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MARINE LIVING RESOURCES OF THE UNION TERRITORY OF LAKSHADWEEP —

An Indicative Survey With Suggestions For Development

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Limited Circulation

19. ENVIRONMENTAL DAMAGE AND CONSEQUENCES

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INTRODUCTION

The atoll environment, in general, is a relatively restricted ecosystem where the impact of interference of man and nature will manifest conspicuously within a short time. The habitat is fragile, diverse and easily vulnerable and the effects of adverse factors on such systems are often of very serious consequences. Almost all inhabited atolls of the world today are facing environmental stress both in the terrestrial and aquatic habitats. The post Worldwar II activities on the Indo-Pacific atolls, such as active settlement, extensive cultivation of crops, military establishments, atomic tests, oil exploitation, pollutions of various kinds, over exploitation of resources, wanton destruction of fauna and flora, introduction of exotic plants and animals, dredging and construction activities among the man made factors; cyclones, sea erosion, El-Nino, pests and predators coupled with natural senescence of corals among the natural factors are the major agents that have effected notable changes in the physiography, morphology and biotic communities of the atolls all over the world. Lack of large buffer zones around oceanic islands is a major impediment in the replenishment of the fauna, if subjected to depletion due to causes either natural or man made.

Many of the oceanic islands are threatened, endangered or modified. The protection and conservatian of various atolls needs different approaches and this can be achieved only with the understanding, co-operation and support of the local people and administrators (Dhal, 1985).

The Lakshakweep atolls are no exception to this global phenomenon of deterioration of reefs and their environs. The post independent years have witnessed brisk developmental activities in these atolls which have visibly improved the living conditions of the inhabitants but not without side effects on the marine and terrestrial habitats (Pillai, 1983; 1985, 1986; Pillai and Madan Mohan, 1183). Pillai (1989) has presented a detailed account of the environmental damages in the Minicoy atoll based on his observations both in the terrestrial and marine habitats over a period of 15 years. Wells (*in lit*) has presented a status report on the ecological problems faced by these atolls stressing the need for conservation of the islands. During the present survey attention was paid to the ecological conditions in man. islands including factors such as siltation, death of corals, bio-erosion etc., and their consequences. These observations are reported in the present communication.

CHANGES IN SURFACE MORPHOLOGY

Ever since human settlement, the natural surface morphology of the islands appears to have been altered. The surface soil was removed in many places and dumped to form hillocks as seen in Minicoy by early settlers to make the land cultivable. Lime stone and sand stones were mined in large quantities as in Minicoy, Kadmat and Kiltan for construction work. In Minicoy the eastern side has still several pits from where lime stone is quarried, In Kadmat island there is solid lime stone stratum at the central part of the island which is mined in large quantities for construction work. Kiltan has a sand stone stratum at a depth of about 1 m which was cut out into large slabs for the construction of residential buildings (Figs. 1, 2). A large number of pits and ponds present are all man made. These longterm activities have changed the terrestrial face of the Lakshadweep atolls as in the case of many other inhabited Indo-Pacific islands.

VEGETATION

Mangroves are not found in Lakshedweep at present. The natural vegetation dominated by *Thespesia* and *Pandanus* along with many others are almost lost. Pillai (1983) has pointed out the recent destruction of natural vegatation at Minicoy atoll in the last few

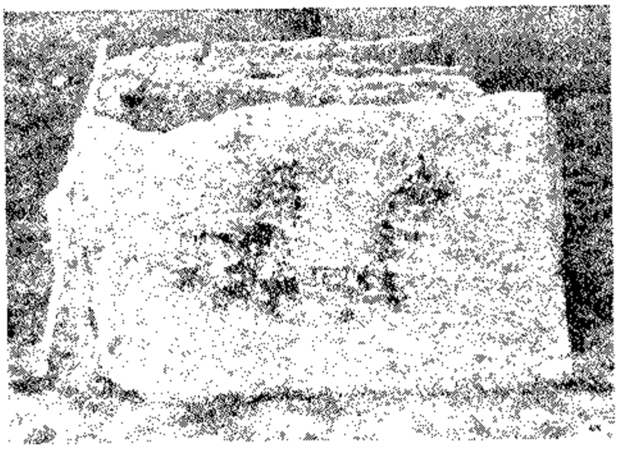

Fig. 1. Sandstone mining at Kiltan, 1974.

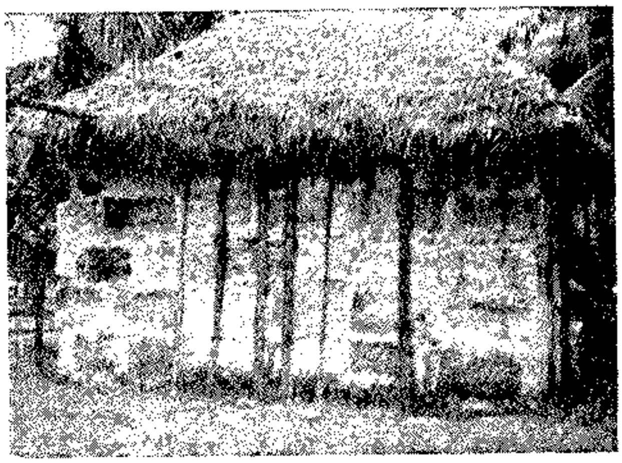

Fig. 2. A dwelling hut constructed with sandstone blocks at Kiltan.

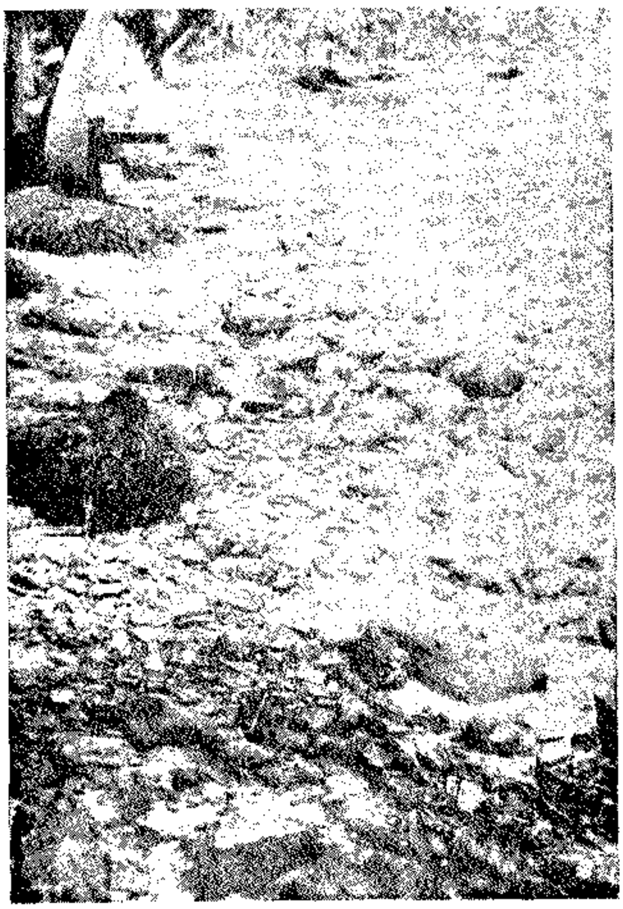

Fig. 3. Human refuse thrown at the Minicoy lagoon, 1982.

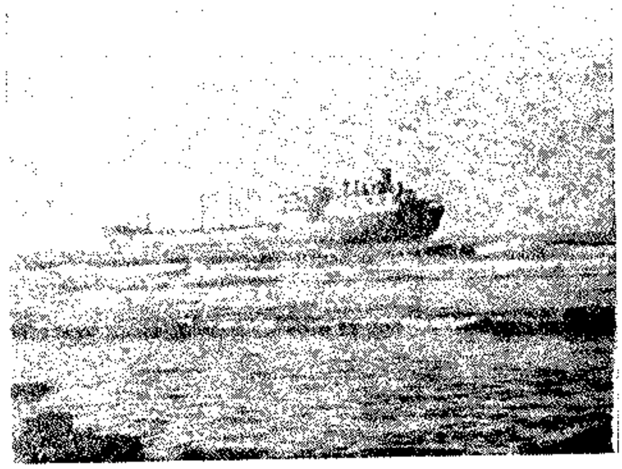

Fig. 4. The American tanker *Transhuron* aground at Kiltan in 1974.

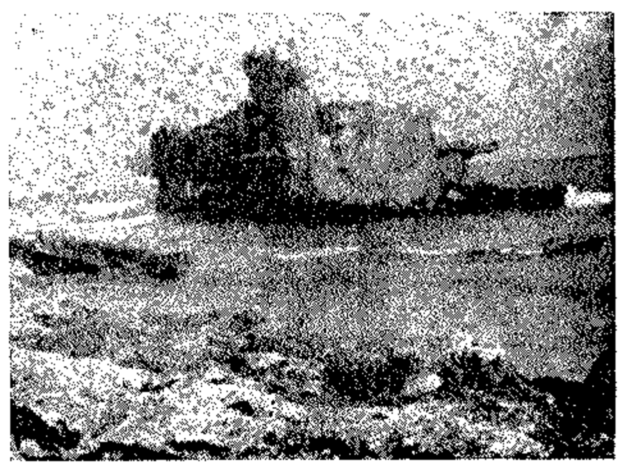

Fig. 5. Transhuron as seen in 1987 January.

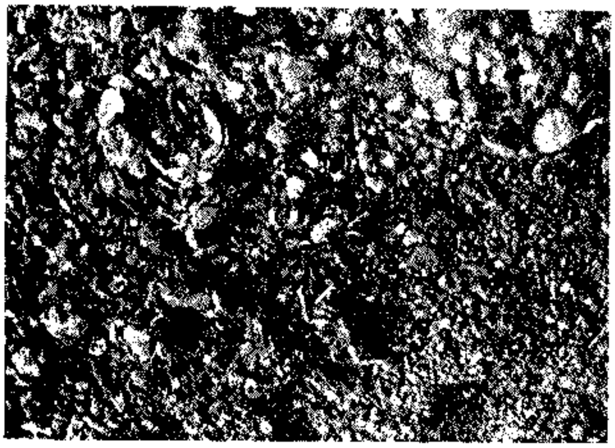

Fig. 6. The blackened intertidal reef flat and dead shore crabs at Kiltan as a result of Transhuron oil spill, 1974.

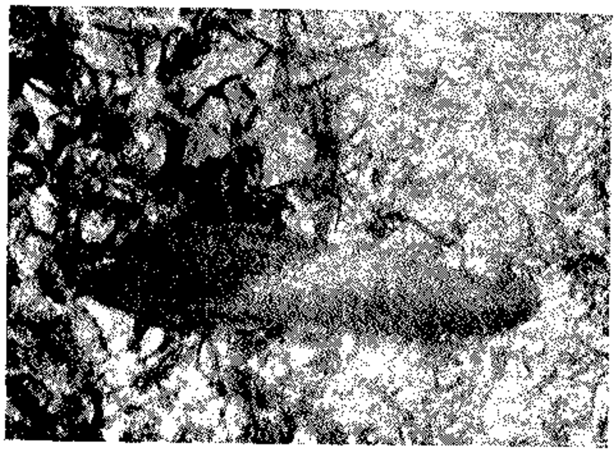

Fig. 9. A closer view of the area with sea grass and holothurians.

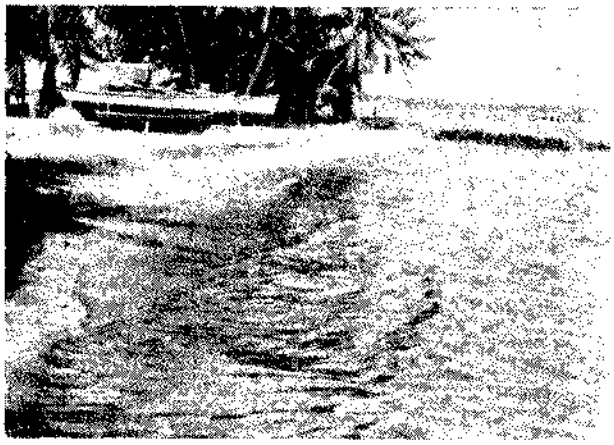

Fig. 7. An instance of oil pollution at Minicoy from undetermined source in 1981.

Fig. 10. Sea erosion at the windward side of of Amini Island, causing deposition of sand on windward reef flat.

Fig. 8. Interference of sand flat on reef flat at the windward side of Amini restricting coral growth to the outer zone.

Fig. 11. Sea erosion of very high magnitude at the lagoon shore of Minicoy as seen in 1932.

Fig. 12. Granite bunds and concrete tripods against sea erosion at Minicoy Atoll.

Fig. 13. The lagoon beach of Chetlat Island.

Fig. 14. The northern tip of Kiltan lagoon is almost filled with deposition of dredged soil. Local people search for *Octopus* along with dead shoals.

Fig. 15. Fishing with cast net and breaking dead and live corals at Kiltan lagoon.

Fig. 16. The shruby thickets of *Thespesia* seen in Kiltan in 1974. None exist today. The vegetation is fast vanishing.

Fig. 17. Destruction to recent natural thickets of *Pandanus* in Minicoy (1982) for expanding settlement and agriculture.

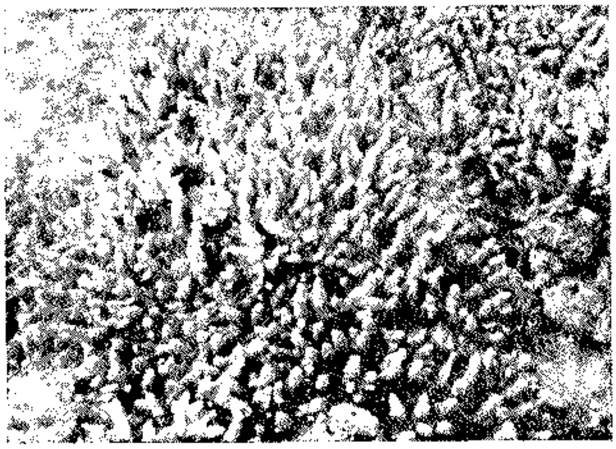

Fig. 18. A thicket of *Acropora aspera* at the windward reef of Amini island (south side).

Fig. 19. Mass mortality to corals at Minicoy lagoon as a result of excessive silting. The giant clam *Tridacna* is also dead in large numbers (1982).

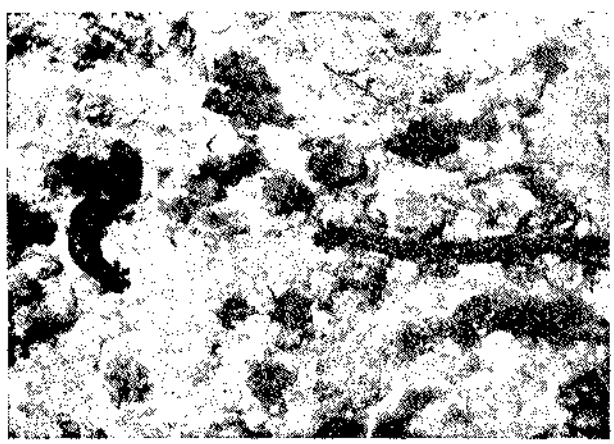

Fig. 20. *Holothuria (Mertensiothuria) leucospilota* feeding on algae to convert in to lagoon sand at Androth.

Fig. 21. Stones turned upside down and left-Minicoy reef flat.

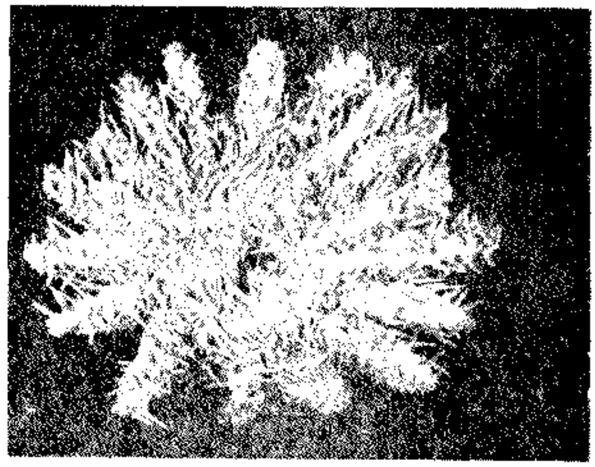

Fig. 23. The crown of thorn *Acanthaster planei.*

years as a consequence of expanding settlement and agricultral operation (Figs. 16, 17) During a study visit to Kiltan in 1974 thickets of *Thespesia* were observed at the northern half. However, none was visible in 1987. The introduction of cattle and goats into atolls has also put servere grazing preassure on the ground vegetation and most atolls in Lakshadweep will shortly face fodder scarcity unless the level of live-stock is scientifically managed (Pillai, 1983). On the whole the natural vegetation of the atolls is fast vanishing and plants introduced from the mainland are taking roots.

THE COASTAL ZONES

The coastal zones of the islands have been subjected to many changes. These include construction activities, sea erosion and pollution of the beaches. Sea erosion is rampant in many atolls as is evident at Minicoy, Kavaratti, Amini and Chetlat (Figs. 10, 11, 12, 13). The loss of land to sea in these tiny islands is of relatively very high magnitude. Preventive measures by putting tripods have already taken shape. But a more careful and effective costal zone management for these islands are called for to protect them from sea erosion. The effect of sea erosion is also manifested in the lagoon by way of the deposition of sediments affecting the coral growth.

POLLUTION

Coastal zones of the atolls are also subjected to pollution by human refuse (Fig. 3), excreta and fish wastes. In Minicoy, the landing places are strewn with the wastes from tunas. The tendency to defecate on the beaches by the local people due to lack of modern facilities is also a major problem along the beaches in many islands.

During monsoon, tar balls and oil from undetermined sources reach the shores of Lakshadweep and was observed in Minicoy. Large quantities of withered oil reached Minicoy in 1981 and got deposited on the beaches near the Jetty (Pillai unpub. observ ation, Fig. 7). But no mortality to animals was observed.

A large scale oil pollution (Figs. 4, 5, 6) from the American Tanker "Transhuron" took place in Kiltan Atoll in September 1974. There was considerable spillage of oil at the northern tip of the atoll and large quantities got deposited along the intertidal and upper reef flats and lagoon shore. A long term study of the immediate and subsequent effects of this spill on marine fauna of Kiltan atoll was undertaken by the scientists of C.M.F.R.I. Approximately 3325 tonnes of oil was thought to be spilled from the Tanker as per the estimate of the officials of Indian oil Corporation who visited the Thanker on aground. The northern tip of the island was the worst affected. Upper zones of the reef flat and the shores were blackened. The southern side of the island along the lagoon beach was also polluted by oil. Floating oil was present for a week in the lagoon along the shore. It was furnace oil with a pungent smell. There was no major fish mortality. However, intertidal organisms met with instant mortality. After a week of the oil spill (5th of October, 1974) large number of the planktonic ostracod *Cyprinida dentata* was found dead and washed ashore on the lagoon side, though vertical and horizontal hauls for plankton in the lagoon and open waters revealed no dead plankton soon after the oil spill. Due to the continued presence of oil at the low water mark in the lagoon the benthic and interstitial organisms in the lagoon and shore slowly started dying after a fortnight of the spill. The worst affected were the holothurians *Holothuria pardalis* and *H. impetiens* in the lagoon; many of which were found dead and washed ashore. *H. rigida* was struggling in shallow waters where oil presisted. many eviscerated and died slowly. *Stichopus chlorodotus* which were profusely present in Kiltan during 1974 also died in large numbers (at present there is a marked reduction in their number in the lagoon). Polychaetes such as *Mesochaetopterus minutes* came out of the tubes and died after a week onwards. However, *Hippa* which were very common in the lagoon shores were healthy and active even after a fortnight of the oil spill. The beach clam *Mactra cuneata* started surfacing on the affected shores after two weeks and many died, showing that prolonged exposure to oil is lethal to them, though they can survive short exposures to crude oil by rightly closing the shells.

On the northern shore, the shore crabs *Eriphia smithi, Leptodius exaratus, Grapsus aibolineatus, Actaeodes hirstutissimus, Pseudoliomera lata* and *P. variolosa* were the species that met with instant mortality. The isopod *Ligia exotica* also faced mass mortality. The hermit-crabs, though found heavily coated with oil on their shells, were not affected. The intertidal gastropods such as *Cellana radiata, Trochus radiatus* and *Drupa tuberculata* were found to be dying after two weeks of the first oil spill. They all met with a slow death.

Live corals were not affected by this spil either on the reef flats or on lagoon shoals. Oil generally floats on the water and unless it gets clogged on the coral colonies oil spills generally do not cause mortality to corals. However, prolonged and chronic oil pollution can affect them adversely.

No beach cleaning operation or any detergent was used at Kiltan during this oil spill. The cleaning was effected by the natural process of wave action. A team (including one of us,) (Pillai) again visited the Atoll in March 1975 to study the prospect of recolonisation of intertidal organisms where mortality was observed soon after the spill. Though adult crabs were absent, smaller ones were observed in rock pools and on intertidal rocks. This indicated that recolonisation was not due to the migration of adults but was only due to the recruitment of larvae after the conditions were improved. However, in the intertidal sandy shores there was no noticeable improvement in the interstitial fauna. Examination of the affected area in 1987 January, nearly after 12 years of the Transhuron oil spill in Kiltan, shows that the area is still having a paucity of shore crabs.

Although there is no major pollution now at Lakshadweep, the coconut husks kept for retting along the beach under stones is one source of pollution. The essence from the coconut fibres oozes into the sea water killing all the intertidal organisms. It has been observed at Kiltan and Chetlat Islands that there are no intertidal organisms under stones where the coconut husks are kept. There is also a coir factory in Kadmat Island from where considerable amount of effluents are let into the sea.

THE MARINE HABITATS

The marine, especially the lagoon habitat in almost all habited atolls in the Lakshadweep has undergone drastic changes. Lack of earlier surveys and documentation of the fauna, except perhaps in Minicoy and Kiltan, as well as paucity of continuous observations by marine biologists is a major handicap in tracing recent change, if any. We have such continuous observations in Kiltan and Minicoy at least for a period of 12 to 15 years based on which some conclusions are already drawn (Pillai, 1971, 1983, 1985, 1985; Pillai and Madan Mohan, 1986). Some habitats are threatened, others endangered, though not fully modified. During the present survey most of these atolls were studied with a view to assessing the effect of human interference. But as already pointed out, effective comparison is not possible due to lack of early information on the ecology and fauna of most of the atolls. Dredging of the reef flats at the channels and lagoon bottom, construction of jettys in the lagoon and near shore, sea erosion and exploitation of the limited resources without restriction are the major factors that have adversely affected the lagoon habitats.

DREDGING

The deleterious effects of dredging (both direct and indirect or instant and long term) on corals was stressed by many scientists (Nashihira and Yamazato, 1994; Wells, 1966). Pillai (1983) has pointed out dredging as a major factor that killed large number of corals in the Minicoy lagoon. The lagoons of Lakshadweep including Minicoy, Kavaratti, Amini, Kadmat and Kiltan were subjected to long term dredging by the Lakshadweep Harbour Department to permit entry of the mechanised vessels into the lagoon. At least in Minicoy and Kiltan it was observed that dredged soil was deposited on the lagoon shoals (as in Minicoy) and lagoon reef flat (as in Kiltan) (Fig. 14) killing corals of extensive areas. Instances of mass mortality of corals are still visible at the northern end of Minicoy near the shore (opposite to old Leper's colony) and at Kiltan. Subsequent sediment transport in the lagoon is adversely affecting the coral growth. For some time in the past the administration stopped all types of dredging in the Lakshadweep, but it was re started in Amini in January 1987. Amini is an island with mostly filled up lagoon and very few corals and fishes are found in the habitat. Without dredging it is rather impossible for the mechanised boats to enter the lagoon. Since the coral growth is poor and there is no live-bait fishery associated with corals the effect of this operation in Amini will be only minimum. However, in Kavaratti, Minicoy and as far as seen at Kiltain dredging has certainly done damage to coral growth.

Natural calamities: Natural calamities like cyclones, storms and tidal waves take a heavy toll of the fauna of the coral reefs. Cyclones not only destroy the vegetation but also the coral reefs and their fauna. An account of cyclones that hit Lakshadweep island has been given by Jones (1989). Though the natural calamities cannot be prevented it is essential to document the damage done to the reefs and associated fauna after cyclones.

THE STATE OF CORAL GROWTH IN LAKSHADWEEP

Corals all over the world are fast dying out due to several reasons. They have dominated the benthic marine communities of the tropical waters for several millions of years and might be experiencing natural senescence and may vanish from the warm waters in course of time following the footsteps of their ancestral-tetra corals. But such an assumption is no solution to the mass mortality of corals experienced in several reef provinces all over the world due to many man made causes and sudden natural calamities Dredging, chronic oil pollution, sedimentation, prolonged exposures El-Ninos, cold water runoff on to the reefs, exploitation, predators and overexploitation for industrial purposes (Pillai, 1975) are some the major factors that hasten the destruction of recent reef corals.

Some of these factors are certainly in operation on the reefs of Lakshadweep and the deleterious effect is apparent, especially during the last two decades, concomitant with developmental activities. Mass mortality to corals has occurred in minicoy in some sites as a direct result of dredging. The large colonies of *Lobophyllia*, *Diploastrea* and faviids mentoined and charted by Pillai 1917 opposite the Leper's colony are all found dead by 1981 as a result of deposition of dredged soil on them. The *Heliopora* and other ramose coral thickets found in 1974 (Pillai unpub.) in Kiltan were mostly found dead in 1987. Dredging has also a long-term consequence on coral growth. The silt and sediments generated by dredging and their excessive transportation over the reefs and into the lagoon coupled with saa erosion are slowly killing many corals.

In Minicoy and Kiltan many massive corals were found to be dead at the top due to silting, and the growing zone of large massive colonies is confined to the periphery. Even without human interference this natural process is taking place on reefs to some exetnt. The small-polyped *Acropora* which forms the dominant lagoon coral in Lakshadweep, is perhaps, the most sensitive to silting (Pillai, 1975). This may be the reason for their large scale death and disintegration in the recent past. In 1974 the lagoon of Kiltan was found to have a very luxuriant growth of *Acopora teres*, *A. aspera* (Fig. 17), *A. corymbosa* and *A. humilis* along with large thickets of *A. formosa*. However, the present survey has indicated that the corals of the Kiltan lagoon have vastly died. Enquires with local people have revealed that there was intensive interference from the local people in the lagoon habitats in the recent past. The lagoon fishes found in association with corals were exploited for food especially by the women folk at low tide They put small nets over the coral colonies and break the branches to drive away the fishes (Fig. 15). During the low tide many people particularly women and children turn the coral stones to collect cowries and other gastropods. They leave the stones upside down without putting them back to original position. All these have caused the disintegration of already dead and live corals throughout the lagoon, Today, Kiltan lagoon looks depopulated and is getting filled up fast due to siltation.

During the present studies one of us (Thomas) made an attempt to estimate quantitatively the percentage coverage of dead and live corals in some sample plots of the islands both in lagoon and reef flat habitats. The sample plots were of the area af approximately 25 sq. m. General observations on the state of growth of corals was also made as summarised below.

Minicoy: The damage to corals in the lagoon of Minicoy has already been brought to the notice of the scientific public (Pillai, 1983). Thomas found that the coverage of corals in sample plots ranged from 5 to 10% of the bottom area. Of these 50 to 80 present was dead - a clear indication of the paucity of live corals in the lagoon at present. The southern portion of the lagoon is fast getting filled with excessive sedimentation, for the sediments brought by the water current from the north of lagoon has no escape further into open ocean since the reef flat is elevated and remain exposed most of the time acting as an effective barrier.

Kavaratti The reef front at windward side of the atoll has a reasonable growth of ramose and massive corals, At the southwest of atoll both in the lagoon and reef there is excessive deposition of silt causing significant damage to corals The coral growth in the lagoon is not rich. The inner side of the lagoon reef has some coral growth but the top portion of the colonies are dead due to silting. At the central part of the lagoon ramose corals are mostly dead with living layers of over growth on some. The Kavaratti lagoon has been subjected to intense construction activities. The percentage coverage of both dead and live corals in sample plots in both lagoon and reef varied from 10 to 60 percent of the area, of which on an average 50 percent of the corals are dead. This indicates more than 50% of corals of Kavaratti is represented by dead and disintegrating corals.

Suheli Par: The lagoon is very deep and wave conditions at the time of visit permitted only limited sampling. The area is not much subjected to any human interference and mortality to corals is due to natural reasons. The reef flats have luxuriant live coral coverage. There was little sign of excessive deposition of sediments anywhere. The lagoon and lagoon reef also have massive and ramose corals. Percentage of dead corals (estimated from the top) varied from 5 to 15% of the total bottom coverage.

Kalpeni: At Kalpeni harbour there is relatively profuse growth of corals throughout the lagoon. especially ramose forms. The lagoon reef flats have massive *Porites* The northern half of the atoll is more rich in coral growth than the southern half It is one of the atolls that has not been subjected to much interference and exploitation of the marine resources. The lagoon still presents a natural look. Percentage of dead corals in sample plots ranged from 10 to 25 and the total coverage of coral growth is from 25 to 50% of the bottom.

Amini: The lagoon of Amini is very shallow with vast areas of sea grass beds. It is being continuously dredged. The lagoon habitat is unsuitable for any significant coral growth though occasional ramose colonies are seen, The inner side of the leeward reef harbours some corals but at the southern half it was observed to be mostly dead. The windward side is subjected to sea-erosion and there is a vast and flat (Figs 8, 9) sea grass meadow between the reef front (algal ridge) and the shore. There is a fairly rich growth of corals at the northern side of the windward side. The dominant species include *Psammocora contigua, Pocillopora* spp., and *Acropora aspera* (Fig. 18) the last mentioned species often forming large thickets In Amini, coral growth is richer in the reef habitats than in the lagoon. There is excessive silting on the windward side and the reef flat is mostly covered with sand that prevents any coral growth near the shore on the windward side of the island.

Kadmat Island: The Kadmat island is long and narrow with a vast lagoon. The lagoon is dredged. There are many shoals most of which are dead without any live corals. On the sandy bottom there are patches of ramose corals of the genera *Acropora* and branching *Porites*, and in that sense the coral growth in the lagoon bottom is fairly rich at many places. The lagoon reef flat and inner side of the lagoon reef harbour a fairly rich coral fauna and the present day growth is very healthy. Massive *Porites* dominate at many sites. The northern half, as in other atolls, is richer in corals than the southern half. *Heliopora* is also a dominant genus on reef flats. From the vast sand flats of Kiltan harbour, sprats (*Spratelloides*) are exploited as live-baits for pole and line fishing for tuna. *Octopus* is common on coral shoals and is collected by local fishermen. On the whole, the present survey revealed that the coral growth in Kadmat is still rich though the terrestial habitat is much altered due to mining of lime and sand stones.

Kiltan: The marine fauna and coral reefs of Kiltan were studied in detail in 1974 by the scientists of CMFRI One of us (Pillai) also studied the corals and coral reefs of this island in 1974 and again in 1975 and the present survey after a decade made him aware of the changes that took place both in the lagoon and reef habitats. On the terrestrial side, mining for sandstones was more intense and there was a total loss of natural vegetation. The coral in the lagoon is mostly dead. All the *Acropora* thickets noticed in 1974 were found to be dead and disintegrating. As already pointed out, the coral colonies were broken by the local people to fish from them, resulting in almost total destruction. Dredging in the lagoon has certainly killed many corals and large areas of lagoon reef flat is (Fig. 15) covered by the soil dredged and dumped on the reef flat. The lagoon is mostly filled at the southern tip and there are few corals. The dominant species of corals in the lagoon in 1974 were *Acropora aspera, A. formosa, A. intermedia A. corymbosa* and *Porites andrewsi* all of which formed large thickets. However, these are not certainly found there at present in a great profusion though the species can be collected still from the various habitats. On the eastern reef flat, near the shore just opposite the Dak Bunglow, there was a profuse growth of *Acropora* in 1974. A re-examination of the site in 1987 showed very little corals in this site. The inescapable conclusion is that the coral growth of Kiltan was affected due to natural silting as well as dredging. The disintegration of ramose corals in the lagoon was hastened by human interferences

Chetlat Island: Chetlat seems to have retained most of its natural conditions in the lagoon habitats. The northern side of the lagoon is shallow, mostly exposed at low tide, and the bottom is covered upto 80% with large dome-shaped colonies of *Heliopora caerulea, Psammocora contigua, Porites andrewsi* and *Porites (Synaraca) convexa*. Other reef corals, though occur, are not very dominant. The inner lagoon reef flat is covered predominantly with the massive coral, *Porites*. No sign of large scale death of corals due to excessive interference from natural or artificial factors was recorded from Chetlat. The reefs and reef associated organisms are rich and the marine habitat presents a healthy look. However, the lagoon is also getting filled by natural processes. The open reef flats have a profusion of encrusting *Montipora* and *Porites*. Fishing activities in the lagoon are very limited and it is learnt that only during active monsoon, the local people fish in the lagoon for food. Live-baits are not exploited in any large quantities from this atoll. Sea erosion is taking place at some sites and preventive measures are being taken by the local administration.

The state of coral growth in some islands such as Androt and Agatti is reported to be good. In the absence of any lagoon in Androth the coral growth on the reef flat alone is of any importance. Agatti is rich in corals and interference, if any, is yet to be ascertained.

PREDATORS

Of recent, the role of the crown of thorns starfish, *Acanthaster planci*, in the mortality of corals in various parts of Indo-Pacific has been stressed by many authors. A review of the recent works on this aspect is presented by Endean (1973). The occurrence of *A. planci* was reported at Kavaratti (Sivadas, 1977) and Minicoy (Murty *et al.*, 1980). Predation of *Acropora* spp. by this starfish (Fig. 22) and consequent death was recorded at Minicoy and Kavaratti. However, the number of the starfishes was not in any great proportion to call it a plague. Recent surveys have not shown the presence of these predators in many of the islands.

BIOFOULING

According to Nair and Dharmaraja (1983) fouling on man-made objects in Lakshadweep is not very severe when compared to mainland waters. The structure and abundance of fouling community is insignificant though rock oysters and serpulids are found on jetties and other coastal installations, as seen in Minicoy, Kavaratti, Amini, Kadmat and Chetlat. Major fouling organisms such as barnacles, bryozoans, mussels and hydroids are extremely rare. Wood boring bivalves and crustaceans occur that cause damage to timber structures.

BIOEROSION

Many boring organisms attack both living and dead corals. The major groups that cause erosion to coral skeleton include algae, sponges, polychaetes, sipunculids, bivalves and echinoderms. The activities of these organisms on both massive and ramose corals cause their break down. The sediments that are produced by the boring activities also contribute to filling up of the lagoon. Though many of these agents occur on the reefs of Lakshadweep, to date no serious study on their occurrence and role in the breakdown and erosion of calcareous material in our waters was taken up. During the present study some observations were made on boring sponges, molluscs and the role of holothurians in converting calcareous algae into sand which are given below:

Sponges:

Many species of sponges are well known for their capacity to bore into calcareous objects such as shells, corals, calcareous algae etc. Studies made in the past have shown that the sponges etch out minute calcareous particles of an average size 56 x 47 x 32μ (length x width x height) from the interior of the substratum by the activity of filopodial structures produced by certain specialised cells so common at the site of boring. These filopodial structures grow and form fine crevices around a future chip. subsequently, these filopodial structures borne by different such cells fuse together to form a filopodial basket around a future chip and then it is pulled out from the site. Such chips are expelled through the excurrent stream of water. These chips contribute much to the mineral fraction of sediments produced in the reef environment and in the Fanning Island, it is estimated that, such chips contribute to about 30% of the total sediment load (Rutzler, 1975 Rutzler and Rieger, 1973).

The quantity of calcareous chips thus produced by the activity of sponges vary considerably both in time and space. It was calculated that in Bermuda reef the total chipping activity of sponge release as much as 250 gm $^{-2}$ year $^{-1}$ which corresponds to a coral layer of 0.1 mm thick. In areas of high sponge concentration this figure may go up to 3 kg $^{-3}$ year $^{-1}$ (or lmm/year). From these figures the part played by sponges in the bioerosion of the reef environment can be well imagined (Rutzler,1975). It has also been calculated that only 2-3% of the eroded substratum is removed in dissolved form.

Composition of boring sponge population in Lakshadweep: An interesting feature noted with regard to the sponge fauna, both island-wise and morphozone-wise, is dominance of boring species in relation to non-boring ones. The percentage occurrence of boring species in the total number of species represented at each island may be given as follows: Kavaratti-46.4%; Kalpeni-36.1%; Suheli-48.3%: Androth-66.6%; Minicoy-50.0%; Amini-38.4%; Kiltan-20.0%; Agatti-60.0% and Kadmat-58.3%.

The number of species of boring sponges recorded is 18 as listed below:

Phylum porifera Grant
Glass Demospongiae Sollas
Order poecilosclerida Topsent
Family Raspailiidae Hentschel

1. *Rhabderemia prolifera* Annandale

Order Hadromerida Topsent
Family Spirastrellidae Hentschel

2. *Spirastrella coccinea* (D & M)
3. *S. cuspidifera* (Lamarck)
4. *S. inconstans* (Dendy)
5. *S. aurivilli* Lindgren

Famfly Clionidae Gray

6. *Amorphinopsis excavans* Carter
7. *Aka minute* Thomas
8. *A. laccadivensis* n. sp.
9. *Cliona celata* Grant
10. *C. vasiifica* Hancock
11. *C. viridis* (Schmidt)
12. *C. carpenteri* Hancock
13. *C. ensifera* Sollas
14. *C. mucronata* Sollas
15. *Thoosa armata* Tapsent

Order Epipolasida Sollas
Family Jaspidae de Laubenfels

16. *Japis penetrans* (Carter)

Order Carnosida Carter
Family Halinidae de Laubenfels

17. *Halina plicata* (Schmidt)
18. *Samus anoyma* Gray

In order to get clear picture on the abundance of the various boring species in each island the total incidence of each species was estimated for Kavaratti, Suheli, Kalpeni, Androth and Minicoy separately, and this indicated that *Cliona celata* Grant dominates in both Kavaratti and Suheli, *C. ensifera* Sollas in Kalpeni and *C. mucronata* Sollas in Androth. However, the distribution pattern noted at Minicoy is quite different since both *C. celata* Grant and *C. vastifica* Hancock are equally dominant. Summarising the distribution pattern of both *C. mucronata* Sollas and *C. ensifera* Sollas, it may be stated that these two are typical coral boring species in both reef and lagoon habitats. At Androth the former dominates while in Kalpeni, the latter. In these two lagoons the activity of *C. celata* and *C. vastifica* is at a low level, and it is not known fully at present whether they are being checked by the activities of *C. mucronata* or *C. ensifera*.

Four species of the genus *Spirastrella* are commonly found in various lagoons surveyed; of which two, viz., *S. inconstans* (Dendy) and *S. cuspidifera* (Lamarck), show the tendency to overgrow the substratum after disintegrating it totally (gamma stage). Both of them usually make extensive galleries inside massive corals. It is very interesting to note that both *C. margaritifera* Dendy and *C. lobata* Hancock which have infiltrated into the molluscan beds of the mainland, mainly along the southwest coast (Thomas, 1983) recently, have not yet made their appearance in the Lakshadweep. it is possible that these may invade the Lakshadweep water also. Attempt to transport pearl oyster, mussel, edible oyster etc., infested with these borers to Lakshadweep, can cause their introduction. Hence, any consignment of molluscs for culture from the mainland or elsewhere to Lakshadweep must be screened properly before it is despatched.

Hartman (1958) feels that the coral reefs do not present as wide a variety of clionids as might be expected. De Laubenfels (1950, 1954) could report only two species from Bermuda and five from the West Central Pacific, while Burton (1934) could record no clionids from the Great Barrier Reef. But the present survey indicates that the boring sponge fauna is rather rich and varied in Lakshadweep.

Damage caused to corals: Analyses of the data collected from the various islands during the present survey indicate a very high rate of infestation in all the islands surveyed. It is noted that the sponge can bore into both live and dead corals alike. The death of coral will never affect the activities of the boring sponge since there is no trophic relationship between them. Under this situation the chipping of calcium carbonate material can go on incessantly even after the death of corals and this will considerably weaken the entire reef frame-work making it more susceptible to the wear and tear caused by waves. Such a weakened substratum will, no doubt, accelerate the activity of secondary borers such as polychaetes, molluscs, sipunculids etc.

Boring sponges can make extensive galleries inside the coral, but the magnitude of damage caused cannot be assessed by exrernal examination alone. This is because the outer layers of the coral remain practically untouched and more or less intact except for a few pores for the excurrent and incurrent papillae to project out. Atleast some of the massive corals examined from different islands were in this advanced stage of boring, and their interior was found practically hollow except for a few calcareous pillars stretching across the different tunnels within the skeleton.

An *Acropora* colony (partly dead) weighing 600 g with a maximum diameter of 15 cm, bearing 48 upright branches arising from a flat base, was collected from Kavaratti, It was found that out of 48 branches 34 were infested severely by boring sponges. Species-wise break up of incidence may be given as follows: *C. ensifera* on 12 branches; *C. celata* on 11 branches, *C. mucronata* on 6 branches; *C. vastifica* on 4 branches and C. *viridis* on 1 branch. Apart from the above mentioned species, other borers such as polychaetes were found boring on two branches, molluscs on two and sipunculids on one branch. The above details indicate that sponges, as a group, dominate among the various groups of organisms that destroy the branching coral colonies in Lakshadweep.

The assessment of damage caused to the stalk portion of branching coral is based on *Acropora* sp. collected from Kalpeni. The stalk portion of this colony has an average diameter of 5 cm and the various boring organisms occupying the cut end of the stalk were identified incidence-wise. Sponge infection could be noted at 8 places, polychaete at 6 places, mollusc at 5 places and sipunculid at 3 places. Species-wise Incidence of sponge indicates that *C. ensifera* has the maximum incidence (3 numbers) followed by *C. celata* and C. *vastifica* (with 2 each). However, the incidence noted in the case of C. *mucronata* is the minimum (one).

Data collected from massive coral, from Kavaratti, show that boring sponges form by far, the most dominant group causing biological erosion here also. Only one species of sponge (*C. celata*) could be collected and this species occupied three different locations inside the coral. The other groups noted were polychaetes, molluscs, crustaceans, sipunculids and algae; polychaetes were noted at two different spots while the others at one spot each, In an area-wise analysis, *C. celata* ranked first.

From pooled data obtained from the above three samples it may be concluded that among the boring organisms, the sponge ranks first followed by polychaetes and sipunculids in Lakshadweep reefs.

Activity factor relationship : The factors influencing the activity of boring sponge in the reef envivonment are many. Rutzler (1975) has experimentally proved that when a coral piece infested by boring asponge is cut into two it will stimulate the boring activity in the resultant bits considerably. Cutting channels across the reef will produce a similar effect and the chipping will go on at an accelerated rate atleast along the cut edges of the channel. Illumination also plays an important role in the accelerated activity of boring sponges (Rutzler, 1975). The clarity of water in the lagoons of the various islands surveyed is rather exceptional and hence this may be cited as an important factor that affect boring in a positive way.

In conclusion, it may be stated that the damage caused to corals by boring sponges is rather widespread in all the morphozones of the reefs investigated. In many cases it was noted that the infestation may kill the corals partly or fully. Localised death of a colony may not produce any far reaching results unless considerable damage occurs to the stalk portion. In any branching colony that occupies the reef front zone, a dead or disintegrated stalk can result in the sliding away of the entire colony into ddeper waters where it will be buried by sediments But, branching colony which occupies level bottom will never experience such a fate since ihe interlocking of the branches of adjacent colonies will keep it in position, even after the total disintegration of the stalk.

Molluscs :

Appukuttan (per. comm.) informs that the mytilid *Lithophage nigra* and *gracilis* making deep and massive burrows at the base of ramose corals are present in most of the reefs of the Archipelago. These molluscs are more common on the reef habitat than in the lagoon. Another mytilid *Botula cinnamomea* which makes shallow burrows was recorded from Minicoy. Its occurrence in other atolls awaits confirmation. Yet another group that burrows into limestone is the venerid *Petricola lithophaga* and *P. divergens*. Both these species were collected from Minicoy reefs. Two spicies of gastrochaenid, viz. *Gastrochaena gigantea* and *G. impressa* also make burrows into corals. The former is widespread while the latter is recorded only from Minicoy. While *Lithophaga* bores the coralline material by chemical action, the gastrochaenids act mechanically to make burrows 1.5 to 3 cm deep. *Jouannetia cumingii* is found throughout Lakshadweep and this species makes deep burrows on massive corals; the siphon of this species project 2 to 3 cm from the burrow. This is also an effective mechanical borer.

A few wood boring bivalves such as *Teredothyra, Uperotus, Teredo, Lyrodus, Bankia, Pholas* and *Martesia* were also recorded from the Lakshadweep waters that cause damage to wooden structures and timber (Nair and Dharmaraja, 1983.

Holothurians:

The role of the holothurians in the lagoon sand formation has to be commented here. Several species of holothurians like *Holothuria (Ludwigothuria) atra, H. (Microthele) nobils* and *H. (Mertensiothuria) leucospilota* feed on the calcareous alga *Halimeda* sp. and convert the same into largoon sand (Fig. 4). In some places 500 to 1000 tonnes of sand is known to pass through the holothurians in an year. This will have a direct bearing on the filling up of the lagoon. In some places liKe Kiltan the holothurian *Holothuria (Ludwigothuria) atra* is thickly distributed with 5-7 specimens in one sq. m. The role of holothurians in filling up the lagoon with sand in such places will be significant.

POPULATION AND ATOLL ENVIRONMENT

Human activities on coral atolls is an important aspect that needs a detailed study in Lakshadweep; for the effect of changing environment on population needs careful assessment for future planning. As pointed out by Weins, (1971) the availability of percapita land, fresh water, reef area and lagoon for population are criteria for estimating the population pressure in restricted geographical areas like small atolls. Though reliable statistical data on these aspects from the inhabitated atolls of Lakshadweep are still required, it may be assumed that due to improved medical supplies, education, sanitation, nutrient food supply, and recreational facilities in the recent decades the population pressure in the atolls is gradually increasing.

CONSEQUENCES OF ENVIRONMENTAL DAMAGE

Mortality to corals set chain actions and interactions bringing out visible changes in the ecosystems. The loss of live corals directly brings out a depletion of associated organisms as well as an advancement of algae and animals that thrive on dead corals. Pillai (1983, 1986) and Pillai and Madan Mohan (1986) have described the adverse impact of mass mortality to corals in Minicoy atoll (Fig. 19). As already pointed out by Endean (1973) the coral skeleton, on death, display a whitish colour due to loss of living matter and many remain so, for a few weeks or month. Soon, they get coated by green filamentous algae and assume a dark green colour. Subsequently, coralline algae make an over coat. Dead corals are more vulnerable to the attack of borers and bioerosion of the colonies starts at a faster rate. Sponges, sipunculids, molluscs and echinoderms start attacking the colonies and the resulting calcareous sediments cause more sedimentation in the reef habitats. When ramose corals die and remain *insitu* they act as effective sediment trappers in between the branches and thus effect filling of the lagoon, ultimately the corals themselves get burried.

Coral associated or coral haunting fishes such as chaetodons, some humbugs (eg. *Dascyllus aruanus* as seen in Minicoy) and rock cod may remain associated with corals when the latter die but may disappear as the algal coating on dead skeletons increases (Endean, 1973). Most of the live coral associates, including fishes, abandon the coral colonies. What is found mostly are borers and a few crustaceans and molluscs.

The death of corals in the Minicoy lagoon was found to have a direct inverse impact on the coral associated fishes and tuna fishery as explained in detail by Pillai (1983). Pillai and Madan Mohan (1986) have noted the microhabitat selection of many coral associated fishes in Minicoy. For example *Chromis caeruleus* the blue puller, which is an important tuna live-bait in Lakshadweep was found to be predominantly associated with arborescent corals like *Acropora intermedia, A. formosa, A. teres* and *A. aspera* (Fig. 18) which were very common in lagoon. The species is also found along with *Pocillopora* spp. and *Stylophora pistillata*. However, recently Pillai has observed their presence among large colonies of *Heliopora caerulea* at Chetlat. As pointed out by Pillai and Madan Mohan (in press) this species coexists with *Dascyllus aruanus*. It was observed that mass mortality to the arborescent corals in the traditional fishing areas of Minicoy coupled with over exploitation have caused a marked dwindling of *C. caeruleus*. It is not successful with dead corals though *D. aruanus* gets adapted to dead corals in the absence of sufficient living habitat of live corals (Pillai and Madan Mohan in press[2]). The resident fishes such as *Archamia* sp , *Apogon* spp; *Pristiapogon* and *Spratelloides japonicus* on corymbose corals are also found not able to adapt to dead corals. The overall result is that death of corals causes a dwindling of many important reef fishes that are used as live-baits in Lakshadweep. Mass mortality to corals and dwindling of resident live-baits may affect the traditional tuna fishery by pole and line, for they form a steady sources for baits, while the availability of migrant forms is unpredictable.

RECOLONISATION OF CORALS AND ECOSYSTEM IMPROVEMENT

Recolonisation of reefs and lagoon habitats by hard corals depends on many factors including the magnitude of the destruction, modification of the habitat, availability of planulae, nature of water current to favour the inflow of planulae; recurrent damage to habitat and the like. When a reef is damaged by catastrophic events (both natural and man-made) there should be some hard bottom still left so that settlement of planulae can take place. As far as one could judge, in some of the lagoon of Lakshadweep as in Minicoy, Kavaratti and

Kiltan, the interference of sedimentation is of high magnitude and there is great sediment transport in the lagoon. Few new settlements of colonies were seen in both Kiltan and Minicoy though over growth of fresh living layers are seen on many dead and intact coral colonies. Reefs subjected to human activities appear to have lost capactty to re-generate since the impact is long lasting (Wells, 1984). Based on a study of the south Indian reefs, Pillai (1975) felt that within a period of 20 to 25 years reasonable recolonisation of *Acropora* will take place provided the conditions for recolonisation are favourable. As far as Lakshadweep atolls are concerned even if any recolonisation on the lagoon is to take place absolutely no further interference should be there. Dredging has to be abandoned. Effective measures to check sea-erosion have to be taken up. Destruction to live corals has to be avoided. It is rather difficult at this stage to say whether active re-growth of corals in the lagoon habitat will take place in future, where significant damages have already taken place.

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