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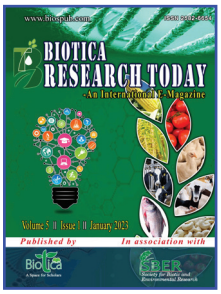

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Coral Reefs: Their Benefits, Threats and Restoration

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Abstract

The coral reefs are most productive, diversified and beautiful ecosystems on the world. They serve a variety of functions and supply coastal communities, particularly those in developing nations, with a wide range of goods and services. The advantages derived from these services and goods are put in jeopardy by a number of anthropogenic behaviours that threaten reef health. These threats vary from local problems like declining water quality, destructive fishing practices, pollution, dredging and sedimentation to global problems like coral bleaching. This article discusses the current biodiversity of coral reefs and management tactics for restoring specific ecosystems.

Introduction

Corals are marine invertebrates belonging to the phylum Cnidaria that have colonies of polyps resembling sea anemones. Primitive marine organisms belonging to the phylum Cnidaria are commonly referred to as jellyfish, sea anemones and corals. Among the Cnidarian classes, Anthozoa is the largest and contains more than 6,000 coral and "coral-like" species. Coral species are crucial reef builders that live in tropical environments and secrete calcium carbonate to create a hard skeleton. Coral possesses hard limestone which includes orders Helioporacea (blue coral), Alcyonacea (soft corals), Scleractinia (stony corals or hard corals) Antipatharians (black corals or thorn corals), Corallimorpharia (false corals and coral anemones and Zoanthidea (button polyps) (Nama and Akter, 2021). Coral reefs are significant ocean habitats that make a strong argument for the dangers of climate change. Reefs have been referred to as "the rain forests of the seas" since they contribute significantly to the biodiversity of the planet.

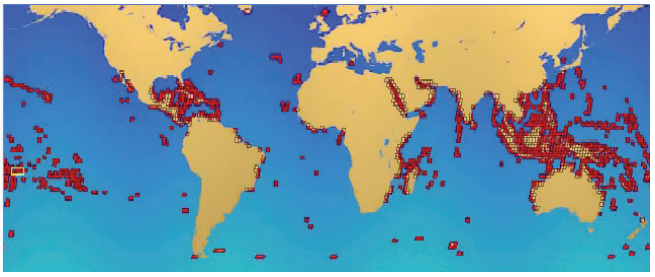

Figure 1: Map showing the distribution of coral reefs in the world (Red dots indicate the global distribution of coral reefs)

The majority of reefs may be found in the Pacific Ocean, Indian Ocean, Caribbean Sea, Red Sea and Persian Gulf, all of which lie between the Tropics of Cancer and Capricorn. Corals can also be found farther from the equator in Florida and southern Japan, for example, where warm currents flow out of the tropics. In India, coral reefs can be found in the Malva,

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Andaman & Nicobar, Lakshadweep Islands, Gulf of Mannar and Gulf of Kutch. Coral patches can be found at the Gaveshani Bank, west of Mangalore, and in Ratnagiri, Malvan and Redi, south of Bombay. From Quilon on the coast of Kerala to Enayem in Tamil Nadu, corals can be spotted along the shore. Among island corals, in Andaman and Nicobar Islands (Fringing and barrier) and Lakshadweep (Atolls) corals are found. Map showing the distribution of coral reefs in the world (Figure 1).

Benefits of Coral Reef

Coral reefs provide vital habitat for a variety of fish and invertebrate species that are both valuable for recreation and economics, provide coastal protection and are hotspots of great biodiversity. Coral reefs are home to one-third of all known marine species despite making up only a small portion of the marine environment (less than 1%). Coral reefs protect the coastlines of 100 nations from coastal erosion and safeguard the mangrove and lagoon habitats that support a variety of life stages of significant marine species (Gurjar *et al.*, 2019). Additionally, these vulnerable ecosystems support fisheries, which are a crucial source of food for people. The ecosystem functions and corresponding goods and services of coral reefs are given in Table 1. Coral reefs provide various benefits such as:

Table 1: Ecosystem functions and corresponding goods and services of coral reefs

Ecosystem functions	Corresponding Goods and Services	Examples for coral reefs
Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Disturbance regulation.	Coastal protection and sediment retention.
Recovery of mobile nutrients and removal or breakdown excess or xenic nutrients and compounds.	Waste treatment.	Nitrogen fixation, waste of assimilation and CO2 and Ca budget control.
Trophic-dynamic regulations of populations.	Biological control.	Feeding places both within ecosystem and between ecosystems.
Habitat for resident and transient populations.	Refugia.	Nurseries and habitats.
That portion of gross primary production extractable as food.	Food production.	Fish and other seafood products.
That portion of gross primary production extractable as raw materials.	Raw materials.	Seaweed, materials for medicine curio, jewellery, coral blocks, sand.
Providing opportunities for recreational activities.	Recreation.	Tourism, recreation, game-fishing.
Providing opportunities for non-commercial use.	Cultural.	Aesthetic, cultural, religious and spiritual values.

- **Coastal protection:** Coral reefs can preserve coastal homes, farms and beaches by absorbing wave energy and preventing shoreline erosion. The estimated $9 billion annual net benefit of reef-protected coastlines.
- **Habitat:** Many different aquatic species, including thousands of fish species, can be found here.
- **Medicine:** Many of the most common and dangerous diseases and illnesses in the world could potentially be treated by species found on reefs that contain pharmaceutical compounds.
- **Tourism and Recreation:** Every year, millions of tourists visit coral reefs, generating significant revenue for the communities that surround them. Some nations get more than half of their gross national product from industries related to coral reefs.
- **Food and feeding:** The fish and shellfish populations that supply one billion people with protein are supported by coral reefs. Reefs are nurseries for many commercially valuable species.

Threats to Coral Reefs

Globally, during the past few decades, there has been a shift from the traditional, mostly sustainable, exploitation of coral reef resources to a significant rise in demand, partly as a result of demographic changes. At the same time, coral reefs have deteriorated due to both anthropogenic disturbance such as declining water quality, over-harvesting of reef species, coral disease, coral mining, coastal development, dynamite fishing, sedimentation, sewage, dredging, overfishing, chemical pollution, oil spills, invasive species, ship groundings, fertiliser and pesticide run-off as a result of changing land-use and natural disturbances such as tropical cyclones, volcanic activity, catastrophic low tides and E1 Nino-Southern Oscillation events. According to experts, 75% of reefs are significantly threatened by the combined effects of local stressors and variables related to global climate change, putting one-third of all corals that construct reefs in danger of going extinct (Burke *et al.*, 2011).

Below, some major threats are discussed.

Blast Fishing

Homemade bombs are still a very common fishing "gear" used to catch schools of reef fish and tiny pelagics and so "making money the easy way," despite the fact that they are illegal in almost all nations across the world. A significant surrounding area is devastated by the explosion, which also kills fish and other invertebrates. As the reef as a whole deteriorates due to blast fishing, many subsistence fishermen's supply chains are destroyed.

Coastal Development

Coral reefs are negatively impacted by a variety of development-related factors that are connected with coastal populations, which are growing at some of the fastest rates in tropical nations. When deep-water channels or marinas are dug up or when rubbish is dumped in them, sensitive habitats may be destroyed or disrupted.

Recreational Activities

In coastal nations, the tourism and leisure sectors generate enormous sums of money. When unchecked recreational activities have the potential to harm the ecosystem itself, which is what the industries depend on. The coral reefs are susceptible to physical harm by negligent swimmers, reckless divers and improperly positioned boat anchors.

Sedimentation

The main stressor for the survival and recovery of coral species and their habitats has been identified as sedimentation. Reef-adjacent sediment can suffocate corals and hinder their capacity to mate, develop and reproduce.

Overfishing

It can change the way the food chain is organised and have cascade impacts, such as fewer grazing fish clearing the corals of excess algae.

Coral Harvesting

Coral harvesting for the aquarium industry, jewellery and curiosities can result in overharvesting of some species, the destruction of reef habitat and a decline in biodiversity.

Ocean Acidification

Oceans absorb more carbon dioxide as a result of rising carbon dioxide levels. This makes the ocean water more acidic and prevents coral from building their necessary calcareous skeletons, which is vital to their existence.

Pollution

To survive, coral reefs require clean water. Pollution, which includes waste oil and litter, destroys reefs all across the world. Hotels and resorts frequently release untreated sewage and wastewater into the ocean, which can harm coral reefs when transported by rivers into coastal waters. Greater amounts of fresh water, fertilisers and sediment may reach the reefs when land development disrupts the natural flow of water, further degrading them.

Restoration Methods

Coral reefs generate billions of dollars in annual tourism revenue because of their natural features. Because of this, the livelihoods of hundreds of millions of people who depend on reefs for food, money and storm protection are under danger, endangering biodiversity. As a result, thousands of conservation programmes across the globe are putting a variety of active physical interventions into action with the goal of rebuilding severely deteriorated reef systems. According to Edwards and Gomez (2007), restoration is the process of restoring degraded ecosystems to their original state.

Reef restoration methods involve both physical and biological restoration. Artificial reef construction is a typical illustration of physical restoration. Techniques for biological restoration include sexual propagation (*e.g.*, releasing fertilised coral larvae into the water) via both broadcasting and brooding corals, asexual propagation (*e.g.*, collecting and transplanting coral fragments) *via* fragments and nubbins and larval settlement (*e.g.*, stabilising loose substrate). Although many of these restoration programmes are successful at promoting the growth of corals, very few make an effort to gauge the overall health of the restored reef ecosystem. For instance, robust fish and invertebrate populations are crucial to the functioning of reef ecosystems and the supply of services, but the bulk of reef restoration programmes continue to insufficiently assess their recovery (Boström-Einarsson *et al.*, 2020). Various restoration methods of coral reefs are showing in Table 2.

Table 2: Restoration methods of coral reef

Sl. No.	Method	Definition
1.	Asexual propagation methods	
	i) Direct transplantation	Transplanting coral colonies or fragments without intermediate nursery phase.
	ii) Coral gardening	Transplanting coral fragments after an intermediate nursery phase.

Sl. No.	Method	Definition
	iii) Coral gardening- Nursery phase	Transplanting coral fragments with an intermediate nursery phase (used to describe case studies that only detail the nursery phase). Nurseries can be *in situ* (on the reef) or *ex situ* (flow through aquaria). Note that following the above definition of restoration, a coral nursery does not constitute restoration, until outplanting has occurred.
	iv) Coral gardening- Transplantation phase	Transplanting coral fragments with an intermediate nursery phase, including outplanting juveniles raised in the nursery.
	v) Coral gardening- Micro fragmentation	Transplanting micro-fragments from corals, with an intermediate nursery phase.
2.	Sexual propogation methods	
	i) Larval enhancement	Using sexually derived coral larvae to release or outplant at restoration site, after intermediate holding phase which can be *in-situ or ex-situ*.
3.	Substratum enhancement methods	
	i) Substratum addition- Artificial reef	Adding artificial structures for purposes of coral reef restoration.
	ii) Substratum stabilization	Stabilizing substratum to facilitate coral recruitment or recovery (often combined with artificial reefs and transplantation of coral fragments).
	iii) Substratum enhancement- electric	Enhancing artificial substrata with an electrical field or direct current.
	iv) Substratum enhancement- Algae removal	Enhancing substrata by removing macroalgae.

(Source: Boström-Einarsson *et al.*, 2020)

Conclusion

Coral reefs are essential components of the ecosystem and help to ensure the existence of other species. They give chances for recreation, jobs for nearby communities and protection against erosion and storms for coasts. They provide new medicines and food as well. Few restoration projects attempt to assess the overall health of the restored reef ecosystem, even if many are successful at encouraging the growth of corals.

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