

CREDIT SEMINAR

ON



Coral Reef Ecosystems



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1. Introduction

Coral reef ecosystems are one of the Earth's most beautiful, ancient and complex ecosystems. It consists of both biological ("coral" community) and geological ("reef" structure) components. They play an essential role in sustaining life in the sea and serve as a source of food and protection for human communities. Coral reefs first formed more than 500 million years ago in warm tropical climates, and since that time they have successfully developed and supported a tremendous array of plant and animal life. Covering less than 0.2% of the ocean floor, it is estimated that coral reefs contain approximately 25% of the ocean's species. Approximately 5,000 species of reef fish have been identified and more than 2,500 species of coral, of which almost 1,000 are reef-building hard corals. About 4,000 species of mollusks alone live on the Great Barrier Reef in Australia. This vast diversity of life has given coral reefs the name "rainforests of the sea." Rainforests, which are habitat for more than 30 million insects, have a greater number of species. However coral reefs have a larger number of vertebrates (animals with backbones) and other major animal groups (phyla).

2. What is Coral???

Coral is a marine invertebrate belonging to the class Anthozoa in phylum Cnidaria. Members of this class are characterized by a body that only opens at one end, the mouth, and have skeletons, either internal or external, of a stone like, horny, or leathery consistency. Some cnidarians, such as jellyfish, float through the water, while others, such as sea anemones and corals, attach themselves to the substrate.

3. Structure and Biology of coral

The body of a coral animal is called the polyp, which is a hollow sac-like structure. At its free end is a mouth surrounded by tentacles, and inside the body is a stomach. The sticky tentacles contain harpoon-like stinging structures, called nematocysts, which enable the polyp to gather food by paralyzing any passing prey. The tentacles then deposit the food in the mouth where it passes down into the stomach. Nutrients are absorbed from the food and any solid waste materials are passed back out through the mouth. Within the stomach are long, tubular mesenterial filaments that the polyp extends to defend itself from attack by other encroaching coral. In addition, the polyps of the hard corals extract calcium carbonate from the sea water and use it to build a hard external limestone skeleton beneath and around their base which secures the fragile polyp to a surface and serves as its protection.

It consists of three layers:

1. Outer epidermis
2. Inner layer of cells lining the gastro vascular cavity, which carries out digestion
3. Mesoglea- which lies in between ring of tentacles

When the calcium carbonate cups of many billions of these polyps fuse together, they form coral reefs (Veron, 2000).

4. Reproduction of coral

Coral polyps reproduce both sexually and asexually. Sexual reproduction occurs when the corals spawn releasing eggs and sperm into the water. The sperm then fertilizes the egg, creating a new individual called a planula larva. Spawning usually occurs in mass in order to give the eggs and sperm a better chance of fertilizing themselves and surviving predators. Although most hard corals are hermaphroditic, containing both male and female sex cells, they sometimes fertilize the sex cells of other colonies thereby ensuring the coral's ability to maintain genetic diversity and adapt to new conditions. Asexual reproduction occurs by budding. The parent polyp clones itself by dividing to form a new polyp which remains attached to the parent polyp's tissue. A coral colony develops by the constant addition of new buds. As the new polyps grow, the old polyps beneath them die, adding their limestone skeletons to the foundation of the reef. In optimum conditions in nature, massive corals may grow up to 8 inches (2cm) a year and branching corals up to 4 inches (10cm) a year. Because of the corals' slow growth, the creation of a reef can take hundreds of years. Coral colonies may also be attached to others of the same or different species, forming large and complex reef structures. Some of these colonies fight one another for more space and light by extending their long arms or mesenterial filaments that the polyp uses to attack and kill the other encroaching polyps. In the right conditions, new colonies can also grow from broken-off fragments of the original colony. In this way, reefs are able to regrow themselves after damage from storms, hurricanes, and cyclones.

5. Types of coral

1. Hard Corals

Reef-building corals (Hermatypic), which secrete a hard external limestone skeleton, are commonly known as hard (stony) corals. They characteristically have tentacles in multiples of six and can be found either individually or in colonies. Common types of hard corals are Massive, Encrusting, Branching, Digitate, Columnar, Mushroom, Tabular and Foliaceous.

Water movement influences the shape of the corals. Where strong waves hit the reef front, where the water is calmer and deeper, the coral branches become more delicate and some take on the shape of large thin plates to absorb a maximum amount of light for their zooxanthellae. Hard corals are the most widely distributed form of coral, occurring in all oceans from the shallow tidal zone to depths of 490 feet (150 m).

2. Soft Corals

Non-reef building corals (Ahermatypic) secrete a flexible or soft skeleton. These are called octocorals. Octocorals include the sea fans, black or thorny coral, Sea whips and Fire and Lace coral. Some of the soft corals produce toxic compounds that make them unappetizing to predators. Soft corals thrive in strong currents where they have access to lots of plankton. They also grow well in areas where hard corals cannot grow, such as dark caves and overhangs. Coral jewelry is made from harvesting soft coral, such as black coral and whip coral. Killing coral to make jewelry and ornaments harms the reef.

6. Zooxanthellae

Some stony corals obtain their food from single-celled organisms called *zooxanthellae*. It uses sunlight for photosynthesis and transfer 95% of the food they produce to coral polyps. Both coral and the zooxanthellae benefit from this association. The zooxanthellae receive protection from currents and herbivores, as well as some nutrients from waste produced by coral polyps.

7. Coral Reefs

Coral reefs are underwater structures made from calcium carbonate secreted by corals. They are made up not only of hard and soft corals, but also sponges, crustaceans, mollusks, fish, sea turtles, sharks, dolphins and much more. Corals grow very slowly - some grow only about 3-20mm per year. Therefore, some reefs form over several million years (Veron, 2000)

8. Importance of Coral Reefs

- It protect coastlines from the damaging effects of wave action and tropical storms
- It provide habitat and shelter for many marine organisms
- It is the source of nitrogen and other essential nutrients for marine food chains
- The fishing industry depends on coral reefs because many fish spawn there and juvenile fish spend time there before making their way to the open sea

- The Great Barrier Reef generates more than 1.5 billion dollars every year for the Australian economy, from fishing and tourism
- The study of coral reefs, is important for providing a clear, scientifically-testable record of climatic events over the past million years or so.
- It is also called as Tropical rain forest of the sea. Because it consists of 25% marine fishes and it provide nursery ground for most of the fishes.
- Coloured corals are used for preparation of ornaments
- Drugs from coral reef animals and plants can be used to treat cancer, arthritis, human bacterial infections, viruses, and other diseases.

9. Types of Reefs

There are three major types of coral reefs

1. Fringing Reef
2. Barrier Reef
3. Atoll

Fringing Reef

Fringing reefs are reefs growing in shallow waters. They closely border the coastline or are separated from it by a narrow stretch of water.

Barrier reef

Barrier reefs grow parallel to the coast, but are separated from land by a deep lagoon. They are found sometimes many kilometres from shore (10–100km). Barrier reefs can grow in fairly deep water. The Great Barrier Reef of Australia extends about 2,010km parallel to the east coast. It is the world's largest reef. It consists of 2900 individual reefs and 900 islands.

Atoll

It is a circular reef surrounding a large, deep central lagoon. It forms when a volcanic islands sink into the ocean over millions of years. It is common in indo pacific region. The Maldives consists of 26 atolls.

10. Factors limiting the distribution of coral reef

Coral reefs are sensitive to even slight changes in environment. Wide varieties of environmental factors are known to influence distribution of coral reefs. There are six major physical factors that limit coral reef development and distribution viz., Temperature, Depth, Light, Salinity, Sedimentation, Wave action.

Temperature

They grow in warm waters that range in temperatures from 18-36⁰C. The ideal temperature range for these corals is 25-29⁰C. Reef development does not occur in waters where the annual mean minimum temperature drop below 18⁰C. Optimal reef development occur in waters where the mean annual temperatures are about 23-25⁰C.

Depth

Coral reef growth is also limited by depth. They do not develop in water that is deeper than about 50-70m. Most reefs grow in depths of 25m or less. This is evidenced by the fact that these structures are restriction has to do with the light requirement of zooxanthellae, living together with hermatypic corals.

Light

Light is one of the most important factors limiting coral reefs. Reef building corals contain symbiotic algae (Zooxanthellae) in its tissue, and for these algae sufficient light must be available for carrying out photosynthesis. Without sufficient light, these algae cannot survive and this leads to the death of the corals. Even if the water is shallow and warm, coral cannot survive if those waters are loaded with sediments as this blocks critical sunlight from penetrating far below the surface.

Salinity

It is an important factor that restricts coral reef development. Hermatypic corals are true marine organisms and are intolerant of salinities deviating significantly from that of normal sea water. (32-35ppt). Where ever inshore waters are subject to continuing influxes of freshwater from river discharge so that the salinity is lowered, reef will be absent.

Sedimentation

Sedimentation is a process caused due to the freshwater runoff from the adjoining landmass. Sediment suspended in the water, settle out on the coral reefs, has an adverse effect on the corals. Many corals can remove limited amount of sediment by trapping it in mucus and carrying it off by ciliary action. Most hermatypic corals, however, cannot withstand heavy sedimentation, which over powers their ciliary-mucus cleansing mechanism, clogs their feeding structures and smoothers them. Sediment in the waters also reduces the light necessary for photosynthesis by the zooxanthellae in the coral tissue. As a result coral reef development

is reduced or eliminated in areas of high turbidity. When this sediment is carried by rivers or streams, the combination of reduced salinity and excess sediment is also responsible for the absence of reefs.

Wave action

In general, coral reef development is greater in areas subject to strong wave action. Coral colonies with their dense, massive skeletons of calcium carbonate are very resistant to damage by wave action. At the same time the wave action provides a constant source of fresh, oxygenated seawater and prevents sediments from settling on the colony. Wave action is also responsible for renewing plankton, which is food for the coral colony.

11. Animals associated with coral reefs

Coral reefs provide habitats for a large variety of organisms. These organisms rely on corals as a source of food and shelter. Some organisms that use corals through mutualism, commensalism and parasitism are within the taxonomic groups of Porifera, Polychaeta, Mollusca, Crustacea, Echinodermata and Pisces (Butterfly fishes, Chaetodontidae, Puffer fishes, Tetraodontidae, Parrot fishes etc). Sponges are found inhabiting cavities in the reef. They remove small chips of calcium carbonate from corals. These sponges such as *Cliona*, cause bioerosion in corals. Sponges inhabit corals for the purpose of protection from predators. Polychaetes such as *Hermodice carunculata* and Gastropods in the family Trochidae depend on corals for food. The giant clam, *Tridacna* sp commonly occur in coral reef areas. They feed on corals such as *Porites* and *Agaricia*. Decapod crustaceans such as shrimps and crabs depend on corals for shelter. Xanthid crabs form cavities in the coral *Acropora palmate*. Fish also depend on corals for protection against predators. There are many other species of fungi, sponges, sea worms, crustaceans and molluscs that bore into coral skeletons. Other organisms that inhabit the coral reefs include variety of fin fishes, Sea urchins, Jellyfish, oysters, clams, turtles, and sea anemones.

12. Threats to coral reef ecosystem

Coral reefs have been experiencing damage from a number of sources. It is estimated that 10% of all coral reefs are already degraded beyond repair, with 30% estimated to be in critical condition and at risk of death within 10 – 20 years. If current pressures continue then 60% of the world's coral reefs may be severely damaged by 2050. The damage/degradation can be due to natural events and or anthropogenic effects.

Natural events

Storms

Coral reefs can be damaged by natural events such as hurricanes, cyclones, and tsunamis. Wave activity can break apart corals, branching corals are more susceptible to storm damage than mound-building corals. Storms rarely kill all corals, and because storms are a natural part of coral reef ecosystems, coral species should be adapted to this type of disturbance and be able to recover following storms. However, human alteration to the environment may make recovery more difficult. For example, the addition of nutrients or removal of herbivores might favour the growth of algae that is able to overgrow coral before they are able to recover.

Coral bleaching

“Bleaching” describes the loss of symbiotic algae by the coral or other host. Most of the pigments in the usually colourful corals depend on the presence of these plant cells. The living tissue of coral animals without algae is translucent, so the white calcium carbonate skeleton shows through, producing a bleached appearance. Bleaching is a general stress response that can be induced in both the field and the laboratory by high or low temperatures, intense light, changes in salinity, or by other physical or chemical stresses. Bleaching is the extreme case of natural variation in algal population density that occurs in many corals (Fitt et al., 2000, 2001). The bleaching and subsequent mortality may result in serious socio-economic impacts, particularly for those nations whose economies are heavily dependent on the revenues generated by reef-based tourism, and reef-based fisheries.

Crown of Thorns

The Crown of Thorns Starfish (COTs) (*Acanthaster planci*) is a predator of coral. These secrete digestive juices out of their bodies and efficiently digest coral polyps. A single COT can eat up to their body size in coral polyps every day (Forbes, 2006). Many of the starfish’s natural predators such as the Hump head wrasse (*Cheilinus undulatus*) and the Giant triton (*Charonia tritonis*) have been over-fished in many reefs. When this happens, COTs can grow unchecked and destroy reefs (Forbes, 2006). COTs infestations have increased reportedly in the recent years. It is believed that overfishing of its natural predators is one of the main reasons for this increase, but increased nutrient runoff is also thought to help survival of its larval stage.

Coral Diseases

A disease is defined as *an abnormal condition of an organism that impairs organism functions, associated with specific symptoms and signs* (adapted from Wobeser 1981). It may

be caused by external factors, such as infectious disease or it may be caused by internal dysfunctions.

Black band disease

Black band disease was first described in the early 1970s as a black band moving on the surface of star corals (*Monstastrea* spp.) and brain corals (*Diploria* spp.). It destroys live tissue as it moves over the surface of the colonies, leaving behind bare white skeleton. This disease may kill entire colonies within a matter of a few months, however tissue loss from a colony can be only partial with recovery after the black band disappears. This black band consists primarily of the filamentous cyanobacterium *Phormidium corallyticum* along with other microorganisms. Research has shown that the death of coral tissue is caused by lack of oxygen as well as exposure to hydrogen sulfide in the tissue adjacent to this black bacterial band. Black band disease occurs when corals are stressed by environmental factors including sedimentation, nutrient levels, pollution, and high water temperatures. These stressors primarily exist during the summer months in the Florida Keys. Black band disease has been observed throughout the world's reef systems with recent outbreaks in the Caribbean and the Florida region.

Dark spot disease

Dark-spots disease was first reported from Colombia during the late 1990s, but the condition appears to be widespread in the Florida Keys and throughout the wider Caribbean. The affected areas appear as dark purple, gray or brown patches of discoloured tissue, circular or irregular in shape that are scattered on the surface of a colony, or at the colony's margin. The discoloured tissue increases in size and radiates outward as the area first affected dies. Darkened polyps often are depressed and appear smaller in size than normal polyps (Bruckner, 2001). DSD is most commonly observed on massive starlet coral (*Siderastrea siderea*) and blushing star coral (*Stephanocoenia intersepta*), but this condition also affects *Montastraea annularis* (Bruckner, 2001).

Red-band Disease

Red-band disease (RBD) consists of a narrow band of filamentous cyanobacteria that advances slowly across the surface of a coral, killing living tissue as it progresses (Bruckner, 2001). Two types of RBD have been described.

- RBD-1 closely resembles Black band diseases, but the band is reddish to maroon in color, and the cyanobacterial filaments are more loosely organized.
- RBD-2 is visibly different from RBD-1, in that the cyanobacterial filaments spread like a net over the colony's surface (Richardson, 1992).

RBD affects massive and plating stony corals, and also sea fans throughout the wider Caribbean.

White-band Disease

White-band disease (WBD) was first identified throughout the Caribbean in 1977 (Green and Bruckner, 2000). This disease is characterized by tissue that peels or sloughs off the coral skeleton in a uniform band, generally beginning at the base of the colony and working its way up to branch tips (Peters, 1997). The band ranges from a few millimeters up to 10 cm wide, and tissue is lost at a rate of about 5 mm per day (Gladfelter, 1991). The effects of WBD can be devastating. In fact, WBD is thought to be a major factor in the decline of elkhorn and staghorn corals in the wider Caribbean (Aronson and Precht, 2001). Since the 1980s, *Acropora cervicornis* has been virtually eliminated from reef environments throughout the region. WBD currently is the only coral disease known to cause major changes in the composition and structure of reefs (Green and Bruckner, 2000).

White Plague

White plague is similar in appearance to White Band Disease, but it affects different species. The disease is characterized by an abrupt line or band of white, exposed coral skeleton that separates living tissue from algal-colonized skeleton, and often a narrow band of bleached tissue may be visible adjacent to exposed skeleton. Usually beginning at the base of a colony, it spreads quickly upward and outward. White plague was first identified in the Florida Keys in 1977.

White Pox Disease

White pox affects elk horn coral in the Florida Keys and possibly throughout the Caribbean. First found in 1996, the disease is characterized by white circular lesions on the surface of infected colonies. (Porter, 2002).

Yellow blotch disease

Yellow blotch disease (YBD) was first identified in 1994 in the lower Florida Keys. Yellow blotch disease begins as pale, circular blotches of translucent tissue or as a narrow band of pale tissue at the colony margin, with affected areas being surrounded by normal, fully pigmented tissue. As the disease progresses, the tissue first affected in the center of the patch dies, and exposed skeleton is colonized by algae (Bruckner, 2001). The area of affected tissue progressively radiates outward, slowly killing the coral. The rate of tissue loss by corals afflicted with YBD averages 5 to 11 cm per year, which is less than that of other coral diseases. (Bruckner, 2001).

Anthropogenic effects

Pollution

Coral reefs can be damaged by a variety of pollutants that are produced by a variety of sources. Agricultural runoff can contain herbicides, pesticides, and nutrient fertilizers. Nitrogen and phosphorus addition can fertilize algae and result in algal blooms. Human sewage, often untreated, can add nutrients, microorganisms, and other pollutants to coral reefs. Nutrients in sewage can cause eutrophication. Bacteria added by sewage pollution are suspected causes of increased incidences of coral diseases such as white band disease. Chemical pollution can also harm coral reefs. For example, oil spills, the result of spills from drilling or discharge of oil from vessels can harm reefs. They can be especially harmful if they occur during coral spawning because the oil can kill eggs and sperm. Solid pollution such as plastics and discarded fishing nets (ghost nets) can also damage reefs.

Over fishing

This affects the ecological balance of coral reef communities, warping the food chain and causing effects far beyond the directly overfished population. *Corallium* spp. are a group of red coral. They are used extensively to make jewellery and curios and are now threatened with extinction due to over-harvesting. Species are also overexploited for medicinal purposes,

mainly in traditional medicine. Many species such as sea horses and pipe fish are over-harvested for Traditional Chinese Medicine (TCM) (Hunt & Vincent, 2006).

Destructive fishing practices

Many fishing practices harm the reef by physically damaging the reef or by killing non-targeted reef fish or other reef organisms. Blast fishing, a method of fishing in parts of the Caribbean, East Africa, and Southeast Asia, uses underwater explosions to damage the swim bladders of fish so that they float to the surface where they are easily captured. The blast of the explosions destroys coral and flattens the reef structure. In some places fishermen use cyanide to stun fish so that they can be captured alive. Small fish and coral polyps may be killed by the cyanide. A style of fishing called *muro-ami* involves scaring fish into a net by pounding on the reef with sticks or other heavy objects that severely damage the coral reef.

Burke et al. (2002) estimate that more than 53% of Indonesia's coral reefs are threatened by destructive fishing practices. It is estimated that over 6,000 divers annually use about 150,000kg of cyanide on 33 million coral polyps worldwide (Briggs, 2003). 85% of the world's traded aquarium fish are caught using cyanide, mainly from Indonesia and the Philippines (Licuanan & Gomez, 2000).

Tourism

Tourism is essential for the economic development of many countries in the region. For example, marine and coastal tourism is the largest industry in the Maldives and accounts directly for 20% of GDP and its wider effects help produce 74% of national income. Almost 40% of the workforce is employed in the industry (Emerton., 2006). When carried out in a controlled and sustainable manner, tourism can be a positive economic earner and should be an incentive for countries to invest in managing coral reef ecosystems to continue attracting tourist revenue. However, when managed poorly, tourism has both direct and indirect negative effects on coral reefs. Snorkelling, diving and boating can cause direct physical damage to reefs, while overexploitation of reef species as food, for aquaria and as curios for tourist markets can threaten the survival of species. In some cases, bad tourism practices are not prevented. For example, tourists are allowed to walk on reefs, causing physical damage to the reef structure and stirring up sediment. Sometimes they even directly collect species off reefs. Boats carrying tourists can damage reefs by dropping anchors directly onto reefs, disturbing species and also causing marine pollution through excessive traffic. Indirectly, careless and irresponsible building of infrastructure directly onto reefs or too close to beaches, river mouths and lagoons, results in increased sedimentation and leaves the infrastructure vulnerable to

damage from extreme weather events. Another indirect effect of tourism is often the irresponsible disposal of sewage and solid waste. Two decades ago, sewage and solid waste were mostly disposed directly into the sea but the current situation has improved greatly. It has been estimated globally that the world's cruise ships discharge 90,000 tons of raw sewage and garbage each day into the world's oceans (Mastny., 2001).

13. Major Indian Reefs

Gulf of Mannar

Location: 8° 48'N, 78° 9'E & 9°14'N, 79°14'E on southeast coast of India, 21 islands

running parallel to a coastline at an average of 8 km from shore.

Type of Reef: Fringing reef at 50-500m from shore often without a well-defined reef flat

Area of Reef: 75.93 sq km (SAC, 2010) 85.5sq km of sea grass bed (Uma maheshwari., 2009)

Salient Features

Temperature: 25-30°C

Gulf of Mannar was declared the first Marine biosphere in India (in year 1989) with 560 sq km of core area (islands and surrounding reefs declared GOM Marine National park in 1980). The biosphere reserve is deemed a priority area under the authoritative reference work published by World Bank, The Great Barrier Reef Marine Park authority and world conservation Union (Venkataraman, 2002).

Biodiversity Profile

1097 species under 254 families and 567 genera which includes 85 species of corals, 15 gorgonids, 16 sea anemones, 24 prawns, 3 lobsters, 21 crabs, 88 molluscs, 106 echinoderms, 2 hemichordates, 2 cephalochordates, 78 tunicates, 553 fishes, 6 reptiles, 63 birds, 6 mammals (Venkataraman *et al.*, 2002) Endemic Hemichordata Phycodera fluva flagship species such as *Dugong dugong*, 3 species of dolphins, 2 species of whales, at least 5 species of turtles and 68 elasmobranchs (Venkataraman *et al.*, 2002).

Major Threats

- Depletion of resources
- Degradation to coral reefs and surrounding islands due to lack of ecosystem approach to fisheries, failure to implement the core objectives of Biosphere reserve (Rajan & Venkataraman, 2012)

- Exploitation of a large number of gorgonids (106 tonnes from 1975-1992), brachyuran crabs, chanks (1-1.5 million/year), trading large number of seaurchin, brittle stars, sea lilies, sea anemones, 60 species of ornamental fishes as aquarium animals.
- Severe depletion of valuable fisheries due to excessive demand and thereby causes non-target biomass dominates the total catch (ZSI, 2011)
- Trawler fishing has more impact on marine resources (Rajagopal, 2011)
- Use of prohibited fishing gear and techniques near islands-Dynamite/Blast fishing, pair trawling, purse seining, use of roller nets, dragnets and seaweed collection.
- Developmental activities in shore, industrial pollution, sewage disposal, waste dumping, heavy sedimentation, excessive algal growth, occurrence of coral diseases.
- Once Mandapam and Tutucorin area were 2 important bases for collection and stacking of coral stones.
- After establishment of national Marine Park Authority, coral quarrying has been completely stopped in Mandapam.
- Dugong hunting/exploitation in Kilakarai by using special bottom set gill nets. Valivalai, thirukkaivalai (Gill nets) and shore seines are also used for capturing dugong (Silas and Fernando, 1985). This may surely lead to species extinction.
- Heated waters released from thermal power plant has also affected the reefs by increasing the coastal water temperature by 3-4°C (3000 tonnes per day dumping of ash that which has severely affected recolonization of *Acropora formosa*).

Gulf of Kutch Coral Reefs

Location: Lat.22°15'-23°40'N and Long. 68°20'-70°40'E.42 islands in its southern part of which 32 islands have coral reefs. Total area is 7350 km².

Reef Type: Mostly fringing reefs with patchy, platform and coral pinnacles. (Bahuguna and Nayak, 1998)

Total Area of Reefs: 352.5 Km²

Salient Features

Extreme temperature Variations is one such issue: In summer the sea surface temperature exceeds 35°C (Max.recorded:44.8°C and drops to 15°C in extreme winter (Min Rec: 7.8°C in Jan) that which causes coral mortalities.

Biodiversity Profile

736 species of fauna and flora have been listed from Gulf of Kutch (Rao and Sastry, 2005) 26 species of coral fauna, under 20 genera rich in algal diversity (120 species) dominated by Sargassum (Anjali Bahuguna *et al.*, 1992) Sipunculans and echinurans are the common inhabitants of the coral and beach rock communities throughout the Gulf of Kutch. 70 species of sponges, 200 species of fishes, 27 species of Prawns, 30 species of crabs and some species of Lobsters and Barnacles, 200 species of molluscs, 3 species of turtles and 3 species of marine mammals. (Coral reefs of India state-of-the-art Report, ENVIS)

Major Threats

- Commercial fishing in the vicinity and subsistence fishing in core area.
- Coral collection for industrial and domestic use resulted in habitat destruction and heavy siltation.
- Commercial shell Collection-continued illegal exploitation. Felling and grazing of mangroves-siltation in reefs.
- Developmental activities-discharge of domestic and industrial effluents, dredging for port activities.
- Unguided educational and recreational activities.
- Destruction of coastal vegetation which is used as fodder for cattle and camels is a major problem enhancing coastal erosion. Sediments deposited on the substratum restrict the settlement of planulae. (Gopinatha Pillai and Rajagopalan, 1979).

Andaman and Nicobar Islands

Location: Located in southeast of Bay of Bengal are 350 islands that have been considered as emerged part of a seismic mountain chain.

Reef Type: Mostly all islands exhibit narrow, linear and extensively well-developed fringing reefs (Vineeta Hoon, 1997).

Total Area of Reef: 1021.46 sq.km (SAC, 2010)

Salinity: 33 ppt

Temperature: 27°-28.5°C

Reef flats have massive porites and favids that form the frame builders (Vineeta Hoon, 1997). Mahatma Gandhi Marine National park and Rani Jhansi Marine National Park are 2 marine protected areas for coral reef conservation.

The Coral reef Ecosystem of Andaman and Nicobar are the most biodiverse reefs comprising:

- 235 Species of corals

- 111 Species of soft corals
- 112 Species of sponges
- 411 Species of crustaceans
- 1422 Species of molluscs
- 430 Species of echinoderms
- 750 Species of fishes
- 4 Species of mammals
- 14 Species of reptiles
- 50 species of Marine birds and 64 species of Algae (Rajan *et al.*, 2011) Leatherback, Hawksbill, Olive ridley and Green turtles are having their nesting sites in these reefs.

Major Threats

- Uncontrolled exploitation of shells (Dorairaj and Soundararajan, 1977).
- Terrestrial runoff and siltation due to developmental activities.
- Coastal pollution from agriculture and urban sources.
- Destructive fishing techniques by foreign poachers, crude bombs containing Ammonium/Potassium Nitrate are dropped into coral reefs.
- Reef subjected to blast fishing
- Threat of target fishing where mainly groupers and snappers are overfished and this leads to stock depletion.
- Most important is tourism threat that result in solid waste accumulation, increased sedimentation, coral damages caused by diverse, boats and snorkelling activities.
- In December 2004, extensive damages caused by earthquake and tsunami. In Nicobar Islands reefs were impacted by tsunami as corals were uprooted and covered with beach sands.

Lakshadweep Coral Reefs

Location: In Arabian Sea situated between the Lat 8°12'N and Long 71°74'E consisting of 36 islands, 14 atolls, 3 platform reefs and 2 prominent submerged coral banks islands vary from 0.1-4.4 sq.km in size. (ZSI, CBD COP-11, 2012)

Reef Type: Mainly atolls except one platform reef in Androth Island. 14 atolls include Baliyapaniya, Cheriyananiyam, Chetlet, Bitra, Kiltan, Kadmat, Ameni, Perumal Par, Bungaram, Agatti, Kavaratti, Suheli Par, Kalpeni and Minicoy.

Total Area of Reefs: 933.7 sq.km including lagoon area of 510 sq km (SAC, 2010)

Salient Features:

Sea Surface temperature: 28-31°C

Sea Water Salinity: 34-39 ppt. (Mamadiar, 1977)

Biodiversity Profile

- 152 Species of Meiofauna
- 69 Species of Polychaetes
- 17 Species of sipuncula, 7 species of Insecta,
- 168 Species of Molluscs
- 72 Species of echinoderms (Ghosh, 1991)
- 104 Species of corals (Pillai, 1989)
- 4 Species of turtle (*Eretmochelys imbricata* (Hawksbill Turtle), *Lepidochelys olivacea*, *Chelonia mydas*, *Dermochelys coriacea* (included in IUCN red list)
- 100 species of flora (Rao, 1991) consisting of seaweeds algae and seagrass)
- Notable feature of coral fauna of Lakshadweep is absence of *Foliosa* and *Echinopora tamellosa*.

Massive coral species: *Porites solida*, *Porites lutea* and *Diploastrea sp.* are common in Minicoy (Gopinatha Pillai, 1986)

Major Threats

- Pollution of Lagoon waters due to increased rate of siltation in lagoon of Minicoy due to sea erosion and increased human activity in lagoon.
- Bleaching event in 1998, recorded 80% coral mortality.
- Cyclones, Storms has been posing severe threat to reefs.
- Explosion of *Acanthaster planci*, predator on corals.
- Increased population pressures on coral colonization (Jeyabaskaran, 2004, Arthur, 2008)
- Low Dissolved Oxygen Concentration and high BOD Value indicate environmental stress in these regions.
- Quarrying corals from the shore and reefs, pitting the ground and removal of surface soil are the major human impacts on the Lakshadweep coral reefs (Gopinatha Pillai, 1986).
- Mortality of corals due to sponge attack has been calculated as 80% for an area of 25 m² /yr (Thomas, 1997).

14. Monitoring and Management of Coral reef Ecosystems

Monitoring coral reefs

Basic monitoring principles

Coral reefs are the most complex marine ecosystems on earth, and it is not practical to monitor all of the reefs animals and plants and their many interactions. However here are some basic principles to keep in mind regardless of your specific monitoring objectives

1. To have long term data for assessing the extent and cause of changes, obtain information on:
 - a. Basic environmental parameters such as temperature, salinity and turbidity.
 - b. The abundance of stony corals, octocorals, algae, sponges and reef fish
2. In order to have both qualitative and quantitative information from well- documented site a combination of photographic and transect or quadrat methods should be applied.
3. Sample the site periodically to record changes in targeted reef organisms.
4. Establish procedures for long term monitoring that are as free as possible from observer bias, and easily repeated by people who may be assigned the task in the future and make sure the procedures are well documented.
5. The site that you select for monitoring should be well defined and easily reachable, so that it will enable the future workers to monitor without any difficulty.

Monitoring techniques

Some of the monitoring techniques are as follows:

Manta Tow Survey

The Manta Tow survey is used to assess broad temporal and spatial changes in the benthic communities of coral reefs. It enables visual assessment of large areas of reef within a short time. It is very useful for studying the effect of large - scale disturbances such as cyclones, coral bleaching and outbreaks of *Acanthaster planci* (Crown of thorns star fish). The technique is also useful for selecting sites that are representative of large areas of reef.

Methodology

The technique involves towing an observer, with a manta board, behind a small boat powered by an out board motor to survey the margin of the reef. Tows are carried out and are broken into tows of 2 minutes duration. After each 2 minute tow the boat is stopped to record

the observations such as percent cover of live coral, dead coral and soft coral. These are recorded in a data sheets, Additional information such as percent cover of sand and rubble, and numbers of *Acanthaster*, *Diadema* or *Tridacnid* clams may be depending upon the objective of the survey. The driver marks the tow number and position of the boat on the aerial photograph. When the observer signals ready then the tow is continued. Tow is continued till the end of the reef (in case of fringing reefs) or around the entire margin of the reef. The speed of the boat should be maintained at 3-5km/hr.

Merits:

- A large area is covered in a short time, which reduces the chance of overlooking population changes or occasional disturbances (e.g. dynamite fishing, COTS, bleaching, disease and storm damage).
- After proper training it is really simple to perform
- Cheap equipment with manta boards easily manufactured locally.
- Suitable for remote locations with minimum support (can be done on snorkel);
- Large distances covered with minimal observer fatigue.
- Relatively accurate (when calibrated with a scuba search) and a cost effective way to determine the abundance of non-cryptic COTS and corals over large areas in clear water.
- Excellent for an overview of the site and assessing the type of reef and the resources.

Demerits:

- Unwanted section of the reef may be surveyed (large areas of sand and deep water) because the tow path is controlled by the driver who views the reef from above the water.
- The observer tend to ignore the animals that are not prominent
- The observer may loose his precision if there are too many information to remember.
- The method is not applicable for areas with poor visibility (less than 6 meters)

Transect Method:

Transects are widely used in coral reef monitoring to assess the status of the corals and its associates. They are very popular among coral biologists because of its simplicity and

reliability. Transects are laid perpendicular to the shore to study the different zones of the reef. The common transect techniques used in coral reef monitoring are as follows:

Line Intercept Transect technique (LIT)

Line Intercept Transect technique is used to assess the sessile soft bottom benthic coral reef community. This technique categorizes the reef community as life form categories and also based on morphological variability. The LIT technique help us to assess the health of coral reef community after bleaching, Cyclone, Anthropogenic disturbances etc. LIT not only gives a picture of coral reef community structure but also the percentage of dead corals, rubbles and silt present in the reef area. LIT surveys are usually performed parallel to the shore to record data from uniform depth. The LIT surveys have to be performed by one or two pairs of persons trained in SCUBA diving (in case of deeper areas) or by snorkelling (in shallow reef areas)

Methodology

For LIT surveys select sites based on general survey using manta tow technique. Then choose two sites, one on the fore reef and the other on the back reef and mark the location by using a marker buoy. In each site lay at least 5 replicate transects of 20 meters in two depth profiles (3m and 9m). One person has to lay the tape while the other should follow him to peg the tapes. After laying the tape the observer swim over the tape recording the life form categories on a data sheet.

Merits

- LIT is the most dependable and simplest technique available for obtaining quantitative percentage cover.
- LIT provides detailed information on spatial pattern
- If LIT is repeated at regular interval, it can definitely provide information on temporal change.
- It is a very simple and requires little equipment.

Demerits

- Difficulty to standardize some of the life form categories
- LIT is limited to the goal of percent cover and relative abundance.

Chain Transect

A chain transect is a relatively inexpensive and accurate way to gather information on species diversity. The relative abundance of different species, and the amount of hard substrate or sand. It is the most effective for documenting changes in abundant larger coral species, and best suited to areas dominated by head (rather than branching corals) corals. It is used to estimate “spatial index” of the reef the ratio of reef surface contour distance to the linear distance.

Methodology

Mark the Transect: In order to lay a preliminary transect, tie one end of a 20m or 30m fibre glass tape to a piece of dead coral at a randomly selected site. Ensure that the line laid is straight. Avoid nylon threads, as they tend to stretch. Permanent transects should be marked with metal stakes to indicate the exact beginning, middle and end of each. A bright coloured flagging may be attached to the stakes to locate the site for sampling.

Position the Chain: Drape a light weight chain cover, around and under all natural fixed surfaces directly below the line and count the number of links that spreads over the surface of species. Finally calculate the percent live coral cover.

$$\text{Percent live coral cover} = \frac{\text{No of links live coral}}{\text{Total no. of links along transect}} \times 100$$

Merits

- Very useful to study percentage cover of life forms and the topographical complexity of reef.
- It is tedious and time consuming.

Demerits

- The reef may be damaged if the chain becomes entangled in branching coral.

Belt Transect

Belt transects cover a large area per census than stationary counts and are considered most useful for counting patchily-distributed species. It is suitable for assessing fish and invertebrate populations.

Methodology

Belt transects method is similar to line intercept transect technique. But it can be used to monitor the reef community quantitatively as well as qualitatively. ‘

In case of visual fish censuses, after laying the transect the observer wait for 5-15 minutes for the fishes to settle down. The observer swims slowly along the transect and count the number of species available in a particular area.

Merits

- The belt transect technique is very useful to study reef fishes and other invertebrates.
- This technique may fail in poor visibility conditions and due to observer bias.

Quadrat

The term “Quadrat” generally refers to square or rectangular sampling unit within which organisms are counted or measured. Quadrats can be used to estimate percent cover of each species or other reef components and obtain information about density, abundance, diversity and colony size. One square meter quadrats are frequently used. Quadrats can be permanently or randomly placed to obtain general data on reef conditions.

Methodology

Select a suitable site and lay quadrats at equal intervals. Record the area covered by the target species in percentage. Quadrats may also be laid at equal intervals on transects line. Quadrats may be permanently mounted on site to record long term variations in a reef community.

Merits

- Quadrats are very useful in recording data pertaining to density and species diversity.
- Quadrats are most suitable for studying octo corals and hard corals

Demerits

- Quadrats are not suitable in highly irregular and three dimensional reefs.

Managing coral reefs

Due to the increased pressures on coral reefs, a variety of programmes and policies have been set up to help conserve the precious ecosystems.

Ecotourism

The International Ecotourism Society defines ecotourism as “responsible travel to natural areas that conserves the environment and improves the well-being of local people”. Ecotourism strives to minimise the impact of tourists on areas, and encourages environmental and cultural awareness and respect in order to provide positive experiences for both visitors and hosts. Its aim is also to provide financial support for the conservation of the areas involved, and to help the economies of the local areas.

International management and policy

The Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) includes around 2000 species of corals, clams and turtles found in reefs around the world and enforces regulations about the trade of reef products (and potentially should lower damage from the souvenir trade). The Coral Reef Ecosystem Fishery management Plan (CREFMP) for the western Pacific is the first ecosystem-based fishery management plan for US waters. Its aim is to encourage the sustainable use of coral reef resources in a way that is ecologically and culturally sensitive, lower the human impacts on coral reef ecosystems via marine protected areas, and facilitate sustainable fishing in local reef communities. It was approved by the Western Pacific Fishery Management Council in June 2001.

International Coral Reef Initiative (ICRI), which was established in 1994. The initiative is a partnership among governments, society and non-government organisations which hope to stop and reverse the global destruction of coral reef systems. It was founded by the USA, and includes countries such as Australia, France, Japan, Jamaica, the Philippines, Sweden, the United Kingdom.

Marine Protected Areas

Marine Protected Areas (MPAs) have been introduced in many regions including Indonesia. These promote responsible fishery management and habitat protection, and any potentially damaging activities are not permitted. MPAs aim to restore coral reefs, provide aesthetic maintenance, increase and protect biodiversity and provide economic benefits to the people in the areas involved. Some marine parks charge entrance fees and sell boat permits and

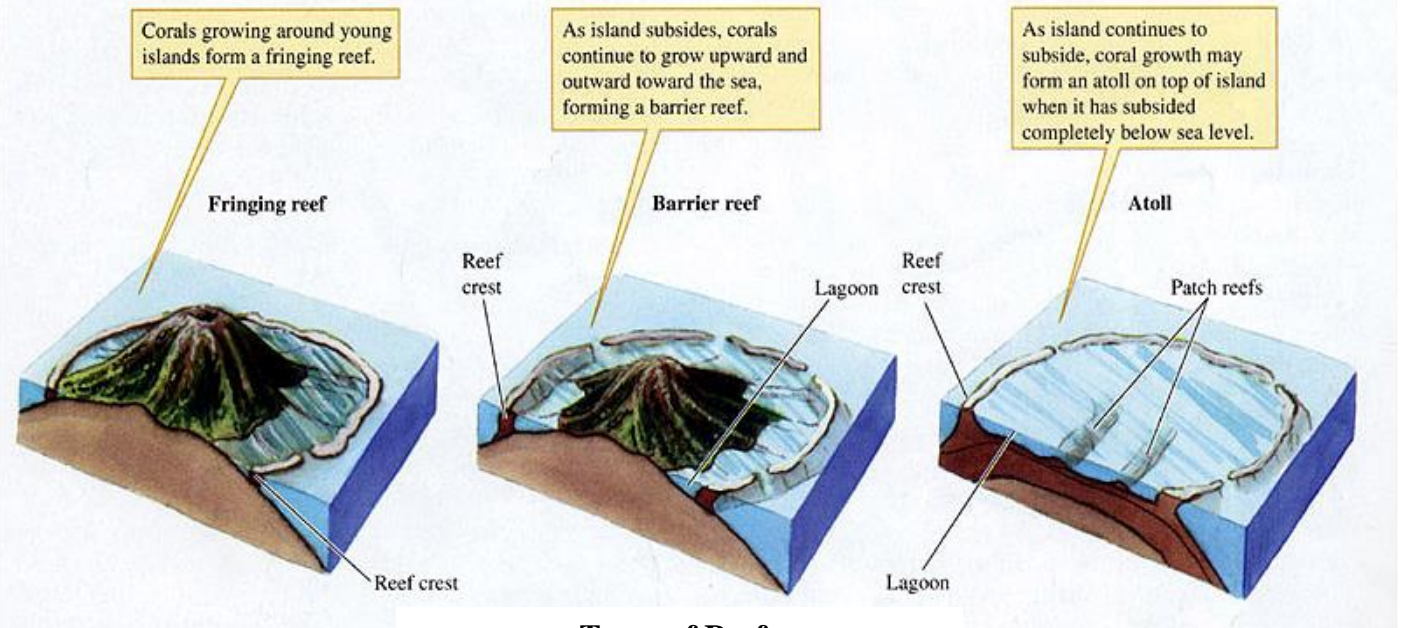
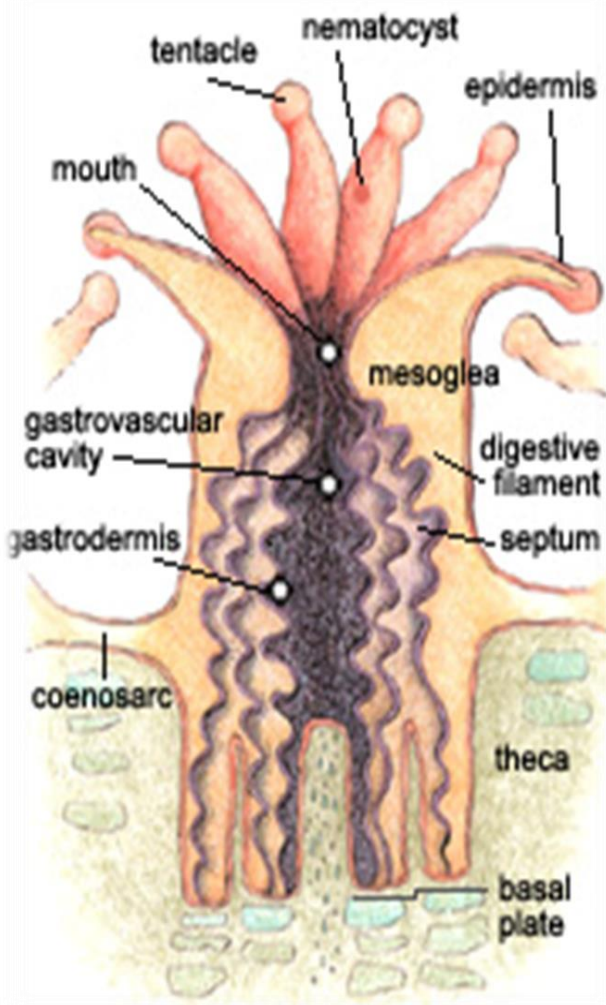
souvenirs, the revenue of which is spent on the development of reefs as resources and sustainable management.

15. Conclusion

Coral reefs contain diverse fish and invertebrate assemblages. This makes them valuable, but difficult to manage. Coral reef ecosystem provides food and shelter for many reef fishes. Conservation of coral reefs will enhance the productivity of ecosystem and also increasing the livelihood of people who rely on them. Reefs must be assessed and monitored to allow management. Ecotourism and MPAs are the major tools for managing the reef ecosystem.

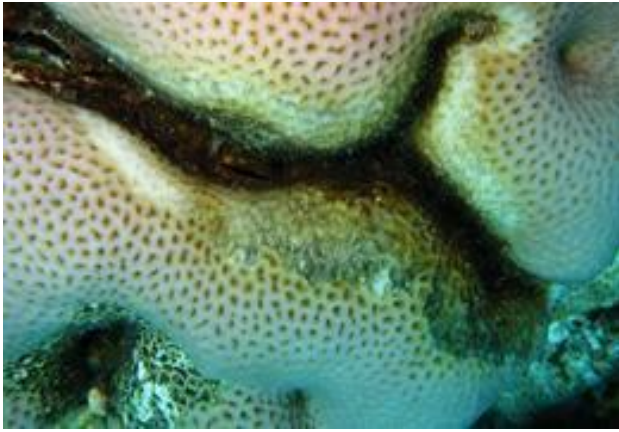
Structure of Coral

Sexual & Asexual Reproduction



Types of Reefs

Black band Disease



Dark spot Disease



White Plaque



Red Band disease



White band disease



Yellow blotch Disease



White Pox Disease

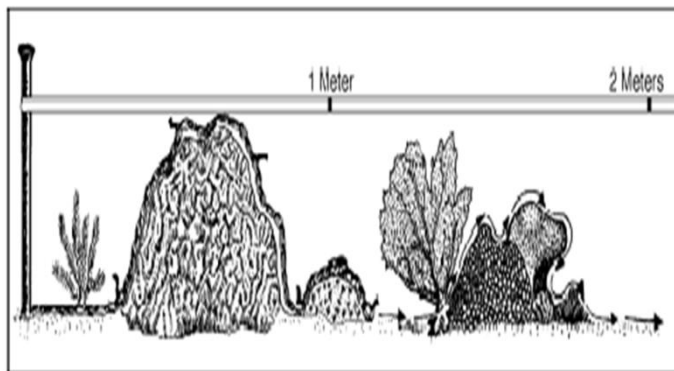
Manta tow Survey



Line Intercept Transect Technique



Chain Transect

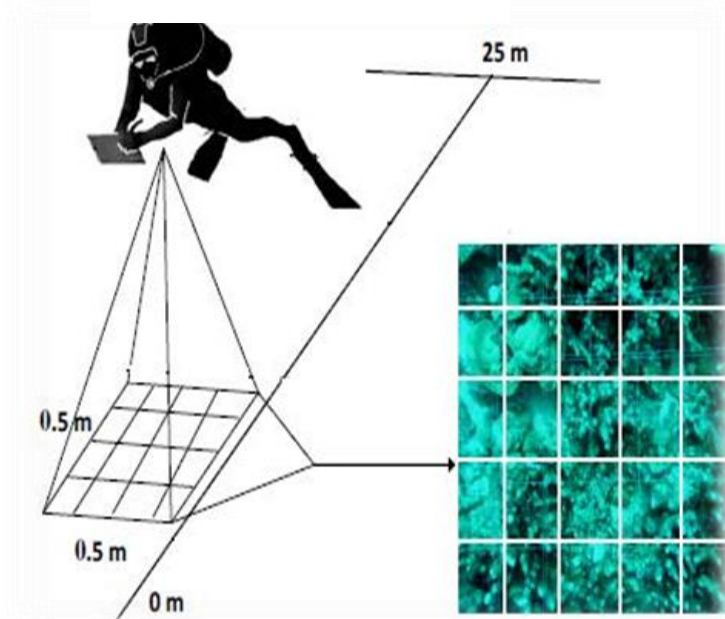


Belt Transect



Positioning the Chair

Quadrat



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