



Carbonated Communities: Effect of Climate Change & Carbon Pollution on Ocean Animals, Part One

Lesson by Lacey Moore

Video Title:

- *Molluscs: Pycnopodia Chases Abalone*

Activity Subject: climate change/carbon pollution, intertidal communities

Grade Level: 6-8 grades

Introduction

This series of two lessons utilizes current scientific research (by Dr. Josh Lord and Dr. Jim Barry) on the effects of climate change and carbon pollution on communities in the intertidal. Much research before this focused on individual species.

In this first lesson, students watch a video depicting a predator-prey relationship and then consider challenges to ocean animals. Then through a combination of a presentation and a video, they are introduced to climate change/carbon pollution's effect on the ocean (ocean acidification and temperature increase) and what is known about how ocean organisms are affected. Students then examine the behavior, growth and interactions of four species that comprise a community in a healthy intertidal ecosystem (and are the subject of the investigation).

In the next lesson, students examine data from the scientists' research using the "identify and interpret (I^2)" method developed by BSCS science learning. They end by constructing an explanation about effects of climate change/carbon pollution (lower pH and higher temperature) on a community of intertidal species.

Assessments Discussions, Exit Ticket

Time 45-60 min

Group Size Varies; individual, groups of 3

NEXT GENERATION SCIENCE STANDARDS

MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

Related:

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations

MS-ESS3-5 Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century

LEARNING OBJECTIVES

After this lesson, students will be able to:

- Explain two effects of climate change on the ocean (higher temperature and lower pH).
- Identify and describe interactions of intertidal species in a healthy ecosystem.
- Hypothesize effects of climate change (higher temperature and lower pH) on the growth, behavior and interactions of intertidal species.

Materials

- Internet connection, computer and projector to watch *Molluscs: Pycnopodia Chases Abalone* (available to download) as a whole class
- “Lesson One-Carbonated Communities presentation” to project for whole class
- “Presentation Talking Points-Part One” for teacher
- “Species Spotlight worksheet” per student
- “Intertidal Species cards,” one set of five per student group of three

Preparation

1. Check to ensure *Molluscs: Pycnopodia Chases Abalone* video is compatible with your technology. Download if necessary.
2. Review “Carbonated Communities presentation” and “Presentation Talking Points-Part One.” You may want to print the talking points (they are also in PowerPoint notes pages).
3. Make copies of “Species Spotlight worksheet,” one per student.
4. Review suggested prior knowledge below and decide if you’ll do additional background building lessons before this one.

Prior Knowledge

This lesson will have more meaning if students have prior knowledge (or will gain more knowledge) about pH, human-released carbon dioxide (referred to in this lesson as carbon pollution) and ocean acidification. Also, this lesson involves students analyzing and interpreting already existing graphs and data collected by scientists. It will be most successful if students have had practice collecting their own data and creating graphs before this lesson.

These are some existing lessons that will add to depth to this learning experience. Do them before or after depending on your students and learning goals. See these suggested lessons in “Resources.”

Procedure

1. WATCH MOLLUSCS: PYCNOPODIA CHASES ABALONE VIDEO AND SET STAGE FOR PHENOMENON OF OCEAN ACIDIFICATION. (10 MIN)

Once students arrive, tell them in the next few classes they will be investigating a challenge facing ocean animals. Project “Carbonated Communities presentation” and play the *Molluscs: Pycnopodia Chases Abalone* video on slide three:

<https://www.shapeoflife.org/video/molluscs-pycnopodia-chases-abalone>. Have students consider these questions as they watch the video: *What are examples of natural animal behaviors and interactions? What challenges face ocean animals?* as they watch the video. At the end of the video, have students think-pair-share about those questions. Write student ideas on the board. Challenge them to find patterns in their ideas. Some natural behaviors and interactions may include predator/prey (like sea star and abalone), competition, finding food, molting/growing, etc. Challenges may be naturally-occurring (e.g., storms, predation, competition, finding food, lower oxygen conditions due to sedimentation caused by rain, etc.) or human-caused (e.g., pollution that includes plastics, pesticide and herbicide runoff, oil spills, more destructive fishing methods resulting in bycatch and habitat damage, ocean acidification, ocean temperature rise).

2. CONTINUE “CARBONATED COMMUNITIES PRESENTATION” INTRODUCING CARBON POLLUTION’S EFFECTS ON OCEAN ANIMALS. (10-15 MIN)

Use “Carbonated Communities presentation” to introduce effects of human-released carbon dioxide on the ocean. Use “Presentation Talking Points-Part One” or the notes on the slide for suggested talking points. Emphasize the question on slide nine: *How might lower pH (ocean acidification) and rising ocean temperatures affect behavior and growth of animals?* Tell students that this is the question they’ll be investigating over the next few lessons. (You may choose to pause this lesson here and do one or more of the hands-on lessons exploring ocean acidification included in “Resources.”)

Share one of the following videos to review (or introduce) some of the concepts:

- Ocean Acidification by Alliance for Climate Education (3 min)
https://www.youtube.com/watch?time_continue=180&v=Wo-bHt1bOsw
- Grist-produced video about ocean acidification (2 min)
<https://www.youtube.com/watch?v=qAkhuETyn5U>
- NRDC’s shortened video (Acid Test) on ocean acidification (3 min)
<https://www.youtube.com/watch?v=aG3n1fAa7vk>

Have students use a 3-2-1 strategy during the video and in their science notebook or on a piece of paper: write three things they learned, two things they want to learn more about and one question they have.

3. INTRODUCE INVESTIGATION AND CHALLENGE STUDENTS TO USE INTERTIDAL SPECIES CARDS TO IDENTIFY RELATIONSHIPS BETWEEN SPECIES. (20-30 MIN)

Continue to use “Carbonated Communities presentation” and “Presentation Talking Points-Part One” (or the notes page) to introduce Dr. Josh Lord and Dr. Jim Barry’s investigation on intertidal communities (abalone, whelks, crabs, mussels and sea lettuce). Students will examine investigation set-up, methods and hypothesis, analyze and interpret data collected by the scientists, make an evidence-supported claim and compare their claim to the scientists’ findings throughout the rest of this lesson and the next.

Once the presentation is over, pass out one “Species Spotlight worksheet” to each student and a set of the five “Intertidal Species cards” to groups of three. Using the information on each card (habitat, size, diet, interesting facts) they’ll construct a food web and consider how ocean acidification and increased temperature might affect each organism. Then they’ll compare their ideas to that of the scientists.

4. EXIT TICKET-HOW MIGHT YOUR SPECIES BE AFFECTED? (5 MIN)

On a scratch piece of paper, have students choose one of the species and quickly describe how it might be affected by ocean acidification and increased temperature. Remind them to write their name on it and collect the papers as students leave. Use student ideas as a formative assessment.

Extension

Have students read the Featured Scientist article on “Dr. James Barry, Sr. Scientist, Monterey Bay Aquarium Research Institute (MBARI)” at <https://www.shapeoflife.org/news/dr-james-barry-sr-scientist-monterey-bay-aquarium-research-institute-mbari>. This lesson focuses on research he conducted with Dr. Josh Lord.

Resources

Lessons

Ocean Acidification Experiment: Impacts of Carbonated Sea Water on Mussel and Oyster Shells: Lesson by NOAA

http://www.cisanctuary.org/ocean-acidification/PDFs-WorkshopPage/Impacts%20of%20Carbonated%20Sea%20Water%20on%20Mussel%20and%20Oyster%20Shells_Oct_%202015.pdf

This hands-on lesson involves students collecting data over time as they expose shells to seawater at different levels of acidity representing current and potential future ocean conditions. They construct an explanation describing the impact of acidified (carbonated) water on different kinds of shells (mussels and oysters).

The Power of pH: Changing Ocean Chemistry: Lesson by Monterey Bay Aquarium

<https://www.montereybayaquarium.org/-/m/pdf/education/curriculum/aquarium-9-12-power-of-ph.pdf>

Students explore pH and how carbon dioxide release from the burning of fossil fuels increase the acidity of the ocean. First they create their own pH scale through a serial dilution of hydrochloric acid and sodium hydroxide. They then compare the pH of fresh and sea water and add carbon dioxide (with a balloon and straw) to observe how pH is affected. Finally, they add calcium carbonate (or crushed shell) to an acidic solution and see what happens. Brief one-page age-appropriate readings on pH and ocean acidification included. (Note: Written for grades 9-12 so may need to adapt.)

Ocean Acidification in a Cup: Exploratorium Science Snack

<https://www.exploratorium.edu/snacks/ocean-acidification-in-cup>

A quick demonstration of how the diffusion of a gas (carbon dioxide) into a liquid (universal indicator) causes ocean acidification. A nice explanation of the chemistry is included.

Interaction at the Air-Water Interface II: Lesson by Carbo-Schools

http://www.carboeurope.org/education/CS_Materials/Air-SeaInterfaceGasExchange2.pdf

This hands-on activity uses floating candles on a universal indicator solution in a closed container to demonstrate how carbon dioxide mixed with water increases acidity.

Interpret the Impacts of Rising Ocean Temperatures on Ecosystems: Lesson by Science Friday

<https://www.sciencefriday.com/educational-resources/interpreting-the-impacts-of-rising-ocean-temperatures-on-ecosystems/> Students use data to model changes in fish populations on the Atlantic coast.

Articles and Background Information

Ocean Acidification: Shape of Life article, <https://www.shapeoflife.org/blog/ocean-acidification>

This describes the amount of carbon dioxide humans have released over the last 200 years (two trillion tons) and its effect on the ocean.

Ocean Acidification: Climate Interpreter Unit for interpreters and educators,

<https://climateinterpreter.org/content/effects-ocean-acidification-marine-food-chain>

Ocean Acidification: Smithsonian Ocean, <https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification>

Comprehensive background about causes and effects of ocean acidification as well as links to many other resources.

Ocean Acidification Can Mess with a Fish's Mind: Scientific American article, <https://www.scientificamerican.com/article/ocean-acidification-can-m/>

This article describes how animal behaviors change in more acidic conditions.

Other Climate Change Resources

Green Ninja, www.greenninja.org

A climate change fighting superhero, Green Ninja, encourages students to take personal action to better the planet. Free brief videos and a “Green Ninja Carbon Command” video game (<https://games.greenninja.org/carboncommand>) engage students in climate change science and creative solutions. A complete middle-school NGSS-aligned curriculum is available.

Research

Lord JP, Barry JP, Graves D (2017) Impact of climate change on direct and indirect species interactions. *Mar Ecol Prog Ser* 571:1-11. <https://doi.org/10.3354/meps12148>

Fabry, V. J., Seibel, B. A., Feely, R. A., and Orr, J. C. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. – *ICES Journal of Marine Science*, 65: 414–432
<https://academic.oup.com/icesjms/article/65/3/414/789605#13762925>

Poloczanska ES, Burrows MT, Brown CJ, García Molinos J, Halpern BS, Hoegh-Guldberg O, Kappel CV, Moore PJ, Richardson AJ, Schoeman DS and Sydeman WJ (2016) Responses of Marine Organisms to Climate Change across Oceans. *Front. Mar. Sci.* 3:62. doi: 10.3389/fmars.2016.00062
<https://www.frontiersin.org/articles/10.3389/fmars.2016.00062/full>

Slide One: Carbonated Communities: How is lower pH (ocean acidification) and rising temperatures affecting ocean organisms in the intertidal?

Slide Two: Carbonated Communities, Part One

Tell students this is what they will be doing in this lesson:

- Explore a phenomenon affecting ocean animals.
- Learn how scientists are understanding this phenomenon's effect on ocean animals.
- Examine relationships between intertidal species.

Slide Three: Watch *Molluscs: Pycnopodia Chases Abalone*

Have students consider: *What are examples of natural animal behaviors and interactions?* and *What challenges face ocean animals?* as they watch the video *Molluscs: Pycnopodia Chases Abalone* (<https://www.shapeoflife.org/video/molluscs-pycnopodia-chases-abalone>).

Slide Four: Think-Pair-Share Questions

Have students think-pair-share about both questions: *What are examples of natural ocean animal behaviors and interactions? What challenges do organisms face in the ocean (natural- and human-caused)?* Ideas may include predator/prey (as in sea star and abalone), finding food, growing/molting, etc. Natural challenges may include storms, competition, predation, finding food, lower oxygen conditions due to sedimentation from rain, etc. Human-caused challenges may include ocean acidification (lower pH), particularly harmful fishing practices (e.g., bottom trawling, etc.), temperature increase, etc.

Slide Five: Unusual Behavior

Scientists are seeing unusual behavior in ocean animals like clownfish who stray too far from home.

Slide Six: Unusual Behavior

And hermit crabs who don't hide as quickly as usual.

Slide Seven: Unusual Behavior

And even abalone, who instead of reattaching, may stay turned over or even turn into the claws (and mouth!) of predators like sea stars, crabs and sea otters.

Slide Eight: Human-Released Carbon Dioxide in the Atmosphere

These animals are behaving unusually as a side effect to the higher levels of CO₂ humans are releasing into the atmosphere. Since the Industrial Revolution in the mid-19th century (@1850s), fossil fuel combustion from the powering of our cars, lights, factories, trains, and electronics has been releasing high amounts of CO₂ into the atmosphere. An upward temperature trend, global warming, results due to the increase of CO₂ and other greenhouse gases creating a thicker "blanket" of atmosphere trapping heat within. Climate change is a broader term referring to naturally occurring changes in climate as well as global warming and all of the side effects caused by increased CO₂ like melting glaciers, heavier rainfall and more frequent drought. Global warming is causing the ocean temperature to increase and contributes to sea level rise due to thermal expansion. The CO₂ in the atmosphere directly mixes into the ocean and causes ocean acidification. This lesson focuses on higher ocean temperatures and ocean acidification due to carbon pollution (human-released carbon emissions).

Slide Nine: Lower pH and Higher Water Temperature's Effect

Have students think on their own about how lower pH and higher water temperatures may affect behavior and growth of ocean animals. Then volunteer their ideas to the class.

Slide Ten: Ocean Temperature Warming

According to the Intergovernmental Panel on Climate Change (IPCC) in 2014, in ocean surface waters, temperature is expected to rise an average of 3 to 5°C by 2100.

Slide Eleven: Effects of Ocean Warming

The effects of increased temperature (warming) on ocean animals include coral reef bleaching and damage, disrupted migration patterns (e.g., tuna, sharks, whales, turtles, etc.), changes to organism growth, reproduction, feeding patterns, etc. plus other effects scientists are still discovering.

Slide Twelve: Lower Ocean pH

Ocean pH is lower too. Surface water have increased in acidity 30% since pre-industrial (before 1850s) times. According to the IPCC in 2014, pH is expected to increase in acidity 99% and drop by 0.3 units. Human blood is in the 7.35-7.45 range. If it drops by 0.3, you will be in a coma. If it drops to 6.8, you will die (same as if it rises to 7.8). Because of the logarithmic nature (like earthquake's Richter scale) of the pH scale, a drop in 0.1 means 30% in acidity!

Slide Thirteen: How Does Ocean Acidification Work?

Here is a video of how ocean acidification works (Alliance for Climate Education's Science Short: <https://www.youtube.com/watch?v=6SMWGV-DBnk>). Play the video for students. You may choose to play it twice. Have them use the 3-2-1 strategy to write three things they learned, two things they want to learn more about and one question they still have (or some other strategy to help students maintain focus during the 3-minute video).

Slide Fourteen: Effects of Lower Ocean pH

Scientists are just beginning to understand all of the effects of lower pH on ocean animals: 1. Changing ocean communities (some species, like jellies, may thrive while others struggle), 2. Disrupted food webs (Pteropods form the basis of some marine food webs. Their shells dissolve over 30 days in seawater with 7.8 pH.) 3. Reduces ability of reef-building corals to produce their skeletons. impacts growth and reproduction of other organisms too. 4. Economic effects for shellfish fisheries and consumers. oysters, abalone, clams and mussels have a harder time building shells and staying alive.

Slide Fifteen: Research

Most research on effects of higher temperature and acidity have focused on individual species. But what about ocean communities, like in the intertidal?

Slide Sixteen: These Scientists Decided to Investigate

Two scientists, Dr. Josh Lord and Dr. Jim Barry decided to investigate.

Slide Seventeen: Investigation-Testable Question

The testable question they came up with was: How does climate change (lower pH and higher temperatures) affect feeding, growth and interaction between species in the intertidal?

Slide Eighteen: Investigation Setting

The ecosystem they decided to investigate was the rocky shore intertidal zone of Monterey Bay, CA. (Students may not know what the intertidal zone is so define if necessary: area between high and low tide marks [above water at low tide and underwater at high tide])

Slide Nineteen: Species Studied in Investigation

Most of the species they chose to study were marine snails-mussels, whelks, abalone- plus the lined shore crab. Sea lettuce was used as food for the abalone.

Slide Twenty: Investigation-Experimental Set-Up

The investigation materials and methods were not simple. To study a community, Dr. Lord and Dr. Barry set up 64 community tanks with Monterey Bay sea water flowing through each.

- In each tank was a juvenile (young) abalone in a small plastic cage (2.5 x 2.5 x 5 cm) covered in 1 mm holes for water flow. Crabs can eat smaller (juvenile) abalone. That's why it was in a cage. But it could still sense the crab's presence.
- An uncaged whelk was in the community tank as well as a caged whelk (10 cm diameter spherical plastic cage). Ten large mussels were placed weekly on the bottom of each tank and 10 were inside each whelk cage. The caged whelks were protected from being eaten by the crabs but could sense the crab's presence.
- Half (32 tanks) also had a lined shore crab.
- Half of the tanks were heated by about 2 °C. Half had CO₂ added to lower the pH by about 0.3 units. The visual shows how the tanks were set up. Some were controls, some had multiple variables like higher temperature and lower pH (added CO₂).

Slide Twenty-One: Investigation-Experimental Set-Up

The investigation took place over 10 weeks-from April 14-June 23, 2016. Here you can see the tanks with sea water tubes attached and the CO₂ tank used to lower pH by 0.3 units.

Slide Twenty-Two: Investigation-Experimental Set-Up

These coolers contained the heaters used to increase the temperature by about 2 °C in half of the tanks.

Slide Twenty-Three: Spotlight on the Species

Tell students that they are going to do an activity examining how species normally feed, grow and interact and then hypothesize how those species may react in lower pH and higher temperature conditions? Pass out "Species Spotlight worksheet" (pages 1-2) and sets of 5 "Intertidal Species Cards" to groups of three. Using the information on each card, challenge students to construct a food web and consider how lower pH and higher temperatures may affect each species.

Slide Twenty-Four: Dr. Barry and Dr. Lord's Hypothesis

Dr. Lord and Dr. Barry hypothesized that lower pH and higher water temperatures would have direct and indirect effects on the species. Direct effects-they predicted there would be minimal effect on crabs but reduced shell growth for whelks and abalone. Indirect effects-they predicted whelks and abalones would eat less and those populations would decrease due to crabs doing well plus the negative impacts on shell growth.

Species Spotlight- Page 1 Student's Edition

1. In your group, read each species card (or each of you share one or two with the group). Share habitat, size, diet and interesting facts of each species. Answer the following questions:

- Who eats who? Use the cards to construct a food web. Draw your food web below.

- How might lower pH (acidification) and higher temperatures affect feeding, growth and interactions between species? Explain in the chart below.

	Crabs	Whelks	Abalones
Feeding			
Growth			
Interactions			



Name _____ Period/Class _____ Date _____

Shape of Life
The Story of the Animal Kingdom

Species Spotlight- Page 2 Student's Edition

- How do you think the scientists determined the variables, controls and experimental set-up (presence of crabs, caged and uncaged whelks, lower pH (added CO₂), normal pH (no added CO₂), high temperatures, normal temperatures)? Explain.

- How do your ideas compare to the hypothesis of Dr. Lord and Dr. Barry?

Intertidal Species Cards- Page 1
Student's Edition

Abalone
Haliotis rufescens



Habitat: Rocky areas with kelp; British Columbia, Canada to Baja California, Mexico

Size: to 30 cm (11.8 in.)

Diet: herbivores: various kelp, coralline algae, bacteria

Interesting facts:

Largest species of abalone. People like to eat it and it's successfully farmed. May live 35 to 54 years. Facing problems due to overfishing, disease, predation of animals like sea otters and illegal poaching. Two species (out of 8 in CA) are listed as endangered and two species are listed as species of concern. Abalones catch passing seaweed for food. When the tentacles sense a piece, the abalone rears toward it, then grabs the seaweed with its big foot.

Lined Shore Crab
Pachygrapsus crassipes



Habitat: west coast of North to Central America and in the western Pacific in Korea and Japan

Size: to 5 cm (2 in.)

Diet: omnivore; mussels, juvenile abalone and other animals in high tide zone and algae in low tide zone

Interesting facts:

Believed to be herbivore or scavenger for years then observed eating smaller mussels and juvenile abalones. This crab is flat and can hide in cracks in the rocks. It has few predators because of its speed and agility. However, if a predator snatches a shore crab's leg, it can shed the limb and escape. A new leg will grow back.

Mussels
Mytilus galloprovincialis



Habitat: native to Mediterranean coast and Black and Adriatic Seas, invasive in much of the world

Size: to 14 cm in length

Diet: omnivore; filter feeder: eats plankton

Interesting facts: Found attached to rocky shores with high water flow open coast. Evidence of people eating mussels dates to 4th century B.C. in Spain. Mussels are still farmed for food. They rarely live below the low tide mark. They prefer fast moving water free of sediment (like wave action) and areas where nutrient-rich upwelling occurs. They are considered a nuisance species (pest) for outcompeting and displacing other species of mussels around the world.

Sea Lettuce
Ulva lactuca



Habitat: high and low intertidal, can grow in water up to 75 ft. deep

Size: to 20 cm (8 in.)

Diet: producer; photosynthesizes and absorbs nutrients from water

Interesting facts: This very green alga is only two cell-layers thick. It is delicate-looking but can withstand pounding waves and hot, drying sun. Sea lettuce overgrows bare rock and is soon eaten by crabs and snails, like abalone. It does well in moderate levels of nutrient pollution and is used to indicate amounts of pollution. It is also used in salads and soup, ice cream, food products and medicine.

Whelk
Nucella ostrina



Habitat: Aleutian Islands (Alaska) to Cayucus (San Luis Obispo area, CA)

Size: to 4 cm (often less than 3 cm)

Diet: carnivore; drills through shells of mussels, barnacles, periwinkles, oysters

Interesting facts: This sea snail drills through shells, injects digestive enzymes into the prey's body and sucks out the tissue using proboscis. Predators are the ochre star and red rock crab. Relatives of this whelk were used to make dye for the famous purple robes of Roman royals.