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Ocean Acidification and Shell Building

Georgia Standards of Excellence:

- **SEV4.** Obtain, evaluate, and communicate information to analyze human impact on natural resources.
    - **b.** Design, evaluate, and refine solutions to reduce human impact on the environment including, but not limited to, smog, ozone depletion, urbanization, and ocean acidification.

Next Generation Science Standards:

- **HS-ESS3-6.** Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Learning Objective:

- Students will discover how increasing carbon dioxide amounts in the atmosphere impact acidification in the ocean.
- Students will investigate the impacts that ocean acidification has on shell and skeleton building organisms.

Essential Question:

- What would be the result of a long-term exposure to low pH on an organism with a calcium carbonate structure?

Key Vocabulary:

- pH
- Ocean Acidification
- Calcium Carbonate
- Aragonite
- Carbonic Acid

Materials:

- Internet connection
- Writing Utensil
- Ocean Acidification and Shell Building Worksheet

Ocean Acidification and Shell Building

Background Information:

- pH measures the hydrogen ion concentration in a solution on a scale of 0 to 14. 7 represents pure water which is the middle point for the whole scale. Anything higher than 7 is basic (or more alkaline), and anything below 7 is acidic.
    - "A solution with a pH of 5 is ten times more acidified than a solution with a pH of 6 and 100 times more acidified than a solution with a pH of 7" (NOAA, Understanding Ocean and Coastal acidification).
- "The term ocean acidification is used to describe the long-term, gradual decrease in the pH of the ocean, caused primarily by absorption of CO_2 from the atmosphere" (NOAA, Understanding Ocean and Coastal acidification).
    - Before the Industrial Revolution and the common practice of burning coal and fossil fuels, the pH of the ocean was 8.16, which is basic. As of today, the ocean sits at an average of 8.0 pH, which is a 30% change over the last hundred or so years, making the ocean more acidic than before.
- Burning fossil fuels imbalances the atmosphere's carbon dioxide percentage by increasing its presence. As atmospheric CO_2 levels increase, so do ocean levels of CO, which has a number of harmful affects on ocean environments.

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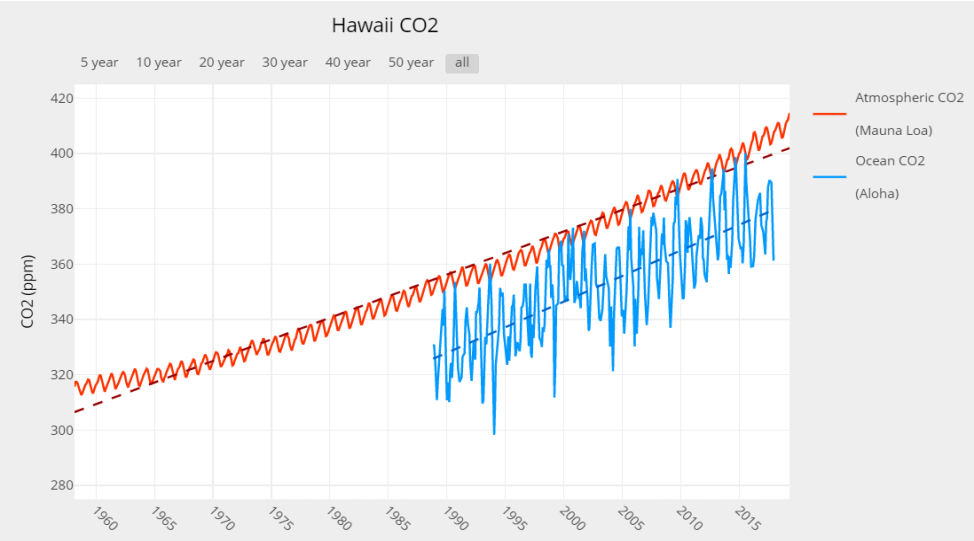
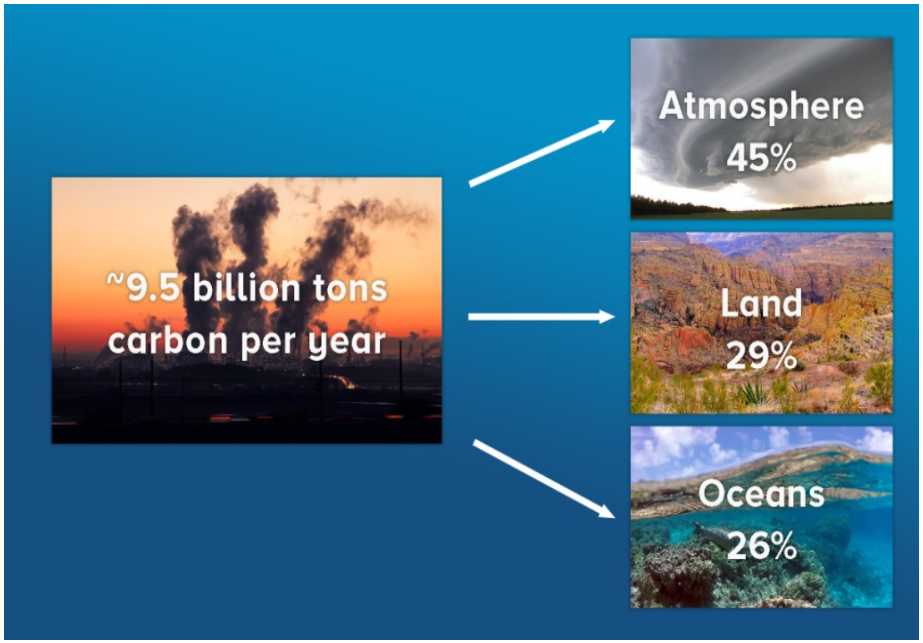
Background Information:

- Global carbon dioxide naturally fluctuates due to organisms respiration rate, seasonally vegetation including algal blooms. This fluctuation is absorbed by the atmosphere and the ocean. However, CO_2 levels have been increasing steadily because of the increased emissions by human activity, ie. burning fossil fuels, in addition to the natural fluctuations from the environment. The atmosphere is absorbing the majority of human emission while the land and oceans absorb the remainder. Current human emission rates are set to increase.





- "When CO_2 combines with seawater, it forms carbonic acid. The carbonic acid further breaks down, releasing hydrogen ions in the process" (NOAA, Understanding Ocean and Coastal acidification).
- The increase in carbonic acid is very detrimental to shell and skeleton building animals like oysters, crabs, turtles and corals because at high enough levels it dissolves the calcium carbonate shells and skeletal structures of these animals.
- "Aragonite is one of the most abundant and the most soluble forms of calcium carbonate...To help understand how much aragonite is available for shell building, scientists measure the aragonite saturation state of seawater. This measurement describes the tendency for calcium carbonate to form or to dissolve" (NOAA)

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Image retrieved from NOAA, Understanding Ocean and Coastal acidification

Ocean Acidification

What Does it Mean for Oysters?

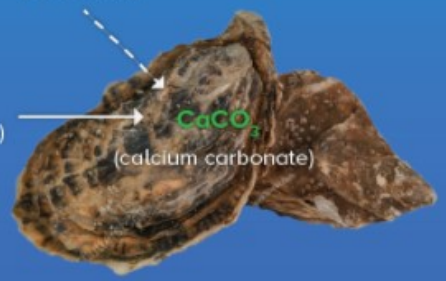
Two chemical equations dictate ocean acidification:

$CO_2 + H_2O + CO_3^{-2} \longrightarrow 2HCO_3^-$ (bicarbonate)

CO_3^{-2} (carbonate)

Ca^2 (calcium)

$CaCO_3$ (calcium carbonate)



Carbon dioxide reacts with seawater and carbonate to form bicarbonate. This reduces the amount of carbonate available in the seawater, which oysters (and other marine life) use to build their shells and skeletons. This decrease in carbonate availability can slow growth and weaken shells.

$CO_2 + H_2O \longrightarrow H_2CO_3$ (carbonic acid) $\longrightarrow H^+ + HCO_3^-$

The burning of fossil fuels releases carbon dioxide into the atmosphere, some of which is then absorbed by the ocean. Carbon dioxide reacts with seawater and carbonate to form carbonic acid which breaks down into hydrogen ions and bicarbonate. The increase in hydrogen ions causes a decrease in pH and an increase in ocean acidity. As the acidity increases, oysters may need to spend more energy regulating the chemistry inside their bodies. This may leave less energy for important things like growth and reproduction.

Adapted from: Ocean Acidification: Its Effect on Gray's Reef Coral, https://nmsgraysreef.blob.core.windows.net/graysreef-prod/media/archive/science/monitoring/images/ocean_acidification_coral_lg.gif

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Activity Instructions:

- Review the background information with the students and pass out the worksheet (included at the bottom of this document).
- Have students answer questions 1-3 using the background information.
- Then pull up a computer and open the two following links from NOAA:
    - Aragonite Saturation State: https://www.nnvl.noaa.gov/view/globaldata.html#ARAG
    - Ocean pH: https://www.nnvl.noaa.gov/view/globaldata.html#ACID
        - Down at the bottom left of each chart, click the box for "Data Values". When you hover the cursor over the chart it should now have a number highlighted above your cursor as well that indicates the data.
- Continue the worksheet and complete questions 4-8 by utilizing the digital charts to answer the questions.

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Evaluate:

- Review the students answers and make sure they are correct.
- Ask:
    - What areas on the map did you use for your comparisons for pH and Aragonite?
    - What is the correlation between these two points over time?
        - Take a sample of student answers and put them together to see how numbers in different parts of the globe vary and how/if the correlations change.

References and Extensions:

"Story Map Series." noaa.maps.arcgis.com. Accessed August 21, 2020. https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=adec7620009d439c85109ab9aa1ea227.

"Ocean Acidification." Ocean acidification | National Oceanic and Atmospheric Administration. Accessed August 21, 2020. https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification.

Ocean Acidification. *National Geographic.* Accessed April 27th, 2017**.** Retrieved from: https://www.nationalgeographic.com/environment/oceans/critical-issues-ocean-acidification/

Ocean Acidification and Shell Building Worksheet

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Instructions: Use the background information of this lesson, supported by your own extended research, to answer the questions below:

1. What is the difference between the pH of pure water and ocean water? Why is this significant?

_____

_____

_____

2. What is ocean acidification, what is the main contributor and how does it aid in the formation of carbonic acid?

_____

_____

_____

_____

3. What is aragonite? How is it important to shell and skeleton building animals?

_____

_____

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Ocean Acidification and Shell Building Worksheet

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Instructions: Use the two following links to answer questions 4-8. Down at the bottom left of each chart, click the box for "Data Values". When you hover the cursor over the chart it should now have a number highlighted above your cursor as well that indicates the data.

Link 1: Ocean pH https://www.nnvl.noaa.gov/view/globaldata.html#ACID

Link 2: Aragonite Saturation State https://www.nnvl.noaa.gov/view/globaldata.html#ARAG

4. On both maps, go to the year 1861. Choose two spots to observe the pH level and Aragonite available. Make sure to record the latitude and longitude of the chosen spot.

(1861)Lat.:_____/Long.:_____/ pH level:_____

(1861)Lat.:_____/Long.:_____/ Aragonite level:_____

5. On both maps, go to the year 2020. Choose two spots to observe the pH level and Aragonite available. Make sure to record the latitude and longitude of the chosen spot.

(2020)Lat.:_____/Long.:_____/ pH level:_____

(2020)Lat.:_____/Long.:_____/ Aragonite level:_____

6. According to this data collected, what has happened to the pH level and Aragonite level over the last hundred sixty years? How are these two factors related to each-other?

_____

_____

_____

_____

Ocean Acidification and Shell Building Worksheet

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Instructions: Use the two following links to answer questions 4-8. Down at the bottom left of each chart, click the box for "Data Values". When you hover the cursor over the chart it should now have a number highlighted above your cursor as well that indicates the data.

Link 1: Ocean pH https://www.nnvl.noaa.gov/view/globaldata.html#ACID

Link 2: Aragonite Saturation State https://www.nnvl.noaa.gov/view/globaldata.html#ARAG

7. If the trend seen from the data on the maps continues, how will shell/skeleton building animals be affected? What problems will this cause for them on a more detailed level?

_____

_____

_____

_____

8. Using what you have learned so far, what solutions to the problem could you hypothesis? (You may use further research to help you answer this question.)

_____

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_____

_____

KEY Ocean Acidification and Shell Building Worksheet

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Instructions: Use the background information of this lesson, supported by your own extended research, to answer the questions below:

1. What is the difference between the pH of pure water and ocean water? Why is this significant?

Pure water is a 7 on the pH scale and is considered true neutral. Ocean water, since it is mixed with different molecules and chemicals, is slightly basic and reads closer to 8.0 or higher on the pH scale. All different kinds of ocean life depend on a stable pH in order to grow and develop and are drastically affected if the pH level of their ecosystems fluctuate.

2. What is ocean acidification, what is the main contributor and how does it aid in the formation of carbonic acid?

Ocean acidification is the long term decrease in pH level of the ocean, making it more acidic than historically known. The main contribution to ocean acidification is the increase in CO_2 in the atmosphere which is thus absorbed by the ocean. Most of the increased CO_2 in the atmosphere is caused by human activity. When CO_2 and H_2O mix, it forms carbonic acid.

3. What is aragonite? How is it important to shell and skeleton building animals?

"Aragonite is one of the most abundant and the most soluble forms of calcium carbonate" (NOAA) and it helps to build the shells and skeletons of animals like oysters, clams, crabs and corals that have a calcium carbonate structure which is similar to humans' calcium formed skeleton. Animals depend on the availability of molecules to form aragonite to pull in as a resource to form their external or internal structures.

KEY Ocean Acidification and Shell Building Worksheet

Instructions: Use the two following links to answer questions 4-8. Down at the bottom left of each chart, click the box for "Data Values". When you hover the cursor over the chart it should now have a number highlighted above your cursor as well that indicates the data.

Link 1: Ocean pH https://www.nnvl.noaa.gov/view/globaldata.html#ACID

Link 2: Aragonite Saturation State https://www.nnvl.noaa.gov/view/globaldata.html#ARAG

4. On both maps, go to the year 1861. Choose two spots to observe the pH level and Aragonite available. Make sure to record the latitude and longitude of the chosen spot.

Students need to choose two points on the map by hovering their cursor over the selected location.

5. On both maps, go to the year 2020. Choose two spots to observe the pH level and Aragonite available. Make sure to record the latitude and longitude of the chosen spot.

Students need to choose two points on the map by hovering their cursor over the selected location.

6. According to this data collected, what has happened to the pH level and Aragonite level over the last hundred sixty years? How are these two factors related to each-other?

No matter which points the students choose, they will see that the pH level is decreasing (meaning that ocean water is becoming more acidic than before) and the level of available aragonite is decreasing as well (meaning that there is less available). As the pH decreases, more carbonic acid is formed in the water which dissolves aragonite and other calcium carbonate structures.

KEY Ocean Acidification and Shell Building Worksheet

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Instructions: Use the two following links to answer questions 4-8. Down at the bottom left of each chart, click the box for "Data Values". When you hover the cursor over the chart it should now have a number highlighted above your cursor as well that indicates the data.

Link 1: Ocean pH https://www.nnvl.noaa.gov/view/globaldata.html#ACID

Link 2: Aragonite Saturation State https://www.nnvl.noaa.gov/view/globaldata.html#ARAG

7. If the trend seen from the data on the maps continues, how will shell/skeleton building animals be affected? What problems will this cause for them on a more detailed level?

The availability of calcium carbonate structures will decrease and thus the animals that rely on this to build their shells and skeletons will spend more energy maintaining what skeletons/shells they have and the skeletons/shells will be weaker as a whole, making the animals more vulnerable to environmental impacts and predators.

8. Using what you have learned so far, what solutions to the problem could you hypothesis? (You may use further research to help you answer this question.)

Students may answer this question with their own guesses, but it is strongly suggested that they do at least a minimal amount of research to help answer the question. Some answers may include: Using renewable energy resources instead of fossil fuels and animal rehabilitation in human maintained facilities including healing, breeding and aquaponics.