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DISTRIBUTION AND DIVERSITY OF MARINE FLORA IN CORAL REEF ECOSYSTEMS OF KADMAT ISLAND IN LAKSHADWEEP ARCHIPELAGO, ARABIAN SEA, INDIA

BY

VIJAY V. DESAI, DEEPALI S. KOMARPANT AND TANAJI G. JAGTAP

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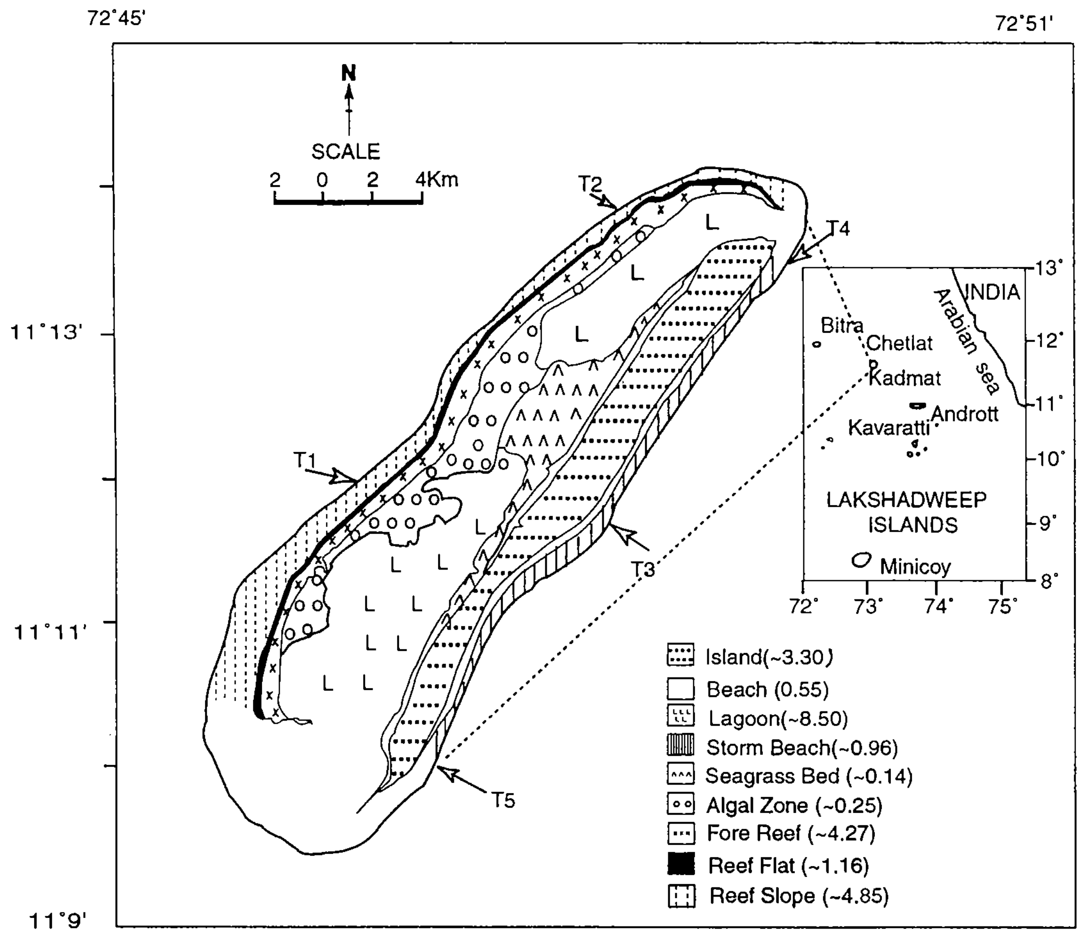

Figure1. Physical data and morphological features of coral reef from Kadmat Island (the numbers in parenthesis refer to an area in km^2).

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VIJAY V. DESAI [1], DEEPALI S. KOMARPANT [2] and TANAJI G. JAGTAP [3]

ABSTRACT

The coral reef of Kadmat Island of Lakshadweep was assessed for its biological components along with relevant hydrological characteristics. Corals were represented by 12 species, the most dominant being *Acropora* and *Porites*. The distribution of coral was mainly confined to the reef slope and fore reef; however, the cover was very poor except for a few patches on the fore reef towards northwest (< 10%). The lagoon and reef flats were almost devoid of corals.

The low counts ($0\text{-}80 \times 10^3$ cells l^{-1}) and poor composition (11 spp.) of phytoplanktons could be due to oligotrophic waters around the island. The high contents of dissolved oxygen (DO) might be due to photosynthetic activities of macrophytes in the lagoon. Seagrass meadow occupied only 0.14 km^2 area of the lagoon leaving 98% of it barren. It was more prominent in the mid- and landward region of the lagoon due to fine and well-sorted thick sediment. Seagrass flora was comprised of two species and was dominated by *Cymodocea rotundata.* Biomass was estimated to be more (26-30.5g m^{-2} dry weight) during premonsoon season. The marine algae were represented by 23 spp. and mainly occurred in the seagrass beds but contributed negligibly to the biomass. *Acanthophora spicifera, Padina boergesenii* and *Jania capillaceae* were common during premonsoon season.

Sand-dune flora was represented by 39 spp. of which 16 spp. were perennial. The most dominant forms were *Spinifix littoreas* and *Ipomea pes-caprae*. The sand-dune region is under constant threat of reclamation for cultivation of vegetables and dwellings. Poor composition, particularly of corals, indicated that the reefs around Kadmat Island were converting into algal or detrital reefs.

[1, 2, 3] National Institute of Oceanography, Dona Paula, Goa - 403004, India.
Phone: 91- (0832) 2456700 * 4390

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INTRODUCTION

Major oceanic reefs in India are confined to Lakshadweep (Arabian Sea) and Andaman and Nicobar (Bay of Bengal) groups of islands. Oceanic islands generally represent a multitiered ecosystem typically comprised of wetland habitats such as corals, seagrasses, seaweeds, mangroves and sand-dune vegetation. These wetland habitats from Lakshadweep, being unique and rich in biodiversity and productivity, are of great ecological and socioeconomic importance (Bakus *et al.*, 1993). However, because of their vulnerability to anthropogenic and natural destruction, they have been considered "Marine Critical Habitats" and hence are of global concern. These coastal habitats have also been categorized as "Ecologically Sensitive Regions" under the Coastal Regulation Zone (CRZ – I) Act (Anon., 1990). However, such regions in general and particularly at the oceanic islands are heavily pressurized, mainly due to overexploitation, deteriorating the overall reef ecosystem. Degradation of particular habitat is mainly associated with poor or total lack of management policies.

It is essential to adopt sustainable management of marine habitats at oceanic islands due to limited land resources. The existing data and information relevant to such habitats, particularly from the Lakshadweep group of islands, are inadequate for an understanding of the environmental and biological characteristics. The present investigation provides data on the structural aspects of various reef components, with emphasis on marine flora, from Kadmat Island in the Lakshadweep group. The data and recommendations would be of great help in rejuvenating the reef environment and formulating strategies for the sustainable utilization of the coral-reef resources.

DESCRIPTION OF THE STUDY AREA

Lakshadweep comprises a group of 36 islands situated between 8^0 and 10^0 13' N and 71^0 and 74^0 E in the Arabian Sea. Kadmat island (Fig.1) is located between 11 ^{0} 10' 52"- 11 ^{0} 15' 20" N and 72 ^{0} 45' 41"- 72 ^{0} 47' 29" E. It stretches ~ 8 km from north to south with width ranging from ~ 50 to ~400 m and measuring 3.12 km^2. The lagoon is on the leeward (western) side with its depth in the range of 2 – 3 m. The storm beach along the eastern side has an average width of ~100 m. A coralline algal ridge occurs along the breaking zone of the storm beach.

Climatology

The climatological data (average of 30 years from 1951-1980) pertaining to Amini Divi Island (Anon., 1999), in close vicinity to the study site, are depicted in Figure 2. The atmospheric temperature fluctuates between a minimum of 23.5^0C during January to a maximum of 33.3^0C during April-May. The average total precipitation has been estimated to be 1500 mm, 98% of which occurs during the period of April to November with the maximum rainfall during June-October. The humidity ranges from 79 – 87% with the maximum during the monsoon period (June to October). The monthly mean wind speed varies from 6 - 29.6 km h^{-1} (Fig. 2).

Geomorphology, Geology, Soil and Topography

The island is a submarine platform with a coral reef in the form of an atoll. It is crescent-shaped having a north-south orientation. The western margin of the lagoon is a submarine bank marked by a narrow reef below. The geology is marked by an upper 1-2 m-thick layer of disintegrated coral, below which is a compact porous crust of conglomerate stone and soil composed mostly of coral sand. Topography is a flat 1-2 m above sea level. Erosion occurs mostly along the shore towards the northeast and northwest.

METHODS

Information on various features of the study site was collected using aerial photographs of 1973 (scale 1:25000) and Indian Remote Sensing (IRS) data of October 1998 (scale 1:2,50,000). The final map was prepared by comparing photo and satellite data-interpreted results with ground truth observations on various features of the reef and island (Fig. 1).

The samplings and observations for physicochemical characteristics of water, floral constituents and sediment characteristics were made along the five fixed transects T1–T5 (Fig. 3) laid down from -10 m on the reef slope up to ~150–200 m above high-tide line on the island. The length of the transect varied from ~ 1-3.5 km depending upon the topography or the contour. The samplings were taken during the postmonsoon (November 1998) and premonsoon (May 1999) season. The collections and observations were made from the depth of -10 m and -5 m on the reef slope and from -1.5 and -2.5 m in the lagoon, and from exposed flats of reef and storm beach (Fig. 3). The subtidal samplings and observations were made by snorkeling and diving. The sediment samples from the subtidal regions were collected by graduated acrylic core while those from sand-dune regions were hand picked. The thickness of sediment (in the lagoon) was measured by pushing a graduated acrylic core to a maximum possible depth in the substratum. Analysis of the organic contents and the granulometric analysis of the sediments were done by following the methods of EL Wakeel and Riley (1957) and Folk (1968), respectively. Water samples were analyzed for various physicochemical parameters such as salinity, dissolved oxygen (DO), NO_3 - N, NO_2 - N, PO_4 - P, by using standard oceanographic techniques (Strickland and Parsons, 1972). Temperature and pH of the water samples were measured using a precision mercury thermometer and a pH meter (Systronics Graph 'D' 327).

For phytoplankton composition analysis, the subsurface water samples were preserved immediately after collection with five drops of Lugol's solution. Phytoplankton were identified using relevant literature (Heurck, 1986; Allen and Cupp, 1935; Subramanian, 1946; Dodge, 1985; and Hallergraeff, 1988). For quantitative analysis, 1 ml of preserved phytoplankton sample was transferred to Sedgewick rafter counting chamber. The cells were counted from three replicate subsamples.

Specimens of marine macrophytes, including seaweeds, seagrasses and sand-dune flora, were collected and preserved in 5% formalin as well as in the form of herbaria for further taxonomic identifications. The preserved specimens were identified using standard literature (Taylor, 1969 a, b; Abbott and Hollenberge, 1976; Tseng, 1983; Hooker, 1897; Cooke, 1960; Gamble, 1967; Hartog, 1970; Silva *et. al.*, 1996). Quantitative data, such as percentages, frequency of occurrence (FO), biomass of seaweeds and seagrasses (total and individual species), were collected using 1 m^2 quadrant technique (Jagtap, 1996, 1998).

The entire mass of vegetation, collected from the randomly chosen five quadrants at each station, was taken on board the Coastal Research Vessel (CRV), "Sagar Paschimi", washed to remove adhering debris, blotted dry and dried in the oven at 60^0 C to a constant weight. Species weighing >5 g (wet weight) were considered for estimating biomass and species weighing <5 g (wet weight) were discarded for biomass estimation as per Anon (1998). The qualitative and quantitative sampling for sand-dune vegetation was carried out on the berm and backshore regions on each transect at every 50 m intervals on the land. The biomass (wet weight) of major flora was estimated by removing the entire crop from three quadrants of 1 m^2 each and weighing it after removing adhered sand. The density of major species was measured by counting the actual numbers of individual and total plants in three 100 m^2 quadrants.

RESULTS AND DISCUSSION

The study region could be classified broadly into six major zones (Fig. 4). The lagoon occupies maximum area (~8.5 km^2) followed by reef slope (~4.85 km^2) and fore reef (~4.3 km^2). Because of large variability in the biotic components from various habitats of the reef, the data were pooled for separate zones of the reef such as reef slope, reef flats, storm beach, fore reef, lagoon, intertidal and sand dunes. The corals were mainly confined to the reef slope and fore reef, while the reef flat was almost devoid of corals. The fore reef towards northeast was observed to support a growth of young colonies of scleractinians, the species of *Pocillopora* and *Porites*. The substratum over the reef slope, reef flat, fore reef and storm beach flat was composed mainly of coral boulders and coral sands. The lagoon is generally sandy, except for occasional coral debris and boulders, towards the extreme northwest and southwest. The sandy substratum was comprised of coralline sand increasing landward.

The surface-water temperatures over the reef slope were slightly lower compared to the same in the lagoon (Table 1), which may be attributed to the greater depths and the high-energy zone compared to the shallow and low-energy region in the lagoon. The salinity values ranging from 34.17 to 35.08 PSU did not vary much in the lagoon and over the reef slope. In general, the nutrient concentrations were observed to be low (Table 1); however, the waters over the reef slope were relatively richer in nutrients compared to lagoon water. The nutrient values were slightly higher during November which may be due to the upwelling processes commonly occurring in the

Arabian Sea during October-November (De Souza *et al.*, 1996). The low nutrient concentrations in the lagoon could be attributed to their utilization by macrophytes, particularly seagrasses and seaweeds, and low retention by loose and unstable sediments (Sankaranarayanan, 1973).

The Lakshadweep waters have been reported to be generally of oligotrophic nature. However, areas that are oligotrophic at certain times can be eutrophic at other times (Bhattathiri and Devassy, 1979). The relatively high (8.2–8.8) pH values in the lagoon compared to water over the reef slope (7.5–8.7) might be due to respiratory processes by benthic flora in the lagoon influencing the biogeochemical processes of these waters (Sankaranarayanan, 1973). Similarly, the higher concentrations of dissolved oxygen (Table 1) in the lagoon water could also be attributed to photosynthetic processes by marine algae and seagrasses. In spite of low concentrations of phytoplankton, oxygen-enriched waters (4.11 - 6.57 ml l^{-1}) around Kadmat Island could only be attributed to the photosynthetic productivity of submerged flora (Odum, 1956; Qasim and Bhattathiri, 1971; Kaladharan *et al.,* 1998).

The phytoplankton counts of 0 to 80 x 10^3 cells l^{-1} over the reef slope and in the lagoon, respectively, indicate poor densities as also was reported earlier (Bhattathiri and Devassy, 1979) from Lakshadweep waters. Phytoplankton was represented by 11 species but *Trichodesmium* sp. was abundant (Bhattathiri and Devassy, 1979). A maximum of six species were observed from the lagoon and three from over the reef waters during November (Table 2). The poor qualitative and quantitative distribution of phytoplankton from the waters around Kadmat Island could mainly be due to the oligotrophic nature of its waters.

The prominent biological feature of any reef is its coral composition, which determines the health of the reef environment. The corals from the study site were mainly confined to the reef slope and fore reef and were represented by only 12 species. The most dominant forms belonged to the genera *Acropora* and *Porites* (Anon., 2000a). Occasional young colonies of *Pocillopora* grew on the reef flat and storm beach. The lagoon region, except the fore reef, was totally devoid of corals. The distribution was patchy with hardly 5% live coral colonies on the reef slope and fore reef. However, towards northeast and northwest, as well as southeast, occasional patches having an average of 10% live colonies were observed. Large numbers of coral colonies, particularly *Acropora* and *Porites,* were observed to be bleached indicating impact of certain stress. A similar phenomenon was observed in the case of corals along the central west coast during the same period (Anon, 2000b). Considering an earlier record of 104 spp. of corals from Lakshadweep region (Pillai and Jasmine, 1990), the distribution and number of coral species observed during the present study were extremely poor indicating severe deterioration of the coral reefs. The large-scale natural death and the bleaching phenomenon of the corals all over the tropics have been related to global warming causing a rise in seawater temperature by 1-2^0 C during the summer of 1998 (Huppert and Stone, 1998). The reef slope towards the northeast and east was totally devoid of live scleractinians except for a few colonies of *alcyonarians*.

The degradation of coral reefs due to various natural and anthropogenic causes results in the formation of algal reefs. The dead coral debris and boulders largely contribute to the sediments in the lagoon and island building processes. Similarly, they provide natural substrate for the growth of macrophytes, particularly seaweeds and seagrasses of great ecological importance and including a few species of commercial potential (Odum, 1971; Ott, 1980; Siddiqui, 1980; Ogden, 1988; Mann, 1988; More and Hudson, 1989; Jagtap, 1998). The seagrass beds from the study region were confined to the lagoon towards the northeast. However, ~98% of the total lagoon area, particularly towards the west and southwest, was totally devoid of corals, as well as macrophytes, except for the stray occurrence of a few algae. The storm beach, measuring about 0.96 km^2 towards the east of the island, also had scanty coral and macrophyte growth.

The coral-reef regions in general, and particularly in Lakshadweep Archipelagos, have been observed to be very productive and harbor large numbers of marine algae and dense seagrass beds (Hacket, 1977; Jagtap, 1987, 1996, 1998; Untawale and Jagtap, 1989; Bakus, 1993; Rodrigues et al., 1997; Jagtap and Untawale, 1999). However, the seaweed flora around Kadmat Island was represented by small numbers (23 spp.) and negligible quantities except for a few forms such as *Padina borgesenii, Acanthophora spicifera* and *Hypnea valentiae* during March (Table 3). Marine algae were mostly confined to the peripheral stretches along the reef flat towards the reef slope and fore reef, in association with the seagrass beds, and on the narrow patches of sand stones at the lower intertidal region along the shore. The intertidal and submerged reef regions harbored very limited algae such as *Turbinaria ornata* and *Halimeda* spp. The economically important species, such as *Gelidiella acerosa* and *Sargassum* spp., occurred on the reef flat of storm beach towards high-tide and low-tide mark respectively, while species of *Gracilaria* and *Hypnea* were restricted to the lagoon.

The poor representation of algal flora in the region could be attributed to their seasonal occurrence. Maximum species diversity and abundance of marine algae along the Indian coast generally occur during the postmonsoon (October-January) period. Species richness, diversity and percent cover of algae from Lakshadweep reefs have been reported to be three times lower during the premonsoon season compared to the postmonsoon months (Rodrigues, *et al.*, 1997). The total absence of algae from the reef region could also be attributed to intensive grazing by herbivores (Millon, 1982; Hay, 1985). Intensive herbivory is reported to consume 50–100% plant production over the coral reefs (Hatcher and Larkum, 1983; Carpenter, 1986). Coral reefs from Lakshadweep islands have been reported to be rich in herbivores among which reef fishes and sea urchins form the dominant grazers (Bakus *et al.*, 1993; Rodrigues *et al.*, 1997).

Major seagrass beds from India are mainly restricted to the lagoon regions from Lakshadweep, Andaman and Nicobar group of islands and the southeast coast of India (Jagtap, 1991). The seagrass flora comprised of 15 spp., of which 7 spp. occur in the Lakshadweep group of islands (Jagtap, 1987,1991, 1998). Varieties of marine algae grow in the seagrass beds as well as in epiphytic forms on seagrass blades and rhizomes (Jagtap, 1996, 1998). The seagrass bed from the Kadmat lagoon was observed to be patchy as were stretches along the shore. Dense meadow occurs towards the northwest region of the lagoon covering ~0.14 km^2 and exhibited marked zonation. Mostly sparse and small patches of *Thalassia hemprichii* occurred in the shallow sandy regions towards the fore reef, while the mid-lagoon deeper region (1.5–2.5 m) harbored mixed dense beds of *Thalassia hemprichii* and *Cymodocea rotundata*. The shallow region (0.5–1.5 m) towards land supports intensive growth of *Cymodocea rotundata*.

A similar kind of distribution trend has been reported from the other islands on Laccadive archipelagos (Jagtap and Untawale, 1993; Jagtap, 1998). The seagrass flora of Kadmat comprised of two spp and higher biomass (17–26 g m^{-2} dry weight) were recorded from the mixed zone in the mid-lagoonal area (Table 4). The drifted biomass of 195 g m^{-2} dry weight was recorded during March when the biomass of the standing crop was higher (26 g m^{-2} dry weight). The frequency of occurrence also increased from 20% to 70% during March, indicating the maximum abundance and biomass, and happens during premonsoon period because of higher wind speed (Fig. 2) causing disturbances in the sea state including lagoon waters. Earlier, (Jagtap and Inamdar, 1991) five species of seagrasses were recorded from the lagoons of Kadmat. It has been observed that the creeping kind and small-sized seagrasses, such as *Halophila* spp., commonly grow as pioneer species and form a suitable substratum for other larger-sized seagrasses to follow during the succession process (Birch and Birch, 1984; Jagtap, 1998). The absence of such species from Kadmat lagoon during this study might be due to out-competition by the existing species during succession. A considerable amount of seagrass biomass contributes towards the detrital food chain (Mann, 1988; Valiela et al., 1985). The organic carbon in the sediments, particularly from the seagrass beds, varied from 0.11 – 0.42% (Table 4). The benthic faunal population from the seagrass beds has been reported to be higher due to high organic carbon in the sediments (Ansari *et al*, 1991).

Coral reefs play a significant role in nutrient recycling and creating sedimentary environment (Macintyre *et al.*, 1987; Ogden, 1988), which is most suitable for the establishment of seagrasses. Colonization and abundance of seagrass depend upon the nature of substratum and its thickness, the source, routes, and rates of sediment transport and its accumulation (Ziemann, 1972; Burrel and Setubel, 1977). The substratum in the lagoon of Kadmat was mostly sandy (94.8–97.95%) admixtured with trace amounts of silt and clay (Table 4). However, the sediment texture in non-seagrass regions in the lagoon was either compact or coarse, while in the seagrass beds and in the immediate vicinity it was comprised of well sorted fine sand with more thickness. The sediments from the lagoons of Lakshadweep islands are comprised of moderate-to-very well sorted sediments towards shore (Jagtap, 1998). Dense growth and abundance of *T. hemprichii* and *C. rotundata* in the mid- and landward region of the lagoon may be due to sufficient thickness of the substratum and well sorted and fine sediments which favor the seagrass establishment and growth (Ziemann, 1972).

The absence or poor growth of seagrasses towards fore reef, west and northwest regions of the lagoon could mainly be attributed to the compact nature, less thickness, and relatively unstable and coarse texture of the sediments, as reported elsewhere (Jagtap, 1998). Seagrass establishment enhances the sedimentation by decreasing speed of water movement and trapping sediments (Wood *et al.*, 1969). Encrusting flora on seagrass blades, particularly diatoms, and epiphytic coralline algae, particularly *Melobesia* sp., form an additional source of lagoon sediments (Humm, 1964; Stockman *et al.*, 1967) besides sedentary corals and coralline algae. It has been found that the epiphytic forms in a peak growth of seagrass contribute 7-52% of total seagrass biomass, mainly contributed by rhodophycean members (Jagtap, 1996, 1998). The calcareous algae, particularly *Halimeda* spp that are commonly associated with coral reefs and seagrass meadows, have been estimated to contribute almost 60% of lagoon sediments (Siddique, 1980) forming suitable substratum for seagrasses to establish.

The perennial sand-dune vegetation was observed to be more predominant along the southeast, southwest, northeast and northwest shores of Kadmat Island. The maximum of 39 spp. was recorded during the postmonsoon (November) period, of which 23 spp. were annual and 16 spp. were perennial (Table 5). The dominant perennial species were *Spinifix littoreas*, *Ipomea pes-caprae*, *Bidens biternata* and *Vernonia cinuea*. *Pemphis acidula* and *Scaveola sericea* were observed along the southwest and southeast regions just behind the fore-shore dunes. The average biomass of *S. littoreas* and *I. pes-caprae* in the northeast and southeast regions of the island were estimated to be 500 and 290 g m^{-2} (wet weight), respectively. So far, two species of *Pemphis* have been recorded from the Lakshadweep group of islands (Sivadas *et al.*, 1983; Jagtap, 1998). Species of *Pemphis* and *Scaveola* have been commonly reported from the islands of Maldives and Laccadive archipelagos and act as pioneer species on the newly formed islands (Hackett, 1977; Jagtap and Untawale, 1999). However, the pioneer sand-dune flora from Lakshadweep appears to be *Spinifix* and *Ipomea*.

The southernmost stabilized atoll of Maldives has been reported to be very dense in *Pemphis* and *Scaveola* forest in the backshore zones (Jagtap and Untawale, 1999). Sand-dune flora is of great importance in accumulating and binding the sediments and governing their movement. Lakshadweep islands are 1.5-2 m above sea level and mainly composed of sandstone and sand. Therefore, the natural sand-dune flora is of great importance to the island from the point of shore stabilization. However, sand-dune habitats around the island have been largely reclaimed for agricultural and urbanization purposes. The entire tourist complex towards the south has been developed by reclaiming sand-dune areas. Species such as *Scaveola, Pemphis* and *Thespesia* could form a potential source of fuel, as well as shore stabilizers, if managed on a sustainable basis.

The present studies revealed that the major biotic components of the reef around Kadmat Island are extremely poor compared with those of other islands of Lakshadweep (Untawale and Jagtap, 1984; Jagtap, 1987, 1991, 1996, 1998; Subharamaiah *et al.*, 1979; Kaliaperumal *et al.*, 1989; Pillai and Jasmine, 1990; Bakus *et al.*, 1993; Rodrigues *et al.*, 1997). Even the existing sand-dune flora from the island is patchy and under constant threat from anthropogenic removal, particularly for vegetable cultivation and construction. The absence and poor cover of corals from the various reef zones clearly indicate that they are turning into dead and detrital reefs. Offshore coral reefs protect islands from eroding by minimizing the impact of wave energy. Some Maldivian atolls, including the inhabited island of Kilisfaruhurra, have been submerged due to green-house effect and sea-level rise (Dixit, 1994). The healthy coral reefs may keep pace with sea-level rise and the continuing land-building process. Similarly, sand-dune flora, as well as seagrass meadows with their associate flora, help in stabilizing the shore besides enhancing the productivity of the reef ecosystem.

Considering constant global warming causing sea-level rise (Hoffmann, 1983), small island development programs, particularly those of the Lakshadweep group of islands which are in an emerging process, should be the top priority under the Coastal Zone Development Program (CZDP) for the "10th five-year plan" of the country. The following suggestions could be of help in formulating CZDP for improving the health, sustainable utilization and protection of Lakshadweep reef ecosystems.

- Establishment of a community program for rejuvenating deteriorated reef by transplantation of corals.
- Cultivation and culture of commercially valuable marine organisms would provide job opportunities and additional income for the islanders. The cultivation of seaweeds, such as *Gracilaria edulis* and *Hypnea* spp, and raft and cage culture of fishes and prawns in the shallow water and lagoons and over the seagrass beds would be of great commercial importance. Similarly, the reef regions are the best grounds for growing commercially potential species of holothurians.
- Cultivation of seagrasses in the lagoon by transplantation may help in increasing productivity and in stabilizing the shore.
- Protection of the existing sand-dune regions and plantation of sand-dune flora, particularly species of *Pemphis, Scaveola* and *Thespesia,* on the berm and backshore zones. This would provide natural fuel, help arrest erosion and enhance stabilization process of the island.
- Long-term monitoring of reef environment would help in Natural Resource Accounting (NRA) of the region, which in turn would help in indicating improvement or decline in the quality of the environment.
- Coral reefs form potential sites for tourist industries because of their recreational, scenic and cultural importance. Recreational tourism has already been initiated at a few of the Lakshadweep islands including Kadmat. Overdevelopment and poor planning of small islands in the tropical ocean, particularly for tourism, have resulted in a major decline in the reef biota (Zea *et al.*, 1998). Therefore, very careful long-term planning should be considered for tourism development, particularly for small emerging islands of Lakshdweep.

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Table 1. Hydrological Characteristic Over the Coral Reef Region Around Kadmat Island

Parameters	Reef slope		Lagoon	
	November 1998	March 1999	November 1998	March 1999
Water Temperature (^{0}C)	28 - 28.5	28.5 - 29	28 - 28.5	29.5 - 30
Salinity (PSU)	34.17 - 34.86	34.99 - 35.08	34.32 - 34.86	34.32 - 34.37
Nitrite (μ mol l^{-1})	0.02 - 0.05	0.002 - 0.007	0.01 - 0.04	0 - 0.005
Nitrate (μ mol l^{-1})	0.72 - 1.36	0.12 - 0.33	0.076 - 0.14	0.03 - 0.22
Phosphate (μ mol l^{-1})	0.085 - 0.125	0.085 - 0.345	ND	ND - 0.02
pH	7.5 - 8.7	8.1 - 8.3	8.6 - 8.8	8.2 - 8.4
Dissolved Oxygen (ml l^{-1})	4.11- 4.84	4.17 - 4.93	-	4.29 - 6.57
Phytoplankton count (no x 10^3 cells l^{-1})	0 - 13	0 - 80	3 - 48	0 - 10

*ND – Not Detectable

Table 2. Distribution of Phytoplankton Species (no x 10^3 cells l^{-1}) in the Reef Slope and Lagoon Water of Kadmat Island

	Reef slope		Lagoon	
	November 1998	March 1999	November 1998	March 1999
Bacillariophyceae				
Achnanthes longipes C. Ag.	-	-	3	-
Asterionella japonica Cleve	3	-	6	-
Diploneis weissfloggi (A.Schmidt) Cleve	-	-	3	-
Gyrosigma sp.	-	-	3	-
Lephocylindrus danicus Cleve	10	-	-	-
Navicula hennedyii W. Smith	-	-	3	-
Pinnularia sp.	3	-	3	-
Thalossionema nitzschioides Grunow	-	-	-	1
Dinoflagellata				
Prorocentrum gracile Schutt	-	-	-	2
P. micans Ehrenberg	-	-	-	1
Cyanophyceae				
Trichodesmium sp.	-	80	30	-

Table 3. Algal Species Observed from Kadmat Island, Lakshadweep During Post-monsoon and Pre-monsoon Period

	Lagoon		Intertidal	
	November 1998	March 1999	November 1998	March 1999
Chlorophyta				
Boergesenia forbesii (Harvey) Feldmann	+	+	+	+
Cladophora sp.	-	+	+	+
Enteromorpha compressa (Linn.) Nees	+	-	+	+
E. intestinalis (Linn.) Nees	+	-	+	+
Halimeda gracilis Harvey ex J. Agardh	+++	+++	+	+
Halimeda sp.	++	++	+	+
Ulva lactuca Linn.	+	-	+	+
Phaeophyta				
Dictyota bartayresiana Lamouroux	+	+	+	+
Padina boergesenii Allender & Kraft	++	++	++	+++
Sargassum duplicatum J. Agardh	+	+	+	+
Turbinaria ornata (Turner) J. Agardh	++	++	+	+
Rhodophyta				
Acanthophora spicifera (Vahl.) Boergesen	+	+	+	+++
Ceratodictyon spongiosum Zanardini	+	-	+	+
Ceramium sp.	+	-	+	+
Gelidiella acerosa (Forsskal) Feldmann et Hamel	++	++	+	+
Gracilaria edulis (J. Ag.) Silva	++	++	+	+
G. variabilis (Grev.) Schmitz	+	-	+	+
Hypnea pannosa J. Agardh	+	+	+	+
H. valentiae (Turner) Montagne	+	+	+	+
Jania capillaceae Harvey	+	+	++	+++
Laurencia papillosa (C. Agardh) Greville	+	+	+	+
Laurencia sp.	-	+	-	++
Polysiphonia sp.	+	-	+	-

+++ Dominant ++ Common + Less common - absent

Table 4. Structure of Seagrass Meadow from Kadmat Island, Lakshadweep

	November 1998			March 1999		
	LFR	MLA	LAL	LFR	MLA	LAL
Depth (m)	1 - 1.5	1.5 - 2.5	0 - 0.5	1 - 1.5	1.5 - 2.5	0 – 0.5
Substratum	S+ CD	S	S	S + CD	S	S
Thickness of substratum (cm)	>2.5	5 - 10	>10	>2.5	5 - 10	>10
Sand % (range)	97.1 - 97.95	97.8 - 98	94.8 - 97.6	-	-	-
Silt % (range)	0.23 - 2.8	1.67 - 1.82	2.02 - 2.48	-	-	-
Clay % (range)	0.1 - 2.03	0.32 - 0.42	0.41 - 2.74	-	-	-
Organic Carbon (%)	0.11 - 0.27	0.21 - 0.23	0.36 - 0.42	1.08 - 1.4	1.52 - 1.96	0.92 – 1
Nature of seagrass beds	SP	LP	BS	SP	LP	BS
Quantitative Aspect of Seagrasses						
Number of seagrass species	1	2	1	1	2	2
Thalassia hemprichii (Ehrenb.)						
% FO	+	+	A	+	++	A
Biomass (gm^{-2} dry wt.)	N	5	NA	N	7.5	NA
Cymodocea rotundata (Ehrenb.) Hempr. Ex. Aschers						
% FO	A	+	++	-	++	+++
Biomass (gm^{-2} dry wt.)	NA	15	17	-	23	26
Total biomass (gm^{-2} dry wt.)	NA	20	17	N	30.5	26
Average total drifted biomass (gm^{-2} dry wt.)	NA	NA	N	NA	NA	195

Legends: N = Negligible, NA = Not Applicable, SP = Small patches, LP = Large patches, BS = Broken stretches, S = Sandy, CD = Coral debris, A = Absent, + = Frequency of occurrence 10 – 20%, ++ = Frequency of occurrence 50 – 70%, +++ = Frequency of occurrence >70%, LFR – Lagoon towards fore reef, MLA – Mid-lagoon region, LAL – Lagoon towards land

Table 5. Sand-Dune Flora from Kadmat Island (Lakshadweep)

	November 1998	March 1999
Acalypha indica, Linn.	+++	-
Aerua lanata, Juss.	+++	-
Bidens biternata (Lour.) Merr. & Sherff	+++	+++
Boerhavia diffusa, Linn.	+++	-
Bonneria sp.	+	-
Corchorus aestuans Hb. Madr.	+++	-
Crotalaria pallida, Klotz.	+++	-
Cucumis sp.	++	-
Dactyloctenium aegytiacum, Willd.	++	++
Desmodium triflorum, DC.	+	+
Eclipta alba Haask.	++	++
Eragrostis pilosa, Beauv.	++	++
Euphorbia hirta, Linn.	++	-
Fimbristylis polytrichoides, Vahl.	++	++
Hyptis suaveolens, Poit.	++	-
Indigofera linnaei, Ali	++	-
Indigofera tinctoria, Linn.	+++	-
Ipomea pes-caprae, (Linn.) Sweet.	+++	+++
Ischaemum sp.	+	-
Lapartea interrupta (Linn.) Chew.	+++	-
Launaea fallax (Jaub. & Spach) Kuntze.	++	++
Micrococca mercurialis, Benth.	+++	-
Oldenlandia herbacea, Roxb.	+	+
Oplisemenus burmannil, Beauv.	+++	-

Pemphis acidula, Forst.	+++	+
Phyllanthus niruri, Linn.	++	-
Portulaca tyberosa, Roxb.	+	-
Pouzolzia zeylanica, Benn.	+	-
Pycreus sp.	++	-
Scaevola sericea Vahl.	+	+
Sida cordata, (Burm. f.) Borssum	+++	-
Spinifex littoreus Merrill	+++	+++
Synedrella nodiflora, Gaertn.	+	-
Tephrosia pumila, Pers.	+++	-
Tephrosia strigosa (Dalz.) Santapau & Maheshwari	+++	-
Tephrosia sp.	+	+
Thespesia populnea, Soland.	+	+
Tridax procumbens, Linn.	+++	++
Vernonia cinerea (Linn.) Less	+++	+++

Legends: +++ = Dominant (Frequency of occurrence >50%)
++ = Common (Frequency of occurrence 30 – 50%)
+ = Less common (Frequency of occurrence <30%)
- = Absent

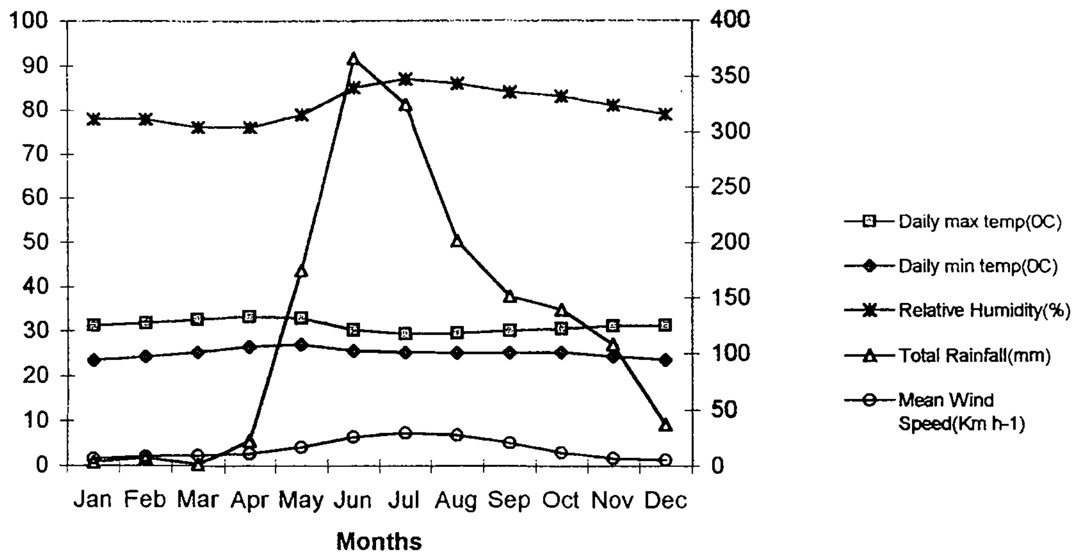

Figure 2. Climatological data (average from 1950–1980) for Amini Divi Island in the vicinity of Kadmat Island.

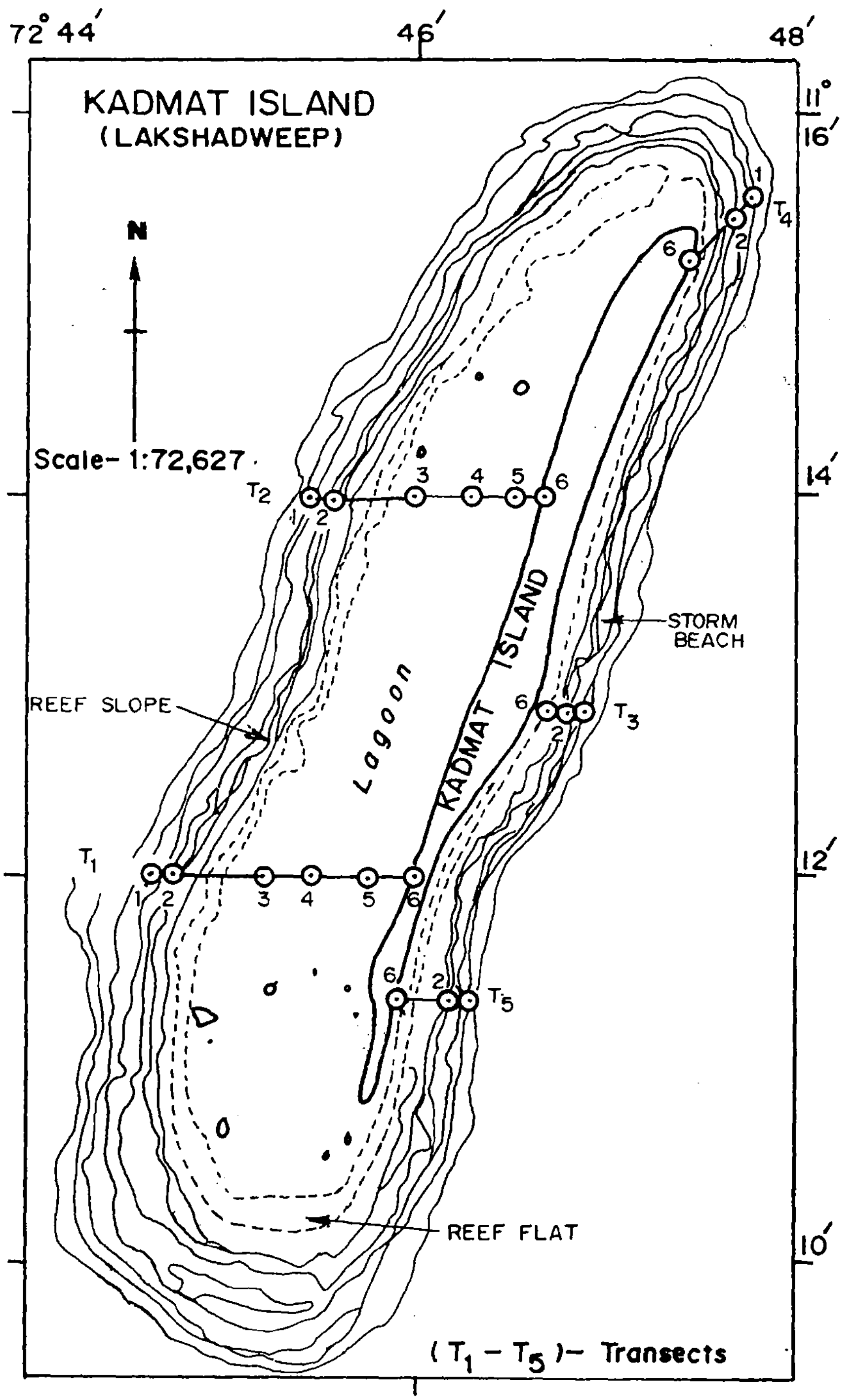

Figure 3. Geographical positions of sampling locations around Kadmat Island (Lakshadweep).

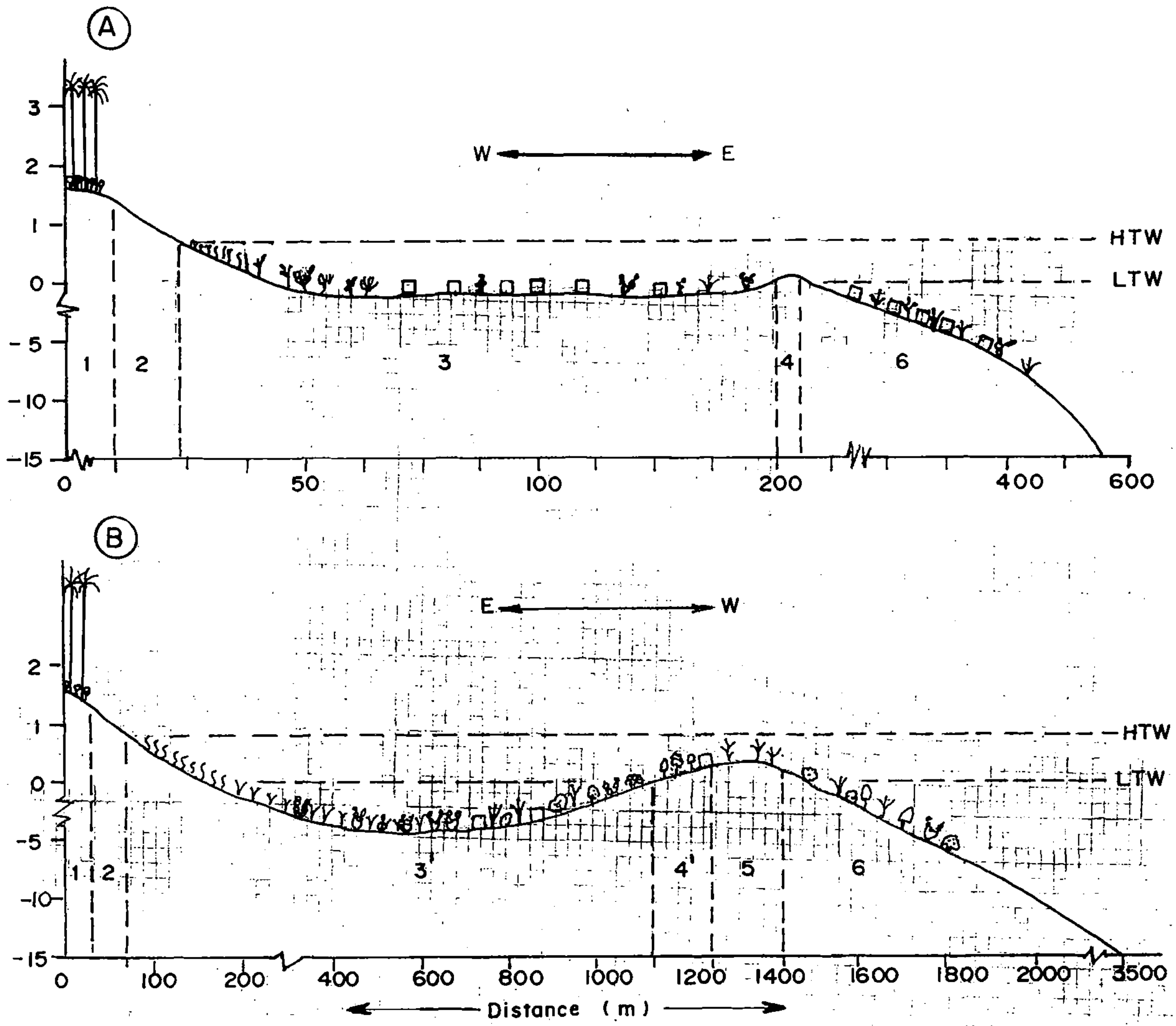

Figure 4A & B. Schematic representation of biotic habitats in the various zones of coral reef of Kadmat Island of Lakshadweep.

1. Island 2. Beach 3. Storm Beach 3'. Lagoon 4.Algal ridge 4'. Fore reef 5. Reef flat 6. Reef slope

Sand dune vegetation	Halimeda
Coral boulders	Acanthophora
Cymodocea rotundata	Jania
Thalassia hemprichii	Turbinaria
Padina	Acropora
Porites	Coconut plantation
HTW High Tide Water	LTW Low Tide Water