CRITICAL HABITAT INFORMATION SYSTEM OF KADMAT ISLAND - LAKSHADWEEP

Government of India
Department of Ocean Development
Integrated Coastal and Marine Area Management
Project Directorate, Chennai
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1. Introduction

Critical habitats are identified as areas, which are vital to the survival of the species at some phase of its life cycle or to the survival of the community, because of the ecological processes, which occur within it (IUCN, 1976). Critical habitats include feeding, nesting, breeding and nursery areas of estuarine and marine animals; major sources of food and nutrients for feeding areas elsewhere (e.g. mangroves); or areas that are particularly rich in species (e.g. coral reef); or highly productive areas (e.g. seagrass); or areas of special scientific interest.

Integrated Coastal and Marine Area Management (ICMAM), Project Directorate has initiated a World Bank funded programme for capacity building in essential areas of ICMAM which encompasses the use of modern tools and techniques like remote sensing and GIS for management of critical habitats. Under this programme, a Critical Habitat Information System (CHIS) using GIS facilitating study of management and monitoring of eleven critical habitats distributed in the east and west coast of India is under preparation. One of the areas chosen is Kadmat Island of Lakshadweep.

Marine ecosystems of the Lakshadweep island are unique and known to have very high degree of biodiversity and a number of endemic flora and fauna. Coral reef of these islands is known to have the richest biodiversity in the entire Indian sub-continent. During the past few decades, there has been rapid development in these islands, which has resulted in the degradation of coral colonies on the reef flats as well as in the lagoon, leading to a notable decline in their biodiversity.

The major objective of this study is to create an Information System on the resources of the Kadmat island using Geographical Information System, incorporating components of Remote Sensing and an external database. This would help the decision makers in effectively monitoring and managing the biological wealth of this area.

The Information System has been developed by the ICMAM Project Directorate using information from a variety of sources. The primary data on biodiversity have been collected under the Project “Development of GIS for Critical Habitats” by the National Institute of Oceanography, Goa. The data on fish catch and socio-economics have been provided by the Directorate of Fisheries, Lakshadweep Administration.

2. Kadmat Island – General Description

The Lakshadweep archipelago 8° N – 12° 30' N, 71° E – 74° E), an Union Territory of India is located about 380 - 400 km off Kochi in the Arabian sea (Fig.1). There are 36 islands including 12 atolls, 3 reefs and 5 submerged banks covering an area of 32 km^2 with a lagoon occupying an area of about 4200 km^2.

Fig. 1 - Map of Lakshadweep Group of Islands

Kadmat island one among the Lakshadweep group of islands in Amini Taluk is located between 11° 15' 52" N – 11° 15' 26" N and 72° 45' 41" E – 72° 47' 29" E. The island stretching North to South is 8 km long, 0.5 km wide and has an area of about 3.12 sq. km. The island has a human population of 3985 (1991 census), approximately 1277 persons/sq. km. Fishing is the main occupation of the islanders. The ecological importance of this island, includes presence of three types of habitats like coral reef, seagrass and nesting ground for marine turtles. Based on the ecological and economic value of this island, the Ministry of Environment and Forests and Union Territory of Lakshadweep Government have declared it as a marine protected area for preservation of these habitats and their resources.

3. Climate and Rainfall

The monthly average annual atmospheric temperature varies from 24.2 to 34.4°C. The area comes under South-West monsoon rainfall during June-September. The average annual rainfall at Amini (nearest island in Kadmat) is 1237 mm.

4. Major Habitats of Kadmat Island

Kadmat island has three types of habitats namely coral reef, seagrass and nesting ground for marine turtles. Such habitats are found in about one third of all shallow coastal waters in the tropics and Kadmat is no exception. All three ecosystems are of major importance and are closely interconnected through hydrodynamic circulation pattern and tropic system.

4.1 Coral Reef

The reef zonation of the Kadmat island has reef flat, reef slope and lagoon. Fringing reefs are adjacent to the shorelines and act as spawning and nursery grounds for a large number of fin and shell fishes (Fig. 2). Kadmat reef has a high diversity with a total of 45 species of corals recorded during 1986 (Pillai and Jasmin 1989). The reef of the Kadmat island is now under severe threats due to natural and man-made activities.

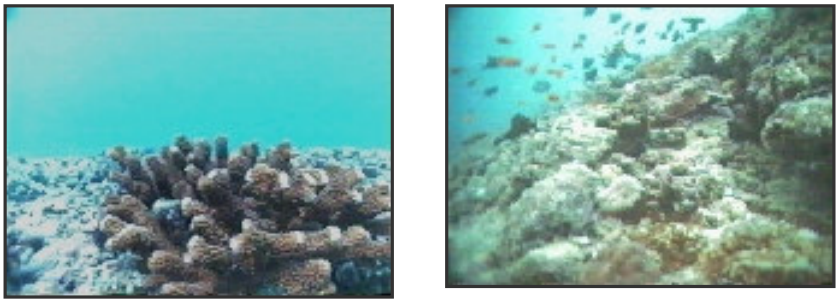


Fig. 2 - Coral Habitat in Kadmat Island

4.2 Seagrass

The seagrass beds are important feeding grounds especially for a number of threatened marine species including turtles and dugongs. They are also important spawning and nursery areas for many species. Seagrass beds are stablising the coastal sediment, substrate and provide vital oxygen to surrounding water masses. The animals like fish which live in these habitats provide an important source of food for coastal and island population. In India 14 species of seagrass were recorded of which 7 species were found in the Lakshadweep group of islands. Seagrass beds in the inter-tidal region of Kadmat island are shown in Fig. 3.

Fig. 3 - Seagrass Habitat in Kadmat Island

In Kadmat island, two species of seagrass i.e. *Thalassia hemprichii* and *Cymodocea rotundata* have been observed.

4.3 Nesting Ground

The island of Kadmat is identified as one of the most important nesting and breeding grounds for marine turtles. In the Indian coastal waters, five species of sea turtles are known to occur. Of these, four species are found in Kadmat island. They are *Chelonia mydas* (Fig. 4), *Eretmochelys imbricata, Lepidochelys olivacea* and *Dermochelys coriacea* (Lalmohan,1989)

Fig. 4 - *Chelonia mydas* (Green Turtle) nesting in Kadmat Beach

Turtle nesting grounds were identified in three places in Kadmat island. They are South Western side of lagoon beach area, South Eastern side of seaward beach area and Northern end of the island. The nesting is mostly observed during the pre-monsoon period (March-April).

5. Biodiversity – Review of past literature

Kadmat is one of the biologically richest islands in the Lakshadweep. Earlier reports on the marine flora and fauna of Kadmat pertain to phytoplankton (Rao, 1990), Zooplankton (Girijavalabhan, et. al 1989).

Table 1 - Overall biodiversity of Lakshadweep Group of islands and Kadmat

1980 – 1990 (No. of species recorded)		
Groups	**Lakshadweep Group of Islands (Overall)**	**Kadmat**
Phytoplankton	28	20
Copepod	32	26
Foraminifera	24	24
Sponges	82	13
Corals	111	45
Polychaeta	28	15
Crustacea	89	89
Mollusca	143	37
Echinodermata	138	124
Turtle	4	4
Birds	25	10
Mammals	8	5
Seaweeds	92	41
Seagrass	6	2
Total	**810**	**455**

Seaweed (Kaliaperumal, *et. al* 1989); Sponges (Thomas, 1989); Corals (Pillai and Jasmine, 1989); Molluscs (Appukuttan, et. al, 1989); Echinoderms (D.B. James, 1989.c); Crustaceans (G. S. Rao, *et al*., 1989); Reef fishes (Jones and Kumaran, 1980); Turtles (Lalmohan 1989. a) and Birds (Lalmohan, 1989. b). The biodiversity of this island compared with all groups of Lakshadweep islands is given in Table-I.

6. Development of the Resources Information System for Kadmat island

The Resource Information System of Kadmat island developed by ICMAM Project Directorate, integrates the existing diverse coastal and environmental data set collected by various organisations on the biodiversity of this island along with data about the landuse, bathymetry and relevant coastal planning and development, to facilitate monitoring and management of the health of the island ecosystem.

The Information System incorporates the following:

- Spatial distribution of corals and seagrass beds around the island.
- Depth contours draped over these habitats to give an idea of depth-wise distribution of corals and seagrass.
- Present status of distribution of phytoplankton, zooplankton, corals, benthos and fishes.
- Information on the previous work done in this area to give an indication of the changes in marine organisms.
- Possible causes for changes in the coral reef environment.

7. Methodology adopted for development of Information System

Remote sensing, DGPS, GIS and RDBMS (Rational Database Management System) along with field survey were used in developing the resources information system for this island. Field and Satellite data were selected as primary sources of information and GIS and RDBMS were used as tools to analyse and develop the complete information system. Data was collected on distribution of phytoplankton, zooplankton, benthos and collection methodology varies with respect to parameters studied.

7.1 Remote Sensing

The present study was carried out using IRS IC 7th March 1997 data (Fig. 5). The Survey of India toposheet was used to rectify the digital data. Base map was digitised using these toposheets and onscreen digitisation of the same was also done in order to get an idea about the present location of the island and their shorelines. The sampling locations were also plotted over the classified map with details such as latitude, longitude, depth and species composition, etc., to substantiate the work done.

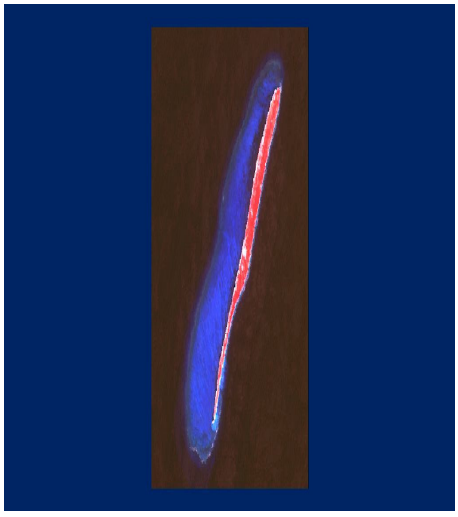


Fig. 5 - Imagery of Kadmat Island

7.2 Relational Database Management system (RDBMS)

RDBMS is the acronym for "**Relational Database Management System**" and is essential a set of collected data stored in the form of tables and a set of programmes to access it.

7.3 Data collected on different parameters

Data on phytoplankton, zooplankton, corals, meiofauna, macrofauna and seaweeds were collected by the National Institute of Oceanography, Goa during November 1998, March 1999 and December 1999. Phytoplankton collection was carried out using a standard phytoplankton net for qualitative and quantitative analysis. Primary productivity was determined using light and dark bottle oxygen technique. Zooplankton samples were collected by half-metre mouth diameter bolting nylon net (0.33 mm mesh size) and volume of zooplankton was measured by displacement method.

The distribution of corals were studied by Line Intercept Transect (LIT) and Scuba diving methods for determining the species diversity. The current fish catch data (Quantitative and qualitative) were collected from Department of Fisheries, Department of Science and Technology and Department of Environment of Lakshadweep Administration in the Kadmat island.

Consequently all these attributes data collected from the various sources were stored as separate tables in the Oracle database and were linked using a common identifier. Tables were created to hold information on:

- Physio-chemical details
- Culturable and non- culturable bacteria
- Flora and Fauna
- Socio-economics

7.4 Geographical Information System (GIS)

Geographical Information System (GIS) is a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referred to the earth. GIS is used for wide application including planning, land-use, geomorphology of the land and coastal areas.

7.5 Methodology

Field survey was done to cover the entire island during March and November 2000. The sampling frequency was also very high since points were recorded at almost every 30 m interval around the island. Sampling locations were accurately recorded using GPS with respect to their latitude and longitude. These points were later used for the digital classification of the island with respect to the habitat. The accuracy of the mapping was ensured due to the tedious and systematic field survey conducted before and after classification for checking and updating the results of classification.

By underwater survey, areas of abundance of corals were identified and observation points were fixed. At each point percentage of live corals was determined visually and confirmation of coral and seagrass distribution done using **ROV** (**Remotely Operated Vehicle**) during November 1999 by a team of ICMAM Scientists.

8. Geomorphology of the Kadmat Island

Kadmat island is spindle shaped, broadest in the middle tapering towards the narrow strip at the southern end. The island does not show any major topographic features but is largely low leveled flat tapped and generally rising to a height of a 2-3 metres above sea level. The geomorphology of the island is shown in Fig. 6. The features associated with the island are reef flat, reef slope, lagoon, sandy beach, island vegetation, etc. The lagoon is quite large and deep along the western side of the island with a narrow beach along the eastern side.

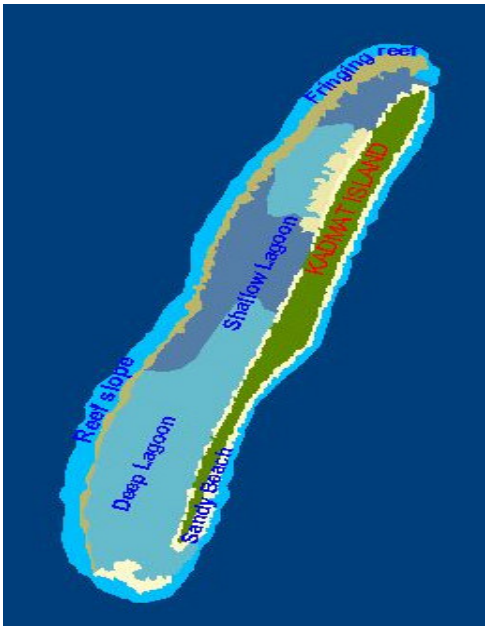


Fig. 6 - Geomorphology of Kadmat Island

The lagoon side of the shore is sandy beach, though at places, beach rock is exposed at the low tide mark. The depth of the lagoon varies from 2 to 3 m. The reef flat is about 50 m width and is totally exposed during the low tide. During the high tide, water exchange takes place between the lagoon and the open sea over the reef.

9. Land use/ Land cover

The island is blessed with copious rainfall and cultivable land is only 5% of the total land area. The island is covered by coconut plantation along with several species of succulent shrubs and low undergrowth that flourish on coral sand. The water supply in the island is from small wells; fresh water is available in these wells throughout the year. Many crops like red grass, groundnut, maize, sweet potato, grains, cereals, millets, papaya, banana and drumstick tree can be grown successfully as inter-crops in the coconut plantation (Fig. 7) without irrigation during the south-west monsoon period.

Fig. 7 - Cultivation of coconut and banana plantation

10. Bathymetry

The bathmetry of the Kadmat island is shown in fig. 8. The lagoon area is shallow and extends up to 1.5 km from the coastline. It has a maximum depth of 1.6 m. The 200 m contour is located at a shortest distance of about 400 m from the coast. It has a tidal range of 0.6 to 1.6 m.

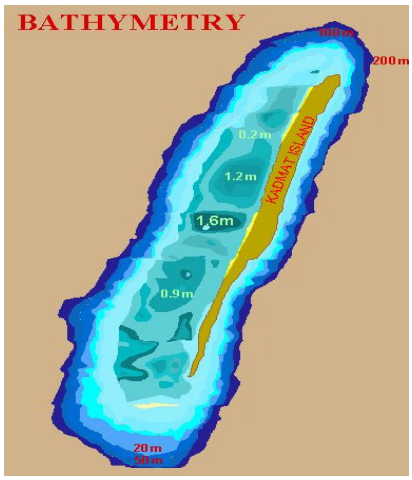


Fig. 8 - Bathymetry of Kadmat Island

11. Mapping of Coral and Seagrass

For mapping of corals and seagrass, field survey was carried out by the ICMAM-Scientists during March and November 2000 in Kadmat island of Lakshadweep. Information on the distribution of coral and seagrass was collected using DGPS, Scuba diving and skin diving methods.

11.1 Coral Reef Area

Fringing reefs are found mostly within and bordering the lagoon. They occur at a distance of 300- 500 m from the shore and mostly within 5 m depth. Patch reef are found scattered in the Northwestern part of the lagoon. The spatial distribution of corals is shown in Fig. 9. Live coral coverage is less than 1%. 9 species of live corals have been recorded in lagoon as well as reef slope area. The recorded species were *Acropora formosa, Acropora robusta, Acropora sp., Acropora subglabra and Acropora tortuosa, Acropora vanghani, Favites sp., Pocillopora verrucosa* and *Lobophytum sp.*

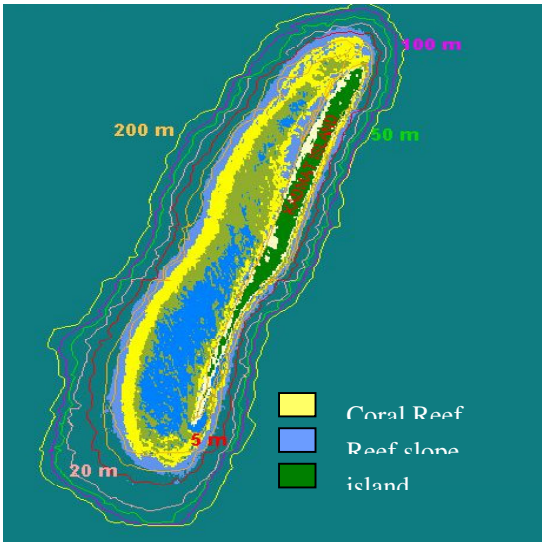


Fig. 9 - Coral Reef distribution in lagoon and reef flat area

11.2 Seagrass Mapping

Seagrass is distributed all around the island covering an area of about 13.8 sq. km. Two species namely *Cymodocea rotundata and Thalassia hemprichii* were recorded.

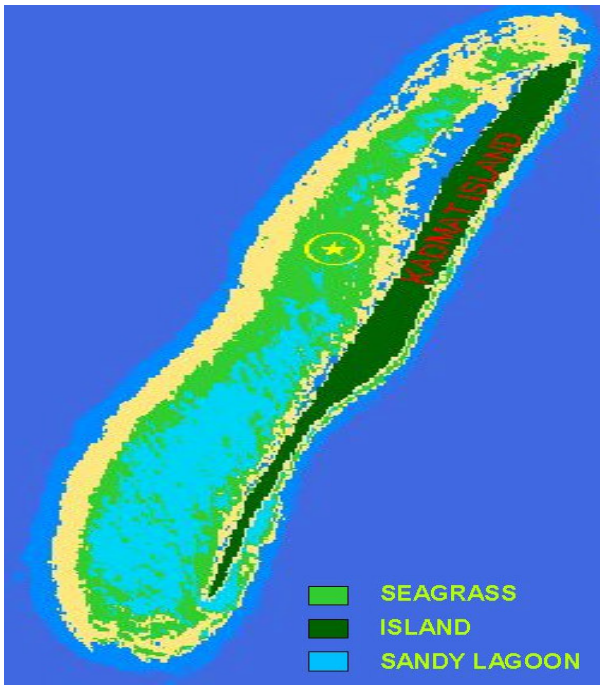


Fig. 10 - Seagrass distribution in Kadmat Island

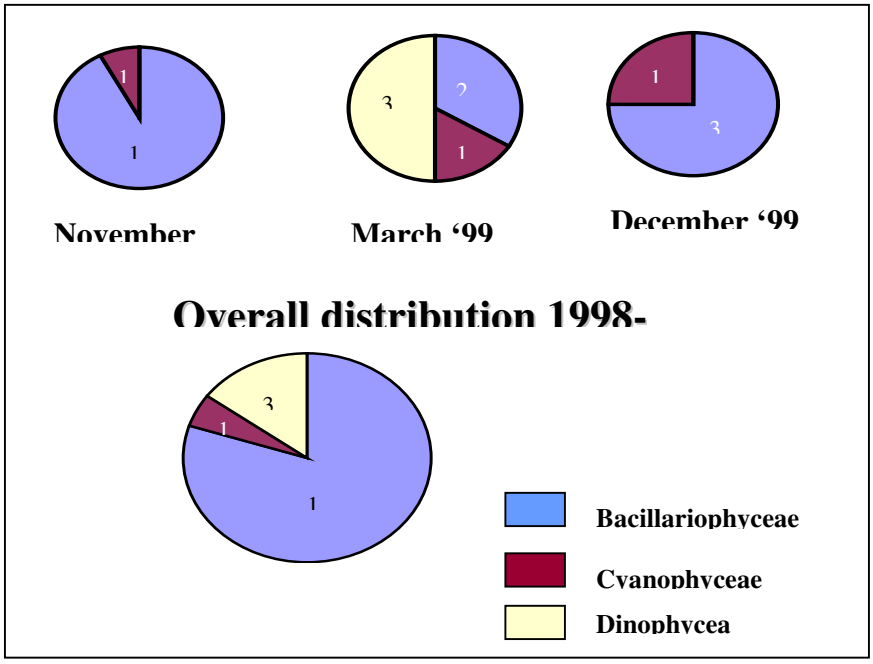
Thalassia hemprichii is dominant towards the reef flat while *Cymodocea rotundata* is dominant along the shore. The patchy group of *T. hemprichii* is also observed in the upper inter-tidal region of the island. The spatial distribution of seagrases are shown in Fig. 10.

12. Marine organisms recorded in Kadmat island

12.1 Phytoplankton Distribution

In the current study (1998-99), 20 species of phytoplankton were recorded, comprising 16 species of Bacillariophyceae, 3 species of Dinophyceae and one species of Cyanophyceae. The qualitative distribution of phytoplankton in reef slope and lagoon area is given in table 2. The abundance of species diversity of phytoplankton is varied in reef slope and lagoon region. Chart 1. shows the seasonal and overall distribution of phytoplankton in Kadmat island.

Chart 1 – Seasonal distribution of Phytoplankton



10 species of phytoplankton were recorded in reef slope area and 6 species were in the lagoon region during post monsoon period. The density of phytoplankton ranged from 1-100 nos./ml. The species diversity and abundance were relatively higher in the month of November. The dominant species recorded were *Achnanthes longipes, Asterionella japonica, Diploneis weissflogii, Navicula sp., Nitzschia closterium, Pleurosigma directum* and *Trichodesmium sp*.

Table 2. Phytoplankton distribution in lagoon and reef slope area

Area	No. of species recorded		
	Nov. '98	March '99	Dec. '99
Reef slope			
Bacillariophyceae	9	2	1
Cyanophyceae	1	1	1
Dinophyceae	-	2	-
Lagoon			
Bacillariophyceae	6	1	1
Cyanophyceae	1	-	-
Dinophyceae	-	2	-

12.2 Zooplankton Distribution

In the current study (1998-99), 19 groups of zooplankton were recorded. The qualitative distribution of zooplankton in reef slope and lagoon area is given in table 3. Copepods constitute one of the most dominant taxa of zooplankton. Totally 36 species of

copepods were recorded, comprising 27 species of calanoida, 7 species of cyclopoida and 2 species of Harpacticoida.

The maximum number of 23 species was recorded (17 species calanoida, 5 species of cyclopoida and one sp. of Harpacticoida) in reef slope area and 13 species were recorded in lagoon area. (Calanoida 7 sp., Cyclopoida 4 sp., Harpacticoida 1 sp.) the November. The density of zooplankton varied from 1-326 nos./cu. m in pre-monsoon to 1-105 nos./cu. m in post-monsoon period. Chart 2. shows the seasonal and overall distribution of zooplankton in Kadmat island.

Chart 2 – Seasonal distribution of zooplankton

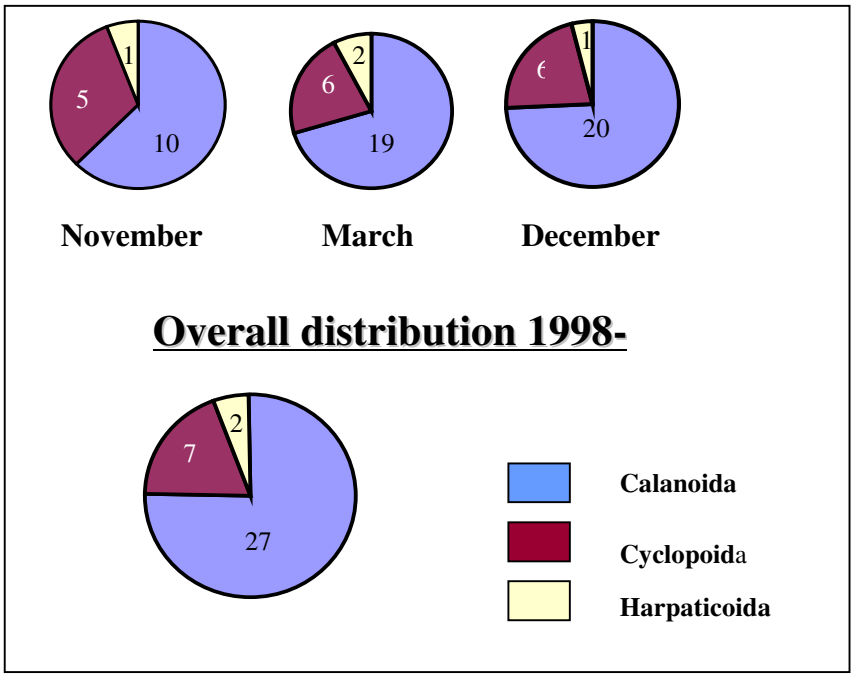


Table 3. Zooplankton distribution in lagoon and reef slope area

Area	No. of species recorded		
	November '98	March '99	December '99
Reef slope			
Calanoida	9	5	17
Cyclopoida	5	5	5
Harpacticoida	1	1	1
Lagoon			
Calanoida	7	7	7
Cyclopoida	4	2	4
Harpacticoida	1	1	1

12.3 Distribution of Foraminifera

In the current study (1998-99) 22 species of Foraminiferans were recorded. The seasonal distribution of Foraminiferans is shown in chart3. There were 10 species of *Quinqueloculina sp.*, 4 species of *Triloculina sp.*, 2 species of *Amphistegina sp* and 1 species each of *Cymbalporetta, Elphidium, Marginopora, Paratotalia, Peneroplis* and *Spiroculina.*

Chart 3 - Seasonal distribution of Foraminiferans

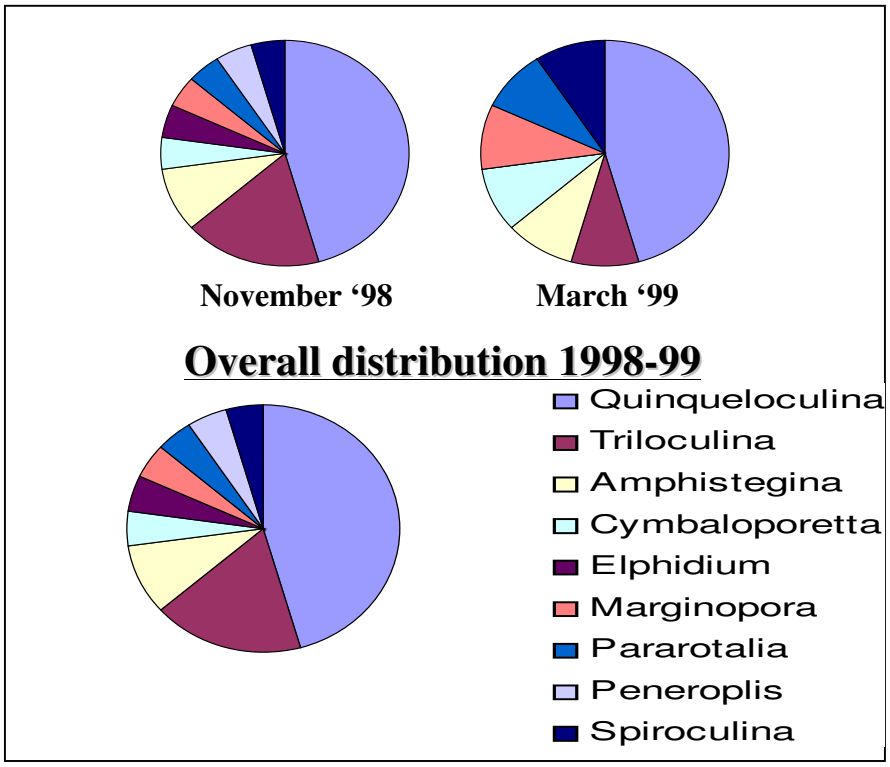


Table 4 - Distribution of Foraminiferans in Inter-tidal and Sub-tidal regions

Inter-tidal Region	No. of species recorded	
	November 1998	March 1999
Quinqueloculina	10	5
Triloculina	3	-
Amphistegina	2	1
Cymbaloporetta	1	1
Elphidium	1	-
Marginopora	1	1
Pararotalia	1	1
Peneroplis	1	-
Spiroculina	-	-
Sub-tidal Region		
Quinqueloculina	10	2
Triloculina	2	1
Amphistegina	1	1

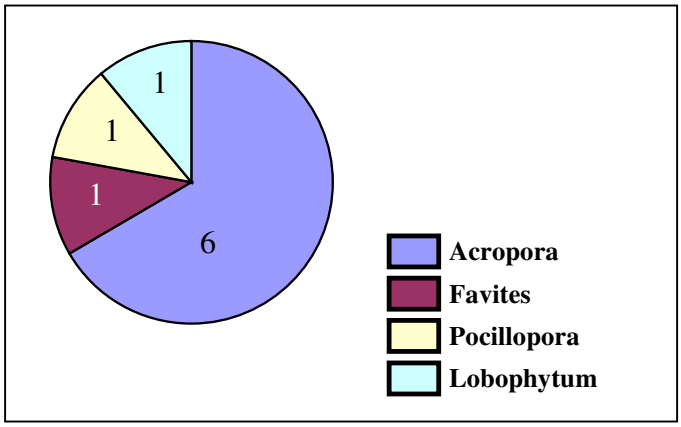
	No. of species recorded	
Cymbaloporetta	-	-
Elphidium	-	-
Marginopora	-	1
Pararotalia	1	1
Peneroplis	-	-
Spiroculina	1	1

The distribution of Foraminiferans in Inter-tidal and Sub-tidal regions is given in Table 4. The maximum number of species was recorded during the month of November compared to March.

12.4 Distribution of Corals

In the current study (1998-99) 9 species of live corals were recorded. The distribution of corals in reef slope and lagoon area is given in chart 4. They are *Favites, Pocillopora and Lobophytum sp. Acropora formosa, Acropora robusta, Acropora subglabra, Acropora tortuosa, Acropora vanghanis and Acropora sp.*

Chart 4: Distribution of corals in Lagoon and Reef slope area



12.5 Distribution of Benthos

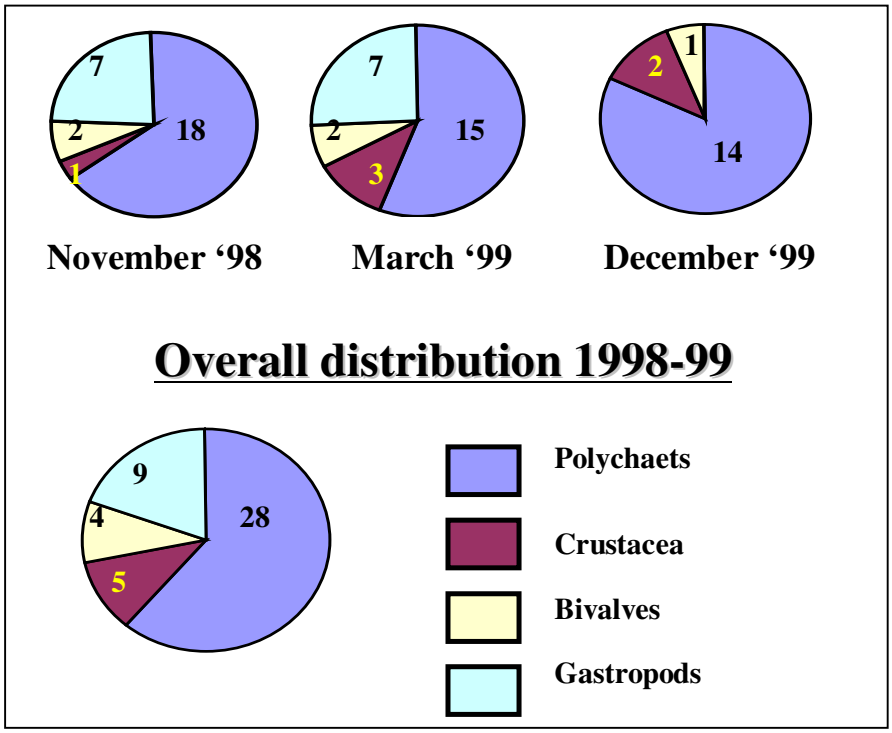
In the current study (1998-99) 33 species of benthic organisms were recorded in reef slope and lagoon area of Kadmat island. The distribution of Macrobenthos in inter-tidal and sub-tidal region is given in Table 5. There were 23 species of polychaetes, 3 species of crustaceans, 3 species of bivalves and 3 species of gastropods.

Table 5. Distribution of Macro benthos in inter-tidal and sub-tidal regions

Inter-tidal Region	No. of species recorded		
	November 1998	March 1999	December 1999
Polychaets	9	7	10
Crustacea	-	-	1
Bivalves	1	2	1
Gastropods	3	2	-
Sub-tidal Region			
Polychaets	17	11	11
Crustacea	1	2	-
Bivalves	2	2	-
Gastropods	7	2	-

During the month of November, 21 species of inter-tidal and 27 species of sub-tidal macro-benthos were recorded. The chart 5 shows the seasonal distribution of benthic organisms in Kadmat island. Maximum number of benthic organisms were recorded in the sub-tidal region.

Chart 5 - Seasonal distribution of benthic organsims



12.6 Distribution of Seaweeds

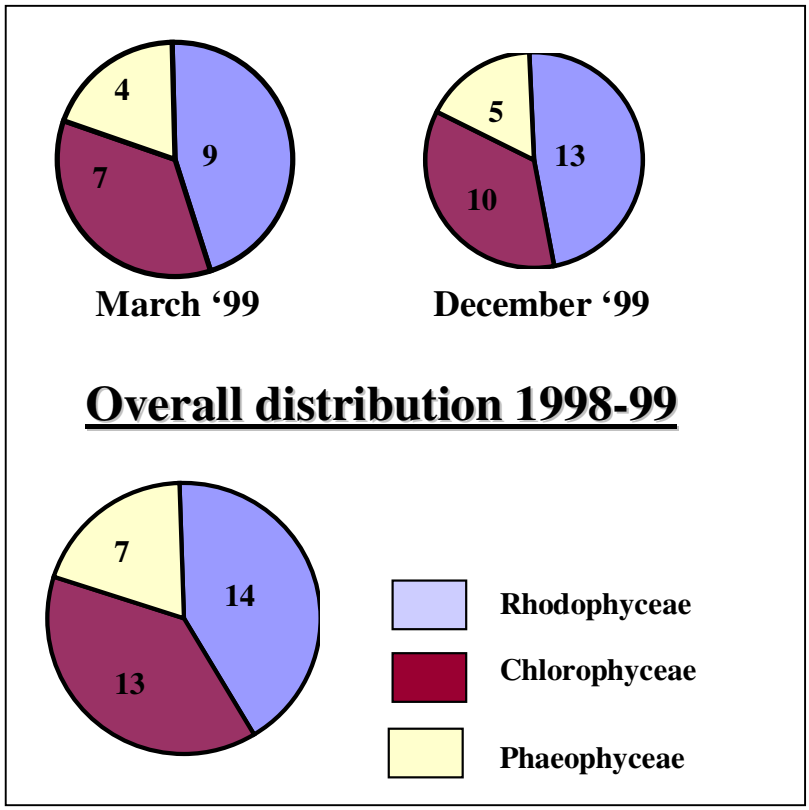
In the current study (1998-99) totally 34 species were recorded. There were 14 species of Rhodophyceae, 13 species of Chlorophyceae and 7 species of Phaeophyceae. The distribution of seaweeds in the reef slope and lagoon area is given in Table 6. A

maximum number of 28 species was observed during the month of November and 20 species in March. The maximum species diversity was observed in the lagoon area only (Rhodophyceae 10, Chlorophyceae 10 and Phaeophyceae 5). The chart - 6. shows seasonal distribution of seaweeds in the Kadmat island.

Table 6. Seaweed distribution in lagoon and reef slope area

Area	No. of species recorded	
	March 1999	December 1999
Reef slope		
Rhodophyceae	4	-
Chlorophyceae	2	-
Phaeophyceae	1	-
Lagoon		
Rhodophyceae	9	13
Chlorophyceae	7	10
Phaeophyceae	4	5

Chart 6 - Seasonal distribution of Seaweeds



12.7 Reef Fishes

In the current study (1998-99) in all 124 species of reef fishes were recorded. They comprised 52 species of capture fishes and 72 species of ornamental fishes. Among capture fishes, 7 species belonged to Chondrichthyes and 45 species were teleosts.

12.8 Marine Turtles

Four species of turtles viz., *Chelonia mydas*, *Lepidochelys olivacea*, *Eretmochelys imbricata* and *Dermochelys coriacea* were found in Kadmat island. The turtle nesting ground was observed in the Northern end of the island during pre-monsoon season.

13 Fishery Resources

Indian marine fisheries are multi-gear and multi-species in nature with diverse fishing practices. Trawl nets and pole line are the principal gears operated in the Kadmat island. The major economic activity of the Kadmat Island community is oceanic tuna fishing. Reef fishes have traditionally been exploited to a very low subsistence level. The lagoon and reef patch fisheries are extremely important to the survival of the islanders, since they provide them with a safety blanket for food security during the monsoon season. During this season, the fishermen are not able to venture into the open sea. The fishermen use locally made wooden craft for fishing. The chief fisheries comprise sharks, rays, tuna, skipjack tuna, perches, carangids, sail fishes, rainbow sardine and cephalopods. The tuna pole and line fishery at present is carried out in a narrow belt around the island.

The marine fish catch from Kadmat island during 1991-95 ranged from 107 tonnes to 300 tonnes. Table 7 and 8 give the quantum of fish landed during 1999 and 2000 at the Kadmat island.

Fresh tuna caught is processed in the canning factory at Minicoy. Otherwise the fishermen dry the tuna in the sun after cooking and smoking. The resultant product is known as “Mas”, the value of which on an average is Rs.75 – 100/kg during 1998. Fish aggregating devices known as “Papan” were introduced in Lakshadweep, which appears to have increased the fish catch.

Table 7 – Group-wise fish landing details (in kg) during 1999

Sl.no	Fish Group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Sharks	230		170	2090	2470						865	400
2	Rays			265			50		90	165	1095	220	
3	Barracuda												
4	Perches	1999	1437	671	210								100
5	Carangids	790	530	392	105							175	305
6	Coral fishes	1285	1287	616	45	125					2680		1295
7	Flying fishes	635	163	190								1	
8	Cat fishes	894	180	1062	820	1015	650	1250	679	825		1565	
9	Goat fishes	459	761	364		960						1	
10	Seer fishes	337		10	365	100				1841	255		85
11	Sailfishes	916	628	30	335	55					50	180	55
12	Rainbow sardine	188			295	252	250			215	75	125	550
13	Trigger fishes	212											
14	Skipjack tunas	10288	106629	29905	15770	400					11860	33850	44395
15	Other tunas	18449	3270	20953	20750	4685	1055	920	541	2115	10620	76715	25355
16	Octopus (Molluscs)	515	1251	749	85							10	
17	Miscellaneous	1656	1668	520	1485	1440	740	685	705	1605	1240	605	1450
	Total	**38853**	**117804**	**55897**	**42355**	**11502**	**2745**	**2855**	**2015**	**6766**	**27875**	**114312**	**73990**

Table 8 - Groupwise fish landing details (in kg) during 2000

Fish Group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Sharks	215	95	4395	365	215	15	210		215	575
Rays		125		20					50	
Barracuda				45						35
Perches					454	229	280	157	515	588
Carangids				60	413	365	285	149	139	226
Coral fishes				65	690	110	552	555	356	436
Flying fishes					593	176	20			30
Cat fishes	545	800		775	3167	532	1868	2935	2035	2578
Goat fishes				25	225	15		92	714	83
Seer fishes	30							680	711	588
Sailfishes	210	120		50	215		125	1455	350	265
Rainbow sardine	140	170		360					73	71
Trigger fishes					30	5				
Skipjack tunas	20650	235		50755	13150					10940
Other tunas	23000	5876	21940	2550	365	754	1657	1630	981	3228
Octopus (Molluscs)	105	195		15	24			30	25	94
Miscellaneous	815	9351	5420	1225	921	874	1363	1338	952	1394
Total	**45710**	**16967**	**31755**	**56310**	**20462**	**3075**	**6360**	**9021**	**7116**	**21131**

14. Socio-Economic Status

According to Census 1991, Kadmat island has a total population of 3,985 consisting of 2032 males and 1953 females. The population density per sq. km. is 1227 nos. Malayalam is the predominant language spoken by the people. The attitude of people towards literacy and education has been recorded to be positive and hence the literacy rate is very high (85%). The educational facilities comprise three nursery schools, three junior basic schools, a senior basic school and a college. For higher education, the students have to come to the main land. Education for girls is highly encouraged and totally free of cost.

Fig. 11a and 11b Coir Fibre Factory at Kadmat

The main occupation is fishing, coconut cultivation and coir twining (Fig 11a,b & c). 230 persons are involved in fishing and allied activities. There are about 10 mechanised boats, 15 country wooden boats and various kinds of gears such as long line, hook, trawl net and shore seine are used for fishing. Four cooperative societies are functioning and they provide rice, kerosene and other commodities to the island people. Main source of income is from tuna fishing and coconut cultivation. The per capita income of fishermen is about Rs.3460/month.

Fig. 11 – Desiccated coconut plant at Kadmat Island

15. Causes for degradation of Coral Reef

In general, major threats to coral reef are human pressure in coastal areas, which have immediate localised impacts and natural pressure, particularly those related to global climate change. It has been estimated that 10% of all coral reefs have been irretrievably damaged and that a much greater percentage is threatened. (IUCN 1976).

The causes of critical habitat degradation are aggregate extraction and dredging, coastal reclamation, over-exploitation of biological resources and unplanned tourism activities. The natural pressures are cyclones, coral bleaching, coral disease, predation of "crown of thorns" global change etc. In Kadmat Island, the following activities appear to pose a major threat to coral reef as well as seagrass habitats.

15.1 Dredging Activities

The main entrance to Kadmat is dredged (Fig. 12) and the dredged materials are dumped into the lagoon resulting in increased sedimentation and consequent high mortality of corals. The dead corals disintegrate and are covered by growth of algae. Due to the absence of corals, the number of fish and invertebrate species has declined.

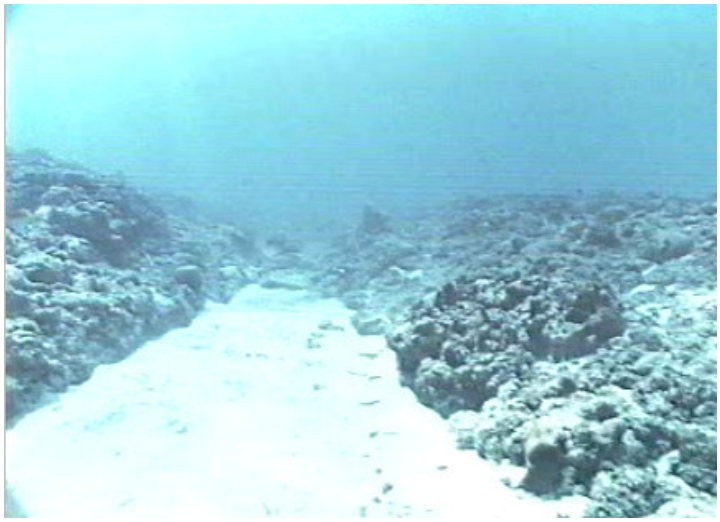


Fig. 12 - Dredging of corals in western side of island

15.2 Coral Blocks and Coral Sand Mining

The sand along the beaches consists of white coral sand, produced by crushing coral blocks of the sub-littoral areas by wave action and transported on to the beach.

The mining of coral blocks (Fig. 13) in Kadmat beach is being done for many years for constructing houses (Fig. 14), fences and producing quicklime. The total amount of coral blocks mined has not been estimated, but it may be that a great amount of coral blocks has been removed from the coral flats and they may affect the changes of geomorphology of islands.

Fig. 13 - Mining of coral blocks

Fig. 14 - Coral used for building construction

The coral mining has resulted in slow death of the reef and decrease in sources of the coral sand to the beach. The coral sand mining has resulted in increase of shore erosion.

15.3 Erosion

Kadmat island had experienced severe coastal disturbance over the last decade. Due to extensive excavation of rocks from the reef flats for building construction, the shorelines has altered and erosion of the beach has become prominent during South-West monsoon. (Fig 15)

Fig. 15 - Erosion in western side of beach in Kadmat island

15.4 Coral Bleaching

Extensive coral reef bleaching appears to have occurred during abnormal seawater warming during 1998. There was an increase of about 1 to 3^{o}c above the normal temperature of seawater in summer season. It is estimated that 95 – 98% of corals were

bleached. Line transect assessment in some reef sites showed decrease in several coral community components after bleaching event. According to Pillai and Jasmin (1986), 45 species of live corals were observed during 1986. However, after the bleaching effect only 9 species of corals were observed in the lagoon as well as reef slope area of Kadmat island. The total live coral cover, number of species, number of colonies and species diversity of other fauna have decreased (Fig.16). Thus, the incidence of coral bleaching and large scale mortality at Kadmat might be related to one of the strongest El-Ninos of this century. El-Nino induced seawater warming was detectable through satellite pictures which revealed that the sea water temperatures have shown an increase of 2 to 3^{o}c during 1998, which is higher than the seasonal maximum in many reef areas.

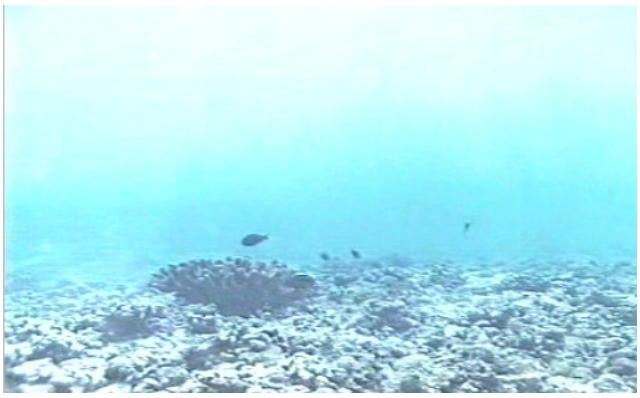


Fig. 16 - Dead coral observed in reef slope area

15.5 Sand Mining

The sand in lagoon area is removed by dredging operation for improving harbours and sea channels in the Kadmat island. This activity disturbed greater or lesser degree of plumbs of fine coral particles which are carried along in suspension by currents, causing coral smothering and changes in reef and sea grass habitats. Fig 17 depicts the coral sand mining in north-eastern side of the Kadmat island.

Fig. 17 - Coral sand mining in North Eastern side of the island

15.6 Coastal Reclamation

During the past few decades there has been rapid development activities in Kadmat island. Coast development activities include building construction and road development in sand dune areas in the island. Reclamation and construction of reef or sand dunes to house sites have totally destroyed the entire area and disturbed the pattern of currents in the lagoon.

15.7 Acanthaster infestations

The crown of thorns star fish *Acanthaster planci* is a large star fish which feeds on coral tissue and has increased mortality rate, especially of *Acroproa* and *Pocillopora* corals leading to decrease in the population of these species.

15.8 Sponge infection (Boring sponge)

Eighteen species of boring sponges were observed in Lakshadweep group of islands. The total percentage of boring sponge species in Kadmat island was 58.3% (P.A. Thomas 1988). The abundance of coral skeleton may be the main cause of the richness of boring sponges. The massive and branching corals are infested by boring sponges.

15.9 Other causes for coral reef degradation

- Overgrowth of the calcarious green algae *Halimeda* invading into live coral areas affecting the growth and survival of the coral species.
- Unplanned and unregulated tourism activity in the island is also one of the important factors for degradation of critical habitats.
- Seasonal stormy weather conditions and wave surge probably cause serious damage to coral communities by shifting and over turning substrate boulders.

16. Suggestions for critical habitats management in Kadmat Island

- Islanders make bricks out of coral shingle and use them for house and building construction. This should be reduced or banned.
- Conduct training and awareness programmes to island people on conservation of corals.
- Regulation on usage of corals and sand from the beaches and coastal waters for construction and other purposes.
- Dredging and underwater blasting in and around coral reef area should be prohibited/banned.
- Prevent dumping of coir waste materials into lagoon areas.
- Dredged materials should not be disposed off in the reef and lagoon areas.

17. Conclusion

The information system can be used as a baseline to conduct monitoring of biodiversity in future.Mapping of corals and seagrass using remote sensing and GIS has demonstrated that these tools can be excellently used for monitoring and management of these habitats in the Kadmat Island.

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