# BACK BAY SCIENCE CENTER

## Ocean Acidification

## ACTIVITY: BACK TO BASICs

**TIME:** 40-50 minutes
**GRADE LEVEL:** 8th-College
**GROUP SIZE:** 8-10

**Activity at a Glance: Students will learn about the effects of increased atmospheric carbon dioxide on our oceans.**

## NEXT GENERATION SCIENCE STANDARDS:

### PERFORMANCE EXPECTATIONS

**MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.**
**MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.**
**MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.**
**HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.**
**HS-LS2-6 Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.**

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Develop a model to describe unobservable mechanisms. (MS-PS1-5)<br>• Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2)<br>**Engaging in Argument from Evidence**<br>• Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)<br>- - - - - - - - - - - - - - -<br>**Connections to Nature of Science**<br>**Scientific Knowledge is Based on Empirical Evidence** | **PS1.A: Structure and Properties of Matter**<br>• Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2)<br>**PS1.B: Chemical Reactions**<br>• Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2),(MS-PS1-5)<br>• The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)<br>**LS2.C: Ecosystem Dynamics, Functioning, and Resilience**<br>• Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat | **Patterns**<br>• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2)<br>Energy and Matter<br>• Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)<br>**Cause and Effect**<br>• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS2-8),(HS-LS4-6) |

| | | |
|---|---|---|
| • Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2)<br><br>**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**<br>• Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-5) | destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. (HS-LS2-7)<br>**LS4.D: Biodiversity and Humans**<br>• Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). *(secondary to HS-LS2-7)*<br>• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. *(secondary to HS-LS2-7),(HS-LS4-6.)* | **Stability and Change**<br>Much of science deals with constructing explanations of how things change and how they remain stable. (HS-LS2-6),(HS-LS2-7) |

**Ocean Literacy 1: The Earth has one big ocean with many features**
**E-** Most of Earth's water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.
**Ocean Literacy 6: The ocean and humans are inextricably interconnected**
**E-** Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).

## BACKGROUND INFORMATION

While most of us are aware of the Greenhouse Effect, fewer have considered the impact that increased levels of carbon dioxide is having on our Oceans. In the last few years, there has been proliferating research on the acidification of our oceans and its cause. This increased acidity is moderating the global biodiversity of our ocean habitats. Entire groups of marine species are being jeopardized. While this phenomenon is seen in all of our ocean basins, local spikes are seen due to compounding human factors. In the face of such a serious situation, what can we do?

Ocean acidification is sometimes referred to as the "hidden" side of the world's carbon crisis. Research globally is pretty conclusive: the increased levels of carbon dioxide from fossil fuel emissions are lowering the pH in our oceans. About 30-50% of the carbon dioxide released from burning of fossil fuels have been absorbed by our oceans. As a result, it has increased acidity up to about 30% since the beginning of the Industrial Age. When carbon dioxide dissolves in seawater, most of it becomes bicarbonate ions ($HCO^{3-}$) and hydrogen ions ($H^+$). This increase in hydrogen ions is what decreases the pH. In addition, some of the hydrogen combines with carbonate to form more bicarbonate, decreasing the concentration of carbonate in seawater.

Scientists at NOAA, Woods Hole and various universities have been tracking this increase found in hydrogen ions in water. If humans don't take any steps to reduce emissions, it is projected that atmospheric carbon dioxide concentrations will have a three-fold increase over present levels. Until the economic downturn in 2008 when many commuting practices changed, actual emissions were on track to exceed this: reaching a five-fold increase in acidification by 2100. A threshold (tipping-point) increase in temperature of 2 degrees Celsius during this century is considered by many to be the point at which we can avoid dangerous human impact. This increase results in about a 10% decrease in carbon uptake in surface waters and may also impact ocean circulation, further reducing the ocean's capacity to absorb atmospheric carbon dioxide and thus increasing acidification. It should be noted, that while water from melting ice caps dilutes concentrations of various components of the carbonate system (conversion of carbon dioxide, in the presence of water into carbonic acid and then the acidic ions of bicarbonate and carbonate) in sea water, including total alkalinity and salinity, it actually increases acidity because the seawater and atmosphere are then out of equilibrium and so the seawater absorbs more carbon dioxide until equilibrium is reached.

Increased ocean acidity has already had an impact on several of our ocean ecosystems. Coral Reefs, Rocky Intertidal, and Polar Regions are showing signs of being degraded. Coral Reefs harbor a tremendous biodiversity of life in our oceans, but a growing number of studies are showing that their coral calcification rate decreases when carbon dioxide levels increase, lessening their ability to build their skeletons. The loss of Coral Reefs has been likened to losing our rainforests. The protection they offer coastal communities against storm surges as well as the economic and recreational impact on fishing and tourism will hit hard. This impacts Rocky Intertidal habitats as well, where the local acid levels are often accentuated by pollutants transported from the watershed communities. While many have attributed the melting of our polar regions to increased water temperature, it's now acknowledged that the acidity of the waters is becoming increasingly corrosive, hastening the dissolution.

Increased acidity in their habitat has had a destructive effect on several aquatic species. Organisms with calcium in their systems, such as oysters, mussels, scallops, sea stars, urchins, pteropods, foraminifera, mollusks, tube worms, and carbonate-forming algae are vulnerable. According to NOAA, mollusk populations of oysters and clams along the West Coast are declining. Crustaceans such as lobsters are also being studied. Although they're still able to produce their shells, the extra energetic cost under acidic conditions and the toll this takes on the animal's growth, hunting and reproduction needs is being researched. A decline in any of these populations has ripple effects throughout the food-web: Birds and marine mammals that rely on them for food are also jeopardized, as are human sport and commercial harvests. Although phytoplankton processes carbon dioxide as part of photosynthesis, there have been several studies that arrive at the same conclusion: the current aquatic food-web will alter as ocean acidification increases. Newly dominant phytoplankton species that are better adapted to the more acidic waters, will likely be non-native species and so less able to support the productive food-chains that currently support marine ecosystems and fishery resources.

Research has tied increased acidification to fossil-fuel emissions world-wide. Calcifying organisms in every ocean from the equator to the poles has been effected. Although not nearly to the extent of atmospheric carbon dioxide-driven acidification, coastal communities have localized spikes due to other compounding human factors. Perhaps the most prevalent and persistent problem is that of excess nutrients, mostly Nitrogen, that result from garden and agricultural fertilizers as well as animal waste and sewage that find their way into the storm drains and waters. The increase of nutrients causes algal blooms in both inland and coastal waters. As the algae die, the proliferating bacteria which decompose them use up much of the oxygen in the water, increasing the carbon dioxide levels. Massive fish die-offs make the news, but the increased acidification usually does not. Besides fertilizers, localized acid rains, residues from cigarette butts and acidic products washed into the waters also lower pH.

The global impact of ocean acidification is daunting. There is enough research to show that it is possible to slow the process. There is even research showing that the acidification could possibly be stopped, if stronger actions are taken. It is also clear that if we do nothing, and continue utilizing fossil-fuel as our main energy source, the process will actually accelerate. Counter-acting global warming at the same time is a bonus. The shipping industry is the sixth largest global producer of greenhouse gas emissions, and has started to downshift to a slow streaming rate. While this saves money for the companies and makes a substantial dent in their carbon dioxide production, this policy is currently voluntary and unregulated. Research has shown that establishing Marine Protected Areas and stopping destructive fishing practices increases the resiliency of marine ecosystems and helps them withstand acidification. After several

years of advocating and lobbying, California established a system of coastal Marine Protected Areas going into effect January 2012. On a federal level, the Omnibus Land Act of 2009 ties the health of our aquatic ecosystems to terrestrial behaviors and establishes a system of monitoring and development grant opportunities.

It is clear that to address this issue we need to be vigilant personally and in our communities to make a difference. Our efforts need to be personal, community-based and global. A personal assessment of how much energy we use can help us make wiser choices (clustering errands, driving more slowly, walking, carpooling, turning off lights, turning surge-protectors off). We can also look at our gardening, pets and boating practices. As consumers, we can use our buying power to demand that our products be energy efficient, and made in energy efficient factories. We can ask our local businesses and governments to be more energy efficient as well, with energy providers (often government-regulated) using a balanced array of sources instead of relying solely on fossil-fuels. Many are finding that in doing this, they are also saving money.

***Chemical equation of carbon dioxide reacting with sea water:***

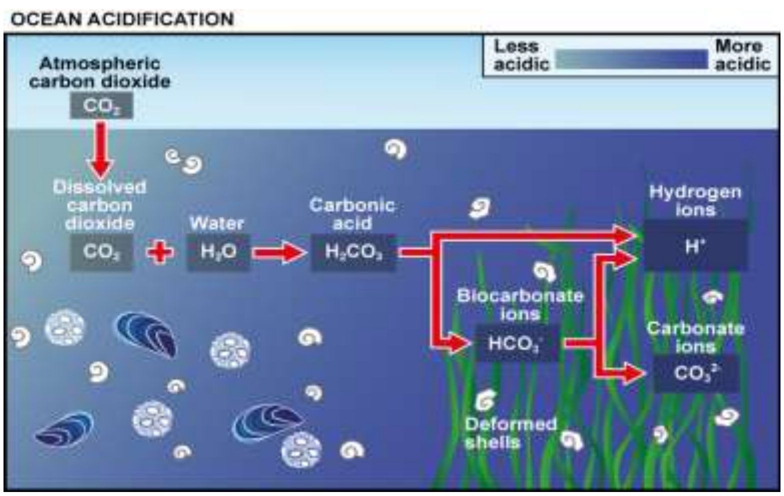
CO2 from the atmosphere dissolves into seawater via the following chemical pathway:

- **First, $CO_2$ reacts with water to form carbonic acid ($H_2CO_3^-$):**
  - **$CO_2 + H_2O \longrightarrow H_2CO_3^-$**

- **Carbonic acid can then dissociate into bicarbonate ($HCO_3$-) and hydrogen ions:**
  - **$H_2CO_3^- \longrightarrow H^+ + HCO_3^{2-}$**

- **Bicarbonate can then dissociate into carbonate ions ($CO_3^{2-}$) and additional hydrogen ions:**
  - **$HCO_3^{2-} \longrightarrow H^+ + CO_3^{2-}$**

****Carbonic acid "steals" carbonate needed by some organisms to build their calcium carbonate shells. And hydrogen ions ($H^+$) cause the pH to lower.***




RESOURCES:
http://act.oceanconservancy.org/
http://www.whoi.edu/OCB-OA/FAQs/
http://www.nrdc.org/oceans/acidification/
http://www.nodc.noaa.gov/
http://www.nrdc.org/globalWarming/solutions/default.asp
http://www.nrdc.org/oceans/acidification/science.asp
http://www.energystar.gov/
http://greenliving.nationalgeographic.com/carbon-footprints/
http://environment.nationalgeographic.com/environment/energy/great-energy-challenge/global-personal-energy-meter/

**TEACHER GUIDE – Ocean Acidification**

**ACTIVITY: Ocean Acidification Experiment**

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

## OBJECTIVES:

Students will be able to –

1. Verbalize that Ocean waters are becoming more acidic.
2. Name 3-5 ways that increased acidification impacts aquatic habitats.
3. Identify 2-4 species that are vulnerable to increased acidity in oceans.
4. Explain how change in species distribution will alter the ocean ecosystems.
5. List 3-5 ways humans can decrease ocean acidification by their own actions.
6. Discuss chemical reactions of sea water and carbon dioxide.
7. Test for pH of solutions and explain the pH scale.

## MATERIALS:

Observation Worksheets and Analysis Questions
Pencils
Student worksheets
Tape
Glass
Salt water
pH paper
Large pH scale
Magnetic board
Chemical equation magnets
Vinegar
Baking soda
Paper and plastic cups
Graduated cylinders
Measuring spoons
Petri dishes
Bromthymol blue (acid-base indicating solution) *diluted 10 mL : 1L water
Sealed samples of sea shells: 1 in air, no water, showing overall size and shape
1 in plain ocean water
1 after 1 day in pH 7, or lower for effect
1 after 1 week in pH 7, or lower for effect
1 after 1 month in pH 7, or lower for effect