Evaluation of Coral Reefs’ Restoration in the South China Sea

Zixuan Shan
Lawrence Academy, Groton, United States of America, 01450
Author’s Email: 2353561519@qq.com

Abstract. As one of the toughest environmental problems Earth is facing, climate change brings many negative impacts, such as rising sea levels, increasing number of natural disasters, adverse changes in the marine environment, and biodiversity loss. The rising sea-level and marine environment changes pose a massive threat to islands and coral reefs in the South China Sea. This paper reviews the evaluation of coral reefs’ restoration in the South China Sea. The result shows that these methods are practical, and they will benefit the restoration and expansion of coral reefs globally.

1. Introduction
Increasing damage on coral reefs has made many countries aware of the negative influences of Climate change. They have started to repair coral reefs with different methods (including China). This paper analyzes the current status of climate change, impact of climate change on coral reefs, and evaluation of the previous repairing measures.

2. Current status of climate change
In April 2007, the fourth report issued by the U.N. Intergovernmental Panel on Climate Change (IPCC) showed that the global average temperature rose by 0.74°C in the past 100 years (1906-2005). The most significant warming occurred in the last 50 years. The following 20 years, the earth’s temperature will increase by 0.2°C every ten years. Even if the concentration of all greenhouse gases and aerosols stabilizes at the level of 2000 in the next twenty years, it will increase by 0.1°C every ten years. By the end of the 21st century, the average global surface temperature increase will reach 1.1~6.49 °C. [1]

Figure.1 The change of average surface temperature in China since 1951(Climate Bulletin of China)
Red: Average temperature of each year. Green: Average temperature from 1951 to 2011[1]
2.1. Rising sea temperature
On January 16th, 2019, scientists reported that the temperature of the Earth's oceans in 2018 is the highest on record. This suggests that the ocean absorbs large amounts of heat as greenhouse gas emissions continue to increase.\[2\] Such phenomenon will be bringing more negative influences in the future. One is that rising sea temperatures have a significant impact on the distribution and survival of marine organisms. The physiological and physical resistance of marine life are susceptible to changes in seawater temperature, such as corals, and increased sea temperatures can have a fatal effect. Coral bleaching is the result of rapid changes in seawater temperature. The microorganisms growing on corals die and lose their pigment so that the corals look white. \[3\]

2.2. Rising sea level
Rising sea level increases the tidal range and wave height and increase coastal erosion along the coast of Shandong and Liaoning. In 2010, Shandong and Liaoning's coastal sea levels were 82 mm and 61 mm higher than expected 12 mm and 13 mm higher than in 2009. According to the survey results of the impact of sea-level change in 2010, the coastline erosion rate of some shores in Gourd island, Liaoning Province, was up to 2.5 meters per year. Some coastlines in Penglai, Shandong had receded 500 meters in the past 50 years, and the maximum was more than 700 meters.\[4\]

3. Impact of climate change on coral reefs

3.1. The acidification of seawater and affected corals' calcification capacity
Seawater acidification poses a severe threat to marine ecosystems. The oceans absorb 33% of the carbon dioxide produced by human activities each year.\[5\] A sharp increase in carbon dioxide concentration can cause dramatic changes in the marine environment. One of the most crucial components of some marine organisms (such as algae, sea urchins, and starfish) is calcium carbonate. Seawater acidification will affect their bones' calcification rate. Such a change in the acid level of seawater would make them more vulnerable to erosion and threaten their survival.

3.2. Coral bleaching
Symbiotic algae, the primary energy source of coral reefs, need a steady temperature between 20°C to 30°C in order to perform photosynthesis. As the seawater temperature rises, the algae cannot provide energy for itself and the coral. Therefore, algae die and cause coral reefs to bleach. \[6\]

4. Evaluation of the previous repairing measures
In the context of climate warming, high water temperature is the main factor threatening global coral reefs. Within a specific range, the rising heat makes many corals self-adjust to adapt to environmental
changes. However, the self-adjust adaptation is not enough for coral reefs to completely protect them from the damage of climate change. Thus, scientists put forth many repairing measures to save the coral reefs in South China Sea.

4.1. Repairing measures

4.1.1. Coral hybridization
By making corals adapted to the environment and corals hybridize, mutant offspring with improved adaptability to the environment are produced. The hybrid offspring of coral transplanted across latitudes have higher thermal tolerance. In theory, coral transplantation and ecological restoration can achieve coral reproduction and expansion.

4.1.2. Coral transplantation
The most widely used technique rapid increase in the number of corals because of its low cost and. Scholars have conducted coral transplantation experiments in many areas. They transplanted four types of corals (Acropora, Pocilopora, Porites, Favites) to degraded areas, conducted long-term observations on coral coverage and species diversity, and found that different corals have apparent differences in adaptability. After coral transplantation adapts to the new environment, the energy supply and the coral symbiotic zooxanthellae structure quickly return to normal.

4.1.3. Horticultural cultivation
Horticultural cultivation refers to the combination of cultivation and transplantation. Scientists cultivate coral fragments or larvae in a specific sea area. When the coral grows to a certain size, it is then transplanted to a degraded coral reef area. Transplanting is the process of collecting corals from healthy coral reef areas and transplanting them to degraded coral reef areas. However, the cost sometimes outweighs the gains since more corals may be lost during transplantation. Horticultural cultivation can cultivate a large number of transplanted individuals, minimize the damage to corals during the transplantation process, and help the transplanted corals adapt to the new environment.

4.1.4. Aquaculture tank cultivation
Corals are placed in artificially constructed tanks to study coral reef ecosystem restoration methods under controllable conditions or using corals as transplantation donors. China, the United States, Australia, Japan, Isreal, and many other countries have carried out this research. The corals cultivated in aquaculture tanks have been mainly used to study restoration mechanisms and other theories and rarely used in transplantation, mainly because of the slow reproduction speed of corals and the high cost of cultivation.

4.1.5. Engineering means
Coral reef repair is to restore the coral reef's structural integrity through engineering means. When shipwreck, illegal mining, and natural disasters destroy the coral reef, repairing the damaged parts is an emergency measure. Researchers use cement and gypsum to bond the cracked coral reef and then transplant it. Such a technique repairs the coral reef and restores the number of corals. There are very few coral reef repair cases, mainly for corals that have been damaged by human error.

4.1.6. Artificial reefs
Artificial reefs are used in the ecological restoration of coral reefs, either by putting them in the coral reef area or building artificial reefs in the coral reefs’ vicinity to form a new coral reef. Many countries (China, the United States, Australia, Japan, etc.) have used artificial reefs for coral repair experiments, verifying that the constructed artificial reefs are ideal substrates for coral growth. There are reports of artificial reefs to restore corals in the South China Sea. Under the premise of protecting fish and controlling the number of benthic algae, artificial reefs are conducive to coral growth.
4.2. Comparisons with other countries

The Japanese government and people regard the ocean as the one of the most essential way to survive and develop. The intense awareness of marine protection also makes Japanese citizens very sensitive and advanced in protecting aquatic resources. Most fishers do not illegally mine coral reefs or conduct destructive fishing. [17] Although their coral reefs have been protected well (comparing to other countries), the Japanese scientists have been using Horticultural cultivation and Aquaculture tank cultivation to repair damaged coral reefs.

The Australian government have extremely strict laws on coral reefs protection. Ships that reach Great Barrier Reef Marine Park on their course would be charged for violating Australian Marine Environmental Protection Acts. In the area of Marine Park, fishing, dumping garbage and commercial navigations are forbidden.[15] Due to the careful protection and strict laws, Great Barrier Reef is protected well. The Australian scientist still use measures like Artificial reefs and Aquaculture tank cultivation to eliminate the negative impacts of climate change on Great Barrier Reef. [17]

5. Conclusion

Affected by climate change, coral reefs in the South China Sea are generally degrading, but scientists have paid attention to this phenomenon. They have done a considerable amount of research on strengthening ecological restoration mechanisms, including increasing reproduction rate, survival rate, and plasticity to the new environment. They have also put forward many theories that can protect coral reefs. After further studying proves that these methods are practical, they will benefit the restoration and expansion of coral reefs globally. [18]

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