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Effects of Coral Reef Destruction on Humans and the Environment

Devarshi Ranjan [a++], Sanjay Chandravanshi [b#], Priyanka Verma [c*], Mayank Bhushan Singh [d], Durgesh Kumar Verma [e], Preeti Maurya [f], Aditya Kumar Upadhyay [g], Raghunath [h], Ankit Kumar Tiwari [i#] and Kanta Kumar Sahu [j#]

[a] ICAR-National Bureau of Fish Genetic Resources, Canal Ring Road, P.O. Dilkusha, Lucknow- 226002, Uttar Pradesh, India.
[b] Department of Fisheries Biology and Resource Management, TNJFU-Fisheries College and Research Institute Thoothukudi-628008, Tamil Nadu, India.
[c] Department of Fisheries Resource Management, College of Fisheries (Dr. Rajendra Prasad Central Agricultural University), Dholi, Muzaffarpur - 843121, Bihar, India.
[d] Department of Aquaculture, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya-224229, Uttar Pradesh, India.
[e] ICAR-CIFRI, Regional Centre, Allahabad, Uttar Pradesh (211002), India.
[f] Department of Aquatic Environment Management, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar- 263145, Uttarakhand, India.
[g] Department of Aquatic Environment Management, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana- 141004, Punjab, India.
[h] Department of Fisheries Resource Management, Kerala University of Fisheries and Ocean Studies, Kochi- 682506, Kerala, India.
[i] Department of Agricultural Animal Husbandry and Dairying (LPM), MGCGV, Chitrakoot, Satna-485334, Madhya Pradesh, India.
[j] Department of Agricultural Extension, MGCGV, Chitrakoot, Satna- 485334, Madhya Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *Young Professional-II;*
[#] *PhD Scholar;*
**Corresponding author: E-mail: priyankaverma6575@gmail.com;*

Review Article

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ABSTRACT

Coral reefs are home to a rich biodiversity and one of the most diverse ecosystems on the planet. It provides home to 35,000–60,000 species of plants and animals (over 25% of all marine life), many of which have not been described by science. It provides food, employment, and tourism to people, protecting coastal areas from storm surges; and acts as nesting grounds for many species of fish that are important for commerce. In recent years, several natural and anthropogenic disturbances have damaged the coral reefs of the world a number of events, including pollution, overfishing, destructive fishing methods, boat anchor falls, tourism, mining coral for building materials, and a warming climate, are destroying coral reefs. To reduce the destruction of coral reefs, mitigation measures, encourage sustainable fishing, following all safety precautions when visiting coral reef areas, provide alternative management plans such as coral restoration, artificial reef management, and coral nurseries to improve the coral cover in degraded areas and also increase public awareness and stewardship program related to coral reef and its associated biota, reduce plastic pollution in the ocean.

Keywords: Coral reef; biodiversity; threats; conservation.

1. INTRODUCTION

A coral reef, also called a rainforest of the sea, is an underwater habitat characterized by reef-forming corals. Reefs are composed of coral polyp colonies held together by calcium carbonate [1]. Most coral reefs are composed of stony corals whose polyps are clustered together. Coral reefs are a part of the phylum Cnidaria and the class Anthozoa which also includes sea anemones and jellyfish. Unlike sea anemones, corals have hard carbonate exoskeletons that protect and maintain the coral. Most reefs thrive in warm, shallow, bright, clear and muddy water. The first coral reefs appeared during the beginning of the Early Ordovician, 485 million years ago, replacing the microbial and sponge reefs of the Cambrian [2].

The amazing diversity of coral reef ecosystems on the planet is the most valuable ecosystem for marine creatures as food, shelter, and breeding ground and also for humans as food, income, and protection [3]. Coral reefs protect coasts from waves and tides and support the local social economy [4]. Both natural and anthropogenic disturbances can contribute to coral reef damage. Coral reef removal, sedimentation, trash, eutrophication, and fishing are examples of anthropogenic disturbance, where disease, acanthaster outbreaks, coral bleaching, and changing climate are natural disturbances. Some previous research indicated that rising CO_2 in the ocean, rising global temperatures, and other effects of climate change were adversely affecting the health of coral reefs. If CO_2 emissions continue to increase at the current rate, there will undoubtedly be a reduction in the size and diversity of coral reefs in the future [5].

2. WORLD CORAL REEF DIVERSITY

In the Coral Triangle, an area of approximately 6 million km^2 that includes several countries such as Indonesia, the Philippines, Papua New Guinea, Timor Leste, and Malaysia, 75% of the world's coral species are located [6]. According to estimates, coral reefs cover 1% of the ocean floor and provide habitat for 25% of aquatic organisms [7]. Corals can be found in both temperate and tropical environments, although shallow water reefs only grow in the area bounded by 30°N and 30°S of the equator. The maximum depth at which tropical corals can grow is 50 m (160 ft). The optimum temperature for most coral reefs is 26–27 °C (79–81 °F), while some reefs grow below 18 °C (64 °F) [8].

3. INDIAN CORAL REEF DIVERSITY

Four regions of India – the Gulf of Kutch (Gujarat), the Gulf of Mannar (Tamil Nadu), the Andaman and Nicobar Islands and the Lakshadweep Islands – are home to most of the world's coral. Some coral fragments have also been reported off the coasts of Maharashtra, Kerala and parts of the east coast. Coral reefs provide a means of subsistence and social well-being to coastal residents, where they are available along the coast of India. They contribute up to 25% of the total fish caught in the accessible area [9,10].

Fig. 1. Major coral reef areas in India
(Source: [11])

4. IMPORTANT CORAL REEFS IN THE WORLD

Most of the world's coral reefs are found in tropical oceans. Below is a list of some of the largest coral reefs in the world.

Important coral reefs in the world	Location
Great Barrier Reef	Coast of Queensland, Australia, Coral Sea
Apo Reef	Philippines, Mindoro Strait
Belize Barrier Reef	Belize
Coral Triangle	Timor-Leste, Philippines, Papua New Guinea, Solomon Islands, Indonesia,and Malaysia
Florida Keys	United States, Atlantic Ocean and Gulf of Mexico
New Caledonian Barrier Reef	New Caledonia in the South Pacific
Red Sea Coral Reef	Eritrea, Israel, Egypt, Saudi Arabia, and Sudan
Amazon Reef	French Guiana, Atlantic Ocean, and coast of northern Brazil
Bar Reef	Sri Lanka, Kalpitiya peninsula
Mesoamerican Reef	Guatemala, Mexico, Belize, Caribbean Sea, and Cost of Honduras,

Source: *https://www.envpk.com/coral-reef-destruction-causes-effects-and-solutions/*

5. CAUSES OF CORAL REEF DESTRUCTION

1. Coral Mining

Generally, it has been seen that people living on the islands use sand, coral rocks, and wood to build houses due to easy availability and less expensive. But in recent times, excessive mining and reclamation of reef flats have put corals at risk [12,13]. The severe flooding of the Malé capital in 1987 by severe storm waves was largely the result of these efforts (excessive mining and reclamation of coral reefs) [14]. Similarly, in Sri Lanka, southern India and Indonesia, coral reefs have been over-mined in search of limestone for cement production [15,16]. Sand has also been mined in an unsustainable manner in Fiji and Mauritius [16].

2. Fisheries

Most fishing in the past was labor-intensive, focused on nearby reefs, and used traditional gear including hooks, lines, nets, and spears. Transportation is constrained by the ability to paddle or sail to nearby reefs and the dangers of long journeys. Thus, fish populations were decreased around populated islands, and fish populations were increased around vast expanses of unpopulated or less populated areas.

Recently introduction of outboard motors has helped to reduce or eliminate some of these restrictions. Additionally, the availability of rubber-powered diving masks and spear guns has dramatically improved the ability to catch fish and extract other resources. For example, tridacnid clams have become practically extinct on many Indo-Pacific reefs [17,18], while the virtual extinction of pearl shell clams in Tokelau has been attributed to diving masks [19]. Scuba spearfishing has led to substantial reductions in target fish species on prosperous islands such as Nauru [20]. Overfishing removes natural restraints on reefs, and this can lead to a rapid transition in population stages from reefs dominated by corals to reefs dominated by macroalgae, soft corals, or echinoids [21]. Populations of algae-grazing urchins have increased due to the eradication of urchin predators, especially ballistids, in several areas including Kenya [22], Okinawa [23], and Indonesia. Grazing urchins, especially *Anchinemetra matthei*, actively destroy newly established corals and damage existing corals. In addition, many pharmaceutical companies obtain drugs and cultural artifacts from reefs, which are currently causing significant coral degradation [24].

3. Pollution and sedimentation

According to Burke *et al.,* [25] and Kroon *et al.,* [26], agricultural pollution threatens at least 25% of the world's coral reefs. Intensive agriculture is a highly erosive process for coral reefs because they expose silt, inorganic and organic nutrients (especially nitrogen), and other toxic substances to streams, aquifers, and sensitive reefs. Nutrient contamination caused a nearly 10% reduction in coral cover in the aquifer-dominated Japanese islands between 1977 and 2005 [27]. Corals exhibit poor recovery with agricultural expansion because heavy sedimentation prevents the seeding of new larvae and damages reefs and discourages herbivorous fish from grazing the algae mats [28]. Therefore pollution prevention and management is very important to save coral reefs.

4. Global warming

The main reason for the extinction of corals is global warming and another is ocean acidification caused by carbon dioxide absorbed from the atmosphere. As a result, the coral would be less able to convert its bones into calcareous, which would prevent them from growing and cause them to collapse. Additionally, as a result of global warming, extremely warm ocean water will damage the top layer of coral, causing it to bleach. Symbiotic algae are extremely sensitive to changes in the marine environment. As a result of rising sea temperatures, marine pollution, and changes in biological species, these algae cannot function normally and thus release compounds that are toxic to corals. As a result, the coral and the symbiotic algae (the energy source for the coral) would become isolated from each other. If there is no pigment-rich algae, the coral will lose its original color and gradually turn white (see Fig. 2). According to a research study, coral bleaching is mainly caused by the use of sunscreens by tourists around the world. Studies have shown that even small amounts of sunscreen used to protect the skin can bleach coral reefs. In fact, oxybenzone, a chemical found in sunscreen and other skincare products, has been found in freshwater and marine recreation areas and can accumulate in aquatic species and break down into dangerous compounds. Studies in various marine environments show that even small amounts of sunscreen can cause significant amounts of coral mucus to be released within 18 to 48 hours and that corals can be completely bleached within 96 hours [29].

Fig. 2. Coral bleaching
*(**Source:** [29])*

6. EFFECTS OF CORAL REEF DESTRUCTION ON THE AQUATIC ENVIRONMENT AND HUMANS

Recent assessments of the condition and abundance of coral reefs show an alarming decline in coral reefs and their biodiversity [30, 31]. A recent investigation by Wilkinson, [32] and Saroj *et al.,* [33] found that human involvement has threatened about 60% of coral populations in Southeast Asia, and about 80% of the population is classified as endangered. Studies estimate that if the ratio of climate change and human influence remains the same, 90% of the world's coral reefs could be destroyed by 2030 and could be extinct by 2050 [34,25]. The world's coral reef populations are rapidly disappearing as a result of multiple human pressures on marine resources, such as over-exploitation, tourism growth, trade in coral reef products, coastal expansion, etc. The increasing destruction of coral reefs has many harmful effects on aquatic animals as well as humans and the environment (see Table 1).

7. METHODS FOR MONITORING CORAL HEALTH

Due to the costly and time-consuming nature of coral health surveys, many coral reef observation programs do not focus on coral bleaching and disease assessment [39-41]. Instead, monitoring programs focus on population zoning and distribution, often using long-duration satellite photography to collect data remotely. When analyzing coral reefs, it is important to take into account a variety of biological, physical, and socio-economic factors, as well as the percentage of coral cover, species composition and distribution [42]. The coral health assessment is done by various methods (see Fig. 3).

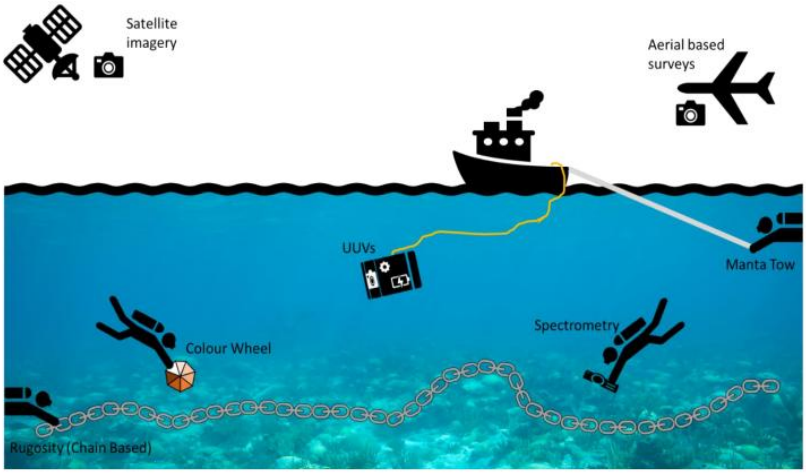

Fig. 3. Examples of some of the methods used to assess the "health" of corals
*(**Source:** [43])*

Table 1. Consequences of the destruction of coral reef ecosystems on the environment and mankind

Consequences	Description	References
Depletion of food, shelter, and breeding grounds	Coral reefs provide vital food, shelter, and breeding grounds for aquatic organisms. Millions of fishes, turtles, and numerous other organisms would become extinct if their natural habitats disappeared.	Mohale *et al.* [10]; Reef-World, [35]
Depletion of human economic generation	According to the United Nations, around one billion people around the world depend on coral reefs for their nutrition and livelihood. If they become extinct, millions of people around the world will be deprived of their basic source of food and income.	United Nations, [36]
Declining coastline tourism industry	Tourists from more than a hundred countries and regions around the world are attracted by coral reefs. According to a 2017 survey, the annual revenue from coral reef tourism was $36 billion. If the coral reef collapses, tourist numbers as well as local businesses will be severely affected.	Spalding *et al.* [37]
Shoreline erosion	Coral reefs also show their wonders on land. Unsurprisingly, they play a vital role in preserving coasts by acting as a natural barrier against huge waves and harsh weather conditions. Without them, shorelines would be at risk of erosion, and sea level rise would force communities living along the coast to relocate from their homes.	Reef-World, [35]; Shafiqa-yusof & Radzi, [4]
Damage to the drug store of the sea	Coral reefs are commonly referred to as "the drug stores of the sea". Reef-dwelling plants and animals may hold the key to developing novel treatments for a variety of diseases and elements. Coral reef possesses anti-inflammatory properties, anticancer properties, bone repair, and neurological benefits. This goes to show that the health of our coral reefs is closely related to our own. To put it another way, losing them all is a terrible idea.	Cooper *et al.* [38]
Hypoxia	The oceans produce 50-80% of the oxygen on our planet. Plankton and other photosynthetic bacteria produce most of this oxygen. This oxygen is used by marine life and humans through the air we breathe. As a result, a healthy climate requires a healthy ocean, and a healthy ocean requires healthy coral reefs.	Reef-World, [35]

1. **Manta Tow Method:** The percentage estimation of live hard and soft coral compared to dead hard coral is determined by the manta tow method. Typically this method involves towing a snorkeling diver (observer) behind a boat at a constant speed. The observer holds a manta board (a bouncy boat with handles) attached to the boat by a length of rope. During each brief pass of the manta tow, the observer makes a visual assessment of particular factors and logs this information on a data sheet [42].
2. **Rugosity:** A chain-based instrument is used by biologists for the coral reef measurement of roughness and irregularity of a surface [44]. This measurement can be used to locate reef areas of high turbidity, which provide additional protection for reef fish from predators and attachment sites for sessile animals including invertebrates, algae, and corals [45,46]. A chain laid across the surface of the rock can be used to measure the roughness; The ruggedness index, C, can be calculated as: C=1-D/L, where D is the length of the fully extended chain and L is the horizontal distance the chain covers following the contours of the reef [46].
3. **Color charts/ wheels:** Divers often use color charts in their surveying methods to rapidly determine coral health. A diver can use this comprehensive color chart to visualize and differentiate coral colors by eye [43].
4. **Satellites:** Remote sensing satellites in low Earth orbit may be able to detect optical signals caused by the loss of the coral pigment zooxanthellae during major bleaching events. With the latest multi-spectral bands and panchromatic bands with a spatial resolution of 15-30 m, the satellite system enables the survey to cover large areas quickly. The amount of data that can be collected from the satellite is limited by depth, with it being able to generate accurate data only up to a depth of about 25 meters of water [43].
5. **Aerial-based survey:** Another remote method for surveying coral reefs is an aerial survey, which uses a light airplane or helicopter flying at an altitude of about 150 m. Light aircraft can fly below the cloud base and scan expanses of vast coral reefs with higher resolution than satellites [43].
6. **Underwater unmanned vehicles (UUV's):** The underwater human surveys can be replaced with underwater robotics, which reduces cost and danger as well as increases repeatability. Additionally, a UUV can travel longer distances in less time while carrying accurate global position data. For example, it may take two scuba divers up to 2.5 hours to cover a 120-m^2 area, giving them an average coverage of 0.13 m^2/s, but a low-cost remote-operated vehicle (ROV) can cover the same area at a top speed of 1 m^2/s (BluROV2) [43].
7. **Underwater spectrometry:** It is also used with a waterproof spectrometer comparable to the PAM, to obtain spectrum data, and to record brightness reflectance measurements. Similar to PAM, these spectrometers should be placed up to 10 mm away from the sample [47]. To describe solar irradiance and generate relative spectral measurements, a reference measurement that uses a Lambertian reflectance standard target is required (often referred to as a spectrolon). Data is often limited by the spectral range and spatial resolution of the spectrometer [43].

8. CONSERVATION AND MANAGEMENT TECHNIQUES FOR CORAL REEFS

Coral reefs are protected under the Wildlife Protection Act of 1972 and the Environment Protection Act of 1986 as well as the Coastal Regulation Zone Notification of 1991. However, no separate legal support was offered for the protection of coral. Coral reef conservation in India is now the responsibility of State Forest Departments, Fisheries Departments, and more recently State Coastal Management Authorities [33]. As already mentioned above that corals are the most important resource for humans, yet most coral species are currently being exploited to an unsustainable level. Therefore, it has become necessary to establish important and sustainable strategies for the management and conservation of coral reefs. I have mentioned some important measures to conserve and protect coral reef ecology below:

1. Recycle and appropriately dispose of trash
2. Reduces the use of fertilizers
3. Use eco-friendly ways of transportation
4. Reduce stormwater runoff
5. Refrain from buying live coral
6. Explore coral reefs knowledge and educate your community
7. Avoid colliding or touching a coral reef
8. Use caution when snorkeling and scuba diving

9. Avoid near-shore development and construction
10. Act against global warming

9. CONCLUSION

Coral reefs are vital to both animal and human survival, so it is important to protect them. The past several decades have seen an imminent threat to coral ecosystems on every continent of the world due to global warming and other influencing factors. There is an urgent need to review current management strategies in light of the global decline of coral reefs. Many researchers have concluded that coral reefs need protection, and they need it without delay. Thereafter, natural processes are difficult to regulate effectively, requiring more research to recover coral reefs. A long-term, more effective strategy would involve coral reefs, which are rapidly disappearing and are currently out of balance. Research studies for the coral ecosystem and its conservation receive significant attention from global environmental protection initiatives. According to a recent study from the University of Queensland in Australia, dead coral reefs are just as important as living reefs, as they can support more life than living corals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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