

A REVIEW ON CORAL REEFS AND THEIR MANAGEMENT

Abstract

Coral reefs are one of the most ancient and dynamic ecosystems of India. One of India's oldest and most active ecosystems is the coral reef. Even though they only make up 0.2% of the whole seafloor in terms of area, coral reef ecosystems often referred to as the rainforests of the sea represent close to one-fourth of all marine species. Coral reefs serve a crucial function in preventing coastal erosion in addition to acting as a haven for a wide variety of marine species. India's 8,000 km of coastline is home to people who rely on coral reefs for their daily needs. India is located in the middle of the Indian Ocean's warm, tropical region, and its maritime areas are home to numerous coral reefs. Coral reefs are being harmed and destroyed because of anthropogenic and natural activity, despite the fact that they are extremely important. The Gulf of Mannar, Palk Bay, Gulf of Kutch, Andaman and Nicobar Islands, and the Lakshadweep Islands are the only places in India with significant reef formations. The other reefs are all fringing reefs, whereas the Lakshadweep reefs are atolls. The country's central west coast has patchy coral in the intertidal zones. The ecosystem of coral reefs is incredibly diverse and intricate. But because to several anthropogenic and natural disruptions, this tropical wonder is currently deteriorating at alarming rates and faces a significant risk of extinction. Despite the fact that India has extensive and complicated reef systems and benefits greatly from them, the country's management and conservation efforts seem inadequate. A review of the literature indicates that improved management, together with experienced marine biologists, contemporary infrastructure, and long-term funding, are necessary. This review also aims to highlight the current focus of bio-ecological research

Authors

Sedyaaw P
Post Graduate Student,
College of Fisheries,
Shirgaon, Ratnagiri.

Koli J. M
Professor,
College of Fisheries,
Shirgaon, Ratnagiri.

on Indian coral reefs and to discuss future research opportunities on some of the major global primary research areas. Moreover, there is a pressing need for effective communication between the scientific community and stakeholders for the strict implication of conservation practice to protect the spectacular coral reef ecosystem.

Keywords: Coral reefs crucial function in preventing coastal erosion

I. INTRODUCTION

Because of their incredible diversity of life and amazing distinctiveness, coral reefs are frequently referred to as the "Tropical Rainforests of the Sea". Reefs are vast biological treasure troves that provide millions of people throughout the world with a variety of economic and environmental services. Corals are useful and beautiful things that are members of the phylum Anthozoa. The massive reefs that are only visible at low tides are built by hermatypic corals and their symbiotic zooxanthellae. Corals are only found in the ocean and, taxonomically speaking, are part of the scleratinia order.

The solitary forms, known as ahermatypes, are both solitary and colonial and lack symbionts. Corals that form reefs are actively growing in the ocean's photic zone. Around the world, a belt of coral reefs can be seen in the tropical waters. Despite their enormous significance, coral reefs are currently deteriorating and disappearing at an alarming rate as a result of both natural and artificial factors. If current rates of erosion are allowed to continue, 90% of the reefs would be in danger by 2030. Understanding the current health of coral reefs and the increasing threats to them is essential. The purpose of the study is to investigate management and conservation measures and to offer light on the growing problem of coral exploitation. (Jhahria 2021)

The coral ecosystem is vital to the economies of many tropical and subtropical nations and offers a variety of benefits to millions of people worldwide. Reefs are a popular tourist destination around the world, but human and natural disturbances have an effect on these remarkable ecosystems alone or in combination (Ove 2011). It is concerning to see the general decline in coral reefs on a global scale. Coral growth rates are dramatically declining along with rising coral mortality rates, which is startling. According to Cantin et al. (2010), rising thermal stress has caused a 15%–30% decrease in the rate of calcification of corals since 1990, and predictions foresee future declines of up to 78% due to greenhouse gas concentrations expected for 2100 (Albright et al 2010). Coral bleaching, ocean acidification, extreme natural events, coral diseases, unmanaged coral fishing, and anthropogenic activities have all put coral reefs in risk, even if rules are in theory enough to go for management and conservation of the reefs in India. Despite being in danger, these sensitive eco-systems must nonetheless be protected. It can be done by putting the legislation into action and starting programmes that are centred on research. The study looks at the variables and management tactics employed to safeguard these biodiversity-rich areas.

II. DISTRIBUTION OF CORAL REEFS IN INDIA

In India, the reefs are distributed along the east and west coasts at restricted places, with platform reefs in the Gulf of Mannar and Palk Bay, patchy reefs near Ratnagiri and Malvan coasts, and fringing and barrier reefs in the Gulf of Kutch, Gulf of Mannar, Lakshadweep, and Andaman and Nicobar Islands. India has a coast line of nearly 8129 km, but the reef formation is restricted to four major centres. The total area of coral reefs in India is estimated to be 2,375 sq. km (DOD and SAC, 1997).

Coral reefs are restricted mainly in seven regions of India, such as:

- Coral reefs in Gulf of Mannar
- Coral reefs in Palk Bay
- Coral reefs in Gulf of Kutch,
- Coral reefs in Andaman and Nicobar Islands
- Coral reefs in Lakshadweep Islands
- Coral reefs in West Coast of India

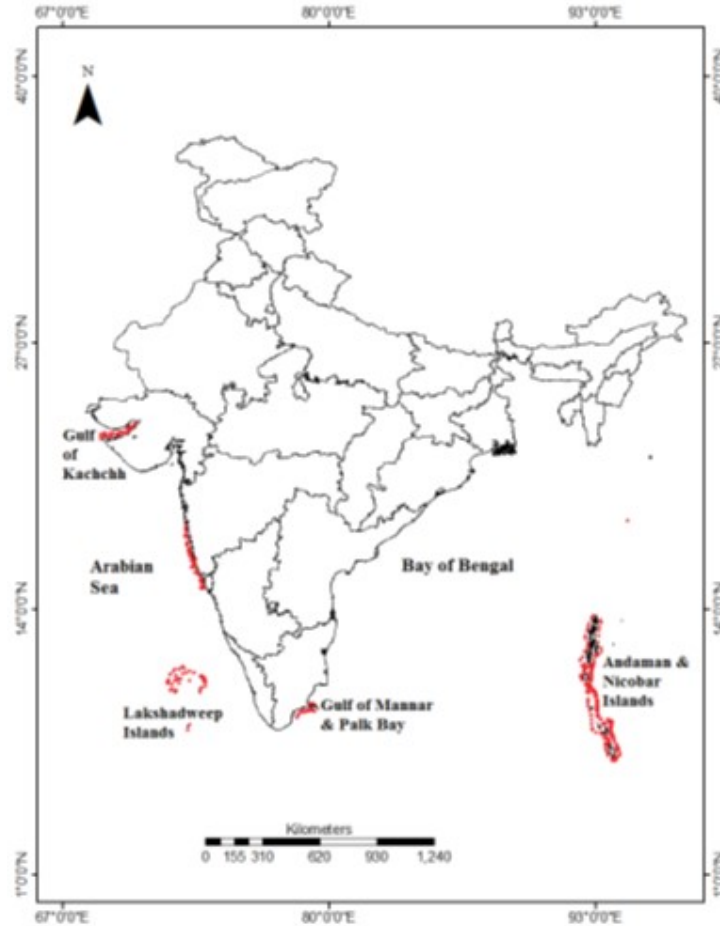


Figure 1: Major coral reef areas in India (Jhajhria, 2021)

- 1. Gulf of Mannar:** On the other side, the Gulf of Mannar reefs are built around a network of 21 islands that run over 140 km between Tuticorin and Rameswaram (Krishnamurthy, 1987). On the southeast coast of India, these islands are situated between latitudes $8^{\circ}47'$ N and $9^{\circ}15'$ N and $78^{\circ}12'$ E and $79^{\circ}14'$ E. An average distance of 8 km separates the 21 islands that run parallel to the shoreline. In the Gulf of Mannar, many reef morphologies, including shore platforms, patches, coral pinnacles, and atoll types, can also be seen. Patch reefs and bordering coral reefs surround the islands. The majority of the time, narrow bordering reefs are found 50 to 100 metres away from the islands.

- 2. Palk Bay:** On the coast of Tamil Nadu, coral reefs may be seen in the Gulf of Mannar and Palk Bay near Rameswaram. Rameswaram Island and the Mandapam peninsula divide the Gulf of Mannar from Palk Bay. Centred at 9°17'N and 79°15', the reef. There is only one bordering reef in the Palk bay, which runs east-west along the mainland from the Pamban channel at the Pamban end of the bridge to Rameswaram Island. This reef is typically less than 200 metres wide and between 25 and 30 kilometres long. The north east monsoon reduces vision and narrows it to just a few metres. From Pamban channel to the southernmost point at Ramnad, the reef flat is very extensive; however, from Pamban to the area south of Rameswaram, it is small.
- 3. Gulf of Kutch:** One of the depressions on the northern side of the Saurashtra Peninsula is the Gulf of Kutch, which is situated between 22°15' and 23°40' N Latitude and 68°20' and 70°40' E Longitude. The beaches are frequently muddy or sandy, with sporadic large sandstone formations. There are over 40 islands with intermittent coral formations, the biggest of which is Pirotan Island. On the sandstone substrate, there are patches of coral visible. The coral fauna in the Gulf of Kutch is less diverse than that in other parts of India. (Pillai, 1996). According to and Radhakrishnan (2014), there are around 352.5 square kilometres of reefs in the Gulf of Kutch.
- 4. Andaman and Nicobar Islands:** Between 6° and 14° N latitude and 91° and 94° E longitude, in the SE of the Bay of Bengal, lie the Andaman and Nicobar group of Islands. There are 350 islands in all. Nearly every island in the Andaman and Nicobar group has surrounding reefs that are narrow, linear, and extensively well-developed (Vineeta Hoon, 1997). Andaman and Nicobar have a combined 135 species spread across 59 taxa (Pillai 1983). 1021.46 sq. km is the entire area that the reef occupies (SAC, 2010). To accurately depict the reefs' current state, there isn't enough recent data about the reefs near the North Andaman and Nicobar Islands.
- 5. The Lakshadweep Islands:** The Lakshadweep islands are dispersed over the Arabian Sea, 225 to 450 km off the coast of Kerala. Geographically, the islands are located between latitudes 8°N and 12°3'N and longitudes 71°E and 74°E. The islands are made up of coral formations that have grown up on the Laccadive-Chagos undersea ridge, which rises quickly from a depth of around 1500 m to 4000 m off the west coast of India. An interrupted network of coral atolls and reefs, including the Union Territory of Lakshadweep, the Maldives, and the Chagos Archipelagoes, make up a continuous undersea bank that extends over 2000 km. This ridge is believed to be a continuation of the Arravali Mountains, and the islands are believed to represent the remains of the mountain cliffs that were submerged. (James et al. 1986). There are 36 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 km² with lagoons occupying about 4200 km².
- 6. West Coast of India:** According to Nair and Qasim (1978), there are submerged banks with lone coral formations along the west coast of India between Bombay and Goa. Coral patches have been observed in the Gaveshani Bank, 100 kilometres west of Mangalore (Nair and Qasim, 1978), and in the intertidal areas of Ratnagiri, Malvan, and Redi, south of Bombay (Qasim and Wafer, 1979). There have been reports of ponies, *Coscinarina*, *turbinaria*, some *Favids*, and *pseudosiderastrea*. Hermatypic corals have been found along the shoreline between Quilon in Kerala and Enayam in Tamil Nadu in the south. In this

region, Pocilipora spp. is the most prevalent genus. Three species of Accropora are present there.

Table 1: Status of coral reefs in India (Jhajhria, 2021)

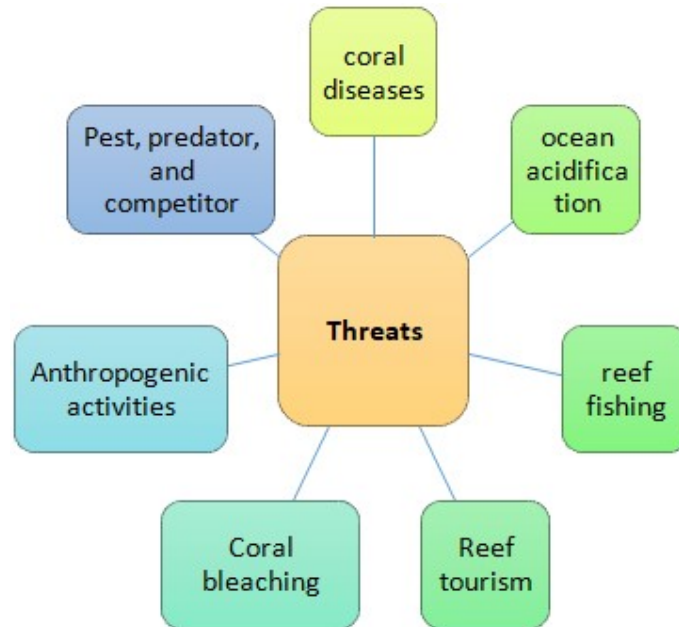
| Particulars | Geographical location | Area of the reef (in Sq. Km) | Destruction during bleaching | Potential for recovery |
|-----------------------------|--|------------------------------|---|------------------------|
| Gulf of Mannar | 21 islands, South East Coast of India 140 km, between Tuticorin and Rameswaram | 94.3 | 60-80 percent loss of live cover. Only 25 percent live corals remaining | Medium Low |
| Gulf of Kutch | 40 islands, Northern side of Saurashtra peninsula | 325.5 | 50-70 percent | Medium Low |
| Andaman and Nicobar Islands | 530 islands | 1021.46 | 15-20 percent | Good |
| Lakshadweep Islands | Uninterrupted chain of coral atolls-stretch of 2000 km | 933.7 | 70-90 percent | Good |

III. TYPES OF CORAL REEFS

There are mainly four types of coral reefs found in India (Saroj et al 2016).

1. **Platform Reefs:** There is no lagoon on these nearly flat reefs. They are found on the continental shelves' shallower portions, and they may be found near atolls or between a shore and a barrier reef. Most of these reefs can be found in the Indian Gulf of Kutch.
2. **Fringing Reefs:** These kinds of reefs can touch the coast directly or border it with a shallow channel or lagoon in between. Fringing reefs can be found in the Indian Andaman & Nicobar Islands, Palk Bay, and the Gulf of Manner.
3. **Barrier Reefs:** A deep waterway or lagoon separates these reefs from the shore of a continent or island. The Andaman and Nicobar Islands in India are the principal locations for barrier reefs. Australia is where the Great Barrier Reef is located outside of India. Following the shoreline are barrier reefs that are separated from the land by large bodies of water.
4. **Atolls:** These barrier reefs are more or less circular in shape or extend continuously around a lagoon without a centre island. Atolls, which are typically a low-lying island with a roughly circular ring of reefs encircling it and are abundant in the Indian and South Pacific oceans, are mostly located in the Lakshadweep islands of India.

IV. THREATS TO CORAL REEFS



- 1. Coral Disease:** Numerous bacterial and fungal infections can also harm corals. Three different disease kinds, including bacterial/fungal infections, black band diseases, and white band diseases, have recently been reported in the Gulf of Mann and Lakshadweep. Several institutions are investigating the precise reason of this Corals die as a result of asfixia on polyps caused by silt and sedimentation. Construction projects, deforestation, reef dredging, and sea erosion all churn up silt and sediment. Coral deaths can also a result of pests and predators. The most harmful predator is the echinoderm *Acanthaster planci*. (Pillai 2010)

The starfish population in Lakshadweep is usual and not particularly dangerous. A large increase in starfish was seen in the Andaman Islands, although little harm was done. The star fish's skeleton becomes white from the coral polyps they eat. The primary bioeroding organisms on a reef are polychaetes and echiuroid, and bioclosion and molluscs that form reefs go hand in hand. Human activity, such as reef blasting, destroys reefs. In the years following independence, the introduction of mechanised fishing vessels resulted in the blasting of the reefs to widen the boat channel in Lakshadweep. The devastation of surrounding reefs on some islands was caused by construction work in the Gulf of Mannar and the mining of coral for various industrial uses. The reefs of the Lakshadweep atoll were harmed by lagoon dredging for navigation. The reefs of the Nicobor Islands and Andaman Islands have largely altered. (Pillai 2010)

The reef sustains significant damage as a result of the outbreak of various epidemic diseases, including the White plague, White pox, White band, and Black ban. Indian Reefs have recently been observed to have high rates of coralline fatal orange disease (CLOD), pink line, pink spot, yellow band, fungal blotch, black band and white

band. (Carpenter et al 2008, Fridman et al 2015, Guldborg et al 2007, Rowden et al 2019 and Jhahria 2021)

- 2. Ocean Acidification:** The amount of carbon dioxide (CO₂) in the atmosphere has increased due to human activity by 36%, and the pH of ocean surface waters has already decreased. Ocean acidification is a set of chemical alterations brought on by the ocean's uptake of CO₂ that lowers pH and carbonate ion concentration. Increased CO₂ has a negative impact on coral calcification rates. (Ardron et al 2014 , Barnett et al 2015, Jones et al 2018, and Ravindran et al 2012).
- 3. Reef Fishing:** Such harm is also caused by destructive and illegal fishing methods. There are still several prohibited practises being used, such as blast fishing. Fish that eat plants are taken out of the water by overfishing, which promotes excessive algal development in their place. In such a way coral reef ecosystem is shifted to algal dominated barren without any fish and corals. Bio-invasion of macroalgae *Kappaphycus alvarezii* (Fig 2) and snowflake *octocoral Carijoa riisei* (Fig 3) have caused detrimental impact on reef corals (Fridman et al 2015).



Figure 2: *Kappaphycus alvarezii*



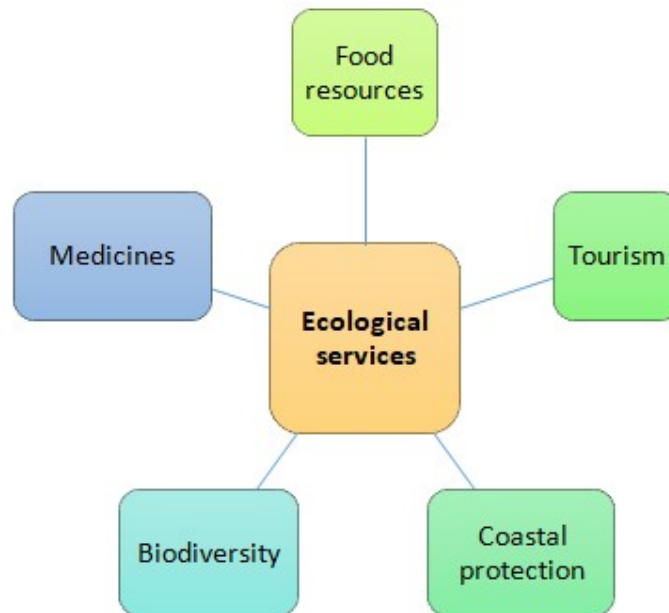
Figure 3: *Carijoa riisei*

- 4. Pest, Predator, and Competitor:** Outbreak of coral eating Crown of Thorns Starfish *Acanthaster plansi* and overgrowth of bio eroding coral boring sponges have been reported from the Indian corals (Hughes et al 2017 and Rajan et al 2015).
- 5. Extreme Natural Events:** A variety of natural disasters, including cyclones, tsunamis, and local geological upheavals, are to blame for the massive coral devastation.
- 6. Reef Tourism:** Unrestrained tourism may be a key factor in the destruction of Indian reefs by purposefully or unintentionally trampling and breaking coral pieces, which results in considerable harm to shallow water corals.
- 7. Anthropogenic Activities:** The main threats to Indian reefs still include illegal shell collecting for hunting souvenirs, unrestrained harvesting, and the importation of numerous exotic marine creatures and items derived from the reef.

8. Coral Bleaching: When sea surface temperatures (SST) rise above a certain threshold, coral reefs experience "bleaching events" (loss of symbiotic algae) because they are so sensitive and vulnerable to thermal stress. Because to the partial or complete eradication of the zooxanthellae symbiotic algae population, coral bleaching is the "whiting of coral tissue"⁶⁰. Bleaching can be caused by a variety of stressors, including increasing sea surface temperatures, higher irradiance, lower salinity, metal pollution, etc. However, the elevated sea surface temperatures brought on by increased global warming are the primary worry. (Venkataraman et al 2017)

V. ECOLOGICAL SERVICES

The "medicine chests" of the sea are widely used as an analogy for coral reefs. Coral reefs may be able to treat serious diseases such skin cancer, leukaemia, lymphoma, ulcers, and heart problems. The distinctive skeletal structure of corals has also been used to develop the most advanced bone-grafting materials. Coral reefs contain large amounts of limestone, which is widely used in construction as an alternative to cement. Additionally, the calcium-rich coral sand has industrial-scale potential as a raw material for the cement industry. (Thinesh et al 2015, Venkataraman et al 2003]. (Jhajhria 2021)



1 Food Resources: Fish, molluscs (clams, scallops, octopi, oysters), crustaceans (crabs, lobsters, prawns), turtles (adults and eggs), and algae are only a few of the many things that humans consume from coral reefs (UNEP/IUCN). Coral reefs provide between 10 and 12% of the canned fish harvested in tropical nations and up to 25% in developing nations (Wilkinson 1993; Gomez 1997). Since many fish are taken by subsistence fishers but never reported, these estimates should be seen as being at the low end of the spectrum. In addition, 9 million metric tonnes of shellfish and molluscs are harvested annually from coral reefs [Jameson et al 1995].

The existence of the people who live in the coastal areas of poor countries depends on the coral reefs that line many of the world's coastlines (Wilkinson et al. 1994; McManus JW. 1197). According to Linden O. (1990), 1 billion people in Asia alone rely on fisheries from shallow coastal waters dominated by coral reefs, so the destruction of these reefs would undoubtedly result in a significant decrease in the amount of animal protein available for consumption by the local populations of the coastal nations.

- 2 **Tourism:** The intrinsic beauty of coral reefs, which annually draws millions of tourists to marvel at their splendour, accounts for a significant portion of their economic value. Tourism is crucial to the economies of many countries across the world, especially those with small islands like the Maldives, Mauritius, the Solomon Islands, Fiji, and those in the Caribbean. In Florida, close-by coral reefs are anticipated to generate \$1.6 billion USD to the local economy each year, and tourism is the single largest foreign exchange earner in the Seychelles (Birkeland 1997). According to Caesar (1992), tourism accounts for 45% of the Maldives' GNP and up to 50% in other Caribbean nations. 350 000 persons were employed by the Caribbean tourism industry in 1990, which brought in \$8.9 billion USD.
- 3 **Coastal Protection:** Around small islands and along continental edges are where you'll find many of the world's coral reefs. As a result, they play a crucial part in preventing erosion of the shoreline caused by ocean swells and tropical storms (Berg et al. 1998; Hinrichsen 1998). Coral reefs' protection enables productive mangrove and wetland ecosystems to flourish in protected regions and serve as crucial fish nurseries for young fish, many of whom live on coral reefs as adults. The buildup of white coral sand along coastlines guarded by coral reefs is a major magnet for thousands of tourists every year.
- 4 **Biodiversity:** Coral reefs are second only to tropical rainforests as the most diverse ecosystem in the world. Only one of the 33 phyla that exist on this planet does not occur on coral reefs and 15 occur nowhere else. Recently, (Malak et al 1997) estimated that coral reefs support between 1 and 9 million species. Of these, only approximately 4000 species of fish and 800 species of coral have been described (Pauly 1997).
- 5 **Medicines:** Pharmaceutical companies are paying closer attention to coral reef dwellers as they look for potential new therapeutic targets. Many bacteria that were once killed by conventional antibiotics like penicillin have developed resistance as a result of their ongoing misuse. As a result, researchers are looking for novel medication sources to combat sickness (Bryant et al. 1998). They provide excellent research subjects since many coral reef inhabitants manufacture bioactive chemicals to protect themselves from competition, predators, and the environment (Shic et al. 1996). In fact, active substances originating from marine species are the focus of 50% of all cancer research (Fenical et al. 1996; Maragos et al. 1996), and coral calcium carbonate skeletons are already employed for human bone grafts.

VI. MANAGEMENT MEASURES

Certain maritime species are protected by the Wild Life Protection Act of 1972. Corals are being included in this act through various means. In 1991, the Indian government published a Coastal Regulation Zone notification, which was later amended. Except for

specific institutes' scientific studies, it is legally forbidden to harvest corals, either dead or alive. All scleractinians and gorgonids are protected by the Wild Life Protection Act of 1972 as of July 2001.. (Pillai 2010)

VII. LEGISLATION

In order to protect coral reefs, the Indian government has produced a variety of legislation. Scleractinians and Gorgonids have been protected by the Wild Life Protection Act of 1972 since July 2001. Coral reefs in India are legally protected under the Coastal Regulation Zone (CRZ) Notification, 2011, and the Marine Fishing Regulation Act (MFRA), both of which were passed in 2000. In India, there are a total of 31 marine protected areas (MPAs), five of which have been surveyed and designated as needing protection. (Jhajhria 2021)

Under the Wildlife Protection Act of 1972, the Environmental Protection Act of 1986, and the Coastal Regulation Zone Notification (CRZN) of 1991 that fall under it, the protection of coral reefs has been emphasised. The conservation of India's coral reefs is also somewhat helped by other laws including the Indian Forests Act of 1927, the Forest Conservation Act of 1980, and the Indian Fisheries Act. However, coral protection is not given a separate legal status even under the Wildlife Protection Act. Coral reef conservation in India is being handled by state-level organisations like the State Forest Department, Fisheries Departments, and most recently the State Coastal Management Authority. Significant ecosystems are protected under the Wildlife Protection Act, however coral reef conservation is not a priority.

As a result, the suggestion for a legal change and the development of policy for coral reef conservation and management in the country essentially entails amending the Wildlife (Protection) Act 1972 to include coral species in the schedules and explicitly state that the extraction of coral is prohibited under the terms of Chapter VA of WPA. The CRZ notification also generally protects land between the Low and High tide lines on the landward side, as well as coastal areas 500 metres from the High tide line. It does not, however, cover coral and coral reefs on the seaward side. The primary coral reef habitats may be categorised as ecologically sensitive under the EPA of 1986, and hazardous companies may be subject to strict regulation. (Saroj et al 2016).

The delicate eco-system of India's coral reefs is watched over, managed, and conserved by the Department of Forests and Wildlife. (Saxena, 2015). The Ministry of Environment and Forests is qualified to develop suggestions for the conservation and wise use of coral reef resources, as well as to develop a successful action plan. The management of coral reef ecosystems is additionally supported by India's National Conservation Strategy and Environment Action Plan (UNDP, 1997).

In India, there is now hardly any legislation or policy governing coral reefs (Panini, 1997). The Environment (Protection) Act of 1986 and the Wildlife Protection Act (WPA), both of which were passed in 1972, are two laws that can be used to safeguard coral reef regions. Coral reef regions do not, however, have a separate legal standing even under the WPA (Saroj et al., 2016). The only reefs that are off limits for development are those in protected areas. The Indian Forest Act (1927), the Forest Conservation Act (1980), and the

venerable Indian Fisheries Act are the other legislation that might have an impact on coral reef regions. The Coastal Regulation Zone (CRZ) Notification (1991) offers the only legal protection to all the coral reefs in India and under these coral reef areas come under the CRZ1 category (Panini, 1997). (Baswapoor et al 2017)

VIII. CONCLUSION

Due to a number of stressors, the coral reef ecosystem is in grave danger of being destroyed, necessitating urgently needed ecological research. Future orientations should be set up adequately to handle the challenges of eco-sustainable coral reef protection in India. The study of coral reefs in India is still in its infancy. There is a tonne of knowledge available regarding coral reefs. The relationship between coral population density and abundance with regard to species found on reefs, however, is still mostly unknown. There is a dearth of knowledge available about the coral reef ecology and its natural resources. Designing feasible management methods for coral reef regions that entail local community involvement becomes particularly difficult as a result. The primary issue is that each institute has a distinct research programme and area of emphasis. In almost all of these institutes, coral reef research has been more of an accidental than a main stream programme. If we are serious about creating management plans for conserving and managing our coral reef heritage, this must change.

To avoid the fascinating ecosystem being destroyed by a number of pressures and to preserve the projected economic growth of the millions of people and businesses that depend on it, in-depth research on the ecology of the Indian coral reef is urgently required. Although there are many challenges, they can be overcome with the help of the central government organisation, state agencies, NGOs, academics, and scientists as well as with political backing and scientific knowledge. It is hoped that the support offered in the form of research money over the past few years by different Indian government agencies, along with the fervent interest displayed by students and the scientific community, may shed some light on coral reef research. Despite all the obstacles, coral reef research has greatly increased in India during the past three decades. Future pathways should be set up adequately to address these difficulties. The National Coral Reef Research Institute within the A&N should be restored, as should a dedicated national "Coral Reef Research" programme with a well-thought-out aim, in order to provide young and eager researchers with a platform to study and manage this important natural resource.

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