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Impact of Ocean Acidification on Marine Flora and Fauna

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Ocean acidification is a process that occurs when carbon dioxide (CO_2) from the atmosphere dissolves into seawater, leading to a decrease in the pH of the oceans. This phenomenon is primarily driven by human activities such as the burning of fossil fuels (like coal, oil, and gas), deforestation, and industrial processes, which release large amounts of CO_2 into the atmosphere.

When CO_2 dissolves in seawater, it reacts with water to form carbonic acid, which then dissociates into bicarbonate and hydrogen ions. This increase in hydrogen ions leads to a decrease in pH, making the water more acidic. The pH scale is logarithmic, meaning that small changes in pH represent significant differences in acidity. As ocean acidification occurs, the pH of seawater drops, making it more acidic.

Ocean acidification can have significant impacts on marine ecosystems and the organisms that inhabit them, particularly those that rely on calcium carbonate to build shells and skeletons. This includes many species of corals, mollusks (like clams and snails), and certain types of plankton. The lower pH reduces the availability of carbonate ions, which these organisms need to build and maintain their calcium carbonate structures. This can lead to weakened shells, slower growth rates, and overall reduced fitness for these organisms.

The potential consequences of ocean acidification

1) **Coral Reefs:** Corals are particularly vulnerable to ocean acidification, as the lower pH affects their ability to create and maintain their calcium carbonate skeletons, which are the foundation of coral reefs. Weakened corals are more susceptible to bleaching events and other stressors.
2) **Shellfish:** Mollusks and other shell-forming organisms may find it more difficult to build and repair their shells, potentially impacting the entire food chain since they serve as a vital food source for many marine animals.
3) **Marine Food Web:** The effects of ocean acidification on smaller organisms can disrupt the marine food web, affecting larger animals that depend on these smaller organisms for food.
4) **Biodiversity:** The loss of coral reefs and other ecosystems due to ocean acidification could lead to a reduction in marine biodiversity, impacting both ecological and economic systems.
5) **Economic Impacts:** Ocean acidification could have economic consequences for industries like fishing and tourism that rely on healthy marine ecosystems.

Addressing ocean acidification requires global efforts to reduce CO_2 emissions and mitigate the effects of climate change. This includes transitioning to cleaner and more sustainable energy sources, implementing conservation measures to protect marine ecosystems, and supporting research into strategies that could help mitigate the impacts of ocean acidification on marine life.

Current status of Ocean Acidification

According to IPCC 6th assessment report on climate change 2021, the estimated past and future global mean surface pH for different emission scenario are

Pre-industrial (1850)	8.17
Current (2021)	8.08
Future (2100) with current emission scenario	7.7

(IPCC, 2021)

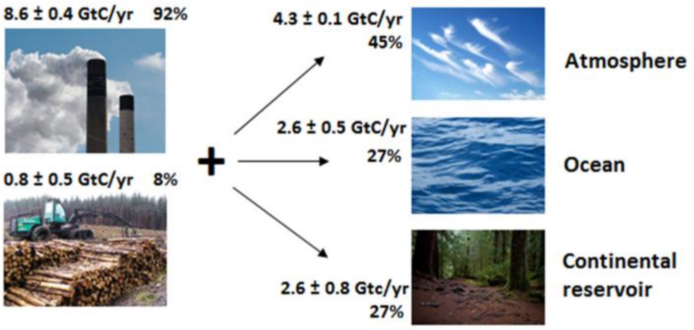

Fig 1. Annual anthropogenic carbon emissions from different sources.

(Melieres and Marechal, 2015)

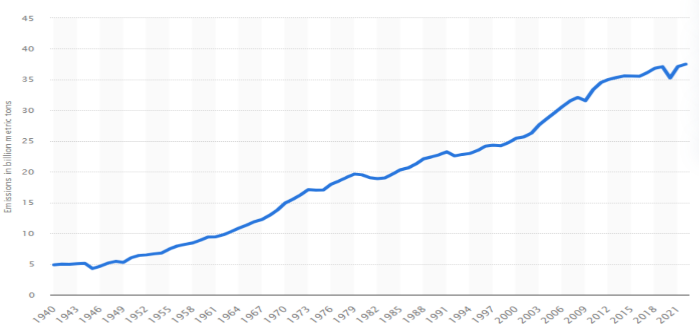

Fig. 2. Annual carbon dioxide (CO_2) emissions worldwide from 1940 to 2021 ***(in billion metric tons)*** *(Tiseo: Statistica, 2023)*

Chemistry of Ocean acidification

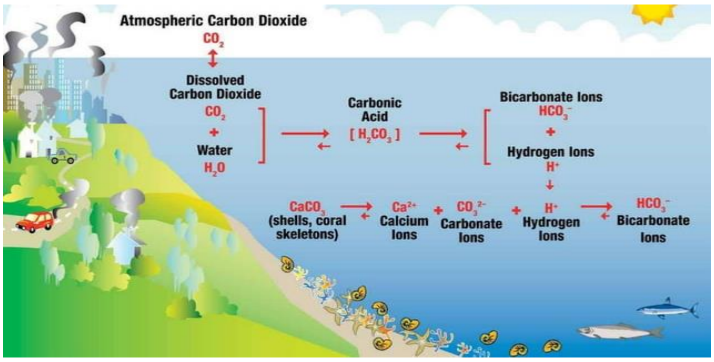

Fig 3. Chemistry of ocean acidification

(Jana and Mondal, 2023)

Ocean acidification leads to significant changes in ocean chemistry, primarily by altering the carbonate system. The carbonate system plays a crucial role in the formation of calcium carbonate minerals, which are essential for the growth of shells, skeletons, and other structures of many marine organisms. Here are some of the key changes in ocean chemistry that occur due to acidification:

1) **pH Reduction:** The most immediate and noticeable change is the decrease in pH, which makes the water more acidic. This decrease in pH occurs because carbon dioxide (CO_2) dissolves in seawater and forms carbonic acid (H_2CO_3), releasing hydrogen ions (H+) into the water. This increase in hydrogen ions leads to a lower pH.
2) **Bicarbonate Formation:** Carbonic acid dissociates into bicarbonate ions (HCO_3^-) and hydrogen ions. Bicarbonate is an important component of the carbonate system and is used by marine organisms to build shells and skeletons.
3) **Carbonate Ion Decrease:** The increase in hydrogen ions reduces the concentration of carbonate ions (CO_3^{2-}) in the water. Carbonate ions are crucial for the precipitation of calcium carbonate minerals. When the concentration of carbonate ions is reduced, it becomes more challenging for organisms to form and maintain their calcium carbonate structures.
4) **Saturation State:** The saturation state of calcium carbonate minerals (calcite and aragonite) is affected by changes in pH and carbonate ion concentration. A decrease in saturation state can make it harder for organisms to produce and maintain their calcium carbonate structures, potentially leading to shell dissolution and reduced growth rates.
5) **Impacts on Calcifying Organisms:** Many marine organisms, such as corals, molluscs, and some types of plankton, rely on calcium carbonate to build shells, skeletons, and other structures. Ocean acidification can hinder their ability to do so, leading to weaker shells, slower growth rates, and overall reduced fitness.
6) **Coral Reefs:** Coral reefs are particularly vulnerable to ocean acidification due to their reliance on calcium carbonate. Corals need to deposit calcium carbonate to build their skeletons, and reduced carbonate availability can impede their growth and recovery after disturbances.
7) **Ecosystem Disruption:** The impacts on calcifying organisms can have cascading

effects on marine ecosystems. Weakened shells can lead to increased mortality rates among certain species, disrupting food webs and affecting the overall balance of marine ecosystems.

8) **Economic and Ecological Consequences:** Ocean acidification can have economic repercussions, particularly for industries reliant on fisheries and tourism. Furthermore, the loss of coral reefs and other marine habitats can negatively impact coastal protection, biodiversity, and other ecological services provided by healthy marine ecosystems.

Impacts of Ocean acidification on marine flora

Ocean acidification have significant impacts on marine flora, particularly those organisms that are part of the phytoplankton community. Phytoplankton are microscopic photosynthetic organisms that form the foundation of the marine food web and play a crucial role in the Earth's carbon and oxygen cycles. Here are some of the key impacts of ocean acidification on marine flora:

1) **Algal Growth and Productivity:** The growth and productivity of certain types of phytoplankton, such as coccolithophores and diatoms, can be influenced by changes in ocean chemistry. Some studies suggest that ocean acidification might enhance the growth of certain types of phytoplankton while inhibiting others. These changes in phytoplankton composition could have cascading effects throughout the marine food web.
2) **Calcifying Phytoplankton:** Some phytoplankton species, like coccolithophores, create calcium carbonate shells. Similar to calcifying animals, these organisms can be negatively affected by reduced carbonate ion availability due to ocean acidification, potentially hindering their ability to build and maintain their shells.
3) **Nutrient Availability:** Changes in ocean chemistry could impact the availability of essential nutrients for phytoplankton growth. Alterations in nutrient ratios could lead to shifts in phytoplankton community composition, favouring certain species over others.
4) **Photosynthesis and Carbon Fixation:** Ocean acidification can affect the photosynthetic processes of phytoplankton. While some studies suggest that certain phytoplankton might benefit from increased availability of dissolved CO_2 (a product of carbonic acid dissociation), others might be less efficient at photosynthesizing under lower pH conditions.
5) **Biodiversity and Community Dynamics:** Ocean acidification has the potential to alter the competitive dynamics between different phytoplankton species, which could lead to shifts in phytoplankton community structures. Changes in phytoplankton biodiversity could have cascading effects throughout the marine ecosystem.
6) **Food Web Impacts:** Phytoplankton form the base of the marine food web, providing primary production that supports higher trophic levels. Changes in phytoplankton abundance and composition could affect the availability of food for zooplankton, small fish, and other organisms, ultimately impacting the entire food web.
7) **Carbon Sequestration:** Phytoplankton play a critical role in sequestering carbon dioxide from the atmosphere through photosynthesis. Any changes in phytoplankton productivity and composition due to ocean acidification could influence the ocean's capacity to act as a carbon sink.
8) **Feedback Loops:** Some phytoplankton species release dimethylsulfide (DMS), a compound that affects atmospheric chemistry and cloud formation. Changes in phytoplankton abundance and activity could potentially impact these atmospheric processes.

It is important to note that the responses of marine flora to ocean acidification can vary based on species, environmental conditions, and other factors. Research is ongoing to better understand these complex interactions and their potential implications for marine ecosystems and the broader Earth system.

Impacts of Ocean acidification on marine fauna

Ocean acidification have a significant impact on marine fauna, including a wide range of aquatic animals such as molluscs, crustaceans, corals, and various types of fish. These impacts can affect the entire marine food web and have cascading effects on ecosystems and human communities that depend on them. Here are some of the key impacts of ocean acidification on marine fauna:

1) **Calcifying Organisms:** Many marine organisms, including molluscs (such as clams, oysters, and snails) and some types of crustaceans, rely on calcium carbonate to build shells and skeletons. Ocean acidification can reduce the availability of carbonate ions, making it more difficult for these organisms to form and maintain their calcium carbonate structures. This can lead to weaker shells, slower growth rates, and increased vulnerability to predation.
2) **Coral Reefs:** Corals are particularly vulnerable to ocean acidification. Reduced carbonate ion availability makes it harder for corals to build and maintain their calcium carbonate skeletons, which are the foundation of coral reefs. Weakened corals are more susceptible to bleaching events, disease, and other stressors.
3) **Fish Behaviour:** Some research suggests that ocean acidification might impact the behaviour of certain fish species. For example, elevated CO_2 levels could lead to altered sensory perception, affecting fish's ability to navigate, find food, and avoid predators.
4) **Fish Development:** Fish eggs and larvae are also susceptible to the impacts of ocean acidification. Changes in water chemistry can affect the survival, growth, and development of these early life stages, potentially leading to reduced recruitment of fish populations.
5) **Ecosystem Disruption:** The effects of ocean acidification on specific species can disrupt marine ecosystems. For example, if shellfish populations decline due to weakened shells, this could affect the predators and other organisms that rely on them for food.
6) **Food Web Dynamics:** The impacts of ocean acidification on various species can lead to shifts in food web dynamics. For instance, if certain prey species are negatively affected, it could impact the predators that rely on them for sustenance.
7) **Economic Implications:** Many coastal communities rely on marine resources for livelihoods, including fisheries and aquaculture. The decline of important species due to ocean acidification could have economic consequences for these industries and the communities they support.
8) **Biodiversity Loss:** Ocean acidification, in conjunction with other stressors such as warming and pollution, could contribute to biodiversity loss in marine ecosystems. This can have far-reaching ecological and economic implications.

It is important to note that the severity of these impacts can vary based on factors such as the species' sensitivity to acidification, their ability to adapt, and the overall ecosystem context. Addressing the impacts of ocean acidification requires a combination of strategies, including reducing carbon dioxide emissions, implementing conservation measures to protect vulnerable species and habitats, and conducting further research to better understand and manage the effects on marine fauna.

Conclusion

Ocean acidification is a gradual process, which is accelerated by anthropogenic activities. It affects marine ecosystem by altering the marine temperature, pH, biotic and abiotic factors, which in turn affects the marine flora and fauna. Ultimately, leading to imbalance in the marine ecosystem balance by affecting the marine food chains and food webs. Hence, it is a serious environmental concern to be regulated by preventive measures to achieve the environmental balance and sustainability in aquatic ecosystem.

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