The Effects brought by Climate Change on Coral Reefs Ecosystem

Wenxin Chen [1, *, †], Yiding Liu [2, a, †], Shunyu Yao [3, b, †], Acacia Yuan [4, c, †]

[1] Wuhan Britain-China School, Wuhan, China

[2] The High School Affiliated to Beijing Normal University, Beijing, China

[3] Nanjing International School, Nanjing, China

[4] Thomas Edison Charter School South, Nibley, Utah, USA.

* Corresponding Author Email: wendycwx@student.ksua.edu.kg, [a]richardliu041111@163.com, [b]shunyuyao@nanjing.school.com, [c]Acacia.yuan@littleblue.usu.edu

[†]These authors contributed equally.

Abstract. In the following conducted investigation, our group members focused on two issues which are closely related to Climate change and the impact on coral reef ecosystem. The first research question is: how climate change influences the coral reefs, and the second question investigated is how climate change impacts on the living habits of organisms lives among coral reefs. There have been great many research projects done within the relative subjects, therefore, our investigation method is to collect the data from previous investigations and develop new understandings based on them in response to our research questions. Through research and investigation, we concluded that the three main types of influence climate change can have on coral reefs are bleaching, oceans acidification and change in the weather patterns, while for the question of aqua organisms' living habits, the change in species' habitat is predicted based on existing research. When approaching the end of research study, why protecting coral reef ecosystem is significant was discussed, and proposals of improving the current situation are made.

Keywords: Climate change, Coral Reefs, Oceans Acidification.

1. Introduction

Coral reefs is a kind of ecosystem which formed by corals that can build up the reef. They are colonies of coral polyps connected to each other by calcium carbonate [1]. Coral belongs to the same class as anemones and jellyfish. The individuals secret hard carbonate exoskeletons that support and protect the coral. Coral reefs are mostly formed in shallow depth of tropical areas while less commonly seen in colder places. Coral reef is the basis of underwater ecosystem, in which underwater plants such as algae, phytoplankton etc. can transfer solar energy into chemical energy [2].

Coral reef ecosystem is built up by animals that have formed mutual benefit relationship with the coral reefs. For instance, Parrotfish are colourful, tropical creatures, and are an example of herbivorous fish live in the coral reefs. It takes parrot fish about 90% of their daytime eating algae off coral reefs. This continuous eating habit played an indispensable role in cleaning the reefs, helping corals stay healthy and thriving, as when algae grow at an over-fast rate, they would become corals competitors of coral reefs in the task of surviving [3]. Sharks rely on the coral reefs greatly as well. Here, coral made up complex structures which allows variety of species to depend on as habitat. Meanwhile, this also provides the reef sharks with plenty of food. On the other hand, the sharks also provide the coral reefs with the substances they need such as Nitrogen. As sharks eat fishes from the reef, they defecate nitrogen waste and help disturbing such chemical around the reef [4].

Coral bleaching is one of the coral reef diseases led by global warming. As temperature on earth grows, the sea water temperautre grows as well. Warmer water will cause corals to expel the algae (zooxanthellae) held in their tissues, turning white completely [5]. Though a coral may be bleached, but it is still alive, but facing more pressure of survival, which brings to the result of a less stable ecosystem [6].

2. Effect of climate change on coral reefs

2.1. Bleaching

The survival of coral reefs is severely impacted by a process called bleaching, the phenomenon in which the coral appears transparent, revealing a white skeleton. Bleached corals do not die, but are more likely to be starved and diseased.

Coral bleaching has various causes. It may be due to an increase in seawater temperature, especially in relation to increased levels of solar irradiance, or to increased levels of chemicals and sediments in the seawater. Corals bleach when they are stressed. The occurring of coral bleaching on the Great Barrier Reef is mainly due to rising water temperatures and increased UV radiation. It only takes four weeks for bleaching to be triggered by a one-degree Celsius rise in temperature. In such a situation, coral polyps may lose a significant number of photosynthetic pigments and the rate of photosynthesis is reduced, making it more difficult for the coral to obtain energy, resulting in bleaching.

There is a symbiotic relationship between corals and an alga called zooxanthellae. These algae lived in the tissues of coral reefs and are used as sources of primary food for corals. When the symbiotic relationship between them becomes existing under stress because of increased ocean temperatures, the zooxanthellae leave the tissues of coral. As a result, without the major food sources, the coral turns white or very pale. With the loss of algae and therefore the loss of food sources, the corals had to endure starvation. Bleached coral is more vulnerable and more susceptible to disease. If the water temperature continues to rise and last a long period, the corals start to die. [7]

Corals are the foundation of coral reef ecosystems. the degradation of its function and the reduction in its numbers represent a disappearance of habitat for many Floras and Fauna that depend on them. Without the coral reefs: the living space and food source on which they depend, the populations of coral-dependent fish and other marine life will decline dramatically.

The Great Barrier Reef is one of the most complex and the most productive ecosystems on Earth. Rising temperatures in the atmosphere and seawater due to climate change will trigger numbers of negative impacts on marine organisms and ocean ecosystems, bringing greatest threat to the coral reefs around the world.

Humans should act on climate change to counter its negative impacts on ecosystems. For example, reducing carbon emissions to slow down the speed of global warming. At the same time, we must make the life of coral reefs more resilient and help them to form adaptations to against the raised ocean temperature that already caused by climate change.

2.2. Ocean Acidification

Ocean acidification is a conservation issue of marine environmental which is closely related to the large amounts of carbon dioxide emitted to atmosphere since the industrial revolution. In this case, the ocean plays a role as a sink and absorption of carbon dioxide. The rise in the uptake of carbon dioxide leads to increased acidity of seawater. Figure 1 shows the changes in surface ocean chemistry over the past 20 years for the Hawaii ocean time series. The top panel shows the decrease in carbonate ion concentration, the middle panel shows the decreasing trend in pH, and the bottom panel shows the simultaneous increase in water and atmospheric CO_2.

Ocean acidification, chemically occurs with an increase in the carbon dioxide concentration in the water. The pH value of the seawater decreases as the concentration of hydrogen ions increases, making the ocean more acidic. More bicarbonate is produced by the reaction between hydrogen ions and available carbonate ions, dissolving more solid calcium carbonate. Thus, increase in water acidity and reduces in the carbonates is two main effects on the chemical environment of the ocean which cannot be overestimated for coral reefs [8].

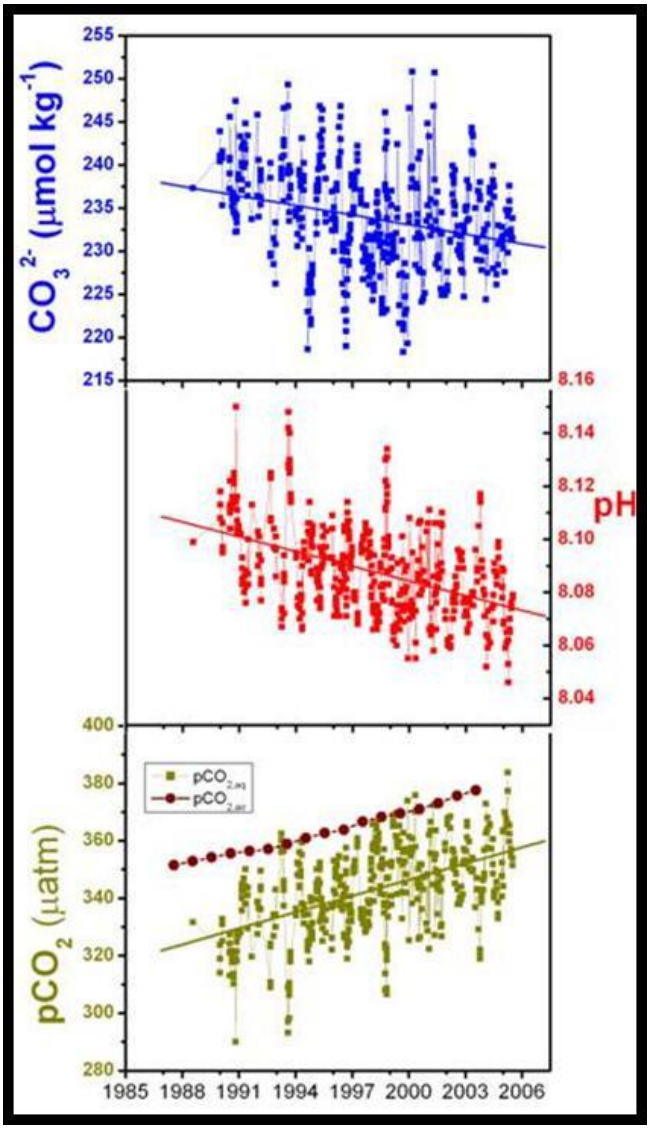


Figure 1. The changes in surface ocean chemistry over the past 20 years for the Hawaii ocean

The major contributing organisms to the formation and solidification of calcium carbonate ($CaCO_3$) in coral reefs include corals, macroalgae, mollusks, and echinoderms. The formation of calcium carbonate in coral reefs provides habitat for a variety of fish and invertebrates. Ocean acidification, temperature, light and nutrients can affect the rate of calcification of organisms that inhabit coral reefs. Changes in seawater chemistry stemming from increased CO_2 uptake prevent many reef organisms from producing CaCO3, affecting the structure and biodiversity of the reef.

The hard coral species must form hard exoskeletons by secreting aragonite, which known as a solid form of calcium carbonate. However, in acidified oceans, where the availability of carbonate is low, it becomes difficult for corals to form the indispensable hard skeletons. Studies have shown that a doubling of CO2 levels in the pre-industrial atmosphere would have resulted in a 10-50% decrease in the rate of calcification of corals and coralline algae, the two most important factors that make up the structure of coral reef ecosystems [9].

Ocean acidification can be a double damage for coral reefs: high CO2 levels not only make the formation of hard skeletons more difficult for corals, but also forced the energy investment in calcification to become costlier for corals [10].

2.3. Change in the weather patterns

At last, changes in storm patterns and precipitation may also affect the growth and health of corals reefs. Stronger and more frequent hurricanes and storms today may lead to the destruction of reefs

that are not equipped to withstand such brutal blows. Meanwhile, precipitation change the freshwater runoff, sediment, and pollutants and these substances provide favorable conditions for algae to grow and turns the water murky. The uncontrolled blooms of algae have led to the emergence of eutrophication, which reduce the amount of sunlight that aquatic plants need to survive, damaging the living environment of coral reefs [10].

3. Change in the living habits of organisms live among coral reefs

Coral reefs and fisheries are seriously threatened by climate change, which will also have a negative impact on the marine ecosystems. The majority of the world's oceans are now warmer than they were decades before, mostly as a result of human-caused climate change. Although the polar regions are most severely affected due to the longitudinal and latitudinal fluctuations of climate change, in some locations the shift may not even be discernible. Furthermore, marine plants and animals, par can be affected by warming particularly in the near-surface waters. An essential part of the oceanic ecology is the coral reef ecosystem, and climate change is a recognized concern to this fragile ecosystem [11].

Coral bleaching is one of the most devastating illnesses, and it has a disastrous impact on coral reef ecosystems all around the world as shown in figure 2. According to studies, warm waters from 2014 to 2017 caused the Great Barrier Reef in Australia, where hundreds of miles of coral were bleached, to experience a global bleaching event that damaged 70% of coral reef ecosystems [12].

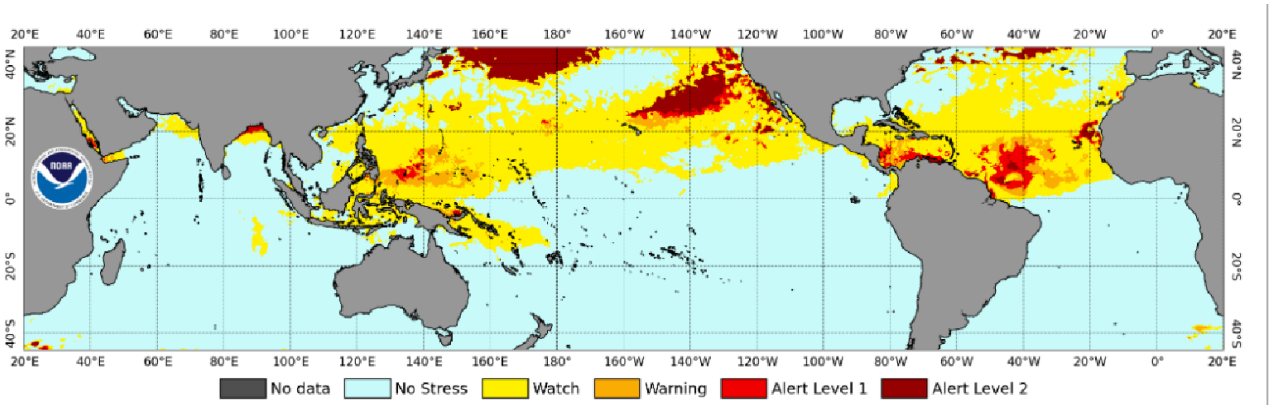


Figure 2. Global Coral Bleaching Heat Stress Alert Area [12]

The oceanic ecosystems are under a great deal of stress due to overfishing, pollution, and other human-caused consequences in addition to climate change. A case in point, Alaska cancelled the entire 2022 snow crab season due to the combination of overfishing over the last a few decades and climate change induced habitat shrinking. Some species are more vulnerable to these stressors and their combined effects and more at risk of going extinct. If significant steps are not done to limit future climate change, the effects on human society could be catastrophic for the marine ecology.

The most biodiversity is found in coral reefs than in any other habitat. Over one-quarter of all marine fish species are found on reefs, which occupy less than 0.1% of the ocean floor. Many other marine organisms rely on these fish species as essential food sources. Furthermore, more than 500 million people globally, especially in developing nations, are thought to rely directly on coral reefs for their daily needs. According to a 2014 analysis that was published in the journal Global Environmental Change, coral reefs are worth $1 trillion in terms of their social, cultural, and economic contributions. By 2100, the loss of reef ecosystem services caused by climate Indicators of the health of the global ecosystem include coral reefs. They act as a precursor to what might occur to other less vulnerable systems if climate change is not immediately addressed. Once the threshold for coral reef survival has been crossed, other systems may begin to deteriorate more quickly and irreversibly.

Warm water coral reefs support a diversity of marine life and human systems. They are one of the systems that is most vulnerable to the warming trend. Additionally, they are particularly at risk since prolonged exposure to water temperatures beyond the average range can result in high mortalities.

Between 2015 and 2017, such occurrences in numerous tropical waters led to severe coral bleaching. Reef regrowth normally requires at least 10 to 15 years [13] after such widespread coral mortality caused by bleaching. While different places experience different affects and some coral species are hardier than others. Further reef deterioration will be unavoidable if climate change proceeds at its current rate. Although more research is required to fully understand the effects on these reefs, coral ecosystems can also shift to cooler oceans or move into deeper waters. Due to their cooler habitat, these cold-water coral reefs are not at risk of bleaching, but other ocean changes such as ocean acidification could weaken or disintegrate them [14].

To locate their optimum range of water temperatures or oxygen levels, migratory species, such as fish, may respond to climate change by relocating to more suitable places, with populations shifting towards the poles or to deeper water. As a result, projections of future fishery yield under various scenarios of climate change only indicate a minor decline of about 4% (or 3.4 million tons) per degree Celsius warming. There are notable geographical variances, though. By the end of this century, tropical fisheries may have lost up to half of their current catches due to significant levels of climate change. Although the size of such gains is unknown, it is possible that fish populations that are currently impoverished by overfishing and other stressors would not be able to migrate to polar regions as expected [15].

The loss of habitat brought on by climate change directly threatens organisms that have evolved to live on or beneath polar sea ice. From microscopic plankton to fish, krill, and benthic invertebrates to whales, seals, polar bears, and penguins, the Arctic and Southern Oceans are home to a diverse range of living things. While some effects of climate change may be advantageous to people, the majority will have a negative impact on the current ecosystems, economies, and cultures, particularly those that rely heavily on natural resources. However, if the world is successful in limiting global warming in this century through intergovernmental measures, the effects of climate change can be significantly lessened.

4. Conclusion

Climate change is becoming a matter that draws the attention of many scientists and researchers. Due to its massive impact not only on humans, but also the habitat of dozens of other creatures. What is already done can't be undone, inappropriate human activities promoted the change of climate. What we can still do is to minimize the damage climate change can cause to our ecosystem by constraining ourselves. The ocean is one of the major components of our ecosystem, and there are dozens of species living in it. Coral reefs is what we are focused on, these species have a high demand in the environment they live in, in other words they are quite vulnerable. Even some subtle changes in the ocean water surrounding them can cause unexpected consequences. Climate change leads to a temperature rise of the sea water, which causes thermal stress that promotes coral bleaching. As the climate changes, coral bleaching is predicted to become more frequent and severe. Infectious disease as well as the melting of ice glaciers from the north and south pole. As a result, ocean levels would climb which then could lead to increases in sedimentation for reefs located near land-based sources of sediments. The increased intensity of the storms means more precipitation, which would boost the runoff of freshwater, sediments, and land-based pollutants. As the amount of carbon dioxide (mostly released from fossil fuel combustion for energy) increases, the world's oceans must absorb more of it, which later would gradually change the ocean chemistry, thus leading to ocean acidification. If the coral reefs are always dying at a faster rate than they are reproducing they would soon become extinct. To save them people should recycle and dispose trash properly, using public transportation and other environmentally friendly ways of transportation, and consume energy both at home and in agriculture, minimizing the application of fertilizers can also contribute. Cities can think of ways such as using rainwater permeable blocks to build roads; therefore, stormwater runoff can be reduced.

References

[1] Coral Reef Alliance, "Coral polyps", https://coral.org/en/coral-reefs-101/coral-polyps/, (2021).

[2] Seaworld Parks & Entertainment, "Reef ecosystem", https://seaworld.org/animals/all-about/coral-and-coral-reefs/reef-ecosystem/, (2022).

[3] Science Daily, "Parrotfish are critical to coral reef health, study finds; Analysis reveals pivotal role of algae-eating fish in coral growth", https://www.sciencedaily.com/releases/2017/01/170123094552.htm, (2022).

[4] WWF Oceans, "The world needs coral reefs, and coral reefs need sharks", https://wwfoceans.medium.com/the-world-needs-coral-reefs-and-coral-reefs-need-sharks-4ddc5db0cd82, (2022).

[5] The New York times, "When Coral's Colorful Show Is a Sigh That It's Sick", https://www.nytimes.com/2020/05/22/science/coral-color-bleaching.html, (2020).

[6] CNET, "Dying coral reefs are being saved by automation", https://www.cnet.com/science/dying-coral-reefs-are-being-saved-by-automation/, (2022).

[7] National Ocean Service, "What is coral bleaching", https://oceanservice.noaa.gov/facts/coral_bleach.html, (2010).

[8] Guldberg O.H., Mumby P.J., Hooten A.J., et al. "Coral reefs under rapid climate change and ocean acidification", Science 318.5857: 1737 - 1742, (2007).

[9] Kaniewska P., Campbell P. R., Kline D.I., et al. "Major cellular and physiological impacts of ocean acidification on a reef building coral." Plos one, 2012, 7 (4): 1 - 12.

[10] American Ocean, "How Climate Change Affects Coral Reefs", https://www.americanoceans.org/blog/how-climate-change-affects-coral-reefs/, (2021).

[11] National Oceanic and Atmospheric Administration, "Coral reef ecosystems", https://www.noaa.gov/education/resource-collections/marine-life/coral-reef-ecosystems, (2019).

[12] National Oceanic and Atmospheric Administration, "Coral Reef Watch Satellite Monitoring and Modeled Outlooks", https://coralreefwatch.noaa.gov/satellite/index.php, (2022).

[13] National Oceanic and Atmospheric Administration, "Coral Bleaching Products", https://www.ospo.noaa.gov/Products/ocean/coral_bleaching.html, (2022).

[14] National Oceanic and Atmospheric Administration, "Investigating Coral Bleaching: Teacher Resources", https://dataintheclassroom.noaa.gov/coral-bleaching/investigating-coral-bleaching-teacher-resources, (2022).

[15] The Intergovernmental Panel on Climate Change, "How is life in the sea affected by climate change?", https://www.ipcc.ch/srocc/about/faq/final-faq-chapter-5/, (2022).

Where to Find Further Information

We warmly invite you to visit our online platform, Scitation, where you can find further help/advice and publishing policies for AIP Conference Proceedings:

- For authors: https://aip.scitation.org/apc/authors/preppapers
- For conference organizers: https://aip.scitation.org/apc/organizers/abstracts

Summary: Points to Consider when Preparing Your Paper

1- Articles should use 8.5 x 11 single column template.

2- Use Times New Roman font, the point size will vary by section.

3- DO NOT alter the margins of our templates. They are carefully designed for AIP's production process: Altering them can cause significant delays. Paper size should be 8 ½ x 11 with margins set at: Top – 1 inch, Left – 1 inch, Bottom – 1.18 inch, right – 1 inch.

4- DO NOT display the title in ALL CAPS (initial cap only)

5- DO NOT include any headers, footers, or page numbers in your document. They will be added to your article PDF by AIP Publishing, *so please do not amend this template to add them to your paper.*

6- Line spacing should be 1.0 throughout the entire article, no double spacing.

7- Make sure all author affiliation associations are correct. This means author vs. affiliation and author vs. email address. If there is only one affiliation for all authors, association is not needed. Author names should be listed in First name Surname format.

8- Use clear, legible graphics and diagrams. Readers of your paper will be grateful. If they cannot read it, they are unlikely to cite it.

9- DO NOT use copyrighted material without permission. Papers using copyrighted material without appropriate permission and acknowledgment will be excluded from the proceedings.

10- No 1-page papers please. 1-page, abstract-only contributions are not acceptable and will be excluded from the proceedings.

11- Prepare and format references with care. References should be numbered using Arabic numerals followed by a period (.).

12- Embed all fonts into your article PDF. The importance of font embedding is discussed in the section Font Embedding (above). PDFs supplied without embedded fonts are often completely unusable for printing or publication purposes. In such cases, we must return those PDFs to the proceeding's editors for font embedding. Failure to embed fonts can cause unnecessary inconvenience to your proceedings editor(s) and publication delays for other authors. Failure to provide a replacement paper in a timely fashion may result in an article being removed from the proceedings.

13- Check your article PDF file! It is not uncommon for errors to appear in PDFs generated from Microsoft Word – corrupted math, figures reflowing, etc. It is essential to very carefully check your article PDF file before sending it to the proceedings editor(s).

14- Avoid large PDF files (10 MB maximum, ideally). For the benefit of your readers, we recommend keeping your article PDF file below 10 MB. This is a recommendation, not a requirement.