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Climate Change and the Change of Trophic Level Interaction in Coral Reefs Based on South China Sea in China

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Abstract. In recent years, coral reefs have been seriously affected by human and natural factors, some of influences are even irreversible. Among them, the impacts of climate change have gradually deepened and attracted people's attention. Other papers which tell about the familiar topic failed to focus on discussing specific questions in certain area of coral reefs. The paper mainly analyzes the interspecific relationship change when facing the climate change of coral reef ecology in the South China Sea. Content of this paper first discusses the severe condition of climate change, like the instability of global climate system. Also, the situation about South China Sea and the effects of climate change are discussed and analyzed. Then, the interspecific relationships of predation, competition, parasitism, and mutualism were discussed. Further, discussed the increase of benthic algae and symbiotic organism reactions. The response from higher trophic level to low level and some researches are determined, too. On this basis, consider the interspecific relationships in the same trophic level. In the future, higher trophic level changes should be determined. Also, people should focus on the change after coral reefs recovering from albinism, about whether their population would change even extinct with the effect of climate change on coral reefs and reefs make a response to it through trophic level relationship change. This paper can provide some corresponding research ideas for more future researches.

Keywords: south China sea, coral reefs, ecosystem, climate change, trophic level.

1. Introduction

Coral reefs are threatened by overfishing, environmental pollution and ocean acidification, the rapid and widespread damage from climate change is the greatest concern today [1]. The reefs are facing an intense decline of a large amount of foundation species and urgent reef degradation which is caused by the pressure from various factors including global range and local function [2]. In addition, in order to respond the new environment and change, a global range of compromises in tropical coral reefs occurred. The compromises include intuitive changes like the normal structure and other for instance, the dynamics of it (tropical coral reefs). In the end, the compromises can result in some common phenomenon like coral bleaching and some shocking event like mass mortality. Currently, people can

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feel more about the irreversible impact from climate change and that is what happening now. Because of the warming amplification and regulation of global warming, the instability of the global climate system has caused frequent weather events, which last for a wider range and a longer time. With the function of warming trends and heatwaves carried by marine factors, the ocean in the Earth have been above the average of the temperature that ocean should be. The trends and other factors are associated with meteorological event, also the oceanographic [2]. This situation is even more critical because the destruction of the normal cycle of the global climate system affected by climate change in recent years. Emission of carbon causes acidification of ocean also occurred the deterioration and degradation of some coral reefs. Such phenomenon and other global climate change like rising temperature and more and more greenhouse gases will be bringing more negative impacts on marine organism such as disturbing the distribution and survival [2].

During the past several years, some papers illustrate the similar topic about coral reefs. One covered the main part of coral reefs in South China Sea (SCS) and analyzed the sensitivity for albinism of different types. Other researchers make a fundamental contribution and reveal the mechanism about the coral and symbiotic organism relationship [4]. Current papers have showed a good start for coral reefs study, but with the time and technology limitation, they failed to focus on discussing specific questions in certain area of coral reefs [5]. It will be an accessible way to combine the field trip program and laboratory imitation to study the response of coral reefs to climate change in the future. Another problem is that official report on coral reefs in the SCS is only updated every two years, it may lead to a gap between our understanding of coral reefs and their accuracy.

The main objective of this article is to base on current data and researches results then analyze what impact that coral reefs ecosystem interspecific relationship will face that carried by climate change. Firstly, this paper briefly introduced the climate change situation and some impacts in the SCS. Then the relationship between benthic algae and climate change and coral symbionts is discussed. Finally, the trend prediction of interspecific relationship is proposed, and the reasons for the limitations existing of the study are analyzed. At the end of the article, aspects for future research are proposed.

2. Climate Change in Global and SCS

In recent years, the global climate change situation is very serious, which seriously threatens the healthy survival of human beings and the sustainable development of the ecosystem. For the past 2019, the pace of global warming has accelerated, and many historical records such as the advance of phenology, glacier melting, and sea level rise have been refreshed at the same time [6]. United Nations Secretary General Guterres said at the global leaders' climate summit that the climate crisis has reached a point of urgency. The past decade has been the hottest on record in the world, and greenhouse gas emissions are the highest in three million years. In order to cope with the severe situation of global climate change, the international community has reached international agreements to better prepare and face the future environmental challenges. Among them, the Paris Agreement which brought out in 2015 put forward the most urgent and long-term goal of temperature control.

2.1. Global Climate Change

The fourth report which in April of 2007 published by the IPCC illustrated that temperature boomed with an unpredictable and worried speed. The temperature in global range rose by 0.74℃ in merely ten decades. In next vicennial period, the anticipation of earth's temperature show that it will increase by 0.2℃ each decade [7]. This is unstoppable because even if the content of all factors which could affect the global temperature like the emissions of greenhouse gases or aerosols material stays in a stable status as 2000's level in 20 years later, the temperature of whole world will still increase 0.1℃ for each decade. Follow this rate and there can be seen that in the end of 21st century, 1.1-6.49℃ are the number that can be achieved by the average temperature amplification in worldwide range on surface [8]. In 2019, the Earth's oceans average temperature was reported by research in January 16th and showed the last year was the highest among current record. with the greenhouse gas emissions keeping rising [9]. In the future, such phenomenon caused a result is that more negative impacts may brought. One is a significant

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impact on marine creatures living. For instance, the organisms in marine, their distribution and survival can be effect by the rising ocean's temperature. But not only on that, marine life's physiological and physical resistance can't be overlooked due to their sensitivity when facing the fluctuation of seawater temperature like corals, increased temperature in seawater can have a fatal effect on them [10].

2.2. Climate change in SCS

In the background of worldwide range climate change, SCS as an important area of world ocean composition part, the climate change also occurs in this place. Generally, the climate change in SCS shows two significant characteristics: rising sea level and sea temperature. Coastline erosion is a huge problem. The relative data for SCS coastline retrogress in recent years is blank, however, in 2009 according to survey the rate of erosion in Liaoning was up to 2.5 m/year [11].

2.3. Evolution Trend of Coral Reef

Based on a report in Scientific American, in the past 30 years the Earth already lost approximately 50% of corals worldwide, and researchers estimate that only about 10% of corals could survive beyond 2050.Not only that, other functions like geo-ecological relate will be changed, the composition and dominant morphological and functional groups of reefs also changed, as well as phase shifts. This is called change of interaction of trophic level which will be discussed in later chapter.

According to the data collected through long-term monitoring, there is no doubt that the number and coverage of coral reefs in the South China Sea have decreased dramatically in the past 50 years. This is reflected in the shrinking range of living coral reefs. (This is the most effective index when it is necessary to indicate the "healthy" state of coral reefs). The long-term declining trend of coral reef coverage in the South China Sea and other parts of the world is shown in Figure 1 [12]. In the most severely degraded coral reef areas, the coral reef coverage has decreased by more than 60% in the last 20 to 30 years, and even nearly 90% in some areas. Coral reefs around the world have also experienced a serious decline recently due to the increase in human activities and global warming. Coral reefs in other areas face the same problems as SCS. Take the Great Barrier Reef as an example. In the past 40 years, the coral coverage of the Great Barrier Reef has decreased from 50% to 20% [13]. while in other places, the living coral coverage of the Caribbean Sea has decreased by about 40% between 1977 and 2001 [14].

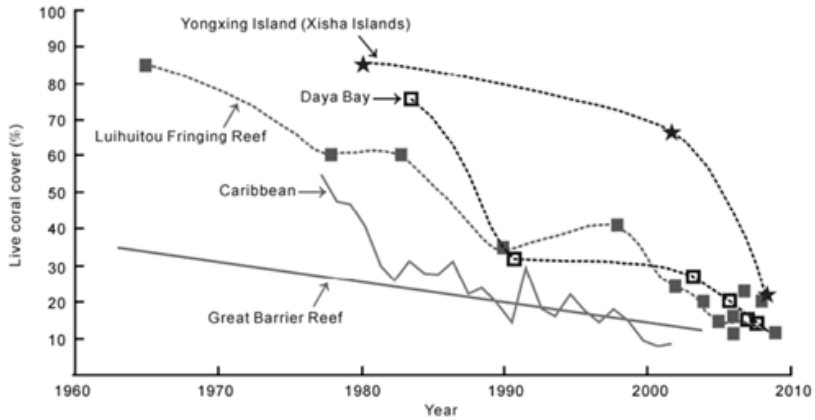


Figure 1. The decline trends and changes of living coral reefs cover etween 50 years, long-term [12].

3. Change in Interspecific Relationships Of Coral Reefs In The SCS

At present, with the concerning about climate change especially temperature rising in global range and ocean acidification relate crisis, there are some studies on the impact of sea water temperature rise caused by climate change. Through the impact on benthic algae, climate change will affect the nutrient relationship in corals, and then affect organisms with high nutrient levels, such as fish. Among these researches, the evidences about coral reefs will respond to climate change also been found. This article

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analyzes the SCS how benthic algae and coral reefs response to impacts of climate change and puts forward the following discussions.

The global coral reef area is less than 0.2% of the ocean area, but it lives in one quarter of all marine organisms and more than one fifth of fish species [15]. There are many kinds of primary producers in the coral reef ecosystem, including phytoplankton, zooxanthellae symbiotic with corals, and other kinds of benthic algae. The primary production efficiency is very high, which can reach 1500-5000gC/ (m2•a).

3.1. Relationship Between Coral Reefs and Algae

Coral is a kind of animal, which has a typical reciprocal relationship with zooxanthellae. zooxanthellae is tiny and rich in photosynthetic pigments. The photosynthesis of zooxanthellae can provide more than 90% of the nutrients needed by corals [16]. Coral reefs without symbiotic zooxanthellae grow very slowly and cannot reach their objective structure. zooxanthellae are very sensitive to the environment, and small changes in seawater temperature or solar radiation intensity may have a great impact on the survival of zooxanthellae. When the temperature rises and the environmental pressure increases, the symbiosis will produce more active oxygen and free radicals, which will destroy the reaction center of the symbiotic algae PSII, leading to the death or rejection of the zooxanthellae [17].

Different from microalgae, the relationship between macroalgae and coral reefs is mainly competitive. They compete for living space and directly or indirectly affect the growth of corals. Macroalgae mainly affect the survival of coral reefs through friction and allelopathy [18]. The direct contact between algae and coral reefs will cause friction damage, affect the shrinkage and feeding of coral reefs, and thus affect the growth and recovery of coral reefs. River found that coral and seaweed coexist in a certain space, and the growth rate of coral decreased by 80% [19]. After the removal of the algae, the growth rate of coral recovered. This may be because corals use the energy needed for growth to repair and resist algae. Allelopathy refers to the chemical substances released by algae that inhibit or affect the growth of other algae or organisms. Experiments show that many kinds of corals will undergo large-scale bleaching after 20 days of direct or indirect contact with algae [20].

3.2. Impacts of Climate Change on Benthic Algae and Coral Reefs

Although there are many factors or reasons for affecting growth of coral reef, the change of temperature is one of the most important factors. Under other similar conditions, corals live in a narrower temperature range than algae, and they prefer relatively low seawater temperature. When the temperature rises gradually, the competitiveness of algae will become stronger, and some of the algae with strong heat resistance can even survive in the sea water above 30 ℃ [21]. At the same time, the large algae plants have larger size, which can shade the sun when growing in large quantities on coral reefs, reduce the photosynthesis rate of zooxanthellae, affect the growth of corals and the photosynthesis of symbionts, and destroy coral tissue.

Further studies have shown that the density change of the zooxanthellae is not completely consistent with the temperature change, and it is non-renewable. When the temperature increased from 26 ℃ to 34 ℃, the maximum light and action intensity decreased by nearly 50%, but when the experimental temperature returned to 26 ℃, the density of the zooxanthellae did not rise significantly, almost unchanged [21]. However, it is worth noting that the photosynthesis intensity has increased significantly compared with the previous one, which indicates that photosynthesis is not only related to the density of zooxanthellae, but also partially related to other factors.

It doesn't need to much evidence to prove that is a great impact on coral reefs could be produced by ocean acidification. The seawater should be weakly alkaline, because the weak acid in ocean has hydrolysis reaction to produce more hydroxyl radical so the pH value of the surface water in ocean is supposed to be about 8.2. When excess carbon dioxide in the air enters the ocean, the ocean will be acidified. The ocean will absorb 33% of carbon dioxide emitted by anthropogenic activities [22]. Due to the impact of human activities, about ten years ago, 2012, water body of the ocean receive excessive carbon dioxide emissions and based on the monitoring number, it showed that pH of water body of ocean had reduced about 0.1. According to the analysis and calculation, the amount of carbon dioxide

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absorbed increases the acidity of seawater by at least about 30%, and ocean acidification will reduce the saturation value of calcium carbonate in seawater [23]. The acid will react with the calcium carbonate skeleton of coral reefs, causing irreversible damage. Studies by Long Cao and Ken Caldeira show that coral reefs have slowed down the formation of their skeletons compared with those before industrialization. At the same time, they predicted that when the carbon dioxide concentration continued to rise to 560ppm, all the coral reefs in the region would die and begin to dissolve [23].

3.3. Response of Coral Symbionts to Benthic Algae Changes

With the gradual change of climate, some corals also have mechanisms to adapt to the environment. Zoxanthellae is not a single species, but is divided into nine different formations (Fig. 2) [24]. There is a large difference in volume and characteristics between different formations of Zoxanthellae, among which formations A, B, C and D are common [22, 24]. There were significant differences in the heat tolerance of different groups of zooxanthellae [22]. Clade C is a genus with the most abundant species, the most widely distributed and the most studied of zooxanthellae, and plays a dominant role in many common corals. However, when consider about the resistance to heat stress, weak resistance is exposure by the most of zooxanthellae of this genus, and are prone to albinism in the process of warming up. A small number of genus C zooxanthellae have strong heat resistance, and some studies show that this genus of zooxanthellae can also evolve a strong heat resistance. However, at present, the rate of ocean temperature rise is far faster than the evolution rate of zooxanthellae. At present, genus C zooxanthellae is still difficult to adapt to high temperatures. Clade D (Durusdinium) is highly resistant to temperature and turbidity. Corals, on the other hand, adjust their heat resistance by adjusting the relative abundance of various groups of zooxanthellae in their bodies to adapt to the rising sea temperature.

By affecting benthic algae, climate change also has a greater impact on higher trophic levels in coral reefs, such as fish, shrimp, etc. When the temperature of the sea rises, leading to coral bleaching, the food structure in the coral reef also changes [25]. The increase in the number of large algae leads to the decrease in the number of carnivorous fish, which is gradually replaced by herbivorous fish that feed on algae.

Some fish can only live in the coral reef ecosystem, such as butterfly fish that mainly feed on coral reefs. The abundance of butterfly fish is highly related to the coverage rate of live corals. With the bleaching of coral reefs, the number is also rapidly decreasing.

At the same time, coral bleaching makes some brightly colored fish unable to be protected by coral reefs, making them more difficult to survive in coral reef communities, which may further reduce the biological richness of coral reefs. Research shows that some fish may be more sensitive to environmental changes than other fish. The number of some fish has been declining rapidly since 2016, and almost completely disappeared in some sea areas.

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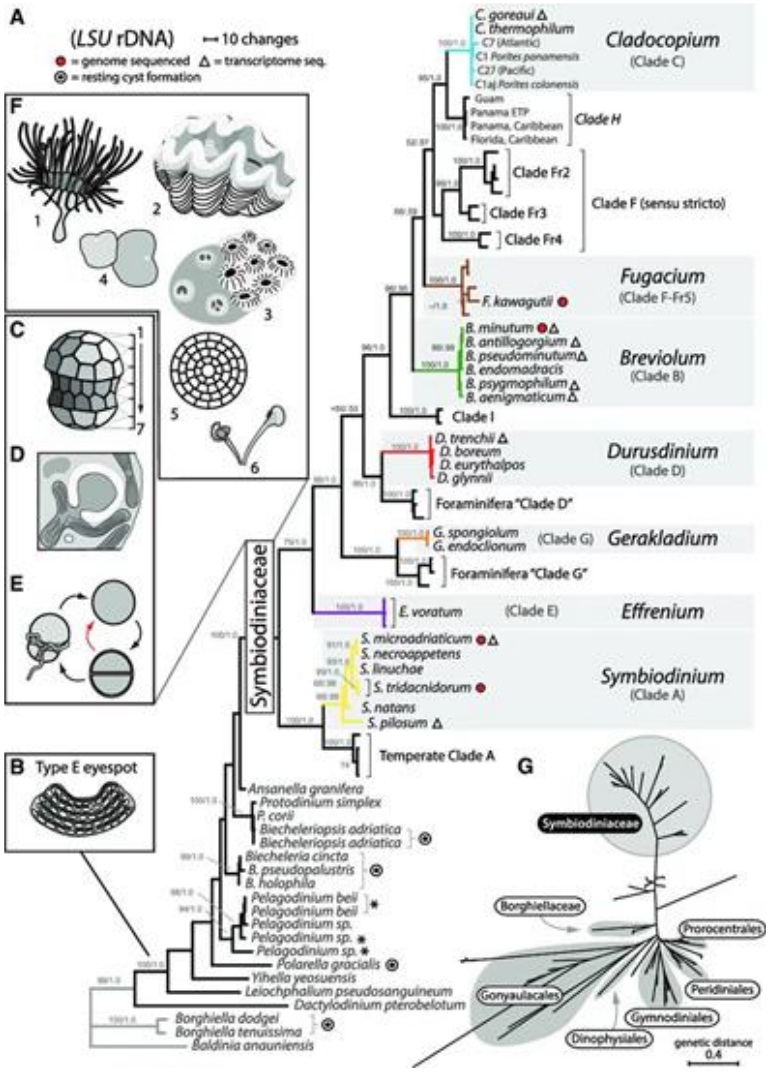


Figure 2. Formation classification of zooxanthellae [24].

4. Challenge and Suggestion

With the climate change of SCS, the coral reefs also change to adapt new environment. So far, any locations of coral reefs have systematic change in mutualism relationship between coral and benthic algae aren't been observed. Other works already make a fundamental contribution and reveal the mechanism about the coral and symbiotic organism relationship [3]. Turf algae alter the competition between algae and coral by altering the pressure on coral reefs by coral symbiotic microorganisms. Rising sea temperatures provide the algae with a breeding ground, further strengthening its dominance in the competitive relationship that leads to coral [4]. Coral reefs albinism is a classical change about the symbiotic relationship, existed researches covered the main part of coral reefs in South China Sea and analyzed the sensitivity for albinism of different types of coral reefs [2]. What's more, the heat-bearing type coral reefs cultivation also has been studied for future work at an early stage.

However, the gaps among those researches should be paid attention and consider the potential or possible reasons, because the study won't stop and the solution for existed gaps should be found out. Current papers have showed a good start for coral reefs study but with the time and technology limitation, discussing specific question in certain area of coral reefs was failed to be completed [1]. In future, it will be a fantastic and accessible way to combine the field trip program and laboratory imitation to study

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how coral reefs group respond to specific or large range climate change. Not only that, another problem is that real situation about coral reefs is dynamic while the report about SCS coral reefs only updated once of two years by CCRMN, this can make a lag between what we know about coral reefs and how exactly it is. About the research for albinism, there is a blank area for analysis of coral reefs energy sources change when it recovers from albinism [3].

The research for effect of algae on coral reefs still stay in a blank. Current studying on the algae failed to classify the variety of algae. Even they all show suppression to the coral reefs but whether the variety can alter the effect is unknown or lack of authoritative evidence and research. Last but not the least, the trophic level relationship still struggles in the symbiotic relationship, about other relationship like competition and predation and parasitism are stay in a blank status.

For now, what should figure the aspect for next stage studying for coral reefs response to climate change. Existed researches suggest that the change after coral reefs recovering from albinism should be paid more attention. For the entire coral ecosystem, the low trophic level change in interaction is not enough, higher trophic level changes, like the reef fish and arthropod animals will be more connect with human life and significant. Whether their population would change even extinct with the effect of climate change on coral reefs and reefs make a response to it through trophic level relationship change. Next, the research for effect of algae on coral reefs need to be classified and refined. Different types of algae have different effects. The result is various so it's necessary to study the different varieties in vary area of coral reefs [4]. In addition, two adjacent coral reefs despite main researches are focusing on one coral reefs. Studies have shown that there may be some relationship between different types of reefs, as generally two different reefs represent two ecosystems [1].

5. Conclusion

Climate change raises stress on coral reefs, which lead to coral calcification and causes negative impact on symbiotic relationship. In this paper, it discusses rise in sea level and temperatures in South China Sea will increase the rate of breeding in algae and lead to a decrease in zooxanthellae's survival rate, that causes coral bleaching, in other word is coral reefs albinism, and competition between higher trophic levels that is the marine animal, that demand for lower temperature of seawater and seeking for protection. Additionally, ocean acidification will slow down the formation of corals, and impacts of coral reef reduction will lead to negative effects. For instance, in South China Sea marine life will be unable to survive, making it more difficult for the marine ecosystem to recover, also marine animals will lose protection from coral reef, leading to reduce in diversity. A strategy to strengthen the amount of coral reef is micro-fragmentation. Micro-fragmentation can be implemented to form a larger coral community since it can anchor to the skeleton of dead coral and has a fast growth rate, as well as a high survival rate. This paper explains and acknowledges how climate change affects corals and how it plays a role in the environment.

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