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Analysis of the Causes of Coral Community Destruction

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Abstract: Coral reefs, which are the most biodiversity-rich marine ecosystems in the world, support the survival of more than 30% of marine life. However, the global coverage of coral reefs has declined rapidly in the last fifty years, and seriously threatens marine ecological security. This study systematically reveals the multi-dimensional factors of coral reef degradation and proposes feasible restoration strategies through literature analysis and comparison with typical cases. This thesis argues that, as an ecosystem with high biodiversity, coral reef ecosystems are susceptible to rapid decline in a short period of time when they are negatively affected by various factors; and that, in view of the severe situation faced by coral communities, it is necessary to speed up the rate of coral reef ecosystem restoration through the double intervention of technology and policy, and to maintain coral reef ecosystems' stability as far as possible. In this thesis, we hope to analyze the causes of coral reef damage in multiple dimensions and list the restoration countermeasures, so as to provide references for the further study of coral reef ecosystems and the proposal of subsequent protection programs.

Keywords: Coral reefs, causes of destruction, case study, countermeasure analysis

1. Introduction

Coral reef ecosystems, as the ecosystems with the highest species diversity in the world, are home to more than 30% of marine organisms despite occupying only 0.1%-0.5% of the marine ecosystem [1]. Because of its significance, coral reef ecosystems have been labeled as the “rainforests of the sea floor” [1].

However, in recent years, the area covered by coral reefs around the world has once been sharply reduced. For example, from the 1980s to the beginning of the 21st century, the coral reef cover of the Great Barrier Reef located in Australia decreased from 28% to 13.5% [2]; while in the South China Sea islands in the beginning of the 21st century, the coral reef cover declined by more than 40% [3]. The main reasons for the large-scale disappearance of coral reefs include climate warming, water eutrophication, and coral diseases [4]. In such a severe form, many scholars have carried out a theoretical analysis of coral reef protection: Qin Zhenjun et al. proposed that man-made assistance to coral migration from low latitude to high latitude can help protect coral [2]; Zhang Yuyang et al. pointed out that coral transplantation is a more direct and efficient method than the re-cultivation of coral larvae [3]; at the same time, there are other scholars have proposed that the genetic exchange of coral across latitudes can make the coral heat resistance [4]. Exchange can substantially increase the heat tolerance of corals and reduce their survival rate [2].

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The purpose of this thesis is to discuss the causes of coral mortality and propose how to prevent the destruction of coral communities and how restore damaged corals, thus pointing out the serious situation facing coral communities and proposing feasible solutions. This thesis will start with the importance of coral reef ecosystems, then analyze the causes of coral reef ecosystem damage, then list specific cases and analyze them, and finally summarize the feasibility of coral reef restoration techniques listed by the relevant researchers.

2. Analysis of the significance of coral reef ecosystem

The coral reef ecosystem is a complex system that consists of reef-building corals and other organisms inhabiting the reef together, while coral reefs are mainly composed of shells secreted by coral polyps as they grow; other organisms, such as shellfish, lime algae, and foraminifera, are likewise capable of forming calcareous skeletons. These skeletons combine with those of corals to gradually build up a large-scale reef structure [1]. Based on this reef structure, coral reefs can effectively withstand large-scale wind and waves, and reduce the impact of sea level changes [5]. Therefore, coral reef ecosystems play a crucial role in maintaining biodiversity and the stability of the gene pool, with more than 800,000 species living on coral reefs, and one quarter of all marine fish occurring only in coral reef waters [1]. Coral reefs have been labeled as the “rainforests of the ocean” because their ecosystems are very similar to those of tropical rainforests [1,2]. However, because of their irreplaceable position in marine ecosystems, the loss of corals can be devastating for the species that inhabit them: for example, overexploitation has led to severe degradation of coral reefs in northern Palau, in the western Pacific Ocean, and to the loss of more than three-quarters of the local fish species [6].

3. Analysis of the reasons for the destruction of coral reef ecosystems

In an ecosystem, biodiversity often determines the stability of the ecosystem in the self-repair ability, the richer the biodiversity, the faster its self-repair speed, the higher the stability. It also means that coral reef ecosystems with rich biodiversity theoretically have a strong self-repair ability [7]. However, as the key species in coral reef ecosystems, the massive death of coral polyps is very likely to lead to the collapse of coral reef ecosystems. In fact, since the 1980s, coral reef communities around the world have been severely damaged. For example, the world's largest coral reef complex, the Great Barrier Reef in Australia, experienced several large-scale coral bleaching events between 2016 and 2020, and the mortality rate of adult corals in its northern part was as high as 67%, while the number of coral larvae dropped to 11% of the original [8]. This result originates from various reasons, such as global warming, environmental pollution and overfishing. In this thesis, we will analyze the causes of coral community destruction from three perspectives: seawater temperature change, human activities and biological erosion in a multidimensional way.

3.1. Temperature

As global temperatures rise, corals are subject to heat stress and coral bleaching. This is mainly due to the fact that the symbiotic algae, which used to live in symbiosis with the coral polyps and provide them with energy through photosynthesis, produce substances harmful to both themselves and the corals when they are exposed to prolonged periods of higher than normal seawater temperatures, leading to the expulsion of the corals from these symbiotic algae [8,9]. Without the symbiotic algae, the coral loses its main source of energy, which in turn leads to bleaching. Bleached corals are extremely fragile and prone to mass mortality due to disease [8,9]. In addition to this, studies have shown that the reproduction of pathogens such as RNA-type viruses accelerates along with an increase in seawater temperature. In 2005, the United States lost more than half of the coral reefs in

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the Caribbean Sea. The southward expansion of warmer waters centered on the northern part of the Antilles Islands (Antilles) led to this event [9]. In addition, not all coral bleaching events are caused by an increase in seawater temperatures; in January 2010, seawater temperatures in the Florida Keys dropped by 6.7 degrees Celsius, which is lower than is typical for this time of year. This was accompanied by the bleaching and death of some corals, a phenomenon that researchers have suggested may be because lower water temperatures are just as likely to cause corals to expel symbiotic algae and expose themselves to disease as they would in warmer waters [9].

3.2. Human activities

During the construction of coastal cities, large quantities of dumped sediments can cause direct physical damage to corals, while sewage discharge from coastal cities can lead to eutrophication of water bodies, which can cause the population of benthic algae to skyrocket and slow down the growth rate of corals [10]. This is mainly due to the fact that algae, when proliferating, block sunlight and slow down the rate of photosynthesis of the algae that live in symbiosis with the corals [10] and. The tools used to carry out fishing operations, such as fishing nets, can also cause direct damage to corals [11]. The rapid development of coastal areas over the past few decades has also exacerbated the plight of coral communities. For example, the population of Hong Kong has grown from 3.1 million in 1960 to 7.5 million in 2020, and large amounts of untreated sewage discharged into the sea as well as frequent coastal recreational activities have caused damage to corals. Coral communities in Tolo Harbor have almost disappeared due to pollution [1]. Further direct destruction of coral habitats has been caused by reclamation projects that dump sediments and encroach on the sea in exchange for larger land areas for the construction of harbors and airports [12].

3.3. Bio-erosion

Biological erosion is also one of the major threats to coral reefs. The introduction of alien species not only squeezes the living space of native species but may also enable them to reproduce in large numbers due to the lack of natural enemies, thus further destroying the local ecological balance and leading to the death or even extinction of a large number of native species. For example, between 2005 and 2018, the erosion of long-spined sea urchins drastically reduced the coral cover of Jikong Pai from 62.5% to 20.6%, and that of Huangzhujiaojiaozui from 66.9% to 10% [1]; while Zanzibar, located in eastern Tanzania, had less than 50% localized coral survival after experiencing an outbreak of sea stars [12]. Most of the biological invasions originate from human activities and are mainly caused by water exchanges of cargo ships and the release behavior of the population: the larvae of exotic species carried from other areas enter and reproduce in local water bodies when cargo ships perform the necessary ballast water exchanges, while a part of the population performs the release behavior of the species after a period of time in captivity. Both behaviors can lead to the introduction of exotic species [12].

4. Global case study of coral community degradation

The coral community located in Daya Bay, China, has experienced significant degradation, with coral cover declining from 76.6% in 1983 to 6.7% in 2020. The once dominant staghorn and rose corals have almost completely disappeared. The main causes of degradation include global warming, industrial wastewater discharge, overfishing, illegal coral harvesting, sedimentation and water pollution [11]. The coral reefs of Weizhou Island in the North Bay have similarly experienced severe degradation over the past few decades, with cover declining by 76-86% from 1984 to 2015. The 1998 El Niño (i.e., a climatic phenomenon that occurs when the interaction between the ocean and the atmosphere is out of equilibrium over a wide area of the equatorial belt of the Pacific Ocean and leads

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to an unusually persistent warming of seawater temperatures in the tropical oceans of the eastern and central Pacific Ocean) triggered a large-scale coral bleaching event, which, together with subsequent seawater pollution from sewage discharges, crude oil spills, and illegal mining activities, was the main cause of the phenomenon [4]. In the 1960s, Luhuitou and its surrounding shore reefs in Sanya, Hainan used to have dense coral communities with coral cover as high as 80-90%. However, with population growth and increased development intensity, problems such as overfishing, destructive fisheries, illegal coral harvesting, sedimentation, and water pollution ensued, leading to severe impacts on the Luhuitou reefs [1]. In 1998, corals from Mexico to Honduras suffered two large-scale coral bleaching events in one year, and Hurricane Mitch gave the local corals a second blow. The bleaching events combined with the effects of the hurricanes destroyed a large number of corals, with coral mortality rates as high as 75% in some areas [12]. In the U.S. Caribbean, the extremely rapid decline in seawater temperatures in 2003 resulted in a mass bleaching event that was more widespread than the previous bleaching event in 1998, with the effects of bleaching spreading from just above 10 m in 1998 to water depths greater than 15 m. In addition, this bleaching event reflected the fact that the coral reefs in the U.S. Caribbean were not as deep as they were in 1998, and that the coral reefs were not as deep as they could be. In addition, the bleaching event was highly variable: some corals showed only small, irregular white patches on the surface, while others showed uniform whitening of the entire colony [12].

5. Analysis of countermeasures against the degradation of coral communities

In the face of the serious situation of large-scale degradation of coral communities, it is extremely important to take appropriate measures. Since the end of the 20th century, each country has carried out active work on the restoration of coral reefs, and carried out experiments such as sexual reproduction of corals, larval cultivation, transplantation, etc. [3], and researchers have summarized the following more effective ways of restoration:

(1) Coral transplantation refers to the transplantation of some coral fragments or intact corals to new areas, and the survival of the transplanted corals can significantly restore the local ecology [2]. As the most direct means of restoration, coral transplantation can rapidly increase the coral cover in a short period of time compared with a new round of larval cultivation of corals. Transplanted corals can also fulfill their full role on the reef, i.e., attracting fish and providing habitats for reef organisms [2, 3]. A typical example is Wuzhizhou Island in Sanya City, Hainan Province, China, where the coral cover rate increased from 9.3% to 35.5% after the restoration of coral transplantation [3].

(2) Modification of the genotypes of corals and their symbiotic zooxanthellae by hybridization, or genetic selection, so that zooxanthellae and corals can reproduce offspring that are adapted to higher temperatures. The coral-coralline symbiosis can adapt to higher water temperatures, thus improving the coral's ability to withstand and recover from environmental changes [13]. Currently, genetic selection of Cordyceps sinensis and coral larvae is mainly carried out in the laboratory [2,3,13].

In addition to the restoration of degraded coral reefs, the protection of corals that are still alive today is also a matter of urgency. Many national and local governments have chosen to amend existing laws or enact new laws to realize the purpose of protecting coral reefs, and have achieved good results, local coral degradation situation has been well controlled [7,14-17]. The signing of some international conventions can also constrain the behavior of national governments to a certain extent: the Convention on Biological Diversity (CBD), which was adopted in 1992 and implemented in 1993, explicitly states that the parties need to adopt conservation and management measures for coral communities in the sea under their jurisdiction, and some of them have already realized the conservation and management measures for coral reefs under their jurisdiction. Some parties have already realized the planned protection of coral reefs under their jurisdiction and the establishment of

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relevant departments [18]. Therefore, the establishment and improvement of laws and regulations can effectively protect coral communities to a certain extent.

Based on the above information, for coral reefs that have been degraded, according to the actual situation, sexual reproduction of corals can be carried out to help corals evolve, or transplantation of corals and other behaviors to help the coral communities in the area to recover, so as to repair to a certain extent the damage to ecosystems due to the death of corals. As for coral communities that show a trend of coral reef degradation, local governments should promote the construction of relevant departments, and improve the existing regulations or formulate new local regulations according to the actual situation, so as to impose constraints on local development behaviors, thus slowing down or stopping the degradation of coral communities and achieving the purpose of stabilizing local ecosystems.

6. Conclusion

As one of the most complex and important ecosystems in the world, the ecological value of coral reef ecosystems is incomparable to that of other ecosystems. However, coral reef ecosystems are also extremely fragile and easily affected by fluctuations in the external environment. Therefore, analyzing the causes of the degradation phenomenon and listing the restoration cases and suggestions are of great research value for the subsequent protection of coral reefs.

This thesis analyzes and discusses the causes of coral community degradation and its countermeasures from the perspectives of multi-dimensional factors and actual cases, and summarizes the systematic status and causes of coral community degradation in different regions and countries. This thesis has the following viewpoints on the causes of coral community degradation: the global temperature rise caused by the greenhouse effect will lead to coral bleaching and death; some human activities will cause direct physical damage to coral reefs; and the invasion of exotic organisms will encroach on and compress the living space of native organisms, and cause irreparable damage to the local ecosystem. Therefore, the restoration and protection of coral reefs is crucial to sustaining coral reef ecosystems, such as assisting the evolution of corals to improve their heat resistance or legislating for their protection.

In the future, each country should actively respond to the policy requirement to slow down the rate of global warming as much as possible; countries with coral communities should improve the laws and regulations on the protection of coral communities and further promote the restoration of coral reefs by increasing the investment of funds. Countries with coral communities should improve their laws and regulations on the protection of coral communities and further promote the restoration of coral reefs by increasing financial investment.

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