Ocean Acidification: Shell Crushing Game

Teacher Guide

Activity Overview

As greenhouse gases such as carbon dioxide (CO_2) are released into the atmosphere, a portion is dissolved into the ocean. This causes the ocean to become more acidic, which makes it difficult for marine calcifiers to build their shells. To demonstrate to students the effect of ocean acidification on these marine calcifiers, the shell crushing game can be conducted. This activity requires some building, materials, and work ahead of time, but once it is built, it can be used over again and is loads of fun! With a constructed crushing lobster claw, students will test the strength of present day and acidified 'shells'. Students will then compare how strong their control and acidified shells were to understand the effects of ocean acidification on calcifiers.

Learning Level

Middle School (6th - 8th)
High School (9th - 12th)

Duration

Class time: 40 - 60 minutes
Teacher preparation: 1 - 2 hours

Next Generation Science Standards

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

HS-ESS3-3 Earth and Human Activity
Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

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Focus Question

How does ocean acidification affect the shell strength of marine calcifiers?

Objectives

Students will be able to:
- Explain how the structure determines function in calcified shells
- Understand and explain some of the consequences of ocean acidification
- Describe marine predator-prey interactions under normal and acidified conditions

Attributions

This activity, created by Dr. Louise Cameron, is based on research conducted in Dr. Justin Ries' Lab and Dr. Jonathan Grabowski's Lab at the Northeastern University Marine Science Center. Dr. Isaac Westfield of the Ries lab helped with the preparation of activity materials. The development of this activity was funded by NSF-OCE 1635423 and NSF-DEB 1655701 to Dr. Katie Lotterhos.

Background

What is ocean acidification?

Most of us know that when we add excess greenhouse gases, such as CO_2, into our earth's atmosphere it causes our planet to warm. Another consequence of greenhouse gas production that isn't talked about as much is ocean acidification. When we release CO_2 into the atmosphere it can do several things:

1. It can stay in the atmosphere. This is what causes global warming.
2. It can get absorbed by plants through photosynthesis.
3. It can dissolve in the ocean. This is what causes ocean acidification.

In fact, our ocean has taken up approximately a third of all anthropogenically produced CO_2 so far – if it didn't, our planet would be warming much faster than it already is! When CO_2 dissolves in seawater it reacts with water (H_2O) to form carbonic acid. This releases protons (H^+ ions) and lowers the pH of the seawater – making it more acidic. These released protons then react with carbonate ions (CO_3^{2-}) to form bicarbonate ions (HCO_3^-).

How does this affect life in the sea?

Many marine organisms are osmo-conformers. This means that the chemistry of their tissues is in balance with the chemistry of their surrounding seawater. Changing the pH of seawater also changes the tissue pH of marine organisms which makes it more difficult for enzymes to function normally.

Many marine organisms, known as calcifiers, also build shells from calcium carbonate. These include shellfish that we eat such as mussels, clams and oysters. They also include habitat forming organisms like corals. To build shells, these organisms need a high concentration of calcium and carbonate, which are the substrates, or building blocks, that react to form calcium carbonate. When protons react with carbonate ions to form bicarbonate ions, the concentration of carbonate ions in seawater decreases. This makes it harder for calcifiers to build shells. Once the concentration of carbonate ions gets low enough it is said to be 'under-saturated' and shells start to dissolve.

Ocean acidification in the classroom

Like many concepts in chemistry, ocean acidification can be hard for students to grasp as it is not easy to visualize. The following activity can be used to demonstrate the consequences of ocean acidification.

Materials

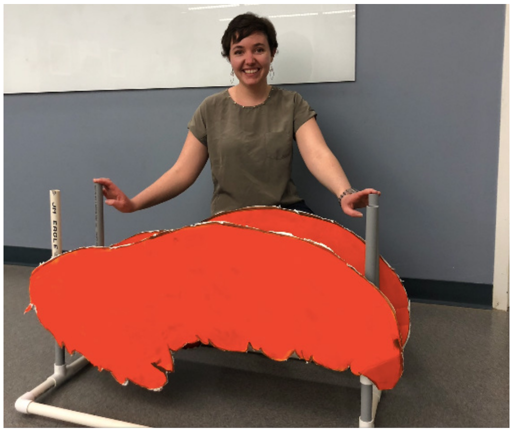
For the lobster claw:

- PVC piping (measurements on p. 4)
- (4) PVC 90° elbow joints
- (8) PVC equal tee joints
- (1) 12”x36” plywood board
- (2) A2 sheets of white foam poster board
- (2) 2”x4’ Styrofoam blocks
- (2) 5” Styrofoam balls
- (2) 27 gallon storage totes
- Acrylic paints (for the claw)
- Wood glue
- Box cutter

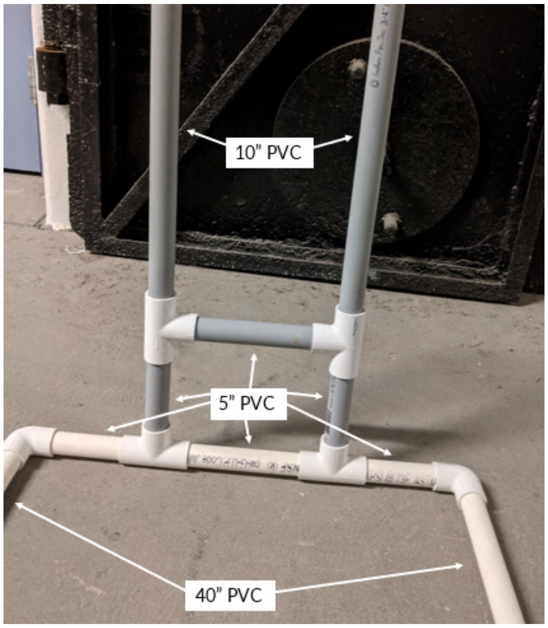
Need access to:

- A drill with a hole saw attachment
- An electric bandsaw
- Safety glasses

Teacher Preparation



1. Gather all materials
    a. Materials can all be purchased at Home Depot or any other hardware store
2. Create the crushing claw
    a. Draw a large lobster claw onto each of your poster board sheets. It should be slightly larger than your plywood board. To the right, see an example of Louise’s final lobster claw, get as creative as you like!
    b. Cut out each claw using your box cutter
    c. Decorate the lobster claw with your acrylic paint and leave to dry
3. Make the claw frame
    a. Cut the PVC into pieces of the following size:
        i. (2) of 40”
        ii. (12) of 5”
        iii. (4) of 10”
    b. Use these pieces of PVC to assemble your frame. To form the base, place an 90° elbow joint at each end of the 40” pieces and attach them to a 5” section, to form two bracket shapes. Use 4 of the tee joints and two of the remaining 5” sections to finish the base of your frame. You will have a large rectangle with four tee joint spaces that will be used to form the stand for your claw.
    c. Form two H-shapes with the remaining PVC and tee joints. Place these into the open ends of the tee joints on your base.



4. Assemble the claw
    a. Line your plywood board up with the H shapes on your stand and draw guide marks to make your holes. Make a hole in each of these using your hole saw.
    b. Glue your plywood board onto the inside of one of your lobster claws and leave to dry. You may need to cut a groove into the poster board to support the stand, or add extra wooden supports. Once the glue has set, glue the other lobster claw to the other side of the plywood.
    c. To add crushing 'grooves', cut your Styrofoam balls in half and glue them to the underside of the plywood.


    d. When completed, the plywood board should rest on the PVC piping in the below picture.

5. Create shell crystals
    a. Use the electric bandsaw to cut your Styrofoam sheets into 2" by 2" by 6" blocks. Set half of them aside as they are: these will be your 'present day' control crystals.
    b. With the rest, use the bandsaw to wear away the edges into curved or angular edges to make 'acidified' crystals. Do this randomly to create lots of different shapes. Place all of your acidified crystals in one storage tote, and all of your control crystals into the other tote.

Procedure

Step 1. Introduce focus question to the class (5 minutes)
Pose the focus question, *"How does ocean acidification affect the strength of shells built by marine calcifiers?"*, to the class and begin the lesson with a short discussion. What do students already know about ocean acidification, and how can they use that information to understand its effect on calcifiers. Ask them to explain their thinking.

If necessary, clarify that marine calcifiers are organisms in the ocean that use carbonate and calcium ions dissolved in the seawater to construct their shells and skeletons, such as mussels or clams.

Step 2. Provide the context for the activity topic (5-10 minutes)
Once the short discussion finishes, begin introducing the topic of the activity: how organisms are affected by ocean acidification. If necessary, begin with a short presentation on what ocean acidification is.

Explain that ocean acidification lowers the concentration of carbonate ions in seawater and makes it harder for marine organisms to build their shells. Each shell is made out of thousands and thousands of calcium carbonate crystals. Normally, these crystals have a regular, rectangular shape. Under ocean acidification, the crystals start to dissolve and are harder to build. The crystals instead appear rounded at the edges. Additional information about this topic can be found in the earlier Background section.

Ask the class how they think the shape of the calcium carbonate crystals will affect the strength of a shell. Do they think it is easier to build a shell with square or round blocks?

Step 3. Set up the activity (2 minutes)
Bring out the lobster claw and the styrofoam blocks. Separate the lobster claw portion from the PVC piping so students can build the 'shell' within the PVC base. On the white board at the front of the classroom, draw a table to write results in. An example is below:

Trial Number	Control Crystals	Acidified Crystals
Trial 1		
Trial 2		
Trial 3		

Step 4. Conduct the activity (20-30 minutes)

1. Explain to the students that the giant lobster claw represents predators, such as lobsters, that will try to consume shelled animals, like mussels or clams. They will be building the shells of the mussels/clams out of the styrofoam blocks, which represent calcium carbonate crystals. The bivalve does not want to be eaten, so they must build it as strong as they possibly can!

2. Call on 3-4 students to try to build a shell out of the square blocks. They should build their shell within the base of the PVC piping structure. The shell should be 3 crystals wide, 3 crystals long, and 5 crystals deep. However, they can't pick and choose which crystals they are using! They must randomly pick the blocks, since a mussel or clam can't pick which crystals to use either.

3. Test the strength of the shell with the lobster crushing claw once the students have finished building. Place the lobster claw portion of the structure onto the PVC piping, and let the claw drop onto the shell. If needed, ask a student or another adult to help with the claw dropping portion.

4. Ask the students that built the shell to count the number of crystals that fell off.

5. Write this number in the appropriate box in the table drawn on the board.

6. Repeat these steps for the control crystals for however many trials you would like with different groups of students. You could repeat it until half the class has a turn building the shell - about 3 times.

7. Remind students that under ocean acidification, the calcium carbonate crystals start to dissolve and are harder to build. The rounded styrofoam blocks represent these acidified crystals.

8. Repeat steps 2-6, but with the acidified (rounded) crystals.

9. *optional* Calculate the mean and standard error of the whole class' results for each treatment. Then, use a t-test to compare the means of each group. Are they statistically different? How could you improve your statistical power?

10. *optional* If there is time, you can have another variable in addition to the control and acidified blocks. Explain to students that in nature, shells are often built with crystals laid down in opposite directions, like Jenga blocks. This is called 'cross-hatching'. Repeat activity steps 2-6 above, but with rectangular blocks cross-hatched.

Step 6. Discuss main takeaways and evaluate understanding of the topic (5-10 minutes)
Ask the students how they think ocean acidification will impact predator-prey interactions in the ocean, since marine organisms use their shells to protect them from predators.

If you did the t-test, how could students increase the statistical power?

If you did the cross-hatching, what are some examples of where cross-hatching might be useful to humans?

Conclude the activity by saying that ocean acidification is changing the pH of our oceans, leading to weaker shells for calcifiers, making them more vulnerable to predators.

Vocabulary

anthropogenic: relating to, or resulting from the influence of human beings

buffering capacity: the amount of an acid or base that can be added to a volume of a buffer solution before its pH changes significantly

calcifier: organisms that use carbonate and calcium ions dissolved in the seawater to construct their shells and skeletons

global warming: the long-term heating of Earth's climate system due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere

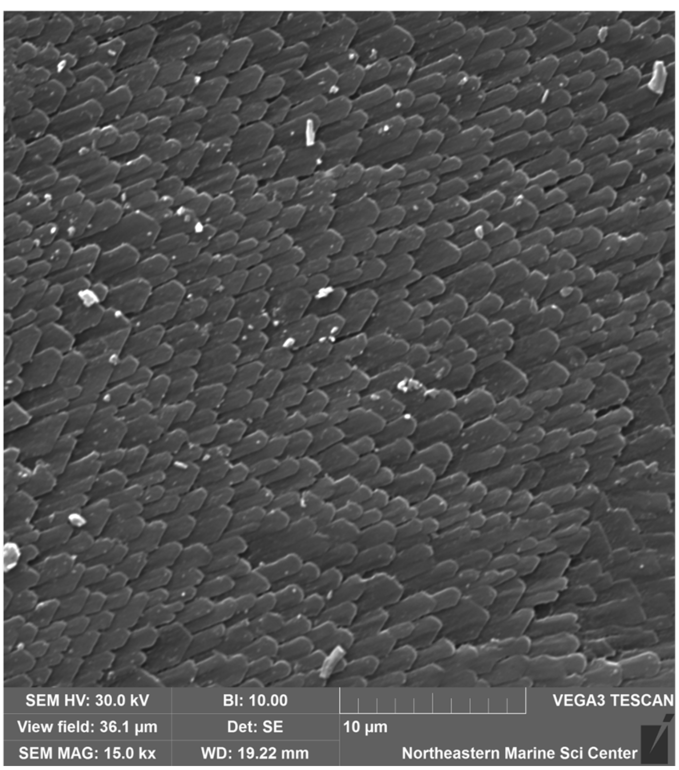
greenhouse gas: gaseous compounds that absorb infrared radiation, trap heat in the atmosphere, and contribute to the greenhouse effect

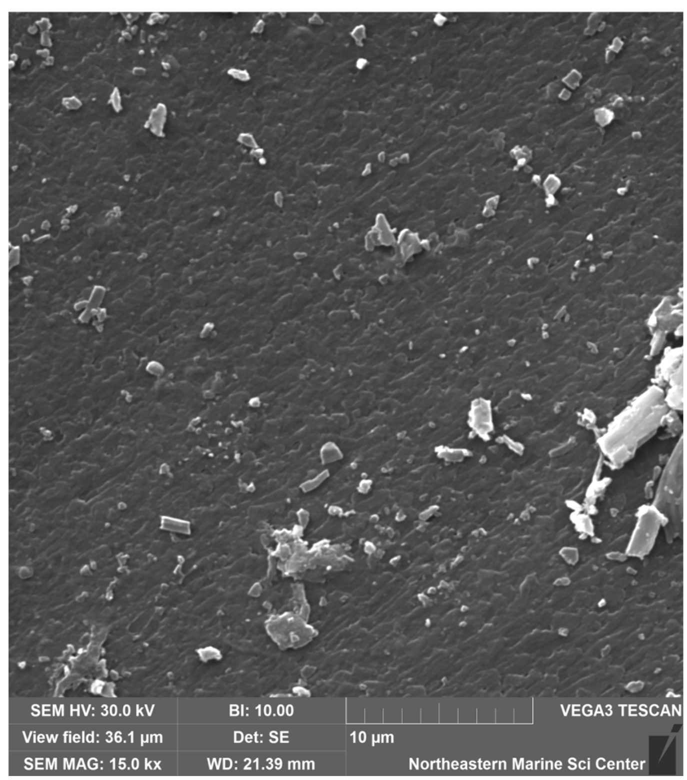
ocean acidification: A reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere

osmo-conformer: marine organisms that maintain an internal environment which is isotonic (equal) to their external environment

Supplemental Material

Below are scanning electron microscope images of scallop shells that are magnified 15,000 times. The blocks that are visible are calcium carbonate crystals. In the image on the left, the calcium carbonate crystals all have roughly the same shape and size, and overlap neatly, which gives the shell a high strength. This scallop was collected from an area with naturally high pH. The image on the right is of a scallop collected from a natrually low pH area. The crystals look more crumbly and do not have well-defined edges. This shell is weaker than the shell from the higher pH area.





About the Scientist

Behind this activity is a scientist working on valuable research in the marine science field. **Dr. Louise Cameron** completed her PhD at the Northeastern University Marine Science Center working in the Grabowski and Ries labs. Her research examined bivalve vulnerability and resilience to ocean acidification. She is currently doing a postdoc with Dr. Aleck Wang at Woods Hole Oceanographic Institute, where she is measuring benthic carbonate chemistry across Atlantic sea scallop fishing grounds to create a spatial model of the sensitivity of Atlantic sea scallop fishing grounds in future ocean acidification conditions. To learn more about Dr. Cameron's research, please use the information below.

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