IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Ocean acidification and its impact on marine ecosystems

Mahima Samanth

Abstract

The Ocean occupies 70% of the earth's surface and plays a crucial role in changing weather and climate. The reduction of the Ph in the ocean for a long period of time which is caused by excessive release of carbon-dioxide in the atmosphere leads to ocean acidification. When carbon-dioxide is absorbed by the ocean water there takes place a series of chemical reactions resulting in the rapid increase of the hydrogen ions and reduction in the carbonate ions that makes the ocean water to be acidic. The carbonate ions are essential for seashells, oysters and corals to exist and ocean acidification may lead to some of their species to go extinct. Increasing acidity of the ocean leads to the increase in the ocean temperature. Ocean acidification also alters the pH of the blood in fish. The ability of some fish like clown fish to detect predators is decreased in more acidic water. The shell fish cannot build strong shells due to the decrease in carbonate. The acidification of the ocean is not uniform throughout the world infact it varies from polar regions to the temperate regions. Ocean acidification may be advantageous to some biological species like sea algae and sea weed as they may be benefitted from higher carbon-dioxide concentrations in the ocean as they may increase their photosynthesis and growth rate but too much carbon-dioxide may make the ocean water too acidic and cause harm to them .

Keywords: Ocean acidification, coral reefs, shellfish

Introduction

As the ocean takes up a large amount of our carbon dioxide emissions, the ocean's chemistry is altering at a rate that has never been seen before. The seas, which make up around 70% of the planet's surface, are vital to life as we know it. They sustain abundant biodiversity, control the climate, and give billions of people a means of subsistence. That being said, Ocean Acidification poses a major hazard to the oceans. Via global warming and ocean acidification, rising atmospheric CO_2 levels represent serious risks to living systems. When more Carbon Dioxide from the atmosphere is absorbed, the pH of the ocean water continuously drops, a process known as "ocean acidification." The pH of saltwater is lowered as CO_2 dissolves and generates carbonic acid in it. The oceans have absorbed around one-third of the CO_2 that humans have released into the atmosphere. Ocean acidification is the process wherein this CO_2 reacts with water to generate H_2CO_3, a weak acid, increasing the acidity of the water. [16] The change in ocean chemistry caused by the ocean's absorption of chemical inputs to the atmosphere, such as sulfur, nitrogen, and carbon compounds, is known as ocean acidification. To put it another way, this is the process by which extra CO_2 dissolves and modifies the ocean's chemistry. Anthropogenic activities that release a lot of CO_2, such burning fossil fuels and changing land use, are the most frequent cause of this. Since the pre-industrial era, the oceans' pH has dropped by roughly 0.1 units, which translates to a 30% rise in acidity.[15], The effects of rapid acidification on marine life are catastrophic. Particularly at risk are calcifying species like corals, shellfish, and certain kinds of plankton. These species' shells and skeletons are made of carbonate ions, but the availability of carbonate diminishes with increasing acidity. Reduced development, hampered reproduction, and even death may result from this. The maritime ecosystem is not the only thing that is affected by ocean acidification. Communities near the coast are also at danger. Fish populations are declining as a result of habitat changes and food availability, which is negatively affecting fisheries as well. Ocean acidification poses a major risk to both human health and the health of the oceans. In order to lessen the effects of ocean acidification and cut greenhouse gas emissions, immediate action is required.[14]

Carbondioxide absorption process in oceans

The oceans' ability to absorb large volumes of CO_2 from the atmosphere helps to mitigate the effects of climate change. A portion of CO_2 that is emitted into the atmosphere from activities like burning fossil fuels or deforestation dissolves in the ocean's surface waters. This dissolution occurs as a result of the weak acid carbonic acid being formed when CO_2 and water mix. The following is a representation of the chemical reaction;

$CO_2 + H_2O \rightarrow H_2CO_3$

Seawater's pH is further lowered by the subsequent breakdown of carbonic acid (H_2CO_3) into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+).

Effects on Seawater pH Levels

Seawater becomes increasingly acidic as a result of the pH decrease, also referred to as ocean acidification. The pH scale has a range of 0 to 14, where 7 is considered neutral, values less than 7 denote acidity, and values more than 7 denote alkalinity. The pH of the ocean drops with increasing acidity, making it more caustic to marine organisms with calcium carbonate skeletons and shells, like corals, mollusks, and some types of plankton. The delicate balance of marine ecosystems may be upset by this increased acidity, which would impact all trophic levels, from tiny zooplankton to larger predators. [20]

Biological process affected by ocean acidification

Several biological activities may be impacted by rising acidity, which alters the carbonate chemistry of saltwater, in addition to other environmental stressors including pollution and warming ocean temperatures.

1. Increasing the rate of photosynthesis

Carbon dioxide increases the rate of photosynthesis, which in turn promotes plant development. Seagrasses are among the many plants that grow more quickly in environments with higher carbon dioxide levels. Sea grasses offer important habitat, but if they outgrow weaker species and lower the biodiversity of the ecosystem, this could be too good of a thing.

2. Building Shells

Carbonate ions are used by many animals and some algae to form calcium carbonate skeletons and shells. These animals will have to work harder to make shells because the availability of carbonate ions is reduced due to ocean acidification.

3. Acquiring the necessary nutrients and minerals

The process of ocean acidification may make it more difficult for marine life to absorb nutrients like iron, phosphorus, nitrogen, and other growth-promoting components. For instance, iron bonds to organic substances when saltwater gets more acidic, preventing marine life from utilizing this necessary element. [19]

4. Maintaining Metabolism

Many physiological processes are fine-tuned to operate within a narrow pH range; outside of that range, the bio-chemical reactions may be too slow or inefficient to keep the organism healthy. Although many species can adjust to changes in their surroundings by actively maintaining a constant internal environment, this maintenance requires a significant expenditure of energy. An adult fish may be able to compensate by eating more, but fish eggs and larvae have limited energy reserves and, therefore, may have less capacity to adjust to more acidic conditions.

Impact of Ocean acidification on the following

Coral Reef

Large underwater structures known as coral reefs are made of the bones of colonial marine invertebrates known as coral. Because the coral species that form reefs use calcium carbonate from saltwater to form a strong, resilient exoskeleton that shields their delicate, sac-like bodies, these coral species are referred to as hermatypic, or "hard," corals. Coral reefs sustain about 25% of marine biodiversity and the way of life for tens of millions of people living in tropical coastal regions of both developed and developing nations, although making up less than 1% of the ocean floor. As sea levels rise and climate change worsen, coral reefs play a crucial role in protecting coastlines by reducing wave energy and storm surges. Additionally, a lot of individuals have emotional and cultural ties to reefs, which raises the significance of healthy coral reef systems to humans.[2] Coral reefs are among the most vulnerable ecosystems to ocean acidification because the ocean's increasing acidity, which is caused by the ocean absorbing massive amounts of carbon dioxide released into the atmosphere through the burning of fossil fuels, inhibits coral's ability to produce the calcium carbonate exoskeletons they rely on for shelter. Coral reefs are already under severe pressure from a number of stressors, including overfishing, pollution, and increasingly frequent bleaching events [17][18] After a coral dies, a huge number of coral polyps assemble to construct the remaining calcareous bones. Coral bleaching, which can result in species losing their environment, is one of the many difficulties that corals confront. The algae known as zooxanthellae, which inhabit coral reefs, depart the coral when environmental factors like temperature shift. As a result, the coral loses color. More and more data points to the significant impact of CO_2 such as coral reef bleaching on the environment. [15] Because ocean acidification (OA) inhibits coral reef growth and reproduction, damaged reefs from acute events like mass bleaching are likely to heal substantially more slowly. So, reducing the impact of OA is required to keep reefs in a net-growth or net-neutral state. [13]

Shellfish

A vast range of species are categorized as shellfish, such as clams, mussels, oysters, scallops, crabs, lobsters, and shrimp. Their protective exoskeletons, which can be made of carapaces, shells, or crustacean exoskeletons, are what set them apart. Since shell production in shellfish depends on calcium carbonate, they are especially susceptible to the impacts of acidification. The delicate equilibrium of carbonate ions in saltwater is upset by ocean acidification, which makes it more difficult for shellfish to form and preserve their protective shells. The concentration of carbonate ions in saltwater drops with increasing acidity, making it more difficult for shellfish like mussels and oysters to extract the required calcium carbonate. As a result, the shells become weaker and thinner, providing less defense against predators and environmental stresses. The availability of carbonate ions is closely related to the growth and reproduction of shellfish. Shellfish frequently devote more energy to maintaining their shells when carbonate levels drop as a result of acidification, devoting resources away from growth and reproduction. Reduced reproductive success and slower development rates can have a domino effect on oyster populations and the environments they live in. [6]

Fish

Fish, which do not calcify, are even killed by ocean acidification. Fish are not covered in shells, yet they will still be impacted by acidification. A fish's cells frequently absorb carbonic acid to bring their pH balance with the saltwater because the surrounding water has a lower pH. This results in acidosis, a shift in the fish's blood pH. The fish is then in balance with its surroundings, but many of its internal chemical processes can be changed. A slight variation in pH can have a significant impact on survival. For example, a reduction in blood pH of 0.2–0.3 in humans can result in comas, convulsions, and even death. In a same vein, fish must put its body goes into overdrive to restore normalcy to its chemistry.[3]

Crustaceans

To fend against predators, ocean animals such as snails have calcium carbonate-based shells. But when people add more carbon dioxide to the atmosphere, the water becomes more acidic, which prevents animals from growing calcium carbonate shells. Crabs' ability to dissolve their shells and use them as navigational aids will also be hampered. For the creation and upkeep of their hard shells and skeletons, creatures that live in shells need calcium and carbonate. Even yet, the ocean's high acidity destroys their skeleton, and maintaining that shell requires more energy. [15]

Seagrasses

It is one of the ocean's most productive and biologically diverse marine ecosystems. Seaweeds and seagrasses are completely different organisms, despite their apparent similarities. Seagrasses are members of the monocotyledon plant family, which also includes grasses, lilies, and palms. Seagrasses bear leaves, roots, veins, flowers, and seeds, just like their relatives. They produce vital habitat for adult fish, invertebrates, and mollusks as well as vital nursery grounds for young fish. Seagrasses are an important source of food for a number of endangered and higher order species, including green sea turtles, dugongs, and manatees. One of the few ecosystems that can profit from increased biodiversity is the seagrass ecosystem, which is essential to preserving the biological richness of the oceans. Although seagrasses can dehydrate HCO_3^-, a large number of them seem to utilise CO_2 (aq) for at least half of the carbon needed for photosynthesis. Increasing CO_2 will likely result in higher seagrass biomass and productivity in seagrass habitats, provided that the water's purity and quality (low suspended sediment) allow photosynthesis to take place. They are declining due to a variety of other factors, most notably pollution entering coastal seas, thus it is unlikely that the increase from acidity would completely offset the losses brought on by these other pressures. [12]

Impact on biogeochemical cycles

Major biogeochemical cycles could be impacted by ocean acidification in a number of ways that would have an impact on the climate globally. These effects won't happen in a vacuum; rather, they'll happen in concert with other global changes that could greatly influence the outcomes in the future, such as ocean warming, deoxygenation, and possibly increased ultraviolet (UV) radiation. [4]

Impact on cultural ecosystem

It is particularly challenging to evaluate how ocean acidification affects the services provided by cultural ecosystems. While some effects on tourism, leisure, and recreation can be measured, such as the possibility that dead coral on reefs will draw fewer tourists and the reduction of ancillary biodiversity, many cultural services, like spiritual enrichment and appreciation of art, are intangible in nature, and it is unclear how biodiversity fits into these services. However, if maritime habitats and species have a high intrinsic value (conservation value in developed nations) or are vital to the history and identity of indigenous peoples, a decline in their abundance could lead to a major loss of cultural heritage. [1]

Impact on human societies

As human societies rely on the products and services that marine ecosystems supply, changes to these ecosystems will have an impact on them. Significant drops in revenue, job and livelihood losses, as well as other indirect economic expenses, could be the effects on society.[7]

It is anticipated that the following ecosystem services will experience a reduction, with accompanying socioeconomic effects:

Food: Food security may be impacted by ocean acidification. Marine species that are significant for both ecology and commerce would be harmed, albeit they might react differently. Oysters and mussels are two of the most delicate types of mollusks.

Protection of the coast: Marine ecosystems, such coral reefs, shield shorelines from storm surges and storms' destructive force, shielding numerous island nations' only livable land. Reefs' protective role keeps loss of life, property damage, and erosion.

The tourism sector may be significantly impacted by the effects of ocean acidification on marine ecosystems, such as coral reefs.

Regulation of climate and storage of carbon: As ocean acidification rises, the ocean's ability to absorb CO2 falls. Ocean acidity decreases the ability of oceans to moderate climate change.[5]

Set of parameters to evaluate extent of Ocean Acidification

1.Sea Surface Temperature

The higher the value, the higher the acidification. As seawater temperature rises, the buffering capacity of seawater decreases, along with a decline in pH. Increased metabolic activity is caused by increasing seawater temperature and decreasing pH. Consequently, a temperature increase of 2°C leads to approximately a 10 per cent reduction in carbon uptake in surface waters, primarily through phytoplankton photosynthesis. That leads decline in photosynthesis and an increase CO_2 levels in sea water[9].

2.Salinity

The degree of acidity decreases with increasing value. Seawater's pH can be lowered by salinity, making it less acidic. This is due to the fact that carbon dioxide molecules may attach to salt ions and find it more difficult to dissolve in seawater. Because salinity makes carbon dioxide more harmful to marine life, it can also worsen the impacts of ocean acidification. This is because the pathways that marine creatures employ to carry oxygen into their cells can be blocked by salt ions. The temperature and the kind of marine creature are two of the many variables that affect the overall, complex relationship between salinity and ocean acidification. On the other hand, low salinity seawater is generally regarded to be where the consequences of ocean acidification are more noticeable. [10]

3. Particulate Organic Carbon

The degree of acidity decreases with increasing value. The type of carbon called Particulate Organic Carbon (POC) is present in the water as suspended particles. Organic materials produced by marine organisms makes up its composition. The relationship between POC and ocean acidification is not very strong. On the other hand, some research has found no relationship between POC and ocean acidification, or perhaps a positive relationship. [11].

4. Particulate Inorganic Carbon

The degree of acidity increases with increasing value. The kind of carbon that is present in the ocean as suspended particles is called particulate inorganic carbon, or PIC. It is composed of minerals created by marine creatures, including calcium carbonate. Ocean acidification and PIC have a close relationship. PIC concentrations in the seawater fall as ocean acidification rises. This is because it is more difficult for marine creatures to generate calcium carbonate due to the increased acidity. Consequently, the amount of PIC particles in the seawater has decreased. [9]

5. Dissolved Oxygen (DO)

The less acidity, the greater the value. The process of photosynthesis by aquatic plants produces oxygen, which increases the oxygen content of the water. Algal blooms are the result of an abundance of nutrients, especially nitrogen and phosphorus, which drive the fast growth of algae. The dissolved oxygen concentration drops as a result of these blooms, which can create thick layers on the water's surface that prevent sunlight from reaching underwater plants. As a result, other aerobic creatures find it more difficult to live, which reduces the biodiversity of the environment. As a result, algae blooms cause the ocean's water to become less oxygenated, which indicates rising CO_2 levels and causes ocean acidification.[14]

Conclusion

Several significant action should be taken to reduce the impact of ocean acidification. Because fossil fuels release too much carbon dioxide, their use should be curtailed. There should be less deforestation and more support for afforestation initiatives. Reducing waste and pollution can be achieved by following the Reduce, Reuse, Recycle, and Refuse strategy. Water conservation should be improved and greenhouse gas emissions should be decreased. Instead than encouraging the use of environmentally beneficial items, plastic usage ought to be outlawed. As of right now, the entire ocean, including coastal streams and estuaries, is being affected by ocean acidification. It is imperative that the government and environmental organizations work together to take a proactive approach to this problem. Strict legislation is needed to save the ocean's vulnerable species. It is imperative that the people be educated and made aware of these issues. It is necessary to create marine protected areas and manage habitats sustainably. The purpose of the National Ocean and Atmospheric Administration's (NOAA) ocean acidification program is to foster relationships between the public, the government, and scientists in order to monitor and study the effects of ocean acidification on ecosystems that are significant to both ecology and economy, such as fisheries and coral reefs.

References

1)Cooley SR, Kite-Powell HL, Doney SC (2009) Ocean acidification's potential to alter global marine ecosystem services. Oceanography 22: 172-181.

2)Jokiel PL (2016) Predicting the impact of ocean acidification on coral reefs: evaluating the assumptions involved. ICES J Mar Sci 73:550-557

3) Baumann \H, S.C. Talmage, C.J. Gobler,(2012) Reduced early life growth and survival in a fish in direct response to increased carbon dioxide, Nature Climate Change 2(1):38-41.

4)Hall-Spencer JM, Rodolfo-Metalpa R, Martin S, Ransome E, Fine M, et al. (2008) Volcanic carbondioxide vents show ecosystem effects of ocean acidification. Nature 454: 96-99.

5)Long, M.C., Deutsch C, and T. Ito, (2016)Finding forced trends in oceanic oxygen. Global Biogeochemical Cycles, 30(2), 381-397.

6)Browman HI (2016) Applying organized scepticism to ocean acidification research. ICES Journal of Marine Science: Journal du Conseil 73:529-536

7)Chierici M, Fransson A (2009) Calcium carbonate saturation in the surface water of the Arctic Ocean: undersaturation in freshwater influenced shelves. Bio geoscience 6:2421-2432

8)T. Wang, Y. Wang, (2020) Behavioral responses to ocean acidification in marine invertebrates: new insights and future directions, Journal of Oceanology and Limnology 38(3):759-772.

9)Turley CM, Brownlee C, Findlay HS, Mangi S, (2010), Ocean Acidification.

10)Gattuso JP, Hansson, (2011), Ocean acidification.

11)Klepas JA, Yates KK, (2009) Coral reefs and Ocean Acidification, Oceanography,22(4),108-117.

12)Guinetto JM, Fabry VJ, (2008), Ocean acidification and its potential effects on marine ecosystems, Annals of the New YORK Academy of Sciences,1134(1),320-342.

13)Dupont S, Portner HO, (2013)A snapshot of ocean acidification , Marine Biology, 160(8).

14)Saini MK, (2024) Selected Perspectives On Ocean Acidification.

15)Cui Z, Huang S, Liu J, Zhu J, (2021), Impact and potential solutions toward ocean acidification, E3S Web of Conferences,308.

16)Thor P, Dupont S,(2018), Ocean acidification, in book: Marine environment protection science, impact and sustainable management.

17)Gazeau F, Martin S, Hansson L, Gattuso JP, (2011) Ocean acidification in the coastal zone, 3:5-14.

18)Caldeira K, Wickett ME(2003), Anthropogenic carbon and ocean pH , Nature, 425,365.

19)Godbold JA, Caklosi A, (2013) Ocean acidification and climate change advances in ecology and evolution, Philosophical Transactions, Royal Society of London Series B: Biological Series,368(1627).

20)Kumar A,(2022) Sustaining life below water, Eco-system based Adaptation,417-501.