

ECOSYSTEM RESTORATION: CORAL REEF AND SEAGRASS

Abstract

Restoration of ecosystems is becoming an increasingly essential aspect of tropical and subtropical marine conservation. Seagrass and coral reefs provide a variety of ecological facilities, including nursery habitat, better water quality condition, coastline protection, and carbon sequestration. Ecological restoration is receiving more attention as a conservation tactic, hence methods to improve restoration success must be explored. Impacts of human activity pose a danger to seagrass, coral reef and the vital ecological services they provide worldwide. To create an environment in which restoration activities are likely to be successful, proper conservation management is necessary before the start of restoration operations. In order to address the fast changes and loss brought on due to climate change and numerous directly human-related impacts, restoration must be seen as a crucial element of our ecosystems long-term viability.

Keywords: Ecosystem, Coral Reef And Seagrass.

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I. INTRODUCTION

Restoration is the intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state (Pandit et al., 2018). With respect to the environment, encompassing crops, woodlands, rangelands, urban area, and wetlands, different responses are displayed. Responses should take local circumstances, indigenous knowledge, and landscape-level tactics into account in order to allow ecosystems to perform vital tasks (Pandit et al., 2018; CBD, 2019). The UN Era on Ecosystem Restoration targets to scale up initiatives to achieve sustainable development goals, including biodiversity conservation, poverty alleviation, improved livelihoods, food security, and climate change mitigation.

Ecosystem restoration involves restoring ecosystems to increase output and capacity to encounter societal needs by reversing degradation and enabling natural regeneration or planting trees and plants. This process aims to restore ecosystem functionality and meet societal needs (UNEP, 2019). According to CBD (2019), "Healthy and interconnected ecosystems assist to improve the security of food and water for the well-being of individuals, and mitigate and adjust to the effects of climate change. The objective of ecological restoration is to lead to the protection and long-term utilisation of biodiversity while generating financial, social, and environmental advantages. It is feasible to pinpoint the causes of degradation, landscaping management objectives, financial concerns, and long-term objectives by seeing ecosystems as socio-ecological places with a variety of roles (Bjork et al., 2008).

II. CORAL REEF

Coral reef are one of the environmentally and economically important ecosystems on our planet. Even though they occupy less than one percent of the ocean's total surface area, they support roughly 25% of marine life and offer up to a billion people ecological goods and services such as protecting coastlines, fisheries production, medical supplies, recreational benefits, and tourism revenues. (UNEP, 2021). Coral reefs are facing a climate crisis due to their sensitivity to warming seas. Up to 50% of their original size has been lost, and IPCC studies suggest that 90% of reef-building corals could be destroyed by 2050. The objective of coral reef restoration has evolved from restoring historical baselines to recovering or preserving ecological processes, functions, and services in the coming decades. Coral reefs in India are primarily Fringing reefs in the Andaman and Nicobar (A&N) Islands, Gulf of Mannar (GOM), Gulf of Kutch (GOK), Palk Strait, and Lakshadweep Islands, with Lakshadweep being atolls.

III. GOALS OF CORAL REEF RESTORATION

1. Socio-Economic Goals

- Attenuate wave energy and reduce disruptions like erosion and floods to preserve coastal protection.
- Restore fisheries production by maintaining habitat and nursery regions for commercially valuable fisheries, and re-establish reef provisioning services.
- Maintain reef aesthetics to encourage local tourism and eco-tourist experiences.

- Promote local coral reef stewardship by supporting communities and Indigenous traditional owners in reconnecting with the ecosystem, improving custodianship, and promoting intrinsic value.

2. Ecological Goals

- Restore the function and structure of the reef ecosystem- Restore deteriorated coral reef ecosystems function, structure, diversity, and health.
- Reduce population reductions and maintain biodiversity through assisting in the revival of damaged coral communities and preserving the intrinsic richness of the reef, which includes genes, the phenotype and environments.

3. Climate Change Adaptation and Support Goals

- Reduce the consequences of climate change and increase reef resilience- Sustainance conflict and recovery mechanisms to decrease impact risks and certify that reefs survive present and predicted climate change.

4. Disturbance-Driven Goals

- React to sudden perturbations to hasten reef regrowth. Encourage the natural process of recovery when reefs are severely damaged by storms, parasite incidents, ship groundings, or additional structural problems.
- Adopt a 'no net loss' mitigation approach, if disturbances cannot be avoided, by moving expected losses before disruption. This approach helps prevent natural healing and protects reefs from structural problems.

IV. CORAL REEF RESTORATION METHODS

The techniques used to restore terrestrial ecosystems were first adapted for use in coral reef restoration. In the 1990s, for instance, the concept of coral gardening called for the mariculture of pieces of coral using silvicultural principles (Rinkevich, 1995). These techniques aim to help coral reefs adapt to climate change and improve their structural integrity. Scientists and ecologists have collaborated to improve techniques for coral ridge adaptation, including coral gardening, ship groundings, and extreme weather events (Precht, 2006). Five of the most widely used strategies for restoring coral reefs are listed below (Bostrom-Einarsson et al., 2020).

1. **Straight Transplantation:** Coral communities or fragments being transplanted without first going through a nursery phase.
2. **Coral Gardening:** Restoration of coral reefs includes ex situ or in situ transplantation of communities or pieces with an interim nursery period.
3. **Substrate Addition:** Substrate addition involves adding manmade structures for recruitment, planting, and fish aggregation.

Electro-deposition promotes mineral accretion, while green engineering involves replicating natural processes and integrating manmade structures into reef landscapes.

- 4. Substrate Manipulation:** Reef substrate manipulation aids repossession processes by stabilizing the substratum and eliminating debris, enabling coral recruitment or regeneration. Algae removal removes macroalgae, promoting recruitment and retrieval.
- 5. Larval Propagation:** After a preliminary stage of collecting and storage underwater or on ground in flow-through aquariums, coral larvae are released to a restoration area. Establishing surfaces for settlement that have received coral larvae injections. Larval discharge is the initial release of larvae to a restoration site.

V. CORAL REEF RESTORATION METHODS IN INDIA

- 1. Coral Restoration in the Gulf of Kachchh:** In collaboration with Gujarat's forest department, the Zoological Survey of India (ZSI) is making a first attempt to restore coral reefs utilising biorock or minerals accretion technology. In the Gulf of Kachchh, a biorock structure was constructed one nautical mile off the Mithapur coast. Biorock is a substance formed by accumulating minerals in seawater on steel structures, submerged in the ocean, and connected to energy sources like solar panels. Ch. Satyanarayana, a scientist at the ZSI, Marine Biology Regional Centre, said that the technique operates by running a little electrical current via electrodes submerged in the water. When an electric current is run between a negatively charged cathode and a positively charged anode placed on the ocean bottom, calcium and carbonate ions mix and attach to the cathode. Calcium carbonate is produced as a result. Coral larvae quickly grow after adhering to the CaCO_3 . The considerable tidal amplitude in the Gulf of Kachchh was taken into consideration while selecting the biorock installation site. At low tide, the biorock installation is four meters deep; at high tide, it is eight meters deep.
- 2. Micro-Fragmentation Method – Florida:** This approach involved placing specific items, such as automobile tyres (as done in Florida), into the water for the purpose of transplanting coral fragments, and alloy constructions were found to be extremely toxic; however, employing iron frames for this operation has been successful. A Florida scientist's invention of the micro-fragmentation technique enables corals to develop 25–40% more quickly. It entails moving tiny fragments of coral from aquariums or nurseries to ocean frames, resulting in a growth rate that is 25–40% quicker.
- 3. The Andaman Islands – Reef Watch Marine Conservation:** Coral restoration in the Andaman Islands was started by Reef Watch in 2018 utilising Mineral Accretion Technology as part of the Reef Develop programme, which was founded in 1993. Natural collection and reattachment of fractured coral fragments to a metal frame, together with low-voltage electric current and floatable solar panels, promotes development. This electrolysis causes the reef to grow 7-12 times faster, providing greater energy to resist bleaching events, warmer temperatures, and disease. The rebuilt buildings have become homes for many creatures, including young fish.
- 4. Gujarat – Mithapur Coral Recovery Program:** With support from Tata Chemicals Limited (TCL), the Wildlife Trust of India and the Gujarat Forest Department joined

forces to launch the Coral Reef Recovery Project in 2008. This is the first instance of active community management of a maritime environment in India. It aims to design and execute suitable conservation methods for the Mithapur Reef, which is located 12 km south of the Gulf of Kachchh in Gujarat. Boulder corals are transplanted to local sites and inspected by the fishing community. They are originally planted at the nurseries (of which there are presently 57), and after ensuring they established themselves and showed indications of development, they are moved to coral gardens. Coral gardens are constructed using locally mined limestone rocks in a tapering pattern. So far, 960 artificial reef units have been built, totaling 2438.4 sq m of surface area dispersed throughout 30,000 sq m of spatial space.

5. **Temple Adventures, Pondicherry:** By scattering pebbles and other objects that turn into spawning sites for fish, the fishermen of Pondicherry have been creating fish aggregating devices. Temple Adventures created an artificial reef at 18m deep using recycled concrete bricks, car shells, and metal bars. Over time, algae formed, attracting planktivores, predator fish, and creating an ecosystem. The 'The Wall' and 'Temple Reef' have seen a rise in marine species sightings, with silver moonies and rabbit fish being prevalent.

VI. THREATS OF CORAL REEF

Coral reefs are in decline globally, and scientists believe they may be threatened unless efforts are intensified to protect them (Frieler et al., 2013). These reefs are vulnerable to human activities, both direct and indirect, as they are found in shallow water near the coast. These events are intricately woven into the social, cultural, and financial foundations of the local coastal communities, leaving them open to abuse and harm. Coral reefs aspect many threats from resident sources, including:

1. Coral reefs are vulnerable to physical destruction and pollution from coastal development, dredging, quarrying, and fishing practices, boat anchors, and recreational misuse. Land-based activities also contribute to pollution, which ends up in coastal waterways.
2. **Sedimentation** The ability of coral species to survive and recover is significantly hampered by sedimentation from development along the coast, storm-water runoff, forests, and the agricultural sector, which suffocates them and impairs their capacity for feeding, growth, and reproduction.
3. **Nutrients** Marine habitats require nutrients from sewage, fertilizer, and animal waste, but excess can lead to algae growth, blocking sunlight and oxygen, impacting ecosystems and attracting harmful bacteria and fungi.
4. **Pathogens** from sewage, rain, and animal runoff infect corals, leading to illness, especially in environmental stress. Pollution increases disease outbreak frequency and severity.
5. **Toxic substances** like metals, organic chemicals, and pesticides in sunscreens, mining, landfill runoff, and industrial discharges can impair coral growth, reproduction, and physiological processes. Pollutants like PCBs, oxybenzone, dioxin, and metals like mercury and lead also affect coral growth, reproduction, and defense responses.

6. **Trash and microplastics** Improper disposal and storm water runoff produce trash and microplastics, causing harm to corals, blocking sunlight, and destroying reef life. Degraded plastics can introduce toxins into coral, fish, sea turtles, and other animals. Proper disposal and discharge from storm drains are crucial to prevent these negative consequences.
7. **Overfishing** alters the food web structure, reducing grazing fish and preventing coral overgrowth. Corals can also be physically harmed by blast fishing, which involves using explosives to kill fish.
8. **Coral harvesting** The removal of coral for the aquarium trade, jewellery, and curiosities may result in over-harvesting, habitat destruction, and a decline in biodiversity.
9. Rising ocean temperatures and altering ocean chemistry pose significant risks to coral reef ecosystems. Rising atmospheric temperatures and seawater carbon dioxide levels cause corals to lose microscopic algae, causing coral bleaching, a phenomenon where they lose their coloring and the calcium carbonate framework's white color. This phenomenon is exacerbated by rising seawater temperatures and atmospheric pressures. Severe or persistent bleaching can harm coral colonies and increase their susceptibility to infectious diseases. Ocean acidification, caused by atmospheric carbon dioxide uptake, alters ocean chemistry by increasing oceanic concentrations and forming carbonic acid. This affects coral and reef growth by reducing the amount of dissolved salts and ions needed for calcium carbonate formation. High acidity levels may dissolve coral skeletons. Local nutrient enhancement from land actions can also raise coastal waters acidity, exacerbated by ocean acidification's consequences.

VII. SEAGRASS

Seagrass beds are one of the world's most valued ecosystems (Costanza et al., 1997). For decades, large-scale losses of these beds have been reported. In the past, worldwide seagrass loss was projected to be 12,000 km² between the mid-1980s and the mid-1990s (Short and Wyllie-Echeverria, 2000). This has resulted in a slew of restoration initiatives (Paling et al., 2009). Seagrasses are aquatic plants with roots, stems, and leaves that can blossom, bear fruit, and generate seeds. They are more evolved than seaweed, with beds growing in warm waters and resembling meadows at depths of 40 meters or more. More than 60 types of seagrass that have been identified in the globe, with the largest seagrass meadows in India being in the Gulf of Mannar and Palk Bay in the southeast and in the lagoons of islands from Lakshadweep in the Arabian Sea to Andaman & Nicobar in the Bay of Bengal. The flora comprises of 14 species and is dominated by *C. serrulata*, *Cymodocea rotundata*, *Thalassia hemprichii*, *H. pinifolia*, *Halodule uninervis*, *Halophila beccarii*, *H. ovata* and *H. ovalis* (Jagtap et al., 2003).

VIII. WHY RESTORE SEAGRASS BEDS?

Seagrasses are vital coastal and marine ecosystems, providing essential services and benefits for sea health, well-being, and coastal community security.

- 1. Fisheries:** Seagrass beds are diverse subtidal ecosystems with diverse fish assemblages, providing nidification and feeding sites for invertebrates and fish. They sustain fisheries and neighboring ecosystems, with temperate eelgrass beds having a 4.6 times higher fish population than sand habitats.
- 2. Climate Regulation:** Seagrasses offer ecological services like sequestering CO₂, making them potential climate change mitigation targets. They are major global carbon sinks, absorbing and storing blue carbon in sediment, making them a significant carbon sink.
- 3. Biodiversity:** Seagrasses ability to store CO₂ has sparked interest in climate change mitigation. They are significant global carbon sinks, absorbing and storing blue carbon in sediment, making them a vital ecological function.
- 4. Genetic Diversity:** Research shows that seagrass species have lost genetic diversity, beds, and connections, which are crucial for developing healthy populations that can resist and adapt to changes in their environments, including climate change, pests, and diseases.
- 5. Habitat Connectivity:** Seagrass habitats, saltmarshes, kelp forests, and bivalve reefs are interconnected, facilitating direct carbon and nutrient transfer, crucial for marine species' ontogenetic and foraging excursions across diverse environments.
- 6. Ocean Acidification Buffer:** Seagrass beds can occasionally lower pH levels (acidic) conditions for up to 30% (Ricart et al. 2021). The time of year, as well as the local oceanographic circumstances, are crucial factors, with greater buffering happening in the spring when seagrasses are extremely productive.
- 7. Disease Control:** In comparison to non-vegetated locations, seagrass decreases *Vibrio* bacteria by 39% for all species and 63% for the potentially hazardous *V. vulnificus/cholerae* subtype.
- 8. Tourism:** Seagrasses offer wildlife habitats, recreational fishing, clear water for swimming, and stable beaches for various activities.

IX. SEAGRASS RESTORATION TECHNIQUES

Seagrass beds are being restored globally using techniques like collecting and transplanting plants and obtaining and planting seeds, focusing on preserving these habitats.

- 1. Transplanting Adult Plants:** This strategy has historically been the most popular, maybe because habitats are made right away. With this technique, mature plants with rhizomes and adhered substrate, mature plants without glued substrate, or shoots without adherent substrate are removed from healthy beds and transplanted into damaged areas. The shoots may be gathered in considerable quantities right on the coast following a storm. Either the substrate is planted with the core plugs directly in it, or they are placed in a biodegradable "pot." The shoots can either be directly connected to the substrate or braided into grids or frames, preferably composed of a biodegradable substance. This form of transplant is distinguished by high rates of transplanted plant mortality, which have been seen in

virtually all trials conducted to date. It also has considerable economic and logistical expenses for both manual and machine transplantation. Furthermore, it has the potential to badly harm or destroy donor beds. No successful transplant project has been demonstrated to date.

- 2. Planting Seeds:** Researchers have focused their attention on this approach in recent years because of its lower costs. Furthermore, the importance of seed sowing compared to clonal reproduction is presently being confirmed, both in terms of seagrass bed expansion and natural recovery. The collecting, care, shipping, and planting operations are simplified and less expensive. The ripe seeds are taken straight from the bed. Large amounts of seeds may eventually reach the shore and be harvested, albeit this sort of gathering cannot be foreseen. After collecting the seeds, they may be planted immediately in the region to be restored or maintained, and then treated in a laboratory to enhance or even induce germination (using temperature and salinity fluctuations) before being sent to sea. In recent years, mechanical planting methods have been developed to speed up the process and minimise costs. As a result, this technique outperforms mature plant transplantation.

The success of the different methods depends on a series of key factors:

- Species of seagrass.
- Donor bed location (oceanographic and climatic parameters, substrate type, etc.).
- The position of the mature plants, branches, or seeds in the future.
- Throughout the procedure, manual or mechanical methods are utilised.
- The extent of the project.
- Time of year.
- Other considerations (experience of the employees involved, uncertain weather conditions, and so on).

X. IDENTIFYING SUITABLE RESTORATION SITE LOCATIONS

In restoration, choosing the right locations is crucial. During the first stages of planning, suitable sites are frequently extensively recognised through broad suggestions of potential places.

- 1. Donor Sites:** Determine and assess the viability of extracting plant material (seeds or shoots) from existing beds of seagrass for application in restoration.
- 2. Sites of Transplantation:** Locate and evaluate appropriateness (for example, biotic and abiotic properties). Assess why seagrass is not currently growing at the site.
- 3. Costs:** Planting in intertidal and shallow subtidal locations will save project costs by promoting seagrass development.
- 4. Designated Status:** Evaluate conservation features in supporter and restoration sites.
- 5. Reference Beds:** Determine the control spots to compare the enactment of restored regions to.

- 6. Seagrass Survival and Persistence:** Assess the possibility of long-term seagrass bed growth by comparing neighboring locations to the planned restoration site. Take into account the best site for long-term seagrass growth within larger restoration zones.
- 7. Current and Historic Distribution:** This indicates likely success in seagrass growth and persistence.

XI. WHAT ARE THE PRIMARY THREATS TO SEAGRASS ECOSYSTEMS?

Seagrass beds in shallow coastal areas often face human contact, causing conflicts between conservation interests and commercial users. Land operations like sedimentation, eutrophication, and pesticides also endanger seagrass health and survival.

- 1. Direct Pressures:** Coastal zone development, mobile fishing gear, recreational boating, and eutrophication, siltation from agriculture, urban waste, and aquaculture cause mechanical harm to the ecosystem. Seagrass beds become sedimented, promoting algae growth and nutrient enrichment. Loss of seagrass exposes the bottom to wave action, causing resuspension and turbidity, leading to a positive feedback loop of eutrophication.
- 2. Indirect Pressures:** Climate-driven changes, global sea levels, CO₂ and UV radiation, and human activities impact marine biodiversity, causing changes in oceanic and coastal food webs.

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