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# Coral Reefs and Their Conservation — A Review

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**Abstract:** Coral reefs are colonies of tiny animals found in marine water which is having nutrients/minerals. Most of the coral reef built from stony coral polyps in a big group of cnidaria. Polyps secrete hard carbonate exoskeletons for support and protection. It is a rainforest of sea which better grow inwarm, shallow, sunny, clear and agitated water,but in deep waters and cold waterthey also exist in small scales. Coral reefs are good for fisheries, tourism and shoreline protection. The annual global economic value of coral reefs is about US$30.1-37.5 billion.

**Keywords:** Coral, reefs, corallum, tourism, fisheries conservation

**Coral Reefs of India**: *Coral reefs in India are being damaged and destroyed at an increasing rate underwater. The Reef condition is generally poor and declining in near shore waters areas of high population density. Relatively pristine reefs are located around uninhabited islands or barrier type reefs located away from population centers. Sedimentation, dredging and coral mining are damaging near shore reefs, while the use of explosives and bottom nets in fishing are damaging offshore reefs in specific site.*

Coral islands and reefs are secretory products of the few skeleton forming Cnidarians. Actually Corallum is the total coral bush and the "Corallite" is the calcareous cup within which the living elements i.e. the coral polyps stay embedded.

These living elements secrete mucous to catch plankton and other food substances which are engulfed. There is a symbiotic relationship between coral polyps and the photosynthetic algae in the reef area. Algae receive nutrients and carbon dioxide from coral polyps and coral polyps get photosynthetic products from algae. Another organism called Zooxanthellae controls the growth and secretory activities of the coral polyps. Coral reefs are shallow water, tropical marine ecosystems which are characterized by a remarkably high biomass production and a rich faunal and flora! diversity perhaps unequaled by any other habitat. Corals require certain conditions to occur and can flourish only in relatively shallow waters, exposed to direct sunlight, with optimum temperature of 23-25°c and free from suspended sediments. There are mainly four types of coral reefs found in India.

1. Platform Reefs: These are almost flat reefs without any lagoon. They rest on the shallower part of the continental shelves and they may present associated with atolls and also between a coast and a barrier reef. These types of reefs are mainly found in Gulf of Kuchh of India.

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2. Fringing Reefs: These types of reefs are closely present with the shore of a mainland and these may be islands or *Fringing reefs',* reefs that grow close to the shore and extend out into the sea like a submerged platform. an extended part of continental coast border. In both cases a narrow channel called Lagoon has an intervening water body. The most significant growth of corals occur at the edges of these reefs. Fringing reefs are found in Gulf of Manner, Palk bay and in Andaman & Nicobar islands of India.
3. Barrier Reefs: These reefs are quite similar with fringing reefs but are disconnected from the mainland by a narrow region of sea probably up to 1000 feet deep, which is not less than the greater depth acquired by lagoons. Barrier reefs are mainly found in Andaman & Nicobar islands of India. Outside India the Great Barrier Reef is located in Australia. . *Barrier :* reefs separated from the land by wide expanses of water and follow the coastline.
4. Atolls: These are oceanic and not associated with land. These consist of low reef rising no more than 28 feet above the sea level and enclosing a central region of water called Lagoon. Atolls in India are mainly found in Lakshadweep islands: a roughly circular ring of reefs surrounding a lagoon, a low lying island, common in the Indian and South pacific oceans.

India with its coastline extending over 7,500 kilometers and subtropical climatic conditions has very few coral reef areas. The absence of reef in the Bay of Bengal is attributed to the immense quantity of freshwater and silt brought by the rivers.

The structure of a reef is formed by the calcareous skeleton that houses corals, a type of soft-bodied, radially symmetrical, marine invertebrates of the phylum coelenterate. Individuals of a colony are called polyps or hydroids. Millions of coral skeletons cemented together over a period ranging from a few thousand to millions of years give rise to such reefs (WWF1992).

Coral reefs of the Indian Ocean were built up during the tertiary and quaternary periods. Coral reefs are restricted mainly in seven regions of India, such as:

1 Coral reefs in Goa coast,
2 Coral reefs in Kerala coast,
3 Coral reefs in Palk Bay,
4 Coral reefs in Gulf of Kuchh,
5 Coral reefs in Gulf of Manner.
6 Coral reefs in Lakshadweep islands,
7 Coral reefs in Andaman and Nicobar islands.

In India coral reef ecosystem is distributed along with both west and east coasts. Images received from satellites gives an idea about scattered patches of corals in the inter-tidal zones and occasionally at subtidal depths to a few meters along the west coast of India. There is significantly more growth of coral reefs in west coast of India than the east coast. The reasons for less formation of coral reefs in east coast are:

1. The sea around the east coast is very shallow,
2. The eastern coastal plains are wider as well as drier than western coastal plains.
3. Due to the highest freshwater flow through several rivers falling in Bay of Bengal.
4. Human activities i.e. anthropogenic effects are more in east coast affecting the formation of coral reefs.

**Table 1: Area Estimates of Coral Reefs in the Country (Km2)**

| Category | Gujrat | Tamilnadu | Lakshadweep islands | A&N Islands |
|---|---|---|---|---|
| Reef flat | 148.4 | 64.9 | 136.5 | 795.7 |
| Sand over reef | 11.8 | 12.0 | 7.3 | 73.3 |
| Mud over reef | 117.1 | - | - | 8.4 |
| Coraline shelf | - | - | 230.9 | 45.0 |
| Coral heads | - | - | 6.8 | 17.5 |
| Live coral platform | - | - | 43.3 | - |
| Algae | 53.8 | 0.4 | 0.4 | - |
| Seaweeds | - | - | 0.7 | - |
| Seagrass | - | - | 10.9 | - |
| Reef vegetation | 112.1 | 13.3 | - | 8.9 |
| Vegetation over sand | 17.0 | 3.6 | 0.4 | 10.5 |
| Lagoon | - | 0.1 | 322.8 | - |
| Sandy substrate | - | - | (67.4) | - |
| Reef patch | - | - | (13.4) | - |
| Deep | - | - | (98.5) | - |
| Uncertain | - | - | (143.5) | - |
| Total | 460.2 | 94.3 | 816.1 | 959.3 |
| Ref: DOD & SAC, 1997 "Coral reef maps of India," D O D and S A C, India | | | | |

**Table 2: Diversity of hermatypic corals in the Indian Ocean**

| Locality | Genera | species |
|---|---|---|
| Gulf of Kutch* | 24 | 37 |
| West Coast Patches* | 17 | 29 |
| Lakshadweep Islands | 37 | 103 |
| Palk bay and Gulf of Mannar | 36 | 96 |
| Tuticorin | 19 | 21 |
| Andaman Islands | 31 | 82 |
| Nicobar Islands | 43 | 103 |
| Total for India* | 37 | 199 |
| Source: Bakus, G.J (1994) and * Pillai, G (1996). | | |

*Reef structure and corals*

Almost all the islands of the Andaman and Nicobar groups exhibit narrow, linear and extensively well developed fringing reefs.

The reef flats are dominated by massive *porites* and *favids* that form the chief frame builders. The shore-ward side is generally with luxuriant growth of arborescent genera such as *Acropora, Pocillopora, Seriatopora, Stylopora* etc. The reefs are rich in soft corals The wind ward side slopes down to a depth of 350-540 m and is subjected to the monsoonal winds. Channel reefs are found on the leeward side of the shore line.

The reef-flat occupies an area of 795.7 sq km. Coral heads and coralline shelf occupies 17.5 and 45 sq km respectively. 8.4 sq km is occupied by mud over reef. Mud deposition on the reef flat near navy bay, flat bay, reef island etc. indicates degraded condition of the reef. The deposition of mud on the reef flat is as a result of felling of mangrove trees and clearing of other forests.

The islands have important nesting beaches for leatherback, hawksbill, olive ridley and green turtles and marine mammals such as Dugong. Several hundred estuarine crocodiles occur in densities inversely proportional to human populations (Clams *Donex* spp and *Actactodea,* several gastropods and species of crabs are found in the sand and shingle of the upper littoral zone. Seagrass beds (*Cymodocea* and *Thalassia*) are found in the nearshore waters. They harbour three species of sea cucumbers, star fish and two species of brittle stars. Bivalves and pearl oysters are found amongst the subtidal dead shingles. 442 fish species are were reported for the Andaman and Nicobar.

The coral formations of the Gulf of Kutch represents one of the extreme northern limits of corals in the Indian ocean. The approach to the corals is difficult due to the existence of vast intertidal mud flats which are difficult to negotiate by foot at low tide. The sudden influx of tidal waters also renders it risky to work on the exposed bank.

These reefs are mostly of fringing type along with offshore platform reefs, patch reefs and coral pinnacles. There are some 40 islands with patchy coral formation of which the largest is Pirotan Island. The coral reefs are in a highly degraded condition. The major source of degradation has been mud deposits on various coral reefs e.g. Bural Chank, Kalubhar, Munde ka bet and Jindra reef. Mud over reef occupies a major portion (117.1 sq km. of the reef). The reef area of the gulf of Kutch is 148 sq km and the total area occupied by the reef is 315 sq & SAC, 1997). km The available data reveals that the area supports 120 spp of algae, 70 spp of sponges, 200' types of fish, 8 types of sharks, 27 spp of prawns, 30 spp of crab along with lobster and barnacles. There are two hundred species of phyllum molluscs with oysters, three species of turtles and three species of marine mammals (dugongs, dolphins and whales) (GEC:1997).

The coral fauna is comparitively less diverse when compared to other parts of India. According to a taxonomic study conducted at 15 reef locations in Kutch viz, Okha, Dholiogugar, Dona, Boria, Magunda, Savaj, Paga, Manmarudi lanmarud, Ajad, Burel reef, Dhani, Kazimbar reef, Narara reef, Goose reef and Piroten islands has reported 40 species of corals (Pillai and Patel I988 in GEC 1997). Ramose corals such as *Acropora, Pocillopora, Stylopora* and *Seriatopora* are not found at present though semi-fossilised specimens of *Acropora* are found on some beaches in moderate density.

**Living coral area rarely exceed 20-30 % (GEC, 1997). The preventive measures taken in the marine national park has resulted in the restoration of the area under reef significantly**

The reefs here are also of fringing type around a chain of islands from Jodhiya in the north to Port Okha in the south.. Because of the extreme environmental conditions, with a large range in temperature and salinity,/tourism the reefs are relatively less developed and harbor a low biodiversity compared to other Indian reefs. The Gulf of

Kutch is also a region of high industrial development - this has been responsible for a large scale of mortality of reef corals in the recent past. The entire Gulf of Kutch reefs have now been declared as a Marine National Park.

***West Coast of India***

The west coast of India between Bombay and Goa is reported to have submerged banks with isolated coral formations Coral patches have been recorded in the intertidal regions of Ratnagiri, Malvan and Redi, south of Bombay and at the Gaveshani Bank, 100 Km west of Mangalore *Ponies, Coscinarares, Turbinaria,* some favids and *Pseudosiderastrea* are reported. All the genera recorded are massive or encrusting without any of representation of ramose forms Siltation is of high rate and salinity may drop to 20 ppt during monsoon in these habitats which may restrict the growth of ecologically sensitive forms of ramose corals.

Hermatypic corals along the shore are reported from Quilon in the Kerala coast to Enayem in Tamilnadu. *Pocilipora* spp is the most common genus in this area. *Accropora* is found with representation of three species. *Pseudosiderastrea* and *Ponies* spp 29 species in 17 genera of scleractinians are also found.

The Lakshadweep islands lie scattered in the Arabian sea about 225 to 450 km from the Kerala coast. Geographically, the islands lie between 8°N - 12°3'N lat. And 71 °E- 74°E longitude. The islands consist of coral formations built up on the Laccadive-Chagos submarine ridge rising steeply from a depth of about 1500 m to 4000 m off the "west coast of India. The U.T of Lakshadweep along with the Maldives and the Chagos Archipelagoes form an interrupted chain of coral atolls and reefs on a contiguous submarine bank covering a distance of over 2000 km. This ridge is supposed to be a continuation of the Arravali mountains, and the islands are believed to be remnants of the submerged mountain cliffs.

There are 36 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 $km^2$ with lagoons occupying about 4200 $km^2$. Only 11 of the 36 islands are inhabited. They are Androtт, Amini, Agatti, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kiltan, Minicoy and the headquarters at Kavaratti. The Minicoy island is separated from the rest of the islands by a 180 km wide stretch of sea known as the nine degree channel. Kavaratti is the administrative headquarters. Agatti houses the only airport and airstrip. A resort catering to international tourists has been functioning in Bangaram since 1988 and a resort catering to national tourists with a dive school has been set up at Kadmat in 1995. In addition tourist huts have been erected at Kavaratti, Minicoy and Agatti.

***Structure of the Reef***

Coral reefs of the islands are mainly atoll except one platform reef at Androth. Almost all the atolls have an orientation of NE-SW with the low lying island on the east, a broad well developed reef on the west, with a lagoon in between, connected to the open ocean by one or more channels. The reef flat occupies 136.5 sq km area. Sea grass occupies 10.9 sq km and lagoon occupies 309.4 sq km The depth of the sea increases outside the coral reef and can reach up to 1500-3000. Androtт is the largest island with an area of 4.84 sq km and the only island that does not have a lagoon. Bitra with an area of 0.10 sq km is the smallest in land area but perhaps has the most magnificent lagoon. All the islands lie north to south, excepting Androth which lies east to west. The distance betweeen them varies from 11 km to 378 km. On the seaward side the reef slopes into the sea. The first plateau is found around a depth of 5-6 mts. The second plateau with sandy patches is found around 25 mts - 30mts During high tide water exchange takes place between the lagoon and the open sea over the reef. The lagoons have sandy bottoms with scattered coral boulders and pinnacles followed by extensive sea grass beds at the landward side. The coral fauna of Lakshadweep is known to harbour a total of 105 species divided among 37 genera 29 new records for species in Lakshadweep. The

lagoon and reef flat faunal elements are dominated by *Accropora* spp., *Pocillopora* spp., *Ponies* spp. and massive and encrusting favids. *Psammocora* spp is common in the northern islands. There is a profusion of blue coral *Helipora coerulea. Millepora* spp. forms the dominant element in the lagoon. One finds a latitudinal difference in coral fauna assemblage in the lakshadweep. Minicoy has some elements such as *Lobophyllia* and *Diploastrea* that are common to the Maldives but rarely found in the northern Islands. Similarly the genera *Montipora* and *Echinopora* recorded from the northern group of atolls are not recorded in Minicoy . There is a unanimous feeling that one had to take proper controls for sewage disposal. The contamination from fecal matter and kitchen waste in the lagoons.

***Others***

Coral patches occur at some intertidal locations and submerged banks on the continental shelf along the west coast. Coral diversity at these sites is generally restricted to few genera. The number of coral species known so far from Indian reefs is 206.

## Human and economic impact on the reef systems

Reefs resources have traditionally been are a major source of food for local inhabitants and of major economic value in terms of commercial exploitation. Reefs in India provide economic security to the communities who live alongside them. In the villages around the Gulf of Mannar the traditional fishermen have been catching reef fish, diving for pearls, sacred chanks, holothuria and sea weed for centuries. In Lakshadweep the reefs are a safety net for food in the monsoon season and also provide the live bait that forms the basis for the commercial Tuna Fishing.

Traditional fishers and people whose livelihood is dependent on the reef perceive reefs as a safety net in their food production system. For them they are happy hunting grounds where clams, octopus, mollusks and other rich food organisms live and provide them with food and cash income. They also perceive the reef as a defense against the erosive forces of the ocean waves. These people would never willingly destroy the reefs since they realize that they have a long term dependency on them and any destruction of the reef would be destroying the goose that lays golden eggs.

To have an understanding of the human ecology of the coral reef islands it is important to understand the relationship between local populations and the reef resources. These are the people whose livelihoods become endangered when the reefs are provided protection under protected areas such as biosphere reserves, sanctuaries or marine parks.

One also has to take into account the corporate sector such as cement and lime industries and their exploitative extraction of the reef and the new sector that is coming up in live ornamental fish and reef fish trade. Coastal populations even if they do not live off the reefs will have a effect on the reef habitat merely by their presence. Sewage disposal is becoming one of the biggest management problems both at the Gulf of Mannar and the inhabited islands of Lakshadweep. All this gives us an idea about interactions between the communities and their ecosystem. It also gives an idea about the political situation and answer questions such as: Who are the main stakeholders of the coral reefs?, are their conflicts arising due to different priorities of users? What are the perceptions of the local population *vis-a-vis* coral reefs etc.

**Table 3**

| | |
|---|---|
| 1. The Department of Fisheries | Fishing research, collection of species for Museum, Aquarium for scientific purposes and awareness creation. |
| 2. *CMFRI* | Collection of specimens for scientific research purposes |
| *3.* Harbour works department: | Mainly for surface transport: dredging and deepening of navigational channels. |
| 4. Port Department | Provide anchoring buoys for mooring ships and boats and conduct servicing of the vessels. |
| 5. Public Works Department: | Provide tetrapods to stall sea erosion on the island |
| 6. Society for Promotion of Recreation and Tourisms (SPORTS) | Tourism promotion, takes tourists into the lagoon to snorkel, scuba dive and use glass bottom boats to view the corals and associated fish life. |
| 7. Department of Science Technology and Environment, | is the nodal and moderating department. They conduct an environment Impact assessment on the 9th five year plan of the Administration of Lakshadweep. Approve the coastal zone Management Action Plan of Lakshadweep. |
| 8. The islanders | building materials, reef fishing and deep sea fishing |
| 9. Tourist | By there very presence add quantities to the waste disposal and sewage problems |

The islanders have developed several traditional tools to capture fish and extract resources from the lagoon. They capture fish by using nets, fish traps, wounding gear and ingenuity. Pole and line fishing for tuna has gained popularity in all the islands. The fishermen use mechanized craft to carry out tuna fishing operations outside the lagoons. However the tuna fisheries are also dependent on live bait. These are one variety of coral associated fish, found only in the lagoon. Hence indirectly the islanders are completely dependent on reef resources for their survival.

The lagoon and reef flats are looked upon as common property resources and therefore equity in resource sharing is an important issue. For example discipline has to be maintained in case more than one person wants to do net fishing. Only one net is placed in the lagoon and the catch is shared by all the parties concerned.

*Coral and shingle extraction*: The islanders make bricks out of coral shingle and use them for house and building constructions. The islanders know that it is the reef that protects the islands and rarely collect boulder coral for individual use. They rely on shingle collection on the lagoon side. They mix cement with the shingle to make bricks and build their homes.

*Developmental and recreational activities*: blasting and dredging in lagoon for navigational channels leads to coral mortality. Tourism poses problems of garbage and sewage disposal, anchor damage by tourist boats, collection of souvenirs.

*Population Pressure*: for the isolated island economy of Lakshadweep, pressure of population is the prime concern. At the present rate of growth, the average density which at 1616 per sq kilometers is the third highest in India, will reach socially unacceptable levels in the near future. Even subsistence use will not be sustainable in the

long run. Garbage and sewage disposal will cause the main threats to the reef. Right now the Toilets are connected to a septic tank and the waste water ultimately finds its way into the lagoon or open sea and creates both unhygienic conditions for the people and upsets the balance of nutrients in the lagoon, causing algal growth to compete with reef growth.

The coral reefs of India come under the jurisdiction of the department of forests and wildlife and it is their responsibility to monitor, manage and conserve these fragile eco-system. The Ministry of Environment and Forests is responsible to develop an effective action plan to manage the reef resources and issue guidelines for the sustainable utilization of coral reefs . The management of coral reef ecosystems has also been affirmed in India's National Conservation Strategy and Environment Action Plan. (UNDP, 1997).

The coastal regulation zone notification, 1991 offers the only legal protection to all coral reefs and In this coral reef areas come under the CRZ1 category. A special category CRZ 4 has been prepared for the Islands of Andaman, Nicobar and Lakshadweep. Norms for regulation of activities within the CRZ state that corals and sand from beaches and coastal water shall not be used for construction and other purposes. Dredging and underwater blasting in and around coral formations shall not be permitted. Section 7 (2) also states that construction of beach resorts/hotels shall not be permitted in ecologically sensitive areas such as marine parks and coral reefs (Notification 8.0114 (E) of 19 February, 1991).

**Table 4: Protection Status of Coral reef areas**

| **Locality** | **Protection** | |
|---|---|---|
| | **established** | **proposed** |
| Gulf of Kutch | Marine National Park (110 Sq Km-1982) | |
| Lakshadweep Islands | collection of corals is banned. | |
| West Coast Patches | Nil | Sanctuary proposed at Malwan - South of Bombay. |
| Palk bay | Nil | |
| Gulf of Mannar | Gulf of Mannar Biosphere reserve. | |
| Andaman Islands | Mahatma Gandhi Marine national Park at Wandoor - 234 sq km. of islands and reefs. | Ritchies Archipelago |
| Nicobar Islands | | |

While the formation of protected areas and the CRZ notifications and Acts are laudable one finds that there seem to be problems in trying to implement them. These problems are magnified due to the difficulties arising out of monitoring coral reefs and lack of trained departmental staff to carry out these activities.

The Government of Tamilnadu has banned the quarrying of massive corals; dead corals on landward sides can be extracted under a lease. Collection of marine organisms are allowed only for scientific purposes around Krusudai

island. Management responsibility of the protected areas and marine biosphere lies with the state department of forests and wildlife. No management or legal protection exists for Palk Bay.

Gulf of Mannar has been declared a Marine Biosphere Reserve. All 21 islands have been notified as reserve lands under sec.26 of the Tamil Nadu Forest Act. Notification of these islands and the sea around the island up to 3.5-5 fathom deep, as a national park under the provisions of the wildlife Protection Act 1972 has also been published. Dugong hunting has been banned and awareness created among fishermen. Zoning for tourism development; education and scientific purposes have been recommended for total protection of marine life including dolphins, turtles and sea weeds The M.S. Swaminathan Research Foundation and the Tamilnadu Department of forests are currently in the process of developing a management plan for operationalising the management activities of the Gulf of Mannar Biosphere Reserve.

Tourists are allowed to visit only the Redskin and Jolly boy islands within the national park.

There is a ban on gathering corals and endangered molluscs however the corals are not included in the wildlife protection act. It is therefore difficult to take action against offenders outside the national park. They cannot be convicted and only the material gathered is confiscated by the department of police. Tourists are not allowed to collect shells, corals etc. for souvenir purposes.

The Gulf of Kutch including 42 islands along the coast of Jamnagar was declared India's first marine protected area' through a series of notifications between 1980 and 1982. The first notification dated 12-8-80 made a sanctuary of approximately 221 sq. Km and it was later extended by a second notification dated 20-7-82 to include 237 sq. Km more The national park comes under the jurisdiction of the Department of Forests.

The Department of science, technology and environment has recently completed an Environment Impact Assessment report of the 9th plan document in which Environment Impact statement in respect of each of the schemes proposed by the plan implementing departments has been prepared and stated from Chapter 1-15. The statement which will have a direct beneficial impact on coral reef management are the following:

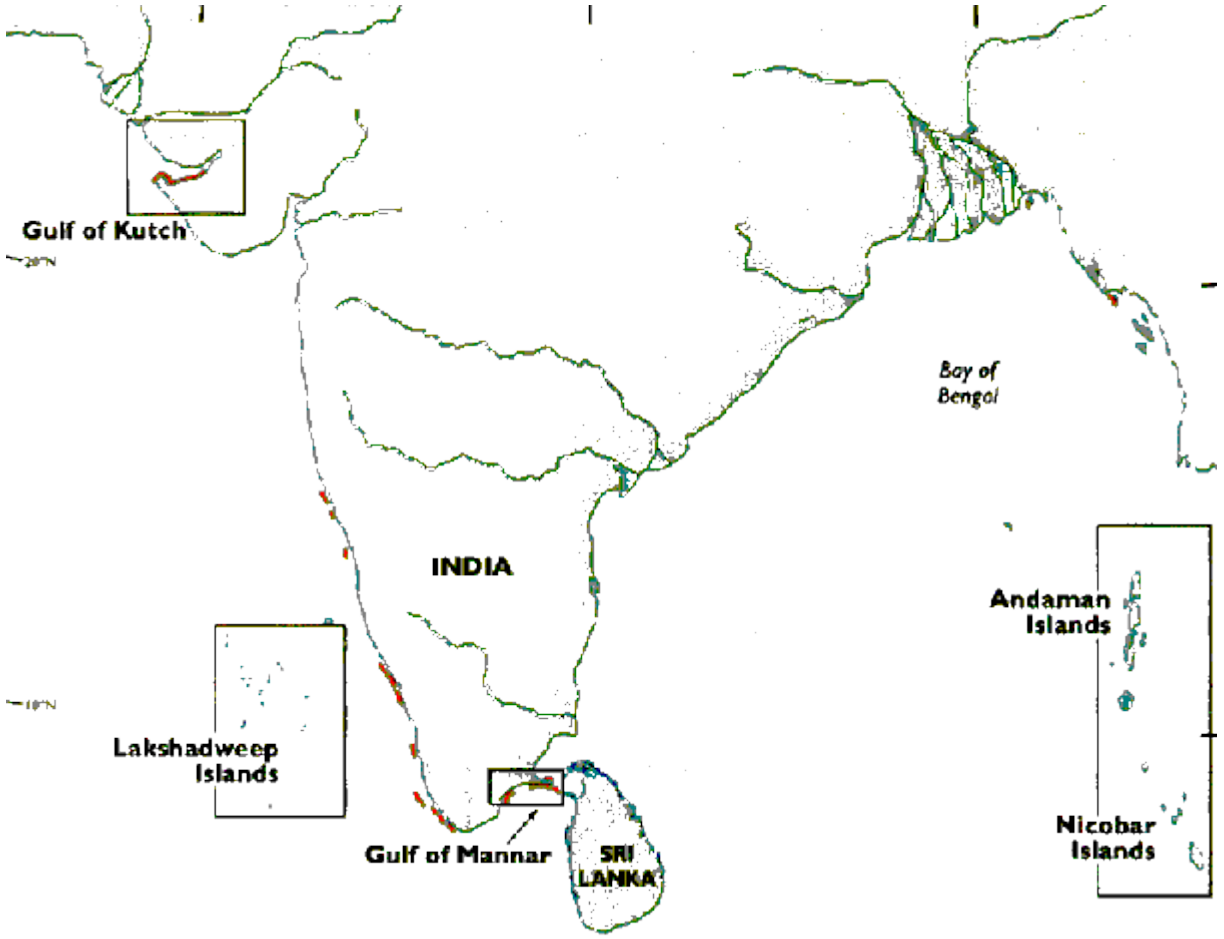
1. Cattle rearing is incompatible with the island ecology and so should be halted.
2. All toilets should be biological toilets to eliminate sewage.
3. Stress on Non conventional energy use.
4. Environment audit of all existing factories in all Government and private sectors to be conducted.
5. The shipping vessels should be so designed that the wastes generated should not be dumped into the lagoon but should be stored and disposed in the seas far from the islands.
6. When new vessels meant to enter the lagoons are to be procured it should be ensured that the draft of the vessels should be limited to the existing depth of the channel and further deepening, dredging will not be permitted as prescribed by the CRZMP.
7. Scheme No 8 providing harbour facilities in all the islands by widening channels and extending and widening jetties should be dropped and no dredging work be done in the lagoon as this increases sedimentation which will ultimately effect the health of the corals.The Department of Science, Technology and Environment also conducts periodic awareness programs and has proposed

establishment of a Marine National Park and National and World environmental Heritage status for some of the chosen islands of the UT of Lakshadweep. Development of an appropriate Sewage systems in association with competent institutions. They propose to monitor the degradation of corals both inside and outside the reef by regular diving and to employ protective measures to prepare a master plan for the conservation of corals. With regard to tourism the following statement has been made " the negative impact of tourism, generation of sewage, waste, increased consumption of water and change in landscape etc. This has to change if we are serious about developing people centered management plans for conserving and managing our reef heritage.

**Status of Coral reefs in India**

| | **Bio-physical** | **Research** | **Perceived threats** |
|---|---|---|---|
| Palk Bay | Slow recovery from 60's coral mining | Mainly on Bio-physical aspects | Population Pressure and associated effects |
| Gulf of Mannar | Slow recovery from 60's coral mining | Bio-physical aspects; associated fauna and Human activities damaging the reefs. | Population Pressure and associated effects |
| Andaman & Nicobar | Fair Excellent, Problems around south island | Bio-physical aspects; associated fauna and Human activities damaging the reefs | Siltation due to logging, Sand mining. |
| Lakshadweep | Excellent off uninhabited islands and endangered along habited islands. | Bio-physical aspects; associated fauna and Human activities damaging the reefs | Population Pressure and associated effects |
| Gulf of Kutch | 30% of the reefs are living | Bio-physical aspects; associated fauna and Human activities damaging the reefs | Sedimentation and siltation due to cutting of mangrove forests, sand mining for industrial use. Population pressure |
| West Coast | Unknown | Limited | Unknown |

**Coral Reefs Distribution In India**




**Others**

Coral patches occur at some intertidal locations and submerged banks on the continental shelf along the west coast. Coral diversity at these sites is generally restricted to few genera. The number of coral species known so far from Indian reefs is 206.

According to Zoologists coral islands and reefs are secretory products of the few skeleton forming Cnidarians. Actually Corallum is the total coral bush and the 'Corallite' is the calcareous cup within which the living elements i.e. the coral polyps stay embedded.

These living elements secrete mucous to catch plankton and other food substances which are engulfed. There is a symbiotic relationship between coral polyps and the photosynthetic algae in the reef area. Algae receive nutrients and carbon dioxide from coral polyps and coral polyps get photosynthetic products from algae. Another organism called Zooxanthellae controls the growth and secretory activities of the coral polyps.

The organisms' that help to form a coral reef are well adaptive in warm, shallow and well aerated places and these satisfactory conditions are found mostly in tropical and subtropical sea regions. Intensity of surface illumination of radiant energy is another important factor for good coral reef formation.

Coral reefs are confined within an area of 72 million square miles in those regions. They are well suited in a temperature range of 22ºC to 26ºC. If this range falls below 17ºC or rises above 28ºC then formation of reef is disturbed.

**Biodiversity of Coral Reefs in India:**

1. All coral reefs are very rich in biodiversity. There is an accumulation of various types of biotic factors in each ecosystem of coral reefs. The composition of coral reefs in India is unique and it includes near about 180 species of biotic algae, 20 species of sea weeds, 20 species sea grasses, 115 species of Poriferans, 5 species of Crustaceans, 110 species of Echinoderms, 600 species of bony fishes. Besides, it should be noted that different species of crabs, gastropods, bivalves, cephalopods are also found in Indian coral reefs.
2. In some areas rich algal diversity has been noted such as Ulva, Sargassum, Cladophora etc.
3. In some cases 70 species of Sponges, 25 species of Prawns, 196 species of mollusks and 5 species of mammals were also noted.
4. Coral reefs are hard limestone forms constructed by continuous cementing process and depositional activities of class Anthozoa, Scyphozoa and Hydrozoa and also a group of calcifying algae. In Lakshadweep islands about 21 gropus of Polychaete worms and different Nematode worms are also found.
5. In different coral reefs of India 25 species of ammonifying bacteria, 12 species of nitrifying bacteria, 3 species of nitrogen fixing bacteria, 25 species of phosphate producing bacteria were also noted. About 55 species of Diatoms and 50 species of phytoplanktons' were also found in different reefs of India.
6. Both stony and soft corals were found in the sub-tidal regions of reefs. The genera of stony corals noted in the Indian reefs are Favia, Goniopora, Favites, Sinularia, Montipora etc. and soft coral genera were found such as Nephthya, Dendronephthya.

**Assessment of Coral Reefs in India**

1) Assessment of Coral Reef cover of the following identified Coral Reef areas in the country using remote sensing and preparation of digital maps of all these areas on 1:50,000 scale and preparation of the Coral Reef Atlas:

(i). Andaman & Nicobar Islands
(ii). Lakshadweep Islands
(iii). Gulf of Mannar (Tamil Nadu)
(iv). Gulf of Kutchh (Gujarat)

2) A GIS study for Coral Reefs in Andaman & Nicobar Islands and device monitoring mechanism and tools covering extent of dead and live Coral as well as status of recovery.

**Data Input and Methodolgy:**

Initial efforts had been directed towards finding suitable satellite data and develop appropriate methodology for coral reef mapping. Satellite data of different sensors were tried for different sites. These included OCM (Ocean Colour Monitor of IRS-P4) data of March, 2003 with a spatial resolution of 360 meter, WiFS (Wide Field Sensor) of IRS-1C of February, 2000 with a spatial resolution of 188 meter, LISS-III data of IRS-1D of January, 2003 with a spatial resolution of 23.5 m meter, merged data of LISS-III and OCM and Landsat (ETM+) data of 2000 with a spatial resolution of 30 meter. High-resolution multispectral data of Quickbird and IKONOS (with spatial resolution of 2.44 meter and 4 meter) are also being procured for parts of Andaman & Nicobar Islands.

WiFS and OCM data are not found suitable for coral mapping because of the coarse resolution of these sensors. As corals occur mostly up to 200-300 meters from shore, these data products can not differentiate and map corals properly. While LISS III data was found reasonably good for assessing and mapping barrier and atoll type coral reefs (like in Lakhsadweep), it is not very useful in mapping fringing reefs like those found in A& N Islands because of suppression of the signatures (tone) of corals by sand as coral reefs are very close to shore. Therefore, despite spatial resolution of 23.5 meter of the sensor, it is extremely difficult to delineate fringing reefs correctly using LISS-III data. The merged data of OCM and LISS-III was also not found suitable for coral reef mapping of A&N Islands. They are not separable and mapable accurately on the FCC. Landsat (ETM+) data was found more suitable for delineation of fringing coral reefs Because of presence of blue band in this sensor as the useful signal that is used for remote sensing of coral environment is between 400 nm and 600 nm. Therefore, Landsat (ETM+) data was used to delineate coral reefs of A&N Islands, Gulf of Mannar and Gulf of Kutchh. The methodology involves downloading of satellite data in digital form to computer followed by geo-rectification. Digital image processing was done using.

*ERDAS IMAGINE* (version 8.7) software on ***Windows XP platform*** with the ISODATA (Iterative Self-Organizing Data Analysis Technique) algorithm to perform an unsupervised classification which is generally used for classification of corals. This was followed by Ground verification and on screen visual editing was done based on ground information. **You have seen captions as** Dried sea cucumbers, Dried seahorses on the market, Large sharkfin for sale shark fin soup, rays on a market southeast Asia ,horseshoe crab on a market, shark fin soup on a grocery shelf in Singapore.

The coral community is really a system that includes a collection of biological communities, representing one of the most diverse ecosystems in the world. For this reason, coral reefs often are referred to as the "rainforests of the oceans."

Corals themselves are tiny animals which belong to the group *cnidaria* (the "c" is silent). Other cnidarians include hydras, jellyfish, and sea anemones. Corals are *sessile* animals, meaning they are not mobile but stay fixed in one place. They feed by reaching out with tentacles to catch prey such as small fish and planktonic animals. Corals live in colonies consisting of many individuals, each of which is called *polyp*. They secrete a hard calcium carbonate skeleton, which serves as a uniform base or *substrate* for the colony. The skeleton also provides protection, as the polyps can contract into the structure if predators approach. It is these hard skeletal structures that build up coral reefs over time. The calcium carbonate is secreted at the base of the polyps, so the living coral colony occurs at the surface of the skeletal structure, completely covering it. Calcium carbonate is continuously deposited by the living colony, adding to the size of the structure. Growth of these structures varies greatly, depending on the species of coral and environmental conditions-- ranging from 0.3 to 10 centimeters per year. Different species of coral build structures of various sizes and shapes ("brain corals," "fan corals," etc.), creating

amazing diversity and complexity in the coral reef ecosystem. Various coral species tend to be segregated into characteristic zones on a reef, separated out by competition with other species and by environmental conditions.

Virtually all reef-dwelling corals have a *symbiotic* (mutually beneficial) relationship with algae called *zooxanthellae*. The plant-like algae live inside the coral polyps and perform photosynthesis, producing food which is shared with the coral. In exchange the coral provides the algae with protection and access to light, which is necessary for photosynthesis. The zooxanthellae also lend their color to their coral symbionts. *Coral bleaching* occurs when corals lose their zooxanthellae, exposing the white calcium carbonate skeletons of the coral colony. There are a number of stresses or environmental changes that may cause bleaching including disease, excess shade, increased levels of ultraviolet radiation, sedimentation, pollution, salinity changes, and increased temperatures.

Because the zooxanthellae depend on light for photosynthesis, reef building corals are found in shallow, clear water where light can penetrate down to the coral polyps. Reef building coral communities also require tropical or sub-tropical temperatures, and exist globally in a band 30 degrees north to 30 degrees south of the equator. Reefs are generally classified in three types. *Fringing reefs*, the most common type, project seaward directly from the shores of islands or continents. *Barrier reefs* are platforms separated from the adjacent land by a bay or lagoon. The longest barrier reefs occur off the coasts of Australia and Belize. *Atolls* rest on the tops of submerged volcanoes. They are usually circular or oval with a central lagoon. Parts of the atoll may emerge as islands. Over 300 atolls are found in the south Pacific.

Coral reefs provide habitats for a large variety of organisms. These organisms rely on corals as a source of food and shelter. Besides the corals themselves and their symbiotic algae, other creatures that call coral reefs home include various sponges; molluscs such as sea slugs, nudibranchs, oysters, and clams; crustaceans like crabs and shrimp; many kinds of sea worms; echinoderms like star fish and sea urchins; other cnidarians such as jellyfish and sea anemones; various types of fungi; sea turtles; and many species of fish.Coral reefs and their associated communities of seagrasses, mangroves and mudflats are sensitive indicators of water quality and the ecological integrity of the ecosystem. They tolerate relatively narrow ranges of temperature, salinity, water clarity, and other chemical and water quality characteristics. Reefs thus are excellent sentinels of the quality of their environment. Proper monitoring of reefs can identify changes in water quality or impacts from land-based activities. Monitoring changes in water quality can help local resource managers understand the implications of actions occurring in watersheds that are associated with particular coral communities. These connections will help in development of sound management plans for coral reefs and other coastal and marine resources.

Man has had a long association with reefs. They are important fishery and nursery areas, and more recently have proved to be very important economically as tourist attractions. Reefs provide protection from erosion to coastlines and sand for beaches. However, reefs located near coastal populations are showing increasing signs of stress and are not faring as well as reefs which are more distant from centers of human population.

There are two types of stresses associated with reef systems: natural and human-induced. The effects of these stresses can range from negligible to catastrophic. Reefs display a surprising adaptation to short-term natural catastrophic events, such as hurricanes, and usually recover to normal community structure. These natural events can even be considered beneficial in regards to biological diversity. Severe storm events on land can topple large trees. This opens up the forest to recolonization and results in a greater diversity of plants. This same process occurs with storm impacts to reefs. The damaged area of the reef is often recolonized by a greater diversity of organisms than existed before the storm. In the long term this event benefits the ecological integrity of the reef.

However, reefs are not well adapted to survive exposure to long-term stress. Some examples include agricultural and industrial runoff, increased sedimentation from land clearing, human sewage and toxic discharges. Many land-based activities have important implications for reefs. Agricultural activities can introduce herbicides, pesticides, fertilizers and runoff from animal feed lots. Sewage discharges can introduce nitrogen and phosphate compounds along with pathogens and mixtures of toxics. Uncontrolled land clearing can result in erosion, with the resultant increase in sediment loads to surface waters. Roadways, parking lots and buildings consist of impervious surfaces. These surfaces increase runoff rates and carry with those waters mixtures of dissolved substances to surface waters. The surface waters in any watershed eventually discharge into coastal or near-coastal waters. These waters can then impact coral communities associated with these discharge points. Thus, activities occurring in distant locations have impacts to reefs which are far away from these activities.

There have been increasing efforts to establish better management and conservation measures to protect the diversity of these biologically rich areas. Management practices have historically focused on the coral reef proper and not considered associated communities, such as seagrasses, mangroves, mudflats or defined watersheds (which transport complex mixtures in their waters), in a meaningful manner. This attempted to manage the reef in isolation, like an island.Current management efforts recognize the importance of including reefs as part of a larger system, where integrated coastal zone management tools and watershed concepts can be used in the development of comprehensive management and conservation plans. When reefs are considered as part of a larger watershed, the recognization of the complexity of environmental stressors can be understood. Management plans can be developed to lessen impacts to mangroves, seagrasses and the reef ecosystem, based upon scientific data and a better understanding of the system. EPA is in the process of developing guidance for a watershed approach to coral ecosystem protection.

The lagoon and reef flats are looked upon as common property resources and therefore equity in resource sharing is an important issue. For example discipline has to be maintained in case more than one person wants to do net fishing. Only one net is placed in the lagoon and the catch is shared by all the parties concerned.

*Coral and shingle extraction:* The islanders make bricks out of coral shingle and use them for house and building constructions. The islanders know that it is the reef that protects the islands and rarely collect boulder coral for individual use. They rely on shingle collection on the lagoon side. They mix cement with the shingle to make bricks and build their homes.

*Developmental and recreational activities',* blasting and dredging in lagoon for navigational channels leads to coral mortality. Tourism poses problems of garbage and sewage disposal, anchor damage by tourist boats, collection of souvenirs.

While the formation of protected areas and the CRZ notifications and Acts are laudable one finds that there seem to be problems in trying to implement them. These problems are magnified due to the difficulties arising out of monitoring coral reefs and lack of trained departmental staff to carry out these activities. A good example is that coral reefs in protected areas have now come under the control of foresters and Wildlife specialists, who have very little understanding of coral reef ecology and many of them have also never seen a reef first hand. They therefore are only following a projectionist policy where possible and banning the entry of people into the protected areas.

The Government of Tamilnadu has banned the quarrying of massive corals; dead corals on landward sides can be extracted under a lease. Collection of marine organisms are allowed only for scientific purposes around

Krusudai island. Management responsibility of the protected areas and marine biosphere lies with the state department of forests and wildlife. No management or legal protection exists for Palk Bay.

Gulf of Mannar has been declared a Marine Biosphere Reserve. All 21 islands have been notified as reserve lands under sec.26 of the Tamil Nadu Forest Act. Notification of these islands and the sea around the island up to 3.5-5 fathom deep, as a national park under the provisions of the wildlife Protection Act 1972 has also been published. Dugong hunting has been banned and awareness created among fishermen.

Zoning for tourism development; education and scientific purposes have been recommended for total protection of marine life including dolphins, turtles and sea weeds.

The M.S. Swaminathan Research Foundation and the Tamilnadu Department of forests are currently in the process of developing a management plan for operationalising the management activities of the Gulf of Mannar Biosphere Reserve.

*Andaman and Nicobar Islands*

All the coral reefs included under the National Marine park status come under the jurisdiction of the Department of Forests and Wildlife. The unprotected area falls under the purview of the department of fisheriesThere is a ban on gathering corals and endangered molluscs however the corals are not included in the wildlife protection act. It is therefore difficult to take action against offenders outside the national park. They cannot be convicted and only the material gathered is confiscated by the department of police. Tourists are not allowed to collect shells, corals etc. for souvenir purposes.

*Gulf of Kutch*

The Gulf of Kutch including 42 islands along the coast of Jamnagar was declared India's first marine protected area' through a series of notifications between 1980 and 1982. The first notification dated 12-8-80 made a sanctuary of approximately 221 sq. Km and it was later extended by a second notification dated 20-7-82 to include 237 sq. Km more (Nambiar et al, 1995). The national park comes under the jurisdiction of the Department of Forests.

Though there is a ban on gathering corals and endangered marine species, the laws relating to the ban are vague and difficult to implement.

*Lakshadweep Islands*

The Lakshadweep islands do not boast of a protected area, however this is India's only atoll Union Territory. This declaration is based on the realization that the long term survival of the Union Territory depends upon the protection, preservation and conservation of its unique and extremely fragile eco-system. All development plans in the islands have to be ecologically compatible and must avoid ecological stress.

The Department of Science, Technology and Environment also conducts periodic awareness programs and has proposed establishment of a Marine National Park and National and World environmental Development of an appropriate Sewage systems in association with competent institutions.

They propose to monitor the degradation of corals both inside and outside the reef by regular diving and to employ protective measures to prepare a master plan for the conservation of corals. Coral reef research in India is still at a preliminary stage Enormous data exists  Its research has been more incidental than a main stream

programme in nearly all these institutes. This has to change if we are serious about developing people centered management plans for conserving and managing our reef heritage.

## Can reserve networks protect coral reefs from climate change?

**(14 April 2011) A new study has conducted a preliminary investigation into, 15 per cent of coral reefs in the Bahamas, the study area, would be able to withstand rising temperature, and would therefore be appropriately placed in reserves**. Rises in sea temperature have already caused several mass coral bleaching events, where corals whiten from the death of algae that live in a mutually beneficial relationship with the coral. This can threaten the coral's survival. Oceans are expected to warm under climate change, which could potentially cause more bleaching and greater loss of coral. Although reserves provide no refuge from climate change, they can provide potential for coral to adapt to the stress caused by climate change.Reefs were classified according to their level of acute stress (as measured by the number of weeks when the temperature was 1o C above the normal temperature) and their level of chronic stress (as measured by the maximum monthly mean temperature of all the years when stress was not acute). Acute stress was highest in central Bahamas and chronic stress was highest to the west near the Gulf Stream. As would be expected, acute stress had a greater negative impact than chronic stress. The study then modelled possible larval dispersion, the results of which indicated that scales of dispersion are large enough to connect reefs into plausible reserve networks. Some connections were more feasible than others and the study estimated that optimizing reserve design to network those more feasible areas could produce a six-fold increase in the level of larval dispersal.

In order to further examine the optimal design of reserve networks, the study considered three scenarios: 1.) corals continue to respond to stress as they are now, 2.) coral genetically adapts and 3.) coral locally acclimatises to rising sea temperatures with minor physical changes (phenotypic). With further modelling the study indicated that, if genetic adaptation occurred, reserve design would have to maximise connectivity and larval dispersion so the "new" type of coral could spread. If phenotypic adaptation occurred, connectivity was not so important and the optimal reserve design would be one that protected areas that had been least affected by stress as these would be the healthiest reefs. Nevertheless a small proportion of sites (15 per cent) were selected as suitable to be reserves under all scenarios, which are likely to be those that both increase connectivity between reefs and protect those reefs that are least affected by stress. This indicated that this 15 per cent should be prioritised as reserves.

The analysis also needs to be widened to consider the ecosystem as a whole and possible socio-economic constraints of creating reserves.

Coral reefs are invaluable resources to local communities around the world, serving as sources of food, jobs and livelihoods, and as coastal protection. Without effective management and enforcement, the trade of coral reef species and products jeopardizes the potential of coral reefs to sustain local communities and future generations. Coral reef species are removed from the reef and traded in numerous domestic and international markets for use as curios, limestone, traditional medicines, live marine ornamentals, coral and "live rock" (e.g. coral rubble with attached living organisms) for aquaria, and construction materials. While these practices provide economic benefits, if done irresponsibly they are destructive and undermine the important long-term benefits provided by reefs, such as shoreline protection, fisheries and ecotourism. Coral mining can include blasting of massive areas of reef with dynamite or large scale removal of coral manually in patches throughout a reef. Many countries have banned coral mining, such as Sri Lanka and Indonesia, but due to lack of enforcement, the practice continues.

Selective harvesting, when practiced under an effectively enforced management plan, can be done sustainably with minimal impact on the reef.

**Mining for construction.** In East Africa, South Asia, Southeast Asia, and the Pacific, corals are mined for limestone and construction materials. Sometimes coral pieces are removed for use as bricks or road-fill. Sand and limestone from coral reefs are also made into cement for new buildings. According to a 1995 study, 20,000 cubic meters of coral per year were collected in the Maldives solely for construction materials (Brown, 1995).

**Mining for calcium.** Dead coral is harvested for calcium supplements.

**Harvesting for souvenirs/jewelry.** Coral species are used in the dried ornamental trade business, collected and traded for souvenirs and jewelry. Coral curios and jewelry are often sold to tourists and exporters.

**Harvesting for marine aquaria**. Live coral is collected for the marine aquarium industry and public aquaria.

**Harvesting for medical use**. Researchers have been using coral for bone graph clinical trials and imports of coral for medical purposes increased 500% from 1991 to 1992.

**Reef destruction and sedimentation**. Mining blasts and removes the reef, destroying it and causing other indirect impacts, such as sand erosion, land retreat, and sedimentation. These can all greatly affect coastal towns, villages and the tourism industry because the coral protects coastlines and builds beaches.

**Slow recovery.** The skeletal framework of reefs, which is removed through mining or removal of reef rock, is built up over hundreds to thousands of years and will take as long to grow back.

**Loss of fish habitat**. Removal of coral and "live rock" from reefs removes critical habitat for fish and other animals.

**Economic losses.** Coral mining creates a significant long-term loss to society, including a loss in fisheries value, coastal protection, and tourism. When considering these factors, the cost of destroying or mismanaging one square kilometer (0.62 square miles) of reef results in losses between US $137,000 and US $1.2 million over a 25 year period (Richmond, 1994).

Undermining the future value of coral reef.

**Exporters:**

In 1997, according to CITES data (of permitted exports), the major exporters of live coral were Indonesia (71%), Fiji (12%), and Solomon Islands (6%). The major exporters of live rock were Fiji (89% by weight) and Indonesia (74% by piece).

Major exporters of worked precious coral for curios and jewelry include Hong Kong, Korea and Taiwan.

**Importers:**

According to CITES, the United States is the largest importer of live coral and reef rock, bringing in more than 80% of the live coral trade (more than 400,000 pieces a year) and more than half of the marine aquarium fish sold worldwide.

Other major importers of coral products are Germany, France, the Netherlands, the United Kingdom, Japan • According to the CITES database, in 1996, permitted coral exports produced 2.5 million pieces of live coral, 739 tons (670,000 kg) of raw coral, and 31,000 colonies of black coral.

About 3,000 tons (2,721,600 kg) of coral enter international trade each year for use in aquariums, according to the Ornamental Aquatic Trade Association.

CITES reported 19,262 tons (17,474,486 kg) of black corals were imported into 70 nations from 1982-1997.

There is strong international concern that some coral reef species are threatened or may become threatened through trade. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is

the main instrument to monitor and regulate the international trade of wildlife. Reef species listed under CITES include 2,000 species of hard corals, black coral, giant clams, queen conch, seahorses and sea turtles. Its mandate is to protect species from overexploitation from international trade.species threatened with extinction. Trade in specimens of these species ispermitted only in exceptional circumstances. The powers may be given for strictness or regulations.

Species that may be impacted if trade is not controlled. Species are supposed to be regulated with permits for importers and exporters. Countries must not only assess and monitor the exports, but also manage the resource so that the collection and trade is not a detriment to its role in the ecosystem. However, many countries lack the capacity and resources to fulfill CITES obligations. All coral species are covered by CITES Appendix II.

1. Improve regulation of coral and reef trade that requires demonstration of sustainable use and collection, for both domestic and international trade.
2. Fulfill monitoring and management obligations under CITES for products traded internationally, as well as a phase-out of U.S. imports of wild coral reef species.
3. Establish “no-take” Marine Protected Areas as ecological reserves.
4. Establish management plans that limit harvesting to a sustainable level.
5. Prevent blasting of coral reefs through legal action and enforcement.
6. Promote certification schemes which give sustainably harvested coral products a market advantage, such as the Marine Aquarium Council (MAC).
7. Educate consumers of coral and coral reef products of the consequences of their choices.
8. Educate local communities on sustainable fishing methods and alternative livelihoods.

The following agreements and partnerships work to stop coral mining and unsustainable trade:
• International Coral Reef Initiative • The Convention on Biological Diversity • International Queen Conch Initiative • North American Wildlife Enforcement Group • World Customs Organization • ICPO-Interpol Asia-Pacific Economic Cooperation • South Pacific Regional Environment Program

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