# The Impacts and Crises on Coral Reef Posed by Various Factor

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Abstract: Since the late 20th century, the proliferation of industry and technology, alongside various biological factors, has led to a progressive decline in the quantity of wild coral reefs within the oceans. The survival of coral reefs and the equilibrium of coral reef ecosystems are under severe threat. The paper primarily outlines the potential threats faced by coral reefs, the impact of human pollution on coral reefs, and the development of novel technologies that offer new directions for the conservation of coral reefs and their ecosystems. This study reveals that with the advancement of biotechnology, certain sponge symbiotic bacteria and dissolved organic matter play crucial roles in maintaining the stability of coral reefs. Emerging cell engineering techniques, such as cryopreservation, indicate a pathway for enhancing coral polyp biomass. Increasing biomass is an innovative measure, yet it requires careful consideration of various tradeoffs to avoid exacerbating adverse impacts. Simultaneously, bioremediation techniques offer potential for degrading microplastics in the ocean and stabilizing aquatic environments.

## 1 INTRODUCTION

Coral reefs refer to underwater structures found in tropical and subtropical shallow seas, consisting of the skeletal remains of reef-building corals and biological debris, possessing wave-resistant characteristics. Within coral reefs, various reef-building organisms such as corals of the order Scleractinia, hydrozoans, and algae are encompassed. Oman's territory encompasses more than 530 square kilo-meters of coral reefs along one of the Arabian Peninsula's longest coastlines, fostering the survival of over 100 coral species and 579 species of coral fish. Despite the unique biogeographical background and evident significance for biodiversity and economy, Oman's coral reef ecosystems are recognized as being among the least researched in the region. Since the late 20th century, these reefs have faced threats from various biotic and abiotic factors, including the adverse impacts of human activities (Burt et al., 2016). Hurricanes have led to extensive loss of shallow-water coral across the entire Daymaniyat Archipelago. Particularly affected are the coral communities dominated by branching Acroporidae and Pocilloporids, where the fragmentation of these coral colonies has resulted in significant losses of coral cover and structural heterogeneity.

Scholars from various fields both domestically and internationally show significant concern for the conservation of coral reefs and biodiversity. Researchers conducted genetic analyses on 47 coral reef species sampled across multiple islands in Hawaii (Selkoe et al., 2016 & Voolstra et al., 2023). The findings of the research highlighted the fundamental connection between ecology and genetics, paving the way for novel approaches to monitor and conserve the biodiversity of coral reef ecosystems. Additionally, advancements in cellular engineering have made significant contributions to the breeding and conservation of coral polyps, playing a crucial role in enhancing the biomass of coral reef ecosystems. Simultaneously, the International Coral Reef Symposium (ICRS) has proposed several feasible measures for coral reef conservation, such as reducing carbon dioxide emissions, enhancing pollution monitoring and improving water quality.

This paper elucidates the pivotal role of coral reef ecosystems in the marine environment, as well as the diverse array of global factors impacting and threatening these ecosystems. Such phenomena have garnered extensive attention and research interest among scholars. Some researchers are employing biochemical approaches to enhance the biomass of coral reefs, including investigating the roles of symbiotic bacteria and dissolved organic matter in the



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stability and protection of coral reefs (Marzuki et al., 2023 & Nelson et al., 2023). With the development of cellular engineering, the cultivation of coral larvae offers a novel approach to enhancing the biodiversity of coral reefs (Hagedorn et al., 2017). However, due to the extensive distribution of coral reefs, some measures are difficult to be implemented on a large scale. There is still a long way to go for the protection of coral reefs and biodiversity.

## 2 CASE DESCRIPTION

From the 1970s onwards, Omani coral reefs have experienced ongoing disruptions caused by repeated outbreaks of the predatory crown-of-thorns starfish. These outbreaks typically occur at least once every decade, leading to rapid changes in the structure of coral communities. At the same time, the extensive damage to Oman's coral reefs was also inflicted by Hurricane Gonu in 2007. The entire Omani sea witnessed significant impact from this cyclone, causing widespread destruction to coral formations (Burt et al., 2016). Furthermore, the substantial amount of marine debris generated by industrial production emissions poses a serious threat to the survival of marine species. As a result, coral reef ecosystems are highly susceptible to various natural and anthropogenic disturbances, posing significant threats to the survival of corals. Urgent measures are imperative for the conservation of coral reef ecosystems.

## 3 FACTORS AFFECTING CORAL REEF ECOSYSTEMS AND POSSIBLE MEASURES TO PROTECT CORAL REEFS AND BIODIVERSITY

Coral reef communities exhibit high biodiversity and productivity, with some individual animal species displaying remarkable characteristics. Coral reefs provide habitat for a myriad of marine organisms, including annelids, mollusks, sponges, echinoderms, and crustaceans, among others. Many species have developed symbiotic relationships with corals, such as zooxanthellae, which utilize the metabolic waste and carbon dioxide from coral polyps to undergo photosynthesis and produce organic matter. These compounds exist in the form of glycerol and glycerol triesters, which are secreted into the extracellular matrix to provide nutrition for coral polyps and are readily absorbed by them. Today, due to industrial pollution emissions and human activities in the oceans, coral reefs experienced a serious global decrease in their coverage area. Consequently, the populations of some species dependent on coral reefs for survival have decreased. Finding effective measures to protect coral reef ecosystems has become a focal point of research in this field. Maintaining biomass, diversity, and ecosystem functionality is a core objective of most initiatives aimed at protecting coral reef ecosystems.

Some human activities like certain fishing practices and construction projects, indirectly induced climate change, can lead to coral loss, resulting in declines in coral fish biomass and changes in coral reef community structure. Undoubtedly, this disrupts the balance of coral reef ecosystems. Research indicates that global warming will directly impact coral reef fish communities through rising sea temperatures or ocean acidification, or indirectly through habitat loss. The coral reefs of Lizard Island, which is part of the Great Barrier Reef in Queensland, have suffered greatly as a result of terrible weather events. In 2014, The northwestern region's shallow reefs suffered significant damage from Hurricane Ita & Cyclone Nathan in the previous year, which caused the coral coverage to drop significantly from twenty-five percent to nine percent. Numerous coral reefs have seen the destruction of their branching corals, which has led to the habitat loss of numerous coral fish species (Triki et al., 2018). Some scholars have pointed out that increasing the biomass of coral fish could help maintain the diversity of coral reef ecosystems. However, this approach does not fundamentally address the issues of expanding coral reef areas or mitigating coral bleaching.

On the other hand, need for industrial output is rising in tandem with the global population growth, leading to the construction of numerous new factories along coastlines. This has directly resulted in a significant discharge of production waste and pollutants into the sea, including a substantial amount of heavy metal contaminants. Using 14 samples of planktonic species, researchers measured the amounts of 19 common elements using Inductively ICP-OES, covering the oligotrophic and mesotrophic zones found in the Red Sea's northern and southern sections. The findings showed that samples from Rabigh City's southwest had noticeably higher amounts of Cr, Ni, Pb, and Zn, which may have something to do with the region's use of crude oil and related activities. These elevated concentrations could be the result of the region's pollution-intensive sectors, like power plants that use crude oil as fuel to generate electricity (Cai et al., 2022). Various indicators suggest that human industrial production is discharging a significant amount of pollutant waste into the ocean. Furthermore, it is worth noting that due to the unique physical properties of heavy metals, they tend to readily deposit in seabed sediments and are difficult to degrade. This could result in heavy metals remaining deposited in marine environments for decades or even centuries, significantly impacting nutrient absorption by coral reefs and potentially indirectly leading to species mortality. Besides, researchers also investigated the influence of monsoons and ocean currents on the distribution of heavy metals. The results indicate a close correlation between the fluctuation of heavy metals and seasonal variations: zinc (Zn) exhibits its highest concentration in the western monsoon, while lead Pb content is highest in the eastern monsoon (Raza'I et al., 2021). This suggests that heavy metals can spread worldwide with monsoons and ocean currents, indicating their impact is inevitably global, posing a serious threat to the entire coral reef ecosystem.

Research has indicated that certain cleaner fish species can promote the diversity of coral reef fish. Among coral reef fish, interactions with cleaner fish represent one of the most prevalent interspecific relationships. Each day on the Great Barrier Reef, an average of 2297 client fish engage in interactions with the cleaner fish species Labroides dimidiatus. Certain client species individuals visit cleaner fish species up to an average of 144 times per day. Researchers discovered that on coral reefs containing cleaner fish species, both the number of visiting client fish species and that of individual visitors were approximately double and quadruple, respectively, in comparison to reefs lacking cleaner fish. This directly enhances the biodiversity of coral reef ecosystems (Grutter et al., 2003).

Governments propose establishing marine protected areas to maintain the balance of coral reef ecosystems. Indeed, this is one of the primary conservation strategies for coral reefs. However, marine protected areas alone cannot mitigate the widespread impacts of climate change on coral reefs. In the ENSO event of 2014 - 2016, coral reefs in the vicinity of Zanzibar experienced coral bleaching, leading to significant coral mortality. Simultaneously, coral bleaching has resulted in a series of adverse effects on the benthic community structure of coral reefs and some omnivorous animal populations. The coral mortality rate across all coral reef locations reached as high as 68%, with a concurrent increase in turf algae cover by 48%. Human efforts to predict climate impacts or propose mitigation measures remain challenging (Elma et al., 2023).

In recent years, many studies have pinpointed fresh avenues for safeguarding and preserving the equilibrium of coral reef habitats. Research indicated the potential applications of high-performance and effective marine sponge-associated bacteria for the elimination of heavy metal contaminants and PAHs. Several types of marine sponge-associated bacteria may be utilized to enhance waste remediation capabilities. These marine sponges typically inhabit coral reef communities, and the bacteria's capacity for removing and absorbing certain heavy metal pollutants holds potential advantageous effects for improving the survival environment of coral reefs. Studies have shown that when sponge habitats are exposed to toxic metals or hydrocarbons pollution, either separately or together, enhances the bacteria-sponge symbiotic model. As sponges adjust to live in the harsh conditions of their surroundings, this happens. Meanwhile, these circumstances are also used by symbiotic bacteria to create mucus. By acting as an enzyme and spreading across the sponge's surface, the mucous material lessens the effects of harmful contaminants (Marzuki et al., 2023). Further research indicates that the process of bacteria adsorbing heavy metals is analogous to the formation of X-EDTA complexes, where X represents the heavy metal, using ethylenediaminetetraacetic acid (EDTA). Extracellular ionic bonds are formed during the heavy metals adsorption procedure, linking the negatively charged bacterial cell surface with similarly charged heavy metals. The adsorption time of heavy metallic ions is less than that of polycyclic aromatic hydrocarbons breaking down. The process of adsorption keeps going until it reaches saturation. SEM, EDS, and XRD analytical instruments can be employed to observe the adsorption mechanisms and alterations of bacterial cells regarding heavy metals. Meanwhile, AAS or ICP techniques can be utilized to determine the adsorption efficiency. By quantifying the adsorption capacity of marine bacteria for heavy metal pollutants, a new direction has been identified for improving the marine environment conducive to coral reef survival.

As scientific inquiry advances, researchers have unearthed the pivotal role of specific marine microorganisms in upholding the durability and steadiness of coral reefs by facilitating the transformation and recycling of dissolved organic matter. Dissolved organic matter refers to organic substances that can pass through a 0.5+ micron filter.

Dissolved organic matter permeates the world's oceans and boasts a biomass comparable to that of terrestrial plants. These organic substances play a crucial role as mediators in coral reef production, nutrient exchange, and biological interactions, whereas the conversion and recycling of organic matter is greatly aided by microbes. In maritime contexts, coral reefs display five fundamental ecological processes: increased productivity, rapid, diversified biogeochemical cycle, high biodiversity, intensive decomposition, and high adsorption. Microbial interactions with dissolved organic matter are central to each of these processes. Initially, microorganisms recycle dissolved primary products, with coral reef microbial communities swiftly utilizing and transforming these compounds. This dynamic mechanism plays a key role in the transmission of coral reef higher trophic levels with carbon by influencing the structure of microbial communities. Additionally, it enhances nutrient utilization and retention; in oligotrophic tropical waters, microbiological remineralization of dissolved organic compounds provides a major nutrient source that allows the main producers in coral reef ecosystems to survive. Furthermore, microorganisms aid in the rapid decomposition of detrital accumulation, and the broader nutritional interactions between microorganisms and DOM play a crucial role in maintaining a net metabolic balance and minimizing detrital accumulation. Finally, coral reef net accretion is facilitated by microbial development and metabolism, which also affect ecosystem net calcification through indirect as well as direct processes. These mechanisms include the use of heterotrophic feeding to stimulate coral development, microbial precipitation to aid in the calcification of aragonite, and microbial remineralization of substances that affect the concentrations of carbonate ions and alkalinity in the area. This fosters the formation of reef-building microorganisms. In summary, many key factors that sustain coral reefs in oligotrophic oceans are to some extent facilitated by microbial-DOM interactions. These mechanisms encompass the transmission of nutrients from DOM to seafloor suspension-feeding groups, the remineralization and transformation of nutrients, the facilitation of diverse biogeochemical cycling, the regulation of dissolved metabolism, and the promotion of highly interconnected trophic structures. These are all core aspects contributing to the high biodiversity of coral reefs (Nelson et al., 2023).

With the developments in cellular and embryo engineering technologies, cryopreservation has emerged as a new possibility for increasing the biomass of coral polyps. Cryopreservation refers to the process of suspending in vitro cultures in a solution containing cryoprotectants, lowering them to a certain subzero temperature at a controlled freezing rate, and maintaining them at this temperature for long-term storage. Researchers have now successfully cryopreserved many types of coral cell cultures, and coral eggs have been fertilized and coral larvae have been produced using these frozen materials (Hagedom et al., 2017). In laboratory settings, researchers have successfully produced significant numbers of coral offspring from cryopreserved coral sperm (Hagedom et al., 2017), making significant contributions to increasing coral biomass in marine environments. However, it is worth noting that the use of cryopreservation to increase and sustain coral biomass has not seen widespread development and production on a large scale. Much work is still needed to make these cryopreserved biological repositories viable partners in coral reef restoration efforts.

# 4 BIOLOGICAL AND MATERIAL SOLUTIONS

Protecting coral reefs from the perspective of increasing biomass is an innovative and challenging approach, but it is essential to ensure the balance of the entire ecosystem and the food web within the food chain. Increasing coral fish species diversity indiscriminately may impact the survival of other creatures (Schiettekatte et al., 2022). Research on fishing activities in the Gulf of Saros in the Mediterranean region has revealed that overexploitation of resources in the bay extends to the entire habitat, affecting low-nutrient levels and top predators. In the late 1990s, overfishing led to a decrease in biomass for the bluefin tuna populations in the eastern Atlantic and Mediterranean, as well as for the Mediterranean swordfish population. This resulted in the proliferation of small to mid-sized pelagic fish, significantly impacting the balance of the marine ecosystem food web (Bradley et al., 2020 & Papantoniou et al., 2021). Hence, human management of biomass requires multifaceted considerations, as even minor disturbances can potentially lead to ecosystem collapse or other significant impacts (Papantoniou et al., 2021). Conservative measures aimed at maintaining the nutritional structure of ecosystems will become the main trend in coral reef protection, ensuring the stability and enhancement of biodiversity within coral reef ecosystems.

Due to inevitable pollution discharge into the ocean in certain circumstances, apart from curtailing emissions at the source, the development and research of new degradation technologies are crucial for mitigating the extent of coral reef exposure to marine pollution. Some emerging ubiquitous environmental pollutants, such as microplastics, ultrafine fibers and nanoplastics, are extremely difficult to degrade in marine environments. Due to their unique physical properties, they easily accumulate in organisms and can lead to organism mortality. Researchers are exploring the possibility of using bioremediation methods to mitigate marine microplastic pollution (Das et al., 2023). The process of bioremediation involves the utilization of organisms to reduce, degrade, or eliminate pollutants from the environment. Until now, researchers have discovered bacterial strains, fungal species, and various plant species that exhibit the ability to degrade, decompose, or ingest microplastics, as evidenced by laboratory experiments (Bradley et al., 2020). This provides a promising direction for reducing emerging marine pollutants. It is also believed to play a crucial role in protecting and balancing coral reef ecosystems, shielding them from the impacts of marine pollution.

# 5 CONCLUSION

Absolutely, among the ocean's most important marine ecosystems, coral reef systems should get international attention and protection. Indeed, with the continuous advancement of technology and the increasing demands of humanity on nature, the survival environment and space for coral reefs are increasingly concerning. Besides, adverse climate changes such as global warming and El Niño events also have negative impacts on the survival of coral reefs. Scientists' exploration and research on various aspects of coral reef ecosystems, including biology, materials, environment, chemistry, etc., play a crucial part in the preservation, expansion, and enhancement of maritime habitats. The paper ' s multifaceted discussion on coral reefs aims to provide feasible directions for coral reef conservation in the scientific community and enhance the importance of marine environmental protection. It seeks to mitigate the threats facing coral reefs from various angles. However, despite being a globally significant species, the protection and propagation of coral reefs still face several challenges. Certainly, challenges persist in understanding the regulatory role of marine microorganisms in aquatic ecosystems within the scientific community. Additionally, the widespread implementation of cryopreservation technology is hindered by limitations in funding and technical resources. Moreover, there are constraints on the number of species capable of degrading microplastics. With the support of advancing technology, it is believed that the challenges related to coral reef survival can be gradually addressed in the near future. Not only that, the biodiversity within coral reef ecosystems will steadily increase, leading to a more stable balance between humans and nature.

# REFERENCES


Burt, J. A., Coles, S., van Lavieren, H., Taylor, O., Looker, E., & Samimi-Namin, K. (2016). Oman's coral reefs: A unique ecosystem challenged by natural and man-related stresses and in need of conservation. Marine pollution bulletin, 105(2), 498–506.

Selkoe, K. A., Gaggiotti, et.al, R. J. (2016). The DNA of coral reef biodiversity: predicting and protecting genetic diversity of reef assemblages. Proceedings. Biological sciences, 283(1829), 20160354.

Voolstra, C. R., Peixoto, et.al, C. (2023). Mitigating the ecological collapse of coral reef ecosystems: Effective strategies to preserve coral reef ecosystems: Effective strategies to preserve coral reef ecosystems. EMBO reports, 24(4), e56826.

Marzuki, I., Rosmiati, et.al, B. (2023). Potential Utilization of Bacterial Consortium of Symbionts Marine Sponges in Removing Polyaromatic Hydrocarbons and Heavy Metals, Review. Biology, 12(1), 86.

Nelson, C. E., Wegley Kelly, et.al, A. F. (2023). Microbial Interactions with Dissolved Organic Matter Are Central to Coral Reef Ecosystem Function and Resilience. Annual review of marine science, 15, 431–460.

Hagedorn, M., Carter, et.al, R. E. (2017). Producing Coral Offspring with Cryopreserved Sperm: A Tool for Coral Reef Restoration. Scientific reports, 7(1), 14432.

Triki, Z., Wismer, et.al, R. (2018). A decrease in the abundance and strategic sophistication of cleaner fish after environmental perturbations. Global change biology, 24(1), 481–489.

Cai, C., Devassy, et.al, S. (2022). Cement and oil refining industries as the predominant sources of trace metal pollution in the Red Sea: A systematic study of element concentrations in the Red Sea zooplankton. Marine pollution bulletin, 174, 113221.

Raza'i, T. S., Thamrin, et.al, A. (2021). Accumulation of essential (copper, iron, zinc) and non-essential (lead, cadmium) heavy metals in Caulerpa racemosa, sea water, and marine sediments of Bintan Island, Indonesia. F1000Research, 10, 699.

Grutter, A. S., Murphy, et.al, J. H. (2003). Cleaner fish drives local fish diversity on coral reefs. Current biology: CB, 13(1), 64–67.

Elma, E., Gullström, et.al, M. (2023). Post-bleaching alterations in coral reef communities. Marine pollution bulletin, 186, 114479.

Schiettekatte, N. M. D., Brandl, et.al, V. (2022). Biological trade-offs underpin coral reef ecosystem functioning. Nature ecology & evolution, 6(6), 701 – 708.

Bradley, P., Jessup, et.al, S. K. (2020). Development of a reef fish biological condition gradient model with quantitative decision rules for the protection and restoration of coral reef ecosystems. Marine pollution bulletin, 159, 111387.

Papantoniou, G., Giannoulaki, et.al, K. (2021). Food web interactions in a human dominated Mediterranean coastal ecosystem. Marine environmental research, 172, 105507.

Das, A. P., Mohanty, et.al, G. (2023). Bioremediation as an emerging technology for the removal of synthetic microplastic pollutants from marine ecosystem. Marine pollution bulletin, 194(Pt A), 115297