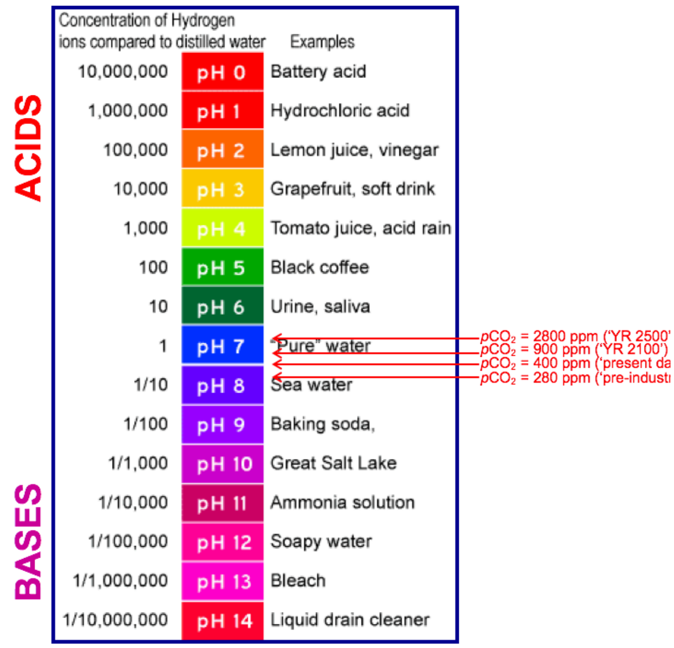
Case Study: Impact of Ocean Acidification on Marine Species

Part 1- Introduction to Ocean Acidification



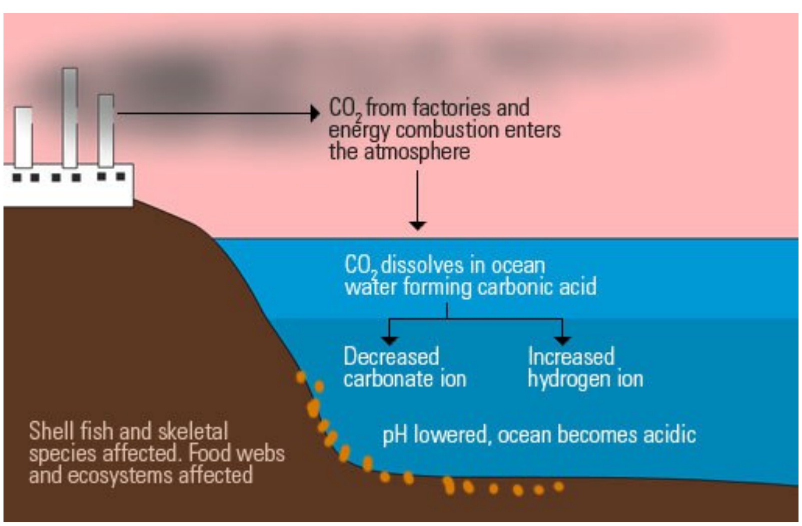
Human activities such as burning fossil fuels and changes in land use have increased the amount of carbon dioxide (CO_2) in the atmosphere from pre-industrials levels of 280 ppm to 400 ppm in 2018. Current atmospheric CO_2 levels are greater than they have been in 800,000 years, and as a result, the fast carbon cycle is no longer in balance. Around 25% of carbon dioxide that is released into the atmosphere is absorbed into the ocean which changes the chemistry of the ocean.

The CO_2 added to seawater reacts with the water molecules lower the pH of the ocean by forming carbonic acid in a process known as *ocean acidification*. The following chemical reaction is taking place and results in *carbonic acid (H_2CO_3)*:

$$CO_2\,(aq) + H_2O \rightarrow H_2CO_3$$

Carbonic acid is the same chemical that gives carbonated beverages their fizz. Carbonic acid, when present in seawater, dissociates into *H+ and HCO3-*.

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$



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As the hydrogen ion concentration of seawater increases, the acidity increases. A pH unit is a measure of acidity ranging from 0-14. The lower the value, the higher the acidity of the environment. A shift in pH to a lower value reflects an increase in acidity.

The current pH level in the ocean has dropped from 8.2 to 8.1 as a result of ocean acidification. This may seem like a small change, but since pH is a logarithmic scale it actually represents a 30% increase in acidity.

The free hydrogen ion produced from the above reaction combines with a dissolved carbonate ion (CO_3^{2-}) to form another bicarbonate ion:

$$H^+ + CO_3^{2-} \rightarrow HCO_3^-$$

This reaction makes less carbonate ions (CO_3^{2-}) available in the seawater that organisms such as corals, oysters, clams, and crabs need to build a hard shell or exoskeleton.

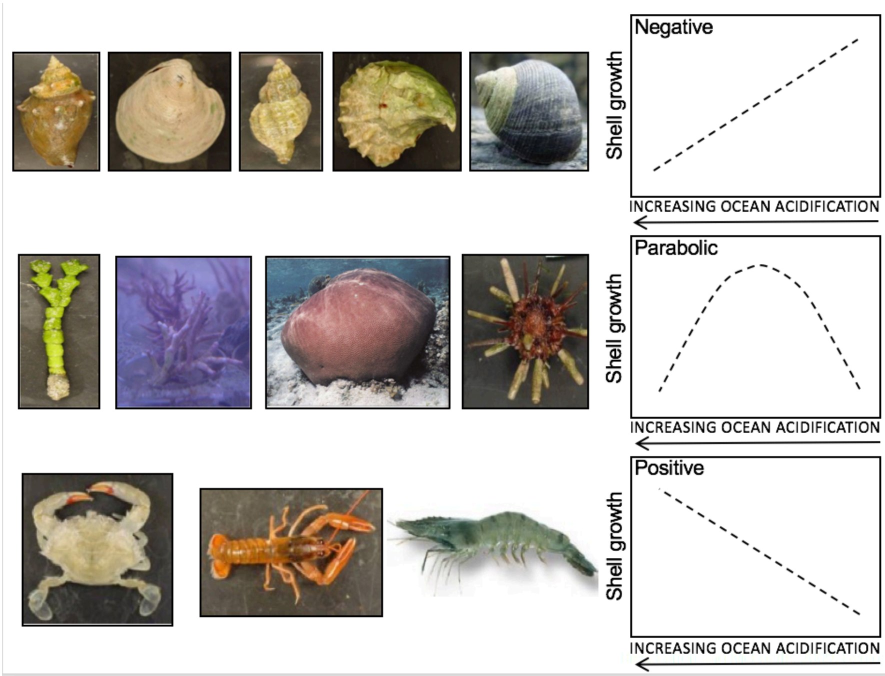
Questions

1. How does the level of CO_2 in the atmosphere influence the pH of the ocean?

2. How do fewer carbonate ions in the ocean affect ocean animals and what are the potential impacts for organisms that need to rely on a hard shell for protection?

Part 2- Impact of Ocean Acidification on Marine Organisms

Ocean acidification is expected to impact ocean species to varying degrees. Photosynthetic algae and seagrasses may benefit from higher CO_2 conditions in the ocean, as they require CO_2 to live (just like plants on land). On the other hand, studies have shown that a more acidic ocean environment has a dramatic effect on some calcifying species including oysters, shellfish, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton. Some organisms also exhibit a parabolic effect to ocean acidification, where shell growth first increases and then drops dramatically.

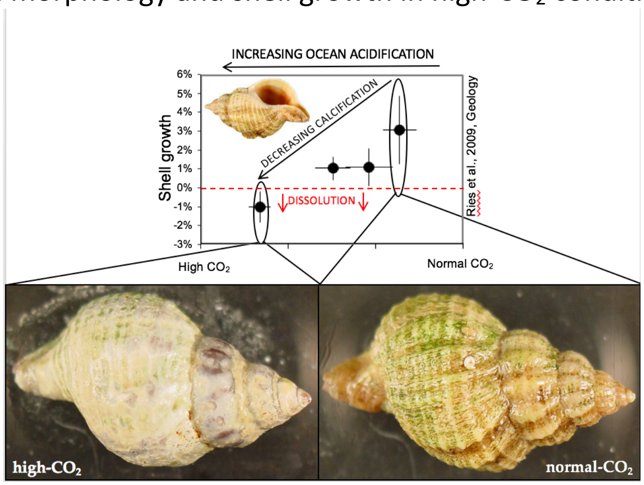


Ocean acidification can be described as "osteoporosis of the sea". Just as humans need calcium to build their bones, sea animals such as snails need carbonate to build strong shells. This can cause their shells to become thinner or more brittle. When shelled organisms are at risk, the entire food web may also be at risk. For example, oyster larvae need carbonate to start building their hard shell. Oyster farmers on both the East and West Coast of the United States have already experienced oyster die-offs when larvae are unable to start building their shell. This multi-million-dollar industry is expected to see more impacts as the pH of the ocean continues to lower.

Questions

1. Using the diagram above, give an example of a marine plant or animal that in response to ocean acidification has: a negative impact on shell growth, a parabolic impact on shell growth, and a positive impact on shell growth.

2. Researchers at the Marine Science Center can alter the level of carbon dioxide in controlled tanks to observe the effect of high CO_2 levels on marine species such as snails. This species of snail uses its ridges to dig in the sand to Use the diagram below to describe differences you observe in shell morphology and shell growth in high-CO_2 conditions.



3. Ocean acidification can have a huge impact on marine food webs and fisheries. The CO_2 that we put in the atmosphere can end up hurting marine animals that we love to eat and that support our economy. What is one thing that you can do to help reduce your carbon footprint?

Marine Science Center Researchers Studying Ocean Acidification

Dr. Justin Ries

Dr. Justin Ries is a marine biogeochemist in the Department of Marine and Environmental Sciences at Northeastern University. His research program investigates a wide range of subjects in the marine and geological sciences, including global climate change and ocean acidification. The common thread throughout Dr. Ries' work is oceanic change, which he investigates over broad temporal scales. By combining field studies with complementary laboratory experiments, Dr. Ries is able to directly explore the biogeochemical processes that have changed the state of our oceans throughout the geologic past, as well as those that will drive changes in the future.