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# Impacts of Ocean Acidification on the Marine Ecosystem and Coral Health: A Meta-Synthesis

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***Abstract—****Ocean acidification remains the ongoing decrease in the pH of the Earth's ocean for over the past 200 years. The rapid increase in anthropogenic CO2 (carbon dioxide) production has led to an increase in the acidity of the Earth's oceans. The research findings revealed that issues like emissions from transportations, industrial plants, over-consumption of fossil fuels, agriculture, and waste management is included. This impacts the marine ecosystem and coral health, marine habitats threatened and human livelihood suffers. Mitigation efforts includes the alkalaniaztion of seawater, maintainance of the terrestrial carbon sinks, and community collaboration internationally to promote legislative frameworks to maintain regulations on carbon emissions and marine and coral protection, within governemnt body of countries. Local stressors within the marine ecosystem and corals is worsening the impact caused by the acidification. A diverse strategy is needed to combat ocean acidification. This review synthesizes current research findings on the marine ecsosystem and coral challenges, ocean acidification potential impacts, and the mitigating methods to reduce the risk of acidification.*

***Keywords—*** *Acidity, Carbon Dioxide, Carbon Sink, Coral Health, Emissions, Legislative Frameworks, Livelihood, Local Stressors, Maintain Regulations, Marine Ecosystem, Marine Habitats, Mitigation Efforts, Ocean Acidification.*

### *Highlights*

- Ocean acidification's impact on marine ecosystem and coral health have negative effect on civilization, biodiversity, and marine ecosystem function.
- Marine Ecosystems specially calcified species and the coral reefs will be affected by rising concentration of carbon dioxide, negating their structural integrity and production, leading to the loss of biodiversity.
- Proposed mitigation efforts have already been made to combat rising acid levels in the ocean which includes alkalanization of the forests as carbon sink, and legislative frameworks that can reduce carbon emissions.

## I. INTRODUCTION

The rising concentration of carbon dioxide (CO2) in the Earth's atmosphere is the main cause of the ocean acidification that affects coral reefs and the marine environment, and human behavior and policies that promote society's dependence on fossil fuels and increase atmospheric CO2 concentrations are the main causes of OA (Jagers et al., 2019). Therefore, the main causes of the effects are human activities such the burning of fossil fuels, transportation, industrial operations, agriculture, deforestation, changes in land use, and waste management. Hence, the mention anthropogenic activities have caused the increase o carbon dioxide concentration. In oceanography, there are highly interdisciplinary field that encompasses various sub-disciplines. Physical oceanography, chemical oceanography, biological oceanography, marine ecology, marine geology, and marine biology are some of the shared fields. Depending on the ecosystem, species composition and interactions, geomorphologic settings, and spatial distribution, as well as the existence of local stressors interacting cumulatively with climate change-related pressures, marine and coastal ecosystems react differently to stressors related to climate change (Trégarot et al., 2024).

Because it makes it harder for many species to find sufficient habitat and food sources, ocean acidification threatens marine biodiversity. Ocean chemistry changes have the potential to change the distribution of species, disturb ecological relationships, and raise the danger of extinction, especially for species whose capacity to adapt or move to more appropriate environments, is restricted. Other marine ecosystems offers important ecosystem service which includes, protecting the shorelines, sustaining fisheries, and generating income for the tourism industry. Ocean acidification may lessen these ecosystems' capacity to offer the said benefits, which might result in the financial losses for workers and heightened susceptibility to coastal threats.

Healthy marine ecosystems are essential to the food and economy of many coastal communities. The livelihoods of people that mainly get their source of income through these coastal areas may be in jeopardy due to ocean acidification, which might cause financial hardship and social instability. This article, aims to provide a thorough assessment of the present state of knowledge about the impacts of ocean acidification on marine life and coral health, with a focus on the challenges, potential impacts, and mitigation methods.

## II. CHALLENGES OF OCEAN ACIDIFICATION

The survival of coral reefs is threatened by ocean acidification (OA), which lowers the carbonate ion concentration needed by corals to create their skeletons (N. Mollica et al., 2018). Marine habitats are threatened by both biodiversity loss and climate change at the same time. Numerous marine species are negatively impacted by ocean acidification, and new research indicates that the effects will be significant when pH levels reach 2100. Findings show that, depending on the species, the effect of acidification on otherwise extremely sensitive important organisms can be lowered by 50 to >90% with increased biodiversity (Rastelli et al., 2020). However, not all calcifying species have the capacity to up-regulate pH; those that do not stand to lose a great deal of calcification as $CO_2$ levels rise. While the ability of calcifiers to up-regulate pH is crucial to their resistance to ocean acidification, the ability of photosymbionts and coral hosts to adjust to rapidly rising ocean temperatures ultimately determines the destiny of zooxanthellate corals (McCulloch et al., 2012). Marine ecosystem services will suffer as a result of ocean acidification, or the changes in seawater chemistry brought on by rising carbon dioxide emissions. These services include aquaculture, coastline protection, wild capture fisheries, and recreation (C. Moore, J. Fuller, 2022). The establishment of monitoring networks and the development of unifying principles for biological responses have been spurred by worldwide and regional initiatives due to the recognition of the diverse nature of acidification and its interaction with other ocean forces. Ocean acidification is becoming recognized as a danger to ecosystem services, and its socioeconomic effects are becoming more obvious and measurable (C. Hurd et al., 2018). There is presently no comprehensive ocean acidification (OA) treaty or legislative framework specifically tasked with tackling OA, and it appears very unlikely that any will be developed in the near future. Making advantage of already-existing international accords is a more practical strategy. It appears that addressing open access as a cohesive issue is outside the purview of current accords, owing to both institutional constraints and the desire of involved parties. Because of this, it is more probable that OA will be handled by a network of agreements, each of which will address certain aspects of the issue within the scope of their respective expertise. It is unclear, therefore, how MEA's current capabilities relate to OA (E. Harrould-Kolieb, O. Hoegh-Guldberg, 2019).

## III. Potential Impacts of Ocean Acidification

The intimate connection between ecosystem services and biodiversity is clearly demonstrated by coral reefs. Despite being rich maritime ecosystems with a great deal of biological variety, the services these ecosystems provide and that diversity themselves are among the most endangered due to global change. Global changes are putting hundreds of millions of people's lives at jeopardy by decreasing and changing the biodiversity of coral reefs (D. Allemand, D. Osborn, 2019). Ocean and coastal acidification is predicted to reduce habitat pH, which will cause mollusks to develop thinner shells with reduced mechanical properties and structural integrity, putting mollusk aquaculture at risk. The decreased ability of oysters to biomineralize under circumstances of acidity may be the reason for the lower sizes of these oysters for commercial sale, according to the results. Since climate change will only make the consequences of this catchment source acidification worse, it will probably have an influence on coastal aquaculture in many parts of the world (S. Fitzer et al., 2018). PPT growth was influenced by changes in chlorophyll a concentrations over time and demonstrated a greater build-up of phytoplankton biomass in open ocean conditions. In every mesocosm, we saw two more phytoplankton blooms, with PPT maxima occurring on days 33 and 56. With the exception of a little rise during the second phytoplankton bloom, when inorganic nutrients were already running low, OA had no discernible impact on PPT. The P/I curve-derived maximum light consumption efficiencies and light saturation indices varied concurrently in every mesocosm, indicating that OA had no effect on phytoplankton photoacclimation. Our overall findings show that, despite significant differences in time-integrated productivity estimates between replicates, OA can have an impact on coastal phytoplankton communities at specific stages of the seasonal succession, potentially having negative effects on the ecosystem fucntions (T. Eberlein et al., 2017). Many of the important ecosystem services that the ocean offers to society, like fisheries, aquaculture, and shoreline protection, may be in jeopardy due to acidification and other climate change-related environmental stresses, especially in light of future climate change and further elevated atmospheric $CO_2$ levels (S. Doney et al., 2020). The calcium carbonate saturation horizon is shoaling due to elevated partial pressure of $CO_2$ ($pCO_2$) in many locations, especially high latitudes and areas that cross over with prominent hypoxic zones. Seawater $CO_2$ chemistry directly affects the capacity of marine organisms, particularly pteropod molluscs, foraminifera, and some benthic invertebrates, to develop calcareous skeletal structures. Through acid-base imbalance and decreased oxygen transport capacity, $CO_2$ also affects the physiology of marine species (V. Fabry et al., 2008). Seaweeds and corals fight for space on the reef. When corals are healthy, the competition between seaweed and corals reaches a balance. However, seaweeds may take over if suffocating factors like eutrophication or effects of climate change prevent corals from growing. Under conditions of ocean acidification, seaweed growth may become more likely to affect coral reefs (Sivakumar et al., 2021).

## IV. Mitigation Methods of Ocean Acidification

Two distinct alkalinization scenarios have been investigated: one involves a yearly lime discharge that is constant throughout the scenario period, and the other involves a steady increase in alkalinization levels that are proportionate to pH drops in the baseline scenario RCP4.5. For the first time, the concept of ocean alkalinization as a climate change mitigation technique is evaluated based on a theoretically possible implementation pathway, offering a first step towards a practical use. Additional research is needed to fully understand the ecological implications of this strategy. However, a potential solution is to stabilize the acidity of the seawater to counteract acidification without running the risk of drastically changing the seawater's chemistry in the opposite direction, which as of right now would have unknowable consequences (Momme Butenschön et al., 2021). The whole 21st century will see the terrestrial biosphere continue to be a carbon sink. The preservation of favorable conditions for calcifying organisms such as polar pteropods and tropical corals, which are significant components of large ecosystems, depends on a rapid decline in $CO_2$ emissions between 2025



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and 2050. This could necessitate the early implementation of CO2 removal techniques in addition to a drastic reduction in emissions (Hofmann et al., 2019). Nature-based Solutions (NBS): (1) Improve knowledge of the relationships between marine and coastal biodiversity and ecosystem services to support NBS better designed for rebuilding system resilience and achieving desired ecological outcomes under climate change; (2) Provide scientific guidance on where and how to implement marine and coastal NBS; (3) Develop ways to improve marine and coastal NBS communication, collaboration, ocean literacy, and stewardship in order to raise awareness, co-create solutions with stakeholders, increase public and policy buy-in, and possibly drive a more sustained investment. NBS have been extensively researched for terrestrial systems, especially urban ones, and have only just begun to be adopted in marine and coastal regions, despite the wealth of potential (O'Leary et al., 2023).

## V. Conclusion

Ocean acidification has serious negative effects on human civilization, biodiversity, and marine ecosystem function. It also poses serious challenges to coral health and marine ecosystems. This article review has provided an overview of the challenges, potential impacts, and mitigation methods related to ocean acidification on the marine ecosystem and coral health. Policymakers, researchers, and to stop ocean acidification and save the marine ecosystem for future generations, communities must collaborate to create and implement practical solutions.

## VI. Recommendation

A diverse strategy is needed to combat ocean acidification, one that includes policymakers establishing laws on lowering carbon emissions, strengthening ecosystem resilience, encouraging the sustainable management of marine resources, protect and restore marine ecosystems, mitigating climate change, reduce local stressors, do more research and monitorings, adaptation strategies and also public awareness and education.

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