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Coral Gardening: An Innovative Technique to Management and Conservation of the Degraded Habitats of Coral

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SUMMARY

The most amazing underwater creation of nature is coral. The corals are being overused by aquarium hobbyists. They employ live rock, corals, and related materials to raise the aesthetic value of marine aquariums. There is a sizable global market for these goods. We benefit greatly from the coral reefs ecological and economic functions. Nevertheless, manmade and natural factors have led to the degradation of the coral reef environment all over the world. As a result, numerous nations pursue cutting-edge practices known as coral gardening and coral aquaculture. This strategy for restoring coral reef habitat is simple and affordable to use in far-off locations. This encourages cultural anthropology to restore culture to its original context in the environment. In addition, anthropology must once again incorporate futures into its ethnographic tools, but not as scenarios of predictions, but rather as the ways in which cultures perceive, imagine, and incorporate the future into their practices, in relation to non-human agents, and within a broader critique of the hegemonic fascination with consumption that we have frequently taken for granted in our models of understanding. This innovative technology can be applied to large-scale coral farming if correct management practices are taken into account.

INTRODUCTION

The "rainforests of the sea" have been referred to as coral reefs. They are one of the most fragile ecosystems on earth and the most biologically diverse marine ecosystem and an increasing amount of them are being destroyed Khalid and Thani (2008). As a result of the accumulation and deposition of limestone (calcium carbonate), marine creatures in the water create coral reefs, which are rocky mounds and/or ridges (Nunez-Lara et al. 2003). A form of dinoflagellate algae known as zooxanthellae and corals has a symbiotic relationship in which corals offer the zooxanthellae refuge and the zooxanthellae supply the corals with energy through photosynthesis. Hermatypic corals, or those connected with zooxanthellae, are primarily found in shallow waters inside the photic zone because of this significant association with a photosynthetic organism. Corals are likewise restricted by temperature to areas that are 30 degrees north and south of the equator; as a result, they are often warm, shallow-water environments (Nash 2014).

Among the Cnidarian classes, Anthozoa is the largest and contains more than 6,000 coral and "coral-like" species. The "stony" corals (Order Scleractinia), soft corals (Order Alcyonacea), fake corals and coral anemones (Order Coralliomorpha), and button polyps all have hard limestone or carbonate skeletons (Order Zoanthidea). A coral reef ecosystem that is functioning well contains a lot of biodiversity. Sea turtles, sea snakes, fish, mollusks, crustaceans, echinoderm, sponges, and diverse coral species all call it home Nama and Akter (2021). Where coral species are in danger of extinction, coral reef rehabilitation may be especially crucial. At one time, the two main reef-building species in the Caribbean, *Acropora palmata* and *Acropora cervicornis,* were both widely spread and present (Van Aken 2016; Bayraktarov et al. 2020). Familie Pomacentridae, which includes clownfish and damselfish, is closely related to sessile invertebrates like corals and sponges. Pomacentridae fishes are considered a keystone group because they are habitat-bound and have strong localized environmental effects that significantly influence their communities (O'Boyle Lois et al. 2020).

Some of the world most productive and biologically diverse ecosystems are coral reefs (Knowlton et al. 2010; Long et al. 2020). Reefs are thought to support 25% of all marine life despite taking up only 0.2% of the ocean floor. Coral reefs serve as vital resources for local populations worldwide, acting as supplies of food,

employment, and livelihoods in addition to housing, feeding, and nursery grounds for a large range of marine organisms. Currently, coral reefs are found in over 100 countries, and around 275 million people worldwide gain direct or indirect benefits from these ecosystems (Loureiro et al. 2022). Over 25% of marine biodiversity is supported by these areas, which occupy less than 1% of the ocean's surface. They also offer a variety of ecosystem services, including coastal protection, fisheries production, medical benefits, recreational advantages, and tourism profits (Rinkevich 2014).

The estimated 2, 55,000 km^2 is total area of the world, which is much less than many earlier estimations (Spalding and Grenfell 1997; Sheppard et al. 2012). It is pretty amazing that coral reefs support close to 30% of all known marine species on a worldwide basis, although taking up less than 0.2% of the ocean floor. The overall worldwide area of the dataset, which covered more than 40 years from 1978 to 2019, is estimated to be 2, 59,647 km^2. It included almost 2 million observations from more than 12,000 sites throughout 73 reef-bearing countries (Tkachenko et al. 2020; Obura et al. 2022). India has extremely few coral reef areas despite having a 7,500-kilometer coastline and subtropical climate (Hoon 1997). According to estimates, India coral reefs cover 2, 375 square kilometres in total (Venkataraman 2006; Jayaprakas and Radhakrishnan 2014; Saroj et al. 2016; Baswapoor and Irfan 2018; Jhajhria 2021).

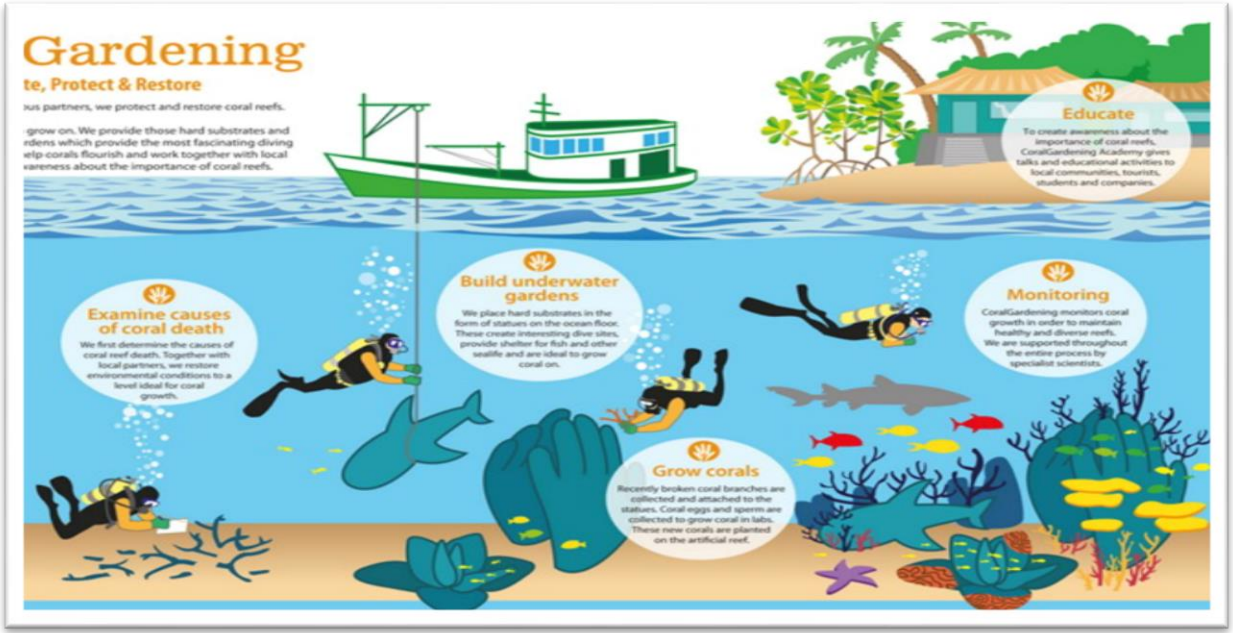

Figure 1- Coral gardening

What is Coral Gardening?

Currently, one well-liked technique for accelerating the rebuilding of coral cover on reefs is coral gardening. It entails moving coral fragments or entire colonies from a donor reef to a damaged one, either immediately or after spending some time in a nursery being grown to a specified size. The term "corals of opportunity" (COPs) refers to live coral fragments that have been naturally broken off by waves or storms and are now dispersed across the reef. Other coral gardening techniques use corals that have been purposefully split off living colonies (*Magris* et al. 2014). A key component of active reef rehabilitation efforts is coral transplantation. In this study, the "gardening notion," which includes two working stages, serves as the basis for the reasoning. Establishing in situ nurseries, preferably floating mid-water nurseries, is the initial step in the process of growing huge numbers of fragments of coral into substantial coral colonies under carefully monitored and ideal conditions. These coral colonies from nurseries are being transplanted onto depleted natural habitats as part of the second phase. In locations less frequently affected by catastrophic disasters, the "gardening concept's" nursery phase excelled. However, thorough studies evaluating the effectiveness of the idea in reefs subjected to protracted environmental stressors or adverse weather have not yet been conducted (Shaish et al. 2010). Coral gardening is the practice of attaching living coral fragments to damaged reefs to restore their cover. Though it has its uses, this technique for restoring reefs to health should only be used as a last resort. It has been gaining favour in the Philippines. A broader and more comprehensive approach is provided while allowing the reef to recover on its own through proper management of reef resources through marine protected areas, the elimination of stressors, and easing of fishing pressure. If coral gardening is the sole practical method for restoring a particular reef, great thought must be given to the choice of site, the coral species to be used, and the management of transplanting sites (Reyes et al. 2017).

Methodology for Coral gardening

One of the most popular coral propagation and repair techniques nowadays is "coral gardening" (Edwards and Clark 1999; Fabian et al. 2013; Allahgholi 2014; Elawad 2015; Westoby et al. 2020). This technique for growing coral involves taking only a small amount of healthy wild coral communities' tissue and skeletons, then growing an initial stock in situ or ex situ coral nurseries (Epstein 2002; McLeod et al. 2021; Samidon et al. 2022).

The main steps for coral gardening are:-

1. Collection of fragments
2. Setting up the nursery
3. Coral collections
4. Nursery operations
5. Out-planting Nama and Akter (2021).

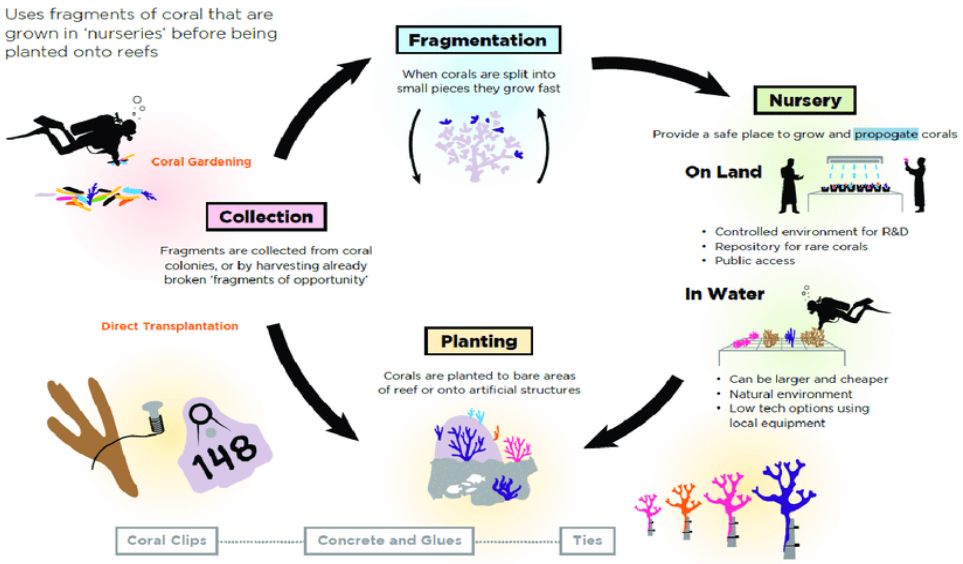

Figure 2- Method of coral gardening

1. Collection of fragments: In Coral gardening employs the method of fragment gathering, which has the following advantages: 1. Use of natural coral fragments that might otherwise become buried or overgrown prevents harm to healthy coral colonies. 2. Using indigenous coral fragments prevents the introduction of foreign material. To ensure the long-term survival and resilience of reefs, maintain the diversity of coral species and genetic variation within species. 3. Compared to natural chances, fragments with a diameter of 5 to 20 cm have a high survival rate. 4. High mortality in sexual reproduction and larval recruitment. 5. Low-cost components and basic technology Utilize artificial reef restoration in ecotourism, research, and educational activities as an adjunct to local MPA management to engage local stakeholders, divers, and volunteers, as well as the general public. Reduce the effects of anthropogenic and natural deterioration by rescuing broken-off coral fragments as an adjunct to local MPA management (Smith 2006; Sartoretto et al. 2008; Rosso et al. 2017).

2. Setting up the nursery: The most important phases in setting up the nursery were to select a suitable nursery site, a nursery design that was appropriate for the site, and cost-effective propagation platforms that would offer suitable attachment and growth settings for nursery corals. The choice of a site is primarily influenced by the wild populations already present, depth and water motion and substratum type, nearby habitat, quantity of nurseries, competitors, and accessibility. There are numerous nursery designs in use around the world, including both floating and fixed types (Shattuck 2005; Rinkevich 2006; Johnson et al. 2011; Somers et al. 2019).

3. Coral collections: The main objective of coral collections is to enhance the survival of fragments and nursery corals while minimizing the impact on donor colonies. To maintain the health of the nursery colonies, the coral fragments must be taken from a healthy potential donor colony. To ensure genetic variety among the corals that are gathered, the geographic area from which natural donor colonies are taken should be sizable. When collecting coral, being close to the nursery location is essential for keeping an eye on the wild colonies and cutting down on transport times, which lessens stress and harm to freshly obtained fragments. The short branch from wild donor colonies can be clipped using a variety of cutting equipment, including stainless steel surgical bone cutters,

diagonal electrical wire cutters, and needle-nose pliers (Pattengill-Semmens 2000; Boavida et al. 2016; Dearden et al. 2016; Young et al. 2012; Francis 2022).

4. Nursery operations: The major objective of nursery operations is to enhance the growth and survivability of corals that have been raised in the nursery. Daily upkeep using hand tools and the establishment of newly mounted fragments to surfaces should be done routinely to promote the coral fragments' growth and health. Algae, fouling creatures, predators like snails, fireworms, and damselfish, as well as the removal or treatment of ill corals, are all things that need to be maintained (Wright 2005; Edwards 2010; Edwards and Gomez 2010; Frias-Torres et al. 2019).

5. Out-planting: It's important to out-plant enough nursery-grown colonies from different donor colonies or genotypes to increase the possibility for sexual reproduction and recruitment. Sponge, palythoa, and algae are examples of creatures that should be avoided while choosing an out-planting location. The same donor colony, include colonies from as many donor colonies as are available in the nurseries, out-plant at a variety of sites to spread the risk of mortality, keep enough space for out-plants within plots and between plots to allow monitoring and maintenance access, and for out-planting maximum spacing should be 50-100 cm between colonies within plots to increase the chances of success. The two basic methods of coral gardening are asexual reproduction and habitat building. The bio rock method is one of the extra methods used to promote coral growth by electrolysis. Habitat development and asexual reproduction are the primary two processes in coral gardening (Van Aken 2016; Boström Einarsson et al. 2018; Cannon and Romain 2021; Mellin et al. 2022).

How to implement the programme?

The next stages are negotiable for Reefscapers. Depending on the expectations of the resort, the marine biologists' job description at the property and the implementation of any additional visitor activities or marine conservation programmes are both up for negotiation.

1. Marine assessment: A senior Reefscaper will visit the resort to conduct an initial marine assessment and identify possible locations for the construction of a coral garden and snorkelling trails.

2. Coral garden development: The first reef-scape will be created and launched on site by the Reefscapers team. The fabrication, shipping, transplanting, and deployment of coral frames are all included in this effort. On the island of Fulhadhoo, Reefscapers run their own production facility for coral frames. After being delivered to Male, the frames are uploaded on the supply boat.

3. Coral frame sponsorship: At any moment during their stay on the island, visitors can sponsor a coral frame, which is constructed and deployed with the local marine biologist. The marine biologist will assist the visitors with attaching coral fragments to the frame and share information about the resort's other marine conservation initiatives as well as coral restoration. When a guest sponsors a frame, they also have the choice to include a dedication that will appear on the adoption certificate and unique tag number for that frame, giving their contribution to conservation a more personalised touch. The guest will also receive updates and pictures from the on-site marine biologist at least once every six months to show how their coral frame has changed over time.

4. Resident marine biologist works: Oversee and keep up the Coral Restoration Program at the resort. Build coral frames with visitors and keep an eye on the coral gardens at the resort. organise marine biology events like guest-focused snorkelling outings and live talks. Develop marketing plans and content to highlight the resort's environmental initiatives. Hold programmes to educate the resort personnel about issues like sustainability and marine protection. Report office operations, updates, and goals for marine biology with illustrations each month. Regarding the resort's marine biologist's job description and the introduction of any additional guest activities or marine conservation initiatives, Reefscapers is amenable to dialogue (Razak et al. 2022).

Factors affecting Coral Gardening

The following are significant elements influencing coral growth:

(1) Coral polyps are shallow-water organisms that are sensitive to temperature because they cannot endure extremely high or extremely low temperatures. Coral is primarily found in tropical waters and seas where the annual mean temperature is greater than 18 °C but less than 30 °C. Coral bleaches and dies if the average mean monthly temperature is higher than 30°C (Hernández-Delgado et al. 2014).

(2) Corals cannot survive in seas deeper than 200–250 feet (60–77 metres) below sea level because there is insufficient sunlight and oxygen, which are crucial for the development of coral polyps. In waters deeper than 77 metres, corals die. Therefore, only the upper portion of the photic zone—between sea level and 200 metres below—is conducive to the growth of coral polyps. The maximum depth for optimal coral growth is 200 to 300

feet (60 to 91 metres) below sea level, although Gardiner found some corals thriving at a depth of 150 to 170 fathoms (Tseng et al. 2015).

(3) The water should be clear and devoid of debris since muddy or turbid water clogs coral polyps' mouths and causes their demise.

(4) It should be noted that although coral polyps require water free of debris, the growth of corals can also be harmed by fresh water. Because of this, corals stay away from river mouths and coastal locations (Hughes et al. 2010).

Benefits of Coral gardening

Since the subject of coral restoration has been quickly developing over the past ten years, the best method and ideas for coral gardening are mostly dependent on regional conditions and project-specific objectives. The advantages of improving coral population numbers and reef health include Ransom and Mangi (2010).

1. Establish a powerful partnership: This kind of coral gardening initiative offers chances for scientists, managers, and conservationists in many organisations to establish powerful relationships Abrina and Bennett (2021).
2. Research platform: Coral gardening nurseries can offer a crucial scientific research platform for aspiring researchers (Schmidt-Roach et al. 2020).
3. Biodiversity conservation: Coral gardening is a crucial step for preserving coral species and reviving the biodiversity of the coral environment. The environment of coral reefs also provides a refuge for young animals and safeguards large predators for numerous species Abrina and Bennett (2020).
4. Food and livelihood: More than 500 million people rely on coral reefs for both their food and means of subsistence, which supports the local communities' economic situation Becken and Curnock (2022).
5. Industrial significance: Human bone grafts have been made from limestone skeletons, while some coral reef species are utilised to treat cancer, HIV, cardiovascular ailments, and ulcers (Epstein et al. 2003).
6. Economic significance: Tourism and recreational fishing are significant sources of income for many developing nations, and a vibrant and beautiful coral reef ecosystem is essential to both (van de Water et al. 2022).
7. Education of local residents: Coral gardening in nurseries teaches residents and tourists about the value of corals and the state of the surrounding reef ecosystems (Kittinger et al. 2016).

CONCLUSION

The restoration of a coral reef ecosystem's genetic diversity and biodiversity is the main goal of coral gardening. This strategy of actively restoring coral is documented with the time and an online database made available by researchers, practitioners, and management. There are numerous coral restoration efforts underway in numerous nations, and some of these programmes have already shown ecological effectiveness on a smaller scale. The primary criteria for selecting the techniques for coral restoration are the local conditions, cost, availability of materials, and appropriateness based on stated objectives. So, along with managing fisheries and improving water quality, coral restoration should take a comprehensive approach. Climate change, which mostly results in coral bleaching, has been one of the main causes of the deterioration of coral reefs in recent years. Numerous experts believe that effective management of reef resources and climate change mitigation cannot be replaced by coral restoration efforts.

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