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The Effects of Ocean Acidification on the Growth and Bleaching Rates of Coral Reefs

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ABSTRACT

Coral reefs play a vital role in the lives of many aquatic organisms and human societies through the services and resources they provide. In the last few decades, however, coral reef populations have faced substantial challenges due to various factors influenced by human populations, with one of the most notable being ocean acidification. Ocean acidification is an increase in acidity of the ocean's surface water as a result of a higher atmospheric carbon dioxide uptake. It is often found to degrade and weaken coral skeletons due to the higher levels of acidity in the water. Though ocean acidification is well known, the extent of its influence on coral reefs and other environmental factors is relatively unknown in the scientific community. This paper primarily seeks to observe and evaluate the effect ocean acidification has on the bleaching rates and growth of coral reef populations. Furthermore, the effect of ocean acidification on the development of coral reefs will be analyzed by comparing and contrasting the effects different carbon dioxide levels have on bleaching and growth capabilities of coral reef populations.

Keywords: *Coral reefs, Marine life, Pollution, Carbon dioxide, Ocean acidification*

INTRODUCTION

Coral reefs are very large underwater ecosystems that are characterized by a collection of reef-building coral (Alrbight & Langdon, 2011). They are one of the most biologically diverse and environmentally valuable ecosystems on the planet. They can provide food for millions of individuals through the fisheries they provide, as well as, support numerous small fish species by providing a fairly safe spawning and nursery ground (Chua et al., 2013). Despite their significant influence and strong ability, coral reefs have consistently been shown to be deteriorating in the last few decades (Chua et al., 2013).

As human beings advance, so does the magnitude of their impact and prevalence on the world. One of the most prominent contributions toward the decline of coral reef populations can be attributed to ocean acidification. Ocean acidification, or OA as it known for short, refers to the decrease in pH of the ocean's surface water as a result of an increased atmospheric carbon dioxide uptake (Gao etal., 2019). The increased carbon dioxide levels can be attributed to a variety of human-influenced factors, the likes of which include pollution and the burning of fossil fuels. This increase in acidity can be significantly detrimental to various marine and underwater organisms, particularly coral reefs. Often due to the high acidity of the water, ocean acidification can cause complications in the development of coral reefs, as well as, their ability to function and feed properly. In addition to this, ocean acidification can most likely affect the symbiotic relationship coral reefs have with other organisms, such as dinoflagellates. The true impact and extent of ocean acidification on coral reefs remains to be seen however, as ocean acidification can influence a variety of factors. This review paper aims to analyze and highlight the effect ocean acidification has on the rates of bleaching and growth capabilities of coral reef populations. Furthermore, ocean acidification's impact on the development of coral reefs will be analyzed by comparing and contrasting the effects different carbon dioxide levels had on the bleaching and growth capabilities of coral reef populations.

Bleaching

Bleaching can be characterized as the expulsion of algae within the coral reef resulting in the development of a transparent color (Gao et al., 2019). Bleaching, as well as, high carbon dioxide levels are often caused by drastic changes in temperature as a result of ocean acidification. In a study run by Anthony et al. (2008), Anthony and his colleagues would evaluate the significant effect ocean acidification has on bleaching rates and calcification and productivity levels within coral populations. In this study, varying carbon dioxide levels would be utilized in conjunction with two different temperatures to examine the rate of bleaching within three different coral reef populations. The coral reef population utilized for Anthony et al. (2018)would include Porolithononkodes. Acropora intermedia, and Porites lobate. Each of these species of coral reefs would be exposed to three different levels of carbon dioxide (base level 380 ppm atmospheric carbon dioxide, intermediate level of 520–700 ppm, and high-end level above category 1000–1300 ppm) at two distinct temperature treatments of either 25-26°C and 28–29°C (Anthony etal., 2008). When there is increased pressure placed on the coral reefs, as a result of ocean acidification, coral reefs respond by expelling the zooxanthellae from their tissue (Albright&Langdon,2011). Due to this, bleaching reactions and rates would be recorded based on the relative decrease in luminance the coral reefs exhibited. The results of the study would prove to be significant as they expressed a strong correlation between increased carbon dioxide levels and bleaching rates overall as ocean acidification more strongly impacted bleaching and productivity than calcification (Anthony et al., 2008). Anthony et al. (2008) found that high carbon dioxide dosing would lead to 40-50% bleaching in the Acropora intermedia coral reef system, with each population reflecting its greatest bleaching effects when exposed to the highest carbon dioxide level and temperature. Though each species reacted differently in terms of the amount of bleaching to the varying carbon levels and temperatures, they all exhibited similar trends and reactions when exposed to the variables. The key strengths of the Anthony et al. (2008) study were the diversity of coral reef populations used and the amount of natural irradiance used. Through having three types of coral populations, the experiment was better able to see the overall effect ocean acidification had on bleaching rates of all different types of coral reefs. The study was weak, however, in the amount of time given to administer the experiment and collect data. By running the study throughout a longer period, this would give ample time for the researchers to conduct the experiment and make improvements were needed. Unlike the study run by Anthony et al. (2008), however, Gao and his colleagues (2019) would examine one species and population of the coral reef when evaluating ocean acidification effects on bleaching. Gao et al. (2019) would expose one species of coral reef to three levels of carbon dioxide dosing (base of 300 ppm, medium 700 ppm, and high 1000 ppm) at three distinct temperatures of 20 °C, 25°C, and 30°C. From the study, Gao et al. (2019) would find that as the temperature and level of carbon dioxide increased so did the rate of bleaching within the population. The bleaching would be evident by the decrease in the brightness of the coral reefs as a result of the progressive loss of zooxanthellans. Furthermore, Gao et al. (2019) would discover that the reef was found to 85% of the time to expel the zooxanthellae and result in a transparent skeleton behind left behind with the color of the coral changed and vibrance lost. Some corals were able to feed themselves after expelling the algae, however, most coral reefs without zooxanthellae starve and eventually die (Gao et al., 2019). The significance of Gao's findings is that they highlight the importance of ocean acidification and human involvement have on the environment and life. It expresses how if human beings do not make a change and pollution and climate change continue at the rate in which they are currently advancing, ocean acidification can cause bleaching to become progressively severe and negatively impact coral reef populations for decades to come. In addition to this, both studies shared strong similarities regarding the methods and structure of experimentation. Both would take into consideration temperature when evaluating ocean acidification's effects on bleaching, something that would prove to benefit as it could be concluded from the data that temperature and carbon dioxide levels in combination contribute towards bleaching. The experiment by Gao et al. (2019) could be, however, improved regarding the diversity of coral populations it used, something Anthony et al. (2008) utilized and excelled in. Overall, the conclusions of the two findings agree with each other as they point toward credible signs that ocean acidification and the increased carbon dioxide levels caused greater bleaching rates among coral reef populations.

Growth Capabilities

Ocean acidification plays an influential role in the growth capabilities of coral reef populations. As the acidity of the water increases, certain developments and necessary early life processes become difficult due to the erosion of the reef and other factors as a result of ocean acidification.

One study that evaluated growth among coral reef populations was conducted by Rebeca Albright and Chris Langdon of the University of Miami. Unlike the study conducted by Anthony et al. (2008), Albright and Langdon (2011) would utilize one species of coral reef population with that being the common Caribbean coral, Porites astreoides. Similarly, to Anthony et al. (2008), however, Albright and Langdon (2011) would incorporate three different carbon dioxide levels (ambient seawater (380 μatm), middle (560 μatm) and end (800 μatm) when testing the effects of ocean acidification on the larval metabolism, settlement, and post-settlement growth of their coral populations. From the data collected, Albright and Langdon (2011) found that ocean acidification primarily influences growth settlement through the indirect pathways where acidified sea water alters community composition as a result, limiting the availability of settlement areas. In addition to this, as the carbon dioxide levels would increase, the coral growth would progressively decrease by a reported 16% at 560 μatm and 35% at 800 μatm respectively. This is very significant as it highlights the difficulties in development that arise due to the composition and progressive acidity of the water as a result of ocean acidification. Additionally, the study's data demonstrates the significance ocean acidification possesses in the potential to negatively impact many of the early life processes of Porites astreoides and may contribute to the substantial decline in sexual recruitment and reproduction abilities of the community. The strength of this study is through its inclusion and observation of not just the settlement, but the post-settlement growth as well. This presents more insight into the impact ocean acidification has on the growth of coral reefs and lays the groundwork for future experimentation from other minds in the scientific community.

Another study examining the effects of ocean acidification on the growth capabilities of coral reed populations was conducted by ChiaMiin Chua and colleagues (2013).In their experiment, Chia et al. (2013) evaluated the effects of ocean acidification, as well as, climate change pose on the developmental abilities of coral reefs throughout their early life stages. Through the use of four treatment groups: control, high temperature (+2°C), high partial pressure of CO2 (pCO2) (700 μatm) and a combination of high temperature and high pCO2, Chia et al. (2013) hoped to identify whether temperature might act in conjunction with ocean acidification to produce a significant effect on the fertilization, development, larval survivorship or metamorphosis of coral reefs. The two coral reef species used for this experiment and exposed to the carbon dioxide levels were Acropora millepora and A. tenuis, from the Great Barrier Reef. A strength of Chia and colleagues' (2013) experiment was the greater diversity among the types of coral reefs tested, an area Albright and Langdon (2011) lacked through their single utilization of the common Caribbean coral, Porites astreoides. The results and conclusion of this experiment proved to be starkly different from that of the experiment conducted by Albright and Langdon (2011). Chia et al. (2013) found there to be very little evidence or consistency regarding the effects of elevated carbon dioxide levels and ocean acidification on fertilization, development, survivorship or metamorphosis of coral reef populations.

What is most significant of the data found from this experiment, is that while Albright and Langdon (2011) did not consider or include temperature when evaluating ocean acidification's effect on growth, Chia and colleagues (2013) did in their experiment. Through the inclusion of temperature in their experiment, while there was no significant correlation between ocean acidification and growth, Chia et al. (2013) were able to address a weakness in a previous study and find a strong correlation that temperature affects the rates of growth of development as evident by their data. This is significant as though ocean acidification may appear not to be a direct threat to coral reef populations, the data concluded by Chia et al. (2013) suggests that rising sea temperatures are likely to affect coral population dynamics due to increasing the rate of larval development potentially leading to alterations in the patterns of connectivity and growth.

Conclusion

Overall, there is significant evidence expressing the effect of ocean acidification on bleaching rates, while there is mixed evidence towards the impact ocean acidifications has on the growth capabilities of coral reef populations. In studies conducted by Anthony et al. (2008) and Gao and colleagues (2019), similar conclusions were made between the experiments as ocean acidification was deemed to have a substantial effect on increasing the rate of bleaching among coral populations. Regarding the effect of ocean acidification on the growth capabilities of coral reefs, there is mixed conclusion and data among the studies analyzed. Albright and Langdon (2011) through use of a single coral species and multiple levels of carbon dioxide conclude that there is evidence suggesting complications in early coral growth due to ocean acidification, while Chia et al. (2013) find no viable signs of a treat to fertilization, development, survivorship or metamorphosis of coral reef population due to ocean acidification.

Each study regarding ocean acidifications impact on coral reef growth has its strengths and weakness in the manner its research was conducted resulting in debate among the accuracy of its findings. Albright and Langdon (2011) have weaknesses in their experiments due to the lack of diversity among the coral reef's species tested, opting for only a single species of Caribbean coral, Porites astreoides. Future studies could add in credibility by including more than one type of coral reef and taking into account other environmental factors that are influenced by ocean acidification such as pressure. Regardless, there is evidence supporting that both individually and collectively bleaching, and growth play a contributing role towards the gradual decline and deterioration of coral populations, of which can be linked to that of human influence. Though the methods in which they affect coral reefs may be different, all of these factors similarly have the potential to leave coral in a weakened and vulnerable state with many susceptible to mortality.

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