize loose sediments. The X^2 analysis suggested a statistically significant positive association although the correlation coefficient was negative and insignificant. The discrepancy in the results is that while the X^2 relies on merely their co-occurences in quadrats, correlation analysis takes into account their abundances. Results on the abundance of macrophytes on the reef flat revealed that although total macrophyte cover (dominated by seagrasses) decreased seawards, algal cover slightly increased seawards. Coral cover also increased seawards. Although an inverse relationship between the abundance of algae and corals has been recorded on the reef flat, both increased seawards, resulting in a statistically significant positive association.

Although not thoroughly investigated in the present study, the distribution of algae appears to be related not only to physico-chemical factors such as wave action, irradiance, temperature and nutrient levels but also to biological factors such as competition and predation (grazing) and the pattern seems to be generated by competition mediated by the interaction of nutrient availability and disturbances caused by herbivory and wave action. Eutrophic waters where herbivory and wave action is low tend to favour large population of frondose algae that can outcompete corals.

Seagrasses, algae and corals coexist on the reef flat at Agatti and there is no complete monopolization of space by any of these organisms, except for seagrasses in loose substrates on the inner reef flat. The distribution and abundance of algae at Agatti is patchy and governed by the monsoons and seasonal fluctuations attributable to wave action and desiccation, besides herbivory. Sea urchins are the major grazers, besides majid crabs and herbivorous reef fishes.

Monopolization of space by organisms colonizing firm substrates is reported to be prevented by disturbance caused by physical or biological factors. Predation, competition and disease are other important processes affecting the structure and dynamics of biological communities. Herbivory is a form of predation that can also be considered as a type of disturbance. The abundance of grazers, notably the sea urchins, and the seasonality of algae prevent the monopolization of space by algae on the reef flat at Agatti. These grazers decreased the competition between corals and algae by making available space for coral settlement. Thus, on the Agatti reef flat, partitioning of space can be attributed to desiccation, wave action and grazing. Nutrient levels are possibly yet another factor.

A combination of physical and biotic factors thus determines the outcome of competition between reef-building corals and algal populations. In the present study, competition between corals and algae appeared to be more significant than competition among coral species. Further studies such as field experiments and the quantification of nutrient levels are required to ascertain the role of grazers and nutrients in regulating the abundance and distribution of algae and corals on the reef flat at Agatti.

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APPENDIX 1

Keys to the identification of scleractinian corals so far recorded in Lakshadweep, based on the external morphological characters of the washed skeleton as observed by the naked eye as well as under microscopic examination, are presented in this Appendix. Additional information such as their colouration when live, is provided wherever possible to facilitate *in situ* identification. Unnamed new species recorded in Lakshadweep are not included in the keys. The keys presented are dichotomous and commence with a brief description of the general characteristics of the suborders leading to species in a hierarchical order. At the end of each key is a number that leads to the identification of the family/ genus/ species of the specimen to be identified.

Caution is called for while using the keys since only those characteristics observed in the present collection are dealt with and hence may be redundant for other localities since, to avoid confusion, descriptions of other possible growth forms the species can take in different environments are omitted. When species were not recorded in the present study, general descriptions were adopted from available literature, taking care to include descriptions of specimens reported from India and neighbouring localities (Pillai, 1967b, 1986b; Pillai, and Patel 1988; Pillai & Scheer, 1976; Scheer & Pillai, 1983; Pillai & Jasmine, 1989).

Keys to the Scleractinia of Lakshadweep

1.	Coralla hermatypic or ahermatypic, colonial or solitary. Corallites plocoid, cerioid, meandroid or hydnophorid. Septa usually in more than two cycles.	 2
	Coralla hermatypic, colonial. Corallites plocoid. Septa usually in not more than two cycles or poorly developed. Thecal walls well developed. Suborder Astrocoeniina	 5
2.	Synapticulae present	 3
	Synapticulae absent	 4
3	Septa trabecular, sometimes solid. Septa dentate or with granulated upper margins. Suborder Fungiina	 6
	Septa laminar, arranged according to Pourtales plan in immature/mature corallites. Coenosteum porous. (Suborder Dendrophyllina) Family Dendrophyllidae	 39
4.	Coralla hermatypic, colonial. Septa margins usually dentate. Suborder Faviina	 9
	Coralla mostly ahermatypic, usually solitary. Septa margins entire. Suborder Caryophylliina	 12

5. Colonies generally ramose sometimes encrusting or submassive. Verrucae present on the surface or calices hooded. Coenosteum solid and spinose. Columella prominent, poorly developed or absent.
   Family Pocilloporidae 13

   Colonies encrusting, massive, submassive, foliaceous or branched. Verrucae absent. Coenosteum porous. Columella poorly developed.
   Family Acroporidac 14

6. Coralla colonial, formed by intra and extratentacular budding. Walls poorly developed or absent. Septa usually confluent between centers. 7

   Coralla solitary, or colonial formed by extratentacular budding. 8

7. Coralla usually encrusting or foliaceous. Corallites cerioid. Septa margins seldom fused, smooth or finely serrated.
   Family Agariciidae 16

   Coralla usually massive, form small rounded clumps. Corallites cerioid, minute, less than 2 mm in diameter. Septa imperforate, short, thick, usually arranged in a petaloid pattern, tend to bifurcate at the periphery. Columella styliform or small.
   (Family Siderastreidae) *Psammocora* 94

8. Coralla colonial. Corallites cerioid. Walls and septa porous. Septa in 2-3 cycles, may bear pali.
   Family Poritidae 18

   Coralla solitary or colonial, free living or attached, discoidal, generally monocentric with a short axial fossa. Septa radiate from the center and continue along the undersurface as costae. Septa and costae bear prominent dentations.
   Family Fungiidae 20

9. Coralla colonial, formed by extratentacular budding. Corallites plocoid, cerioid or ploco-cerioid. 10

   Coralla solitary or colonial, formed by intratentacular budding. Corallites irregularly cerioid or meandroid, mono to tristomodael. 11

10. Corallites also formed by intratentacular budding. Septa margins regularly dentate.
    Family Faviidae 23

    Corallites thin walled, plocoid, projecting, circular or oval, sometimes distorted. Septa highly exert, edges smooth. Coralla encrusting, massive or columnar. Coenosteum vesicular.
    (Family Oculinidae) *Galaxea* 116

11. Coralla colonial, encrusting or foliaceous, ramose or columniform. Calices irregularly cerioid or meandroid. Septa with twisted, spinulose dentation.
Family Merulinidae 33

Coralla solitary or colonial. Corallites large, mono to tristomodael or meandroid. Septa with large, coarse dentations or lobes.
Family Mussidae 34

12. Coralla hermatypic or ahermatypic, solitary or colonial. Colonies phacceloid to phacelo-flabellate with mono to tristomodael centers. Septo-thecal walls solid. Septa granulated. Costae present.
Family Caryophyllidae 36

Coralla ahermatypic, solitary, free in adult stage, compressed, fan shaped with a deep, elongate fossa. Walls thin. Septa with smooth to wavy margins, smooth or granulated sides. Costae absent.
(Family Flabellidae) *Flabellum pavoninum*

13. Coralla usually branched, sometimes submassive. Calices borne on rudimentary branches termed verrucae. Septa poorly developed. Columella usually poorly developed or absent.
Pocillopora 40

Colonies branched with the branches expanding at the tips. Calices circular with walls developed on one side only. Coenosteum devoid of verrucae. Septa 6, well developed, join the columella. Columella prominent, styliform.
Stylophora pistillata

14. Coralla encrusting, submassive to massive. Axials absent. 15

Coralla usually ramose, sometimes submasive or encrusting. Corallites differentiated into axials at tips of branches and radials along the rest of the branch. Septa poorly developed. Coenosteum porous, ornamented with moderately to highly elaborate spines which sometimes fuse to give a costate appearance to the theca.
Acropora 44

15. Corallites minute, rarely more than 1 mm in diameter. Coenosteum coarse and spongy, ornamented with pappilae, trabeculae or spines. Trabeculae may fuse to form foveolations.
Montipora 69

Coralla with level to slightly projecting conical corallites, more than 1 mm in diameter. Coenosteum spiny, with few elaborations.
Astreopora 74

16. Corallite centers discernible. 17

Corallite centers not discernible. Coralla encrusting, laminar. Surface hydnophorid due to concentric collines running between rows of indistinct calices. Calices parallel to each other, centers 2-3 mm apart. Septo-costae confluent between centers, heavily granulated. Columella present.
Pachyseris speciosa

17. Coralla encrusting to massive, columnar. Calices circular, oval or polygonal. Walls septo-thecal, solid, level. Some or all septa converge towards the center, margins smooth or finely dentate. Septo-costae confluent between centers, granulated or beaded. Columella styliform, poorly developed or absent.
Pavona 76

Coralla encrusting to massive. Surface undulating, with valleys separated by high collines. Calices polygonal, deep, with acute walls. One to several centers enclosed in valleys, separated by laminar linkages developing into ridges. Septa in two cycles, granulated. Columella present.
Gardineroseris planulata

18. Columella well developed. Walls moderately porous. 19

Colonies encrusting. Columella poorly developed. Walls highly porous. Calices circular, superficial, closely set. Septa reduced to spines. Tentacles 12.
Alveopora superficialis

19. Colonies encrusting, massive, columnar or ramose. Calices usually greater than 2 mm in diameter. Septa well developed, in three cycles. Pali present or absent. Column and tentacles usually extended during the day and night. Tentacles 24.
Goniopora 80

Colonies encrusting, massive or ramose. Calices usually less than 2 mm in diameter. Septa in two cycles, usually bear pali. Polyps usually not extended during the day, if extended only the tentacles are exposed.
Porites 82

20. Prominent central fossa present. Coralla solitary, free living in the adult stage. 21

Prominent central fossa absent. Coralla colonial, free living. 22

21. Coralla discoidal or oval, flat or convex, up to 50 cm in diameter. Septa numerous, usually perforate, radiating out from the central fossa, margins with large triangular dentations. Costae reduced to rows of blunt to sharp spines.
Fungia 90

Coralla oval, flat with an elevated central dome, a flat undersurface, imperforate, less than 10 cm in diameter. Primary septa arranged around the central fossa. Costae with well developed granulations.
Cycloseris somervillei

22. Coralla elongated, elliptical or bean shaped. Secondary fossa numerous, equal to nearly equal the central furrow. Tentacles always extended.
Polyphyllia talpina

Coralla large, circular to oval, dome shaped, without central fossa. Corallites compact.
Sandalolitha robusta

23. Corallites generally meandroid. 24

Corallites plocoid or cerioid or ploco-cerioid. 25

24. Coralla, encrusting, massive. Walls septo-thecal, thin and perforate. Septa slightly exert and continuous over walls. Septal margins bear coarse teeth. Paliform lobes absent. Columella well developed, trabecular, continuous between centers.
Platygyra 111

Coralla massive. Valleys regular and indefinite, up to 8 cm in length and about 3 mm wide. Septa regularly arranged, margins finely dentate, sides granulated. Exert ends of septa adjoined to adjacent centers. Theca thick, imperforate. Columella prominent, lamellar with a lobed upper margin. Pali absent.
Leptoria phrygia

25. Coralla encrusting, massive or foliaceous. 26

Coralla massive and dome shaped. Calices plocoid, circular, 10-20 mm in diameter, regularly packed in the form of low cones. Septa well developed, with large septal dentations, thick over walls. Columella well developed.
Diploastrea heliopora

26. Corallites regular, plocoid to ploco-cerioid, circular or conical and slightly projecting. 27

Corallites cerioid to plocoid, irregular to regular and usually not projecting. 28

27. Coralla encrusting, massive, subfoliaceous or ramose. Corallites less than 3 mm in diameter. Coenosteum non costate, granulated, blistered or spinulose. Septa stop at the wall, septo-costae absent. Paliform lobes poorly developed. Columella trabecular.
Cyphastrea 115

Coralla encrusting or foliaceous. Corallites 3-4 mm in diameter. Coenosteum spinulose with elaborate tips. Costae equal or subequal, formed by rows of spines. Septa exert, margins with frosted teeth. Columella well developed, trabecular. Paliform lobes well developed.

Echinopora lamellosa

28. Corallites formed mainly by extratentacular budding. 29

Corallites formed mainly by intratentacular budding. 32

29. Paliform lobes usually well developed 30

Paliform lobes poorly developed. Coralla encrusting or massive. Corallites cerioid to plocoid, irregular in shape and size, level or projecting. Costae poorly developed or absent. Septa continuous between centers or interrupted by an intercorallite groove, margins minutely dentate. Columella consist of vertical pinnules.

Leptastrea 113

30. Calices plocoid 31

Calices cerioid Coralla encrusting or massive. Calices monocentric to polycentric, tending to meander. Septa of equal thickness over walls but broader below. Spines on septal margins small, closely set. Columella small.

Goniastrea 107

31. Coralla encrusting, massive or subfoliaceous. Corallites plocoid. Septa alternate, dentate. Pali present.

Montastrea 100

Coralla encrusting or massive. Corallites plocoid, monocentric, small, 2-4 mm in diameter, uniformly spaced or clustered. Septa dentate, granulated, with a distinct paliform crown. Septo-costae of adjacent corallites not adjoined, beaded. Columella small, comprising of pinnacles.

Plesiastrea versipora

32. Colonies encrusting, massive or foliaceous, formed mainly by intratentacular equal to nearly equal budding. Corallites plocoid to ploco-cerioid, oval or polygonal, usually projecting. Septa alternate, dentate. Paliform lobes present or absent.

Favia 97

Coralla encrusting submassive or massive with cerioid polygonal corallites, formed mainly by intratentacular unequal budding. Septa of unequal thickness over walls, margins spinulose or ragged. Paliform lobes poorly developed.

Favites 102

33. Coralla encrusting, massive. Colonies characterized by conical collines bearing septa surrounded by centers. Columella discontinuous.

Hydnophora 117

Coralla foliaceous contorted and perforate. Calices in rows or separated by transverse partitions of valleys. Valleys and collines straight, spreading by repeated lateral branching. Septa slightly exert, continuous over collines, margins coarsely toothed. Columella fused into a continuous mass. Live colonies yellow in colour.

Merulina ampliata

34. Colonies massive to submassive or phaceloid. Corallites cerioid to plocoid, mono or polycentric. 35

Colonies massive. Corallites mendroid, neighbouring valleys joined by a common wall which may bear a median groove. Septa margins with long spinose teeth.

Symphyllia 118

35. Colonies hemispherical, phaceloid, mono to tristomodael. In tristomodael corallites, centers joined by trabecular linkages. Costae unequal, dentate. Septa swollen at the wall, exert, with large teeth decreasing in size towards the columella, outermost tooth prominent. Septa sides granulated.

Lobophyllia corymbosa

Coralla flat or hemispherical. Corallites cerioid to plocoid, angular in outline, monocentric. Septa swollen at the wall, exert, with large echinulate dentations on their upper margins. Columella deep, formed by the fusion of septal ends.

Acanthastrea echinata

36. Coralla ahermatypic, solitary, attached or free living. 37

Coralla hermatypic, phaceloid to phacelo-flabellate with mono to tristomodael centers. Walls septo-thecal. Septa numerous, thin, arranged in 3-5 orders, with the primary septa slightly exert. Septa prominent, margins smooth, finely granulated. Columella absent. Polyps with tubular tentacles, extended during the day and night.

Euphyllia glabrescens

37. Coralla free living in adult stage 38

Coralla fixed, turbinate. Septa exert, arched, with granulated sides. Pali in several crowns, merge with the columella.

Paracyathus

38. Coralla usually cylindrical. Septa thin, straight, with smooth margins. Pali present.

Caryophyllia 119

Coralla disc or bowl shaped, borne on a pointed base. Costae well developed. Pali weak or absent.

Stephanocyathus nobilis

39. Colonies hermatypic, submassive, foliaceous or crateriform. Corallites plocoid, conical, level to projecting. Septa numerous. Coenosteum porous. Columella conspicuous.
Turbinaria 120

Colonies ahermatypic, subramose or tall and arborescent. Corallites cylindrical or turbinate. Septa few, with smooth or finely dentate margins, arranged according to Pourtales plan in immature corallites. Walls costate. Columella trabecular.
Tubastrea 122

40. Surface with well developed verrucae 41

Surface devoid of true verrucae. Colonies with thin elongated or thick stunted branches expanded at their tips. Calices 0.7-1.5 mm in diameter. Columella absent or present as a low boss. Coenosteum ornamented with spines.
Pocillopora damicornis

41. Branches laterally compressed 42

Branches not laterally compressed 43

42. Calices deep, 1-1.3 mm in length. Colonies caespitose. Branches in about 1.5 cm thick at the tips. Verrucae prominent, large and ascending. Columella absent or present the form of a low boss.
Pocillopora eydouxi

Calices nearly 0.7 mm in diameter, closely set. Branches upright. Septa in two cycles, well developed. Verrucae spreading and rounded at their tips. Columella styliform.

Pocillopora ligulata

43. Branches upright. Verrucae well developed, uniform, 3-6 mm high and thick. Calices about 1 mm in diameter. Septa and columella usually absent.
Pocillopora verrucosa

Branches broad, sprawling. Coralla caespitose. Branches 5-6.5 cm broad, 1.5-1.7 cm thick at the growing edge. Verrucae uniform, about 2 mm in diameter. Calices 1-2 mm in diameter. Septa poorly developed.
Pocillopora meandrina var nobilis

44. Axials well defined 45

Axials not well defined. Colonies stout, circular tipped plates or columnar branches borne on an encrusting base. Radials large, densely arranged, tubular, partly or fully appressed, 1-5 mm exert, with thickened outer walls and horse-shoe shaped openings.
Acropora (Isopora) palifera

45. Incipient axials numerous 46

Incipient axials generally absent 48

46. Colonies encrusting or corrymbose. 47

Colonies arboresent, erect, main branches subdividing and bearing numerous ramuli. Axials 0.8-1.4 mm in diameter, up to 12 mm exert. Radials 1-1.5 mm in diameter at the tips, slightly broader below, tubular, about 11 mm exert, with nariform openings. Many immersed corallites present on main branches. Live colonies pale brown in colour.
Acropora echinata

47. Coralla encrusting plates, bearing small branches with numerous axials. Axials 3-8 mm exert, 2.5-3 mm in diameter. Radials 1-1.3 mm in diameter, few, with oval to nariform openings.
Acropora granulosa

Coralla corymbose plates consisting of horizontal, radiating and highly anastomosing branches supporting short branchlets. Axials abundant, about 2 mm in diameter, 1.5-6 mm exert. Radials sparse, most of them sub-immersed. Tubular corallites lipped.
Acropora efflorescens

48. Radials in different shapes and sizes 49

Radials in one or two shapes and sizes 60

49. Branching irregular 50

Branching regular 54

50. Branching arborescent or caespito-corymbose 51

Coralla with thick horizontal main branches distally proliferating into numerous branchlets. Axials tubular, circular, 1.5-2.5 mm in diameter. Tubular radials up to 3 mm exert with dimidiate openings.
Acropora danai

51. Branching arborescent 52

Branching caespito-corymbose. Colonies with main branches less than 1 cm thick and small branchlets. Axials 1.8-2 mm in diameter, less than 1.5 mm exert. Radials neatly arranged, ascending, dimidiate, with flaring outer lips. Live colonies brown in colour.
Acropora selago

52. Branches thick, more than 2 cm 53

Branches thin. Coralla with almost straight tapering branches, 1-1.2 cm thick. Axials 2.5-3 mm in diameter. Radials tubular to immersed, with oval or circular openings, of uniform size facing one direction or of different sizes with different orientations.
Acropora formosa

53. Colonies with thick irregular branches curved at the tips. Axials 2.5-4 mm in diameter. Radials of mixed sizes, unevenly distributed, with nariform or dimidiate openings. Immersed corallites present in between and on lower portions of the coralla. Many giant corallites irregularly distributed along branches.
Acropora robusta

Colonies with branches about 3.5 cm thick. Axials thick walled, about 4 mm in diameter, up to 3 mm exert. Radials of mixed sizes, shapes and orientations. Larger radial corallites 2-3 mm thick, appressed to tubular, the former with circular to nariform openings.
Acropora austera

54. Colonies caespitose, corymbose, caespito-corymbose or arborescent. 55

Colonies sub arborescent. Colonies with a narrow base of attachment. Branches 10-12 mm thick, giving off small branchlets. Axials 2-3 mm in diameter, thick, with circular openings. Radials 2-3 mm in diameter, spreading, with circular to nariform openings. Lower portions of the branch bear immersed corallites.
Acropora squarrosa

55. Colonies arborescent 56

Colonies caespitose, corymbose or caespito-corymbose. 58

56. Radials with upper walls developed 57

Radials with upper walls poorly developed or absent. Colonies with branches 1.2-1.7 cm thick at the base and tapering above. Axials 2-3 mm in diameter, 1-2 mm exert. Radials of mixed sizes, with dimidiate to nariform openings; upper walls slightly developed, ascending.
Acropora pulchra

57. Colonies open with branches 1.5-3.8 cm thick. Axials 2.6-3 mm in diameter, 0.8-1 mm exert. Radials neatly arranged, of two sizes, 2-3 mm in diameter, up to 4 mm exert, with circular, dimidiate and nariform openings.
Acropora nobilis

Colonies with tapering digitate branches, about 1-2 cm thick. Axials conical, 4 mm at the tips. Radials 3-4 mm in diameter, as much exert, with circular to oval openings.
Acropora hemprichi

58. Radials not appressed 59

Radials appressed. Coralla caespitose or caespito-corymbose with branches about 8 mm thick at their tips. Axials 2 mm in diameter, 1-2 mm exert. Radials strongly appressed, with oval to nariform openings. Colonies usually creamish in colour when live.
Acropora valida

59. Colonies caespitose or caespito-corymbose with thin branches, about 8-9 mm thick. Axials 2-3 mm in diameter, 1 mm exert. Radials 2-3 mm in diameter, large, labellate, with flaring outer lips and circular to nariform openings. Numerous sub-immersed corallites present at the base of branches.
Acropora forskali

Colonies caespitose or caespito-corymbose with branches 1-3 cm thick. Axials 2.5-3 mm in diameter, about 2 mm exert. Radials 1-1.5 mm in diameter, of different sizes and shapes, exert, with nariform or dimidiate openings. Immersed corallites present at the base of branches.
Acropora indica

60. Colonies arborescent 61

Colonies caespitose, corymbose or caespito-corymbose. 62

61. Colonies with characteristically long and thin branches, 1.5-2 cm thick. Axials 2-3 mm in diameter, with funnel shaped openings. Radials lipped, mostly sub-immersed to immersed, with dimidiate openings, about 1 mm sparse, almost absent along lower parts of branches.
Acropora teres

Colonies with upturned branch tips. Axials up to 4 mm in diameter, less than 3 mm exert. Radials of two sizes, larger ones 2-3 mm in diameter, thick lipped, with upper walls missing and prominent lower walls.
Acropora aspera

62. Colonies usually corymbose. 63

Colonies caespitose, corymbose or caespito-corymbose. 66

63. Branches thin 64

Branches thick. Colonies corymbose, with thick, tapering branches. Axials less than 3.5 mm. Radials of two sizes, larger corallites uniform in size and shape, 2-2.5 mm in diameter, about 3 mm exert, with dimidiate to nariform openings.
Acropora monticulosa

64. Radials not appressed 65

Radials strongly appressed. Colonies corymbose plates with branches about 2-4 mm thick. Axials 1-2 mm in diameter, up to 1.5

mm exert, with slightly flaring margins. Radials 1.5-2 mm in diameter, evenly arranged around axials, with ascending lips and nariform or dimidiate openings.

Acropora hyacinthus

65. Coralla corymbose. Axials 2-4 mm in diameter, up to 1.5 mm exert. Radials sparse, neatly arranged, of uniform size, lower walls expanded as rounded lips.

Acropora millepora

Colonies corymbose with main branches prostrate and coalescent. Branchlets 2-5 mm long, 4-10 mm thick. Axials 1.5-2.3 mm in diameter, exert up to 1 mm, with large circular openings. Radials spreading, labellate with thick rounded tips, 2-3 mm in diameter, as much exert, neatly arranged in rows.

Acropora corymbosa

66. Radials strongly appressed 67

Radials not appressed 68

67. Colonies caespitose to caespito-corymbose. Branches about 10 mm thick. Axials about 2 mm in diameter, up to 1 mm exert. Radials 1-1.5 mm in diameter, appressed at the base of the branch, becoming tubo-nariform at the tips. Immersed corallites present in between larger corallites. Live colonies creamish in colour.

Acropora cerealis

Colonies caespito-corymbose with the main branches dividing into 2-3 branchlets, 8-10 mm thick. Axials 1-2 mm exert. Radials large, appressed, usually of one size, with wide nariform to dimidiate openings, 2-3 mm in diameter at the base of the branches, becoming smaller towards the tips. A few immersed corallites present on lower parts of the branches.

Acropora tenuis

68. Colonies corymbose, caespitose or caespito-corymbose. Branches 1-3 cm thick, digitiform. Axials 2-5.6 cm thick, 1-2 mm exert. Radials of two sizes, larger corallites longer and broader towards the base. Larger radials 2-4 mm in diameter, exert, tubular, with nariform or dimidiate openings.

Acropora humilis

Colonies corymbose to caespito-corymbose with slightly tapering branches. Branches 2-5 cm long, 8-10 mm thick. Axials thin, tubular, 1 to 2 mm exert and broad. Radials 1.5-2.2 mm in diameter, ascending, tubo-nariform at the tips of branches, nariform with thickened outer walls elsewhere. Dimidiate corallites also present. Immersed to sub-immersed corallites present at the base of branches.

Acropora nasuta

69. Surface with foveolations 70

Surface devoid of foveolations 71

70. Spines of individual septa fuse at their tips. Corallites 1-2 mm in diameter. Colonies massive, surface raised into foveolations. Thecal pappilae may or may not completely encircle calices. Septa in two cycles, reduced to spines. Coenosteum spinulose, those on thecal pappillae bearing highly elaborate tips.

Montipora foveolata

Spines of individual septa do not fuse at their tips. Corallites immersed as well as exert, about 0.8 mm in diameter. Colonies encrusting or submassive. Exert corallites funnel shaped. Septa in two cycles. Primary septa fuse at the center.

Montipora venosa

71. Surface with pappillae or tubercles 72

Surface with small irregular mounds. Coralla encrusting or massive. Calices evenly distributed between mounds, small, 0.5-0.8 mm in diameter, those on convex surfaces foveolate, with papillae completely or incompletely encircling calices, others usually immersed. Coenosteum spongy with elaborate echinulations.

Montipora turgescens

72. Coralla encrusting 73

Coralla foliaceous. Calices about 1 mm in diameter, inclined towards the periphery of the coralla, either immersed or completely or incompletely encircled by papillae, the latter being fine and bearing spinules with highly elaborate tips. Septa in two cycles, mainly reduced to row of spines. Primary septa bifurcate at the wall.

Montipora foliosa

73. Coralla encrusting. Surface with small gibbosities. Calices 0.7-0.9 mm in diameter, irregular, deep, closely set to 1 mm apart. Primaries well developed. Coenosteum finely reticulate, ornamented with small spines.

Montipora explanata

Coralla encrusting or submassive with papillae of irregular shape and size which fuse, partly or wholly encircling a calice or group of calices. Corallites immersed or exert. Thecal rim discernible in most immersed corallites. Primary septa 6, reduced to rows of spines, clearly visible, fuse at the center. A second cycle usually seen. Coenosteum coarse and spongy.

Montipora tuberculosa

74. Corallites usually conical, level to projecting. 75

Corallites usually immersed. Colonies massive to encrusting. Corallites evenly spaced, about 1.8-2 mm in diameter. Two cycles

of septa usually present; third cycle rarely seen. Primary septa well developed, tapering towards the fossa. Coenosteum comprised of compact spinules having elaborated tips.
Astreopora listeri

75. Corallites 1.5-2.8 mm in diameter, level to 5 mm exert, slightly conical in shape. Coralla massive, cushion shaped or flat and encrusting with an even surface. Corallites evenly spaced, about 3 mm apart. A few smaller immersed corallites present between large corallites. Septa in three cycles, primary septa with smooth margins. Coenosteum consist of spinules with elaborated tips, so arranged on walls so as to give a costate appearance.
Astreopora myriophthalma

Calices large, up to 4 mm in diameter, with thick circular openings. Colonies massive, cushion shaped or flat. Smaller corallites present between the large corallites. Coenosteum coarse and spongy.
Astreopora ocellata

76. Calices usually arranged in rows, walls not developed. 77

Calices not arranged in rows, walls well developed. 78

77. Colonies encrusting, massive or foliaceous. Calices deep, in close proximity to each other, usually arranged in rows, 1-3 mm apart. Septa in two orders, heavily granulated. Columella poorly developed and styliform.
Pavona decussata

Colonies encrusting, columnar or massive; irregular due to low continuous collines 2-4 mm high, enclosing one or more rows of calical centers. In some colonies, collines tend to become sinuous. Calices about 1 mm in diameter, distributed in rows or groups in between collines. Septa in two orders.
Pavona varians

78. Septa in two orders. 79

Septa in three orders. Coralla encrusting, columnar or massive with calices arranged in valleys or placed in groups. Septa with granulated sides, dentate margins. Columella absent or poorly developed.
Pavona venosa

79 Coralla columnar or plate like. Calices circular, about 2-3 mm in diameter, 2 mm apart, level to projecting to about 1 mm along proximal parts. Septa in two orders. Columella styliform.
Pavona maldivensis

Coralla encrusting to submassive. Calices 1.5-2.5 mm in diameter, level. Septa in two orders. Columella styliform.
Pavona duerdeni

80. Colonies massive, hemispherical 81

Colonies encrusting to ramose. Calices about 2 mm in diameter, 1.5 mm deep. Septa steep. Pali six. Columella occupies the base of the calice.

Goniopora minor

81. Colonies massive, hemispherical, free. Calices circular, 3-6 mm in diameter, 2-5 mm deep, walls slightly perforate. Septa in three cycles, steep, sides granulated, margins dentate. Pali poorly developed. Columella spongy and large.

Goniopora stokesi

Colonies massive, hemispherical. Calices circular or polygonal, about 3 mm in diameter, walls porous. Septa in three cycles, sides granulated, margins dentate. Coenosteum thick and porous. Columella trabecular.

Goniopora lobata

82. Corallites not arranged in rows 83

Corallites arranged in rows. Colonies encrusting, surface irregular and hillocky. Calices about 1 mm in diameter, walls about 0.5-1 mm thick. Pali weakly to well developed. Ventral directive septum free or fused. Palar synapticular ring well developed. Columella styliform, fused to septa by radii or absent.

Porites lichen

83. Coralla massive or branched 84

Corallites encrusting, massive or branched. Coralla encrusting or massive, surface sometimes lobulated. Calices polygonal, 1-1.5 mm in diameter, separated by thin walls. Mural denticles sometimes fuse to form a thin ridge. Ventral triplet fuses to form a trident. Pali 8, well developed. Columella, compressed, styliform, joins septa by five radii.

Porites lutea

84. Coralla massive to submassive 85

Coralla branched 86

85. Coralla massive. Colonies massive to submassive, surface smooth or undulated. Calices polygonal, 1.5-2 mm in diameter, about 1 mm deep, walls with 24 frosted denticles. Septal margins with 2-3 septal denticles, the last septal denticle forming a poorly developed pali. Ventral triplet does not fuse to form a trident. Palar synapticular ring well developed. Columella styliform.

Porites solida

Coralla massive, hemispherical. Calices about 1.5 mm in diameter. Walls made up of three rows of denticles. Septa with two denticles between pali and wall. Trident formation absent. Eight weakly developed pali usually present. Columella rod shaped.

Porites lobata

86. Calices usually polygonal, greater than 1 mm in diameter 87

Calices less than 1 mm in diameter, circular, superficial, plocoid, separated by thick porous coenosteum. Colonies ramose. In some colonies the basal laminar portions of branches have calices separated from each other by a single row of mural denticles. Septa 12, only 6 prominent pali reach wall level. A single septal denticle present.

Porites (Synarea) convexa

87. Calices superficial 88

Calices deep 89

88. Colonies free, ramose, with short anastomosing branches constricted at their base and broadened at their tips. Calices about 1 mm in diameter, polygonal, shallow, separated by a thin ridge of finely echinulate mural denticles. A single denticle present between the wall and pali. Septal denticles and columella appear frosted due to echinulations. Pali well developed. Ventral triplet fused or free. Columella styliform.

Porites nigrescens

Colonies usually branched, sometimes with an encrusting or massive base. Calices shallow, superficial. Septa thick, triangular. Laterals of the triplet short. Pali frosted, up to 8 in number. Two septal denticles present between pali and wall.

Porites cylindrica

89. Colonies branched, branches 3-4 cm long, 10-25 mm thick at the base. Calices polygonal, about 1.6-2 mm in diameter, with thin walls made up of frosted denticles. Ventral triplet does not fuse to form a trident. Upper margins of septa with a single denticle. Pali well developed. Columella a compressed plate.

Porites compressa

Coralla free, with crowded or lax branches, 1.5-2.5 mm long, about 10 mm thick and tips slightly swollen. Calices polygonal, 1.2-1.5 mm in diameter, funnel shaped. Septa wedge shaped, with 3-4 highly frosted serrations. Ventral triplet usually fuse to form a trident. Pali slightly larger than serrations. Columella made up of a flattened frosted tubercle.

Porites minicoiencis

90. Coralla perforate 91

Coralla imperforate. Coralla circular, convex, about 13 cm in length. Lower order septa exert, about 1 mm thick near the central fossae, with small triangular dentations. Higher order septa with lobed dentations. Sides of the septa with minute conical spines.

Costae unequal, major ones decreasing in size towards the center, hirsute.

Fungia (Verrillofingia) concinna

91. Septal dentation large 92

Septal dentation fine. Coralla elliptical or irregular in shape. Septa numerous, margins with triangular serrations. Tentacular lobes prominent, triangular, margins crenulated. Costae numerous, spinose or lobed with spinose tips. Live corals usually brown, sometimes with pink centers.

Fungia (Pleuractis) scutaria

92. Costal spines bear echinulations 93

Costal spines simple. Coralla circular, 8 cm in diameter, perforate. Septa in 2-3 orders, made up of slender spines, single or bifurcate at the tips. Septa made up of large dentations bearing pointed tips, granulated. Higher order septa do not form costae. Lower order septa markedly exert at the center and periphery. Sides of the costae spinulose. Columella trabecular.

Fungia (Danafungia) scruposa

93. Coralla free, circular to oval, regular or irregular in shape, flat or slightly to markedly arched, 13-20 cm in longest diameter. Septa numerous, about 1 mm thick, lower order septa highly exert particularly at the center where they dip vertically down. Septa bear large triangular dentations. Interseptal distance about 3 mm. Costae thickly cover the underside of the coralla comprising of conical spines which bear fine spinules that bifurcate at their tips. Tentacular lobes present. Columella pappilose. Live colonies usually brown.

Fungia (Fungia) fungites

Coralla circular, flat or arched. Septa highly unequal with lower order septa markedly exert over the central fossa. Lower order costae bear long, coarse echinulate usually branched spines.

Fungia (Danafungia) danai

94. Coralla branched or columnar. 95

Coralla encrusting or submassive 96

95. Coralla columnar. Calices shallow, 2.5-3 mm apart, walls absent, 6-8 septa reach the styliform columella. Septal edges bear frosted teeth.

Psammocora digitata

Coralla branched. Branches tend to anastomose and coalesce. Calices flushed with the coenosteum, 1-1.8 mm in diameter, 1-2 mm

apart. Calices sometimes arranged in valleys. Septa 6-20, dentate, sides granulated. Primary septa club shaped. Columella styliform.
Psammocora contigua

96. Septo-costae petaloid. Calices polygonal, 2-3 mm in diameter, single or in series of 4-5 calices arranged in short meandering valleys. Collines low and acute. Columella styliform, surrounded by 6-8 pali. Live colonies brown, green or yellow in colour.
Psammocora haimeana

Septo-costae usually not petaloid. Coralla encrusting to hemispherical, with irregular calices and well developed walls. Calices polygonal, 2-4 mm in diameter, single or in rows arranged in valleys. Septa 24. Pali distinct. Coenosteum granulated. Columella small and granulated.
Psammocora profundacella

97. Calices large, greater than 3 mm. 98

Calices small, less than 3 mm. Coralla encrusting, columnar, hillocky. Calices 2-2.5 mm in diameter, circular, level to projecting, closely set to 1 mm apart. Septa alternate, exert, arched and thickened at the wall. Major septa 24, with prominent pali. Walls costate. Columella trabecular.
Favia stelligera

98. Calices regular to distorted, level to projecting 99

Calices level, regular. Coralla massive. Corallites usually level, oval, 10-14 mm long, 9-11 mm broad, 3-4 mm deep. Septa 28-38, exert, arched, bear 4-6 teeth on margins. Costae conspicuous, fused or remain opposed in between calices. Columella trabecular.
Favia speciosa

99. Coralla massive, dome shaped or flat with plocoid corallites. Corallites circular, oval or irregular, 12-20 mm wide, level to projecting. Septa with elongated, inwardly projecting dentations on their margins and granulated sides. Pali usually present. Coenosteum vacuolated. Columella small and trabecular.
Favia favus

Colonies massive, hemispherical with plocoid to ploco-cerioid corallites. Corallites circular to oval or distorted, 6-13 mm in diameter, level or projecting up to 2 mm. Plocoid corallites 1-4 mm apart. Septa 30-40, in three orders, margins regularly dentate, those reaching the columella bear pali. Costae correspond to septa, similarly dentate. Coenosteum vesicular. Columella trabecular.
Favia pallida

100. Grooves and tubercles absent 101

Grooves and tubercles present between calices. Colonies massive and encrusting. Corallites plocoid, circular or polygonal, 7-14 mm in diameter, regular or irregular. Septa in three orders. First order septa thickened over walls, with well developed pali. Septa dentate, granulated. Third order septa reduced to ridges down the walls.s. Costae strongly unequal. Columella compact and spongy.

Montastrea valenciennesi

101. Coralla massive. Corallites plocoid or ploco-cerioid, circular, 5-12 mm in diameter, irregularly distributed. Septa in three orders; first order septa with irregular dentations that increase in size towards the columella. Second and third order septa do not reach the columella. Septal sides and dentations heavily granulated. Costae unequal and correspond to septa.

Montastrea curta

Colonies encrusting or massive. Corallites plocoid, large, 7-12 mm in diameter. Septa in two orders, bear large dentations. Primary septa with dentations that increase in size towards the center forming one or more paliform lobes. Second order septa reduced to ridges down the walls. Costae unequal and dentate. Columella trabecular or spongy.

Montastrea magnistellata

102. Calices usually greater than 8 mm in diameter. Septa with large prominent dentation 103

Calices small, less than 8 mm in diameter. Coralla encrusting. Corallites polygonal, 5-6 sided, usually less than 8 mm in diameter. Intercorallite wall with a raised ridge. Septa 24-28, equal, exert, stop at the middle of the ridge. Septal edges with 8-12 teeth, the last tooth developing into a pali. Columella poorly developed.

Favites pentagona

103. Corallite wall thick. 104

Corallite wall usually thin. Coralla encrusting or massive with an irregular surface. Corallites circular, 1-2 cm wide, 4-6 mm deep. Up to four septal cycles present. Septa increase in size towards the columella, margins sharply dentate with frosted tips, usually stop at the top of the wall. Pali weakly developed, present only on major septa. Columella compact and spongy.

Favites abdita

104. Calices less than 1.5 cm in diameter. 105

Calices greater than 1.5 cm in diameter. Coralla encrusting, sometimes hillocky. Corallites polygonal, 15-20 mm long. Septa 50, slightly thickened at the walls, exert, continuous between centers. Septal margins with 6-8 prominent frosted teeth, last tooth the largest. Columella large and trabecular. Polyps partly extended during the day.

Favites complanata

105. Calices less than 1 cm in diameter 106

Calices greater than 1 cm in diameter. Colonies encrusting to massive with an uneven surface. Corallites cerioid, polygonal, 10-12 mm wide. Septa 40-45, in two orders, dentate, dentations becoming longer towards the base, adjoined over walls. Second order septa reduced. Columella compact and spongy.

Favites flexuosa

106. Coralla encrusting or submassive with an irregular surface. Corallites cerioid, circular or slightly polygonal, 4-7 mm in diameter, with thick walls. Septa in 3 orders, granulated, adjoined over the walls, primary septa becoming secondaries in adjacent corallites. Pali separated from regular dentations of septa by a deep notch. Columella spongy.

Favites russeli

Coralla encrusting to massive with a hillocky surface. Corallites polygonal, penta or hexagonal, 5-6 mm in longest diameter. Septa 20-30, alternating, margins dentate, sides granulated, continuous over the wall. Columella trabecular.

Favites melicerum

107. Corallites usually meandroid to sub-meandroid. 108

Corallites cerioid. 109

108. Corallites monocentric to sub-menadroid. Colonies encrusting or submassive. Calices, cerioid, 8-12 mm in greatest breadth, may join to form sub-meandroid valleys. Septa 30-45, in two orders. First order septa slightly exert. Columella weakly developed, trabecular or spongy.

Goniastrea pectinata

Corallites meandroid. Coralla encrusting, massive or submassive. Meanders about 8 mm wide. Septal margins finely dentate, exert, adjoined between adjacent centers. Columella trabecular. Polyps pale brown in colour.

Goniastrea australensis

109. Septa in three orders. 110

Septa in two orders. Coralla encrusting. Calices 6.5-9 mm in diameter. Septa in two orders, margins dentate, sides granulated. Secondary septa present as ridges down the walls. Adjacent septa not continuous over walls. Columella compact and spongy.

Goniastrea aspera

110. Walls thin. Colonies massive and spherical. Corallites deep, polygonal with straight sided walls, about 3-5 mm in length. Septa in 3 orders, 12-18 per calice, arrow shaped and continuous over walls. First order septa exert, steep. Septal dentations increase in size towards the columella. Columella trabecular.

Goniastrea retiformis

Walls thick and ridged. Colonies massive. Calices even, polygonal with a neat cellular arrangement, 3-7 mm in diameter. Septa in 3

distinct orders. First order septa slightly exert, reach the columella. Second order septa, deep, do not fuse with the columella.
Goniastrea edwardsi

111. Corallites meandroid. 112

Corallites cerioid to submeandroid. Coralla massive and rounded with short valleys. Corallites usually monostomodael, polygonal, 3-5 mm in length. Walls perforated. Septa thin and slightly exert with the lower portion broader than on the top. Septa margins dentate, sides granulated. Pali absent. Columella narrow and trabecular.
Platygyra sinensis

112. Coralla encrusting or massive, usually with long meandering valleys. Short valleys also present. Septa exert, steep, granulated sides, margins with large and ragged tipped dentations. Thecae narrow at the top and perforated. Columella spongy to trabecular.
Platygyra daedalea

Walls thick, septa rounded. Colonies massive with monocentric to long valleys. Walls thick. Septa evenly spaced with succesive cycles of septa usually indistinguishable. Septa adjoined over walls, margins with regular dentatations, tending to increase in size towards the columella. Pali absent. Columella moderately developed.
Platygyra lamellina

113. Corallites sub-cerioid to cerioid 114

Corallites plocoid. Colonies massive. Corallites about 4-6 mm in diameter, uniformly distributed or clustered especially on concave parts of the coralla. Septa in 3 cycles. Primary septa exert especially on the elevated side, thick, reach the calice center. Intercalicular groove and tubercles present. Coenosteum covered with fine granules. Columella absent.
Leptastrea bottae

114. Colonies encrusting with circular calices, 3-9 mm in diameter with four cycles of septa, primary septa slightly exert and swollen over the walls. Septa margins steep, serrated, sides smooth or finely granulated. Intercalicular groove present. Columella pappillose.
Leptastrea transversa

Colonies encrusting or massive. Calices 3-8 mm long with thick walls. Septa 40-60, in four or more cycles, usually finely dentate. Calices separated by a groove with the septo-costae stopping at the grooves. Columella consist of pinnacles or pappillae.
Leptastrea purpurea

115. Colonies with plocoid corallites, 1.5-2.8 mm in diameter, projecting up to 2 mm. Colonies encrusting, massive or submassive. Corallites circular, well spaced or irregularly squashed together.

Septa 24. Costae correspond to septa, ornamented with spines. Coenosteum blistered.

Cyphastrea serailia

Colonies with corallites plocoid, tending to be cerioid, 1-2 mm in diameter, level or slightly projecting. Coralla encrusting and hillocky. Septa 20 with well developed pali. Septa margins dentate, sides granulated. Costae equal, with granulated spines.

Cyphastrea micropthalma

116. Corallites circular or oval, 3-6 mm in diameter, up to 4 mm exert, 2-4 mm apart. Colonies encrusting or massive. Septa in three cycles, up to 28. About 12 septa reach the columella. Costae corresponding to septa can be traced up to the base of the corallite. Coenosteum finely blistered with vesicles in between. Columella made up of a solid mass or few dentations.

Galaxea astreata

Corallites circular to oval, 7-12 mm in diameter, 3-10 mm exert, 2-3 mm apart. Colonies massive, hemispherical. Septa 40-50, usually in four cycles; a fifth cycle sometimes present. 10-14 septa reach the columella. Costae discernible only on upper portions of corallites. Coenosteum comprises of hollow vesicles. Columella poorly developed or absent.

Galaxea fascicularis

117. Monticules 2-10 mm in width and 5-7 mm high. Colonies encrusting or laminar tending to be massive or columnar. Monticules well developed, conical or elongated,long and sinuous on some parts of the coralla. Adjacent monticules 3-6 mm apart. 6-18 septa reach the top of the colline. Septa margins finely dentate. Columella trabecular. Tentacles usually extended during the day.

Hydnophora exesa

Monticules 1-3 mm in width and height. Colonies massive with regular conical monticules. 5-10 septa reach the top of the monticule, margins dentate, sides granulated. Columella lamellar, encircle monticules. Tentacles usually not extended during the day.

Hydnophora microconos

118. Valleys more sinuous. Colonies massive, hemispherical, meandroid. Valleys 2-3 cm wide, collines about 3-6 mm thick. Centers regularly placed, linked to each other by 3-4 toothed laminar linkages. Septa in 2-3 orders, not adjoined over the wall, well separated by an ambulacral groove. Columella trabecular, tending to become spongy. Live colonies brown with green centers.

Symphyllia nobilis

Valleys less sinuous. Colonies hemispherical or flat. Valleys of indefinite length, running from the center to the periphery. Centres joined by 3-4 laminar linkages running lengthwise along valleys and having their edges dentate. Collines 3-5 mm thick. Septa in 3-4 orders, alternate, usually continuous over collines, with 3-4 large septal dentations along upper margins. Well defined ambulacral

groove absent. Columella trabecular or spongy.
Symphyllia radians

119. Coralla goblet shaped. Calices slighltly elliptical with 12 primary septa dividing the calice into 12 chambers. Pali 11-18.
Caryophyllia arcuata

Coralla cornuate. Septa in five cycles, exert. Pali 17-18. Major septa 14-17, highly exert, dividing the calice into 14-17 chambers.
Caryophyllia clavus

120. Septa usually less than 18 121

Septa usually more than 18. Colonies massive, encrusting or unifacial fronds. Corallites irregular, 3-4 mm in diameter, close together or up to 3 mm apart, immersed or about 4 mm exert. Budding peripheral. Septa 18-30, in a single order. Some septa bifurcate at the coralla wall. Columella spongy and hemispherical.
Turbinaria frondens

121. Coralla comprises of irregularly folded unifacial laminae with some of the folds developing into tubes. Corallites almost evenly distributed, slightly exert, calices 1.8-3 mm in diameter. Septa 18-20, usually in two orders; some larger calices with three orders. In some calices 2-3 septa fuse before joining the columella, the latter being large and spongy, coenosteum spongy.
Turbinaria mesenterina

Coralla cup shaped with the corallites unifacial with ridges and furrows on the underside. Corallites arranged in a wavy manner, 2-2.5 mm in diameter, closely set to 2 mm apart, level to about 1 mm exert. Septa 16-18. Columella a single lamella, coenosteum spiny.
Turbinaria crater

122. Coralla subramose usually forming clumps on the underside of coral boulders. Corallites 4-8 mm in diameter, plocoid, formed by extratentacular budding. Septa in three or four cycles with dentate margins, dentations being more pronounced on higher order septa. Coenosteum in between spongy.
Tubastrea aurea

Colonies arborescent with the main branches budding off to form branchlets. Corallites somewhat arranged in rows, exert, distance between adjacent corallites 3-15 mm. Septa in two orders and bear granular sides.
Tubastrea micranthus