6th Grade Ocean Acidification Unit

Lesson	Time
Salish Sea Challenge	Recurring
1. Human Smokestack & Carbon Cycle	60 minutes
Extension: The Other CO2 Problem Video	7 minutes
Extension: Red cabbage pH indicator	45 minutes
Extension: Carbon footprint calculator	15 minutes
2. pH of Household Solutions	30 minutes
3. Ocean Acidification and Oyster Life Cycle	45 minutes
4. I'm Melting Demonstration	15 minutes
Career Explore: Ocean Acidification and Jobs	25 minutes
Extension: Dissolving Shells Experiment	120 minutes (two 60 minute sessions)
5. Blaine Harbor Water Quality Station	25 minutes
6. Blaine Harbor Water Quality Lab Station	25 minutes
7. Blaine Harbor Organism Inventory Station	25 minutes
Extension: The ABC's of Ocean Acidification	60 minutes
8. A Tale of Two Cities & Reflection	30 minutes

Objectives

Over the course of this unit students will:

- Identify the phenomenon (color change) and interpret that a chemical reaction occurred.
- Identify sources of carbon and carbon dioxide.
- Understand the pH scale by measuring a variety of solutions.
- Understand how life thrives within an optimal pH range.
- Use a model to understand natural and human caused pressures that impact life cycle stages

- Identify the phenomenon (dissolution) and interpret that a chemical reaction occurred.
- Measure water quality parameters to determine the health of a water body in their local watershed.
- Understand how changes in ocean pH affect calcifiers such as oysters.
- Demonstrate understanding of the carbon cycle, ocean acidification, and human impacts.
- Explore careers related to ocean acidification.

Background

Ocean acidification is the ongoing increase in the acidity of the Earth's oceans, caused by the uptake of carbon dioxide (CO_2) from the atmosphere. All life forms on earth are carbon based, so an understanding of the carbon cycle will help students recognize different sources of carbon dioxide and how excess carbon emissions can impact oceans. Shellfish are calcifiers that make their shells by removing calcium carbonate ($CaCO_3$) from water and depositing it as the shell or exoskeleton. The mollusc shell is formed and repaired by the organ called the mantle. The mantle deposits calcium carbonate minerals that are extracted from water through the gills to form the shell, a process that requires cellular energy. A pH environment slightly higher than neutral favors shell formation. Increased atmospheric carbon dioxide from fossil fuel combustion causes ocean acidification. A shift to lower pH (higher H^+) conditions make the carbonate ion, CO_3, unavailable for shell formation. That means, the mantle has to pump the excess hydrogen ions (H^+) out in order to make the carbonate ion (CO_3) available to make the shell, which requires a lot of cellular energy. As a result, shell formation may be interrupted or shells may be thinner, putting organisms at greater risk of predation. Shellfish life cycles can be disrupted: motile oyster larvae (spat) may not be able to attach to a substrate and survive to adulthood. As oceans become warmer and more acidic their shells will either thin, or the animals will have to expend more energy on producing thicker shells. This change will affect shellfish populations, the ocean food web, and the shellfish industry.

Standards Alignment

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-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts

Analyze & Interpreting data Scientific knowledge is based on empirical evidence. Engaging in argument from evidence	PS1.B Chemical reactions LS2.C Ecosystem Dynamics,Functioning and resilience	Patterns Cause and effect Stability & change

Salish Sea Challenge

Subject
Human Impacts on their Environment

Objectives
The students will:

- Choose actions to be better stewards of their environment
- Record actions to quantify program impacts

Materials
Printed Salish Sea Watershed Challenge double sided

Size/setting/duration
Entire class/ classroom/ recurring

Background
GSSC uses the Salish Sea Challenge to empower students to be stewards of the Salish Sea. The Salish Sea Challenge is used in all of GSSC's programming and serves as a thread through all of the scaffolded units. Documentation of these actions is vital to show program impacts and serve as our grant funding deliverables.

Procedure

- The Salish Sea Challenge should be presented to students in the first lesson of the unit and sent home for discussion with their families. While this list is extensive, it is not comprehensive. Students can also record actions to improve the environment that are not on the list.
- Weekly in-class reminders should be given to track their actions.
- In order to assess the impacts that your class had on the environment through the Salish Sea Challenge, you will need to have students return the Salish Sea Challenge with the table on the back filled out, or hand out the post-survey, so that we are able to quantify the impact of the program. These results can be scanned and emailed to garden.salishsea@gmail.com. Students can participate in sharing their Challenge achievements during a class reflection session.

Lesson 1: Human Smokestack and Carbon Cycle

Subject
Carbon Cycle and Ocean Acidification

Objectives
The students will:

- Identify the phenomenon from the lab activity (color change) and interpret that a chemical reaction occurred.
- Identify sources of carbon and carbon dioxide.

Materials
Human Smokestack Investigation

- One set of clear plastic cups per student with covers labeled #1 and #2 and a clean straw
- Tap water (½ cup in each)
- Red cabbage pH indicator in a dropper bottle (use pipettes to add 9 ml to each cup, 6 ml will work if materials run low)
- White surface (paper or cardboard)

Carbon Cycle

- Ocean Acidification Slideshow (slides 2-14)

A hard copy of the Salish Sea Watershed Challenge

Size/setting/duration
Entire class/ classroom and outdoor space/ 60 minutes

Background
Both pH paper and chemical indicators are commonly used to indicate pH. Red cabbage juice can be used as a pH indicator because it changes color in the presence of an acid or base. The plant pigment anthocyanin is the active ingredient responsible for the color change. Red cabbage changes color due to the change in hydrogen ion concentration. Acids produce hydrogen ions in aqueous solution and have a pH less than 7. Bases contain hydroxide ions and have a pH greater than 7. At a pH of 7, a substance is neutral (neither acid nor base) due to equal numbers of hydrogen and hydroxide ions.

Procedure

1. Begin this lesson by reviewing the concept of controlled and manipulated (changing) variables. Cup #1 will be our controlled variable and cup #2 will be the manipulated variable.
2. Give students two cups (controlled #1 and manipulated #2, both with water and red cabbage indicator solution) with lids and a straw and ask students to blow into cup #2 for 1 minute. This experiment works best with a white surface (white paper) under the cups, and

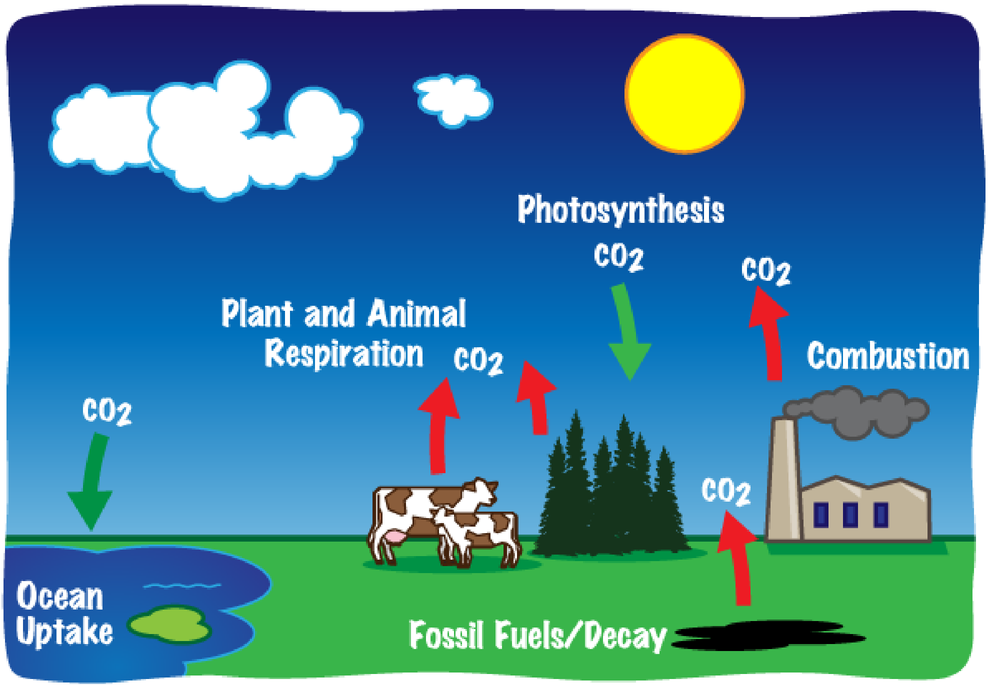
students may want to look at a partner's cups as the class is exhaling into them in order to view the change. Ask students what change they saw. Ask students for hypotheses about why this change may have occurred. (10 minutes)

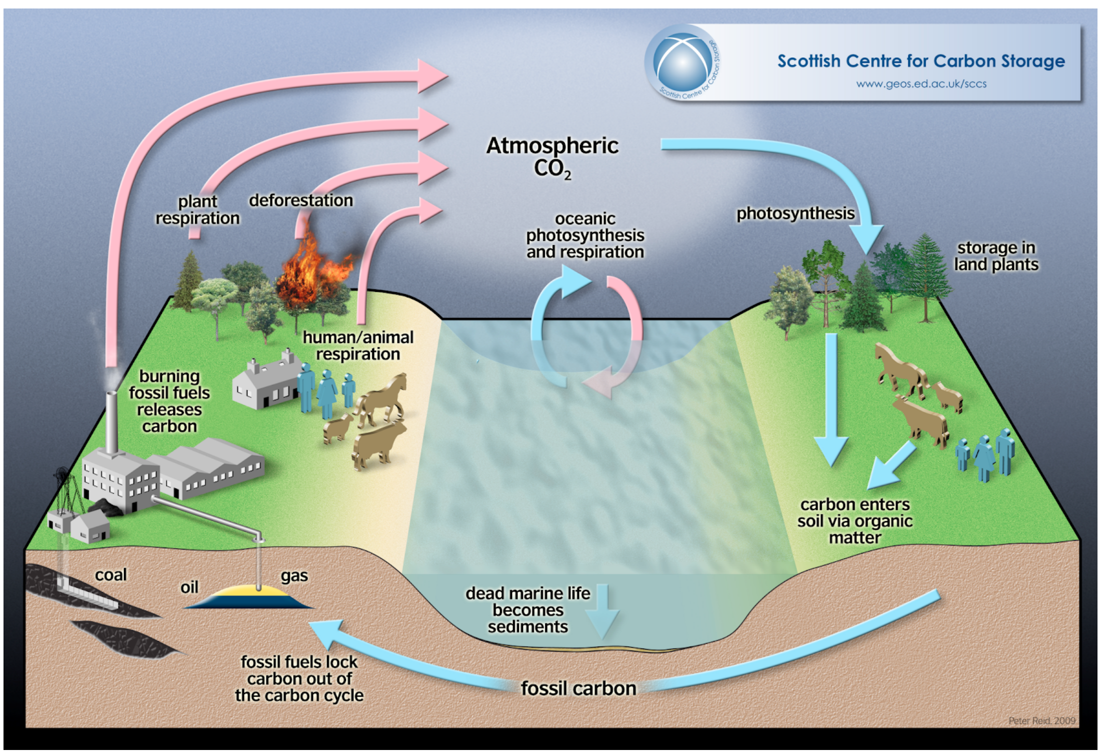
3. Introduce students to the word **respiration** and explain how breathing into the cup added carbon dioxide (one of the bi-products of respiration) into the water which changed its chemistry.
4. Explain that human respiration (breathing) is one of the natural ways that humans are part of the carbon cycle. Ask students for ideas of other sources of carbon and write them on the board. With the class, sort the list into natural and unnatural sources of carbon. Show students a diagram of the carbon cycle and explain how carbon moves through the system. (15 minutes)
5. Take students outside. Ask students to draw a model of the different carbon sources that they see and to draw arrows to show how carbon is moving through the system. (15 minutes)
6. Once students are done with their diagrams, go back into the classroom. As a class talk about different sources of carbon that were seen (add to a list in the front of the class). Ask students which sources of carbon they did not see (make sure that the ocean is included). Ask students which of these carbon sources were natural, which were unnatural, and label the carbon sources on the list. (10 minutes)
7. Brainstorm ways that students can have an impact on the carbon cycle.
8. Hand out the Salish Sea Challenge - This is a list of ideas for ways that you can have a positive impact on the health of your watershed and decrease the amount of CO2 you are releasing. Take these home and make a commitment with your families to be stewards of the Salish Sea and practice watershed healthy habits.

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-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
Analyze & Interpreting data Scientific knowledge is based on empirical evidence. Engaging in argument from evidence	PS1.B Chemical reactions LS2.C Ecosystem Dynamics,Functioning and resilience	Patterns

Graphics


Photosynthesis
CO2
CO2
Plant and Animal Respiration
CO2
Combustion
CO2
CO2
Ocean Uptake
Fossil Fuels/Decay


Scottish Centre for Carbon Storage
www.geos.ed.ac.uk/sccs
Atmospheric CO_2
plant respiration
deforestation
oceanic photosynthesis and respiration
photosynthesis
storage in land plants
human/animal respiration
burning fossil fuels releases carbon
carbon enters soil via organic matter
coal
oil
gas
dead marine life becomes sediments
fossil fuels lock carbon out of the carbon cycle
fossil carbon
Peter Reid, 2009

Vocabulary

- Steward - a caretaker or person who practices sustainable ways to help protect our environment for future generations
- Conservation - protection of things found in nature
- Respiration- a process in living organisms involving the intake of oxygen and release of carbon dioxide

Additional Exercise

Students can work in class or at home with their families to assess their carbon footprint using a carbon footprint calculator. This shows students where they can change their habits to reduce their negative influence on the environment. Included is an optional worksheet to help students evaluate their carbon footprints.

- This calculator has a middle school level option for students to use independently or in class. (The EXPLORE option does not require you to create an account)
- This calculator is designed for kids and can be used for younger students.

Classes may also want to spend more time working through the carbon cycle. Have students use the second (full page worksheet) to draw their initial ideas of what should be included in the carbon cycle, and then modify it in another color as they learn more.

Classes can also make their own red cabbage indicator or pH paper.

Students can watch The Other CO2 Problem.

Worksheet

The Human Smoke Stack

Procedure

1. Gently blow bubbles through a straw into the solution in Cup #2 for **one minute**.
2. Record the color of the solution in each cup.

	Control variable: Cup #1: No breath	**Manipulated variable: Cup #2: Added breath**
Color		

How did the solution in Cup #2 change when you breathed into it?

Write your hypothesis for why this change occurred:

We acknowledge and respect the treaty rights of the Coast Salish Peoples to the lands and waters of the SalishSea, and we recognize their stewardship since time immemorial.

The Carbon Cycle

In the space below draw a model of the carbon cycle. Use arrows to show the movement of carbon. Include the following processes: decomposition, respiration, and photosynthesis.

We acknowledge and respect the treaty rights of the Coast Salish Peoples to the lands and waters of the SalishSea, and we recognize their stewardship since time immemorial.

Salish Sea Watersheds Challenge

Scoop the Poop! Rain washes pet and livestock poop down storm drains and into our waters. P*oo*-lution can make people and animals sick and cause harmful algal blooms.

- ❏ **Scoop it, Bag it, Trash it!** I will carry bags to clean up my dog's poop when on walks.
- ❏ I will encourage my cat to use a litter box, scoop the poop, bag it, and trash it.
- ❏ I will keep livestock away from creeks and ditches, scoop the poop and cover manure piles to keep rain out.

Be Wildlife Smart! Feeding wildlife causes an inflation in their population, which increases the amount of their waste in the area where feeding occurs. It can also make wildlife more aggressive, destructive, and once human food is taken away leads to starvation.

- ❏ I will keep wildlife wild by ***not*** providing easy access to food and shelter. Always secure garbage cans, keep pet food inside, put chickens in the coop at night, and block holes to attics or crawl spaces.

Be Septic Smart! We will maintain our septic system. Failing systems can cause property damage, cost a lot of money to fix, and cause water pollution that can make people sick.

- ❏ **Evaluate before it's too late!** We will have our septic system evaluated every 1 or 3 years (depending on the system). Evaluations help find small fixes that can prevent large problems. Go to www.whatcomcounty.us/septic or call (360) 778-6000 for more information
- ❏ **Pump the Tank!** A professional will pump the tank when solids are 1/3 of tank volume.
- ❏ **Don't Strain Your Drain!** We will avoid system overload by spreading out laundry and dishwasher loads. Solids need to settle in the tank. Too much water too quickly can overload the drain field, causing failure.

Be Yard Smart! Protect your storm drains! Your yard is a place that can be a minefield of pollution. Especially if you use fertilizers, pesticides, or have animals, but you can do more to help prevent pollution from your yard getting into waterways.

- ❏ Plant native species in your yard, especially the base of hills and shorelines! Make sure, if you have a septic field, to plant species with short root systems.
- ❏ Only rain in storm drains! I will not dump toxics in drains or on the ground.
- ❏ We will not wash our car in the driveway, where the soap and oil can wash into the storm drain, which goes into the Salish Sea.
- ❏ We will position gutters to drain onto grass or garden beds and use porous materials like paving stones, sand or gravel.

Be Boat Smart!

- ❏ We will make sure the valve on the boat's holding tank is kept in the closed position.
- ❏ We will use the pump outs at the marina and never dump the holding tank into the water.
- ❏ Rinse boats and kayaks off if transferring between bodies of water.

Be Seafood Smart!

- ❏ I will make sustainable seafood choices by buying Marine Certified Seafood (MSC).

Reduce My Carbon Footprint & Conserve Energy!

- ❏ I will ride a bike, walk, or take public transportation instead of driving.
- ❏ Flying produces a ton of greenhouse gasses. Be conscientious and think about reducing how many flights you take a year or check out carbon offset programs.
- ❏ I will turn off lights, appliances, and computers when not in use and put high energy-using items like water heaters on timers.
- ❏ We will buy local products to support our local farmers and reduce transportation.
- ❏ We will plant trees, vegetation, and cover crops.
- ❏ We will compost our yard and food waste.
- ❏ I will choose a low carbon diet.

Reduce, Reuse, and Recycle!

- ❏ **Reduce!** Find plastic free and reusable alternatives to plastics you use. Minimize purchase of products with plastic packaging, avoid single use plastics and carry a reusable bottle.

- ❏ **Reuse!** Get creative and find ways to give plastic items a second life.
- ❏ **Recycle!** When you use plastic items make sure to clean and properly recycle them.

Date	Action	Number or tally times completed

Name______________________________________ Date ____________________ Core __________

My Carbon Footprint

Go to the following website:__https://depts.washington.edu/i2sea/?page=calculate
Complete the "Basic Calculator" designed for Middle School

Conclusion

Answer the following questions once you have reached the *red* "Conclusion" page.

1. What is your total footprint of CO_2 per year (in kg)?

2. What is the average footprint of CO_2 per year for one person in Washington (in kg)?

3. What is the average footprint of CO_2 per year worldwide (in kg)?

4. Complete the table with the total CO_2 for YOU for each category below.

Category	CO_2 produced by YOU (in kg)
HOME (green)	
FOOD (orange)	
PURCHASES (yellow)	
TRANSPORT (blue)	

5. Use the data in your table and graph paper to make a bar graph that shows the amount of CO_2 (dependent variable) for each category (independent variable). Make sure your graph includes all 5 elements of a quality graph.

Use your graph to answer the following questions.

6. In which category do you produce the most CO_2? Provide evidence from your graph to support your answer.

7. How important do you think it is for you to lower your Carbon Footprint? Why? Explain your reasoning.

8. Name one *realistic* thing that you could do differently that would *significantly* lower the amount of CO_2 you produce.

Lesson 2: pH of Household Solutions

Subject
The pH Scale

Objectives
Students will:
- Understand the pH scale by measuring a variety of solutions.
- Understand how life thrives within an optimal pH range.

Materials
pH of Household Solutions experiment materials for each group:

- Solutions to test: vinegar, lemon juice, club soda, pure water, baking soda, tums (optional: human smokestack before and after)
- Litmus paper cut into 1/2 to 1 inch lengths in a cup
    - Teacher note: Be careful not to handle the end of the litmus paper that will be dipped into the solution as the oils from your skin can change the results.
- A laminated pH scale that goes with the litmus paper
- A discard cup for used litmus paper.
- White surface (paper or cardboard).
- Optional: Hach kit with color wheel (for comparison)

Size/setting/duration
Entire class/ classroom/ 60 minutes

Background
Both pH paper and chemical indicators are commonly used to determine pH. Red cabbage juice can be used as a pH indicator since it changes color in the presence of an acid or base. The same plant pigment in the red cabbage indicator (anthocyanin) is responsible for the color change of the pH paper. Acids produce hydrogen ions in aqueous solution and have a pH less than 7 which will turn the paper red. Bases contain hydroxide ions and have a pH greater than 7 and will turn the paper blue. At a pH of 7, a substance is neutral (neither acid nor base) due to equal numbers of hydrogen and hydroxide ions which will turn the paper a yellowish green.

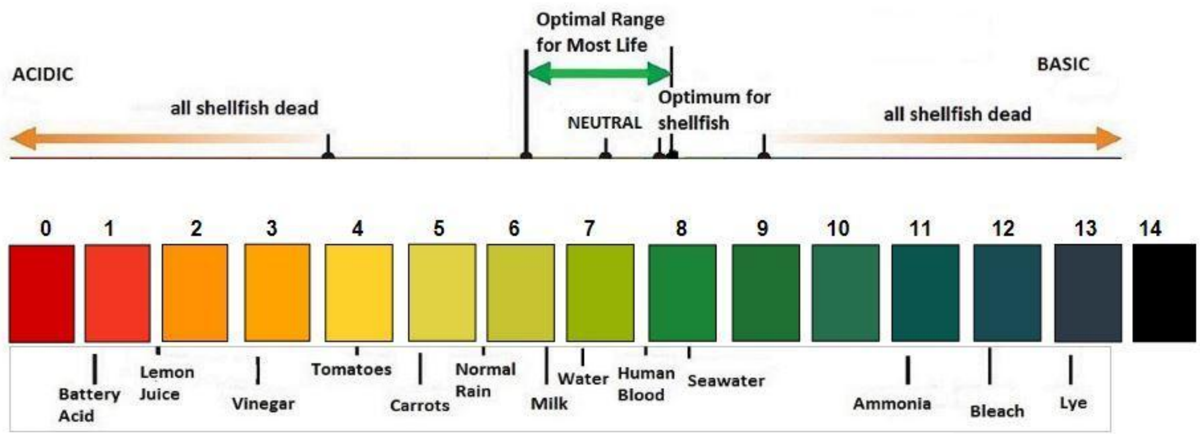
Procedure

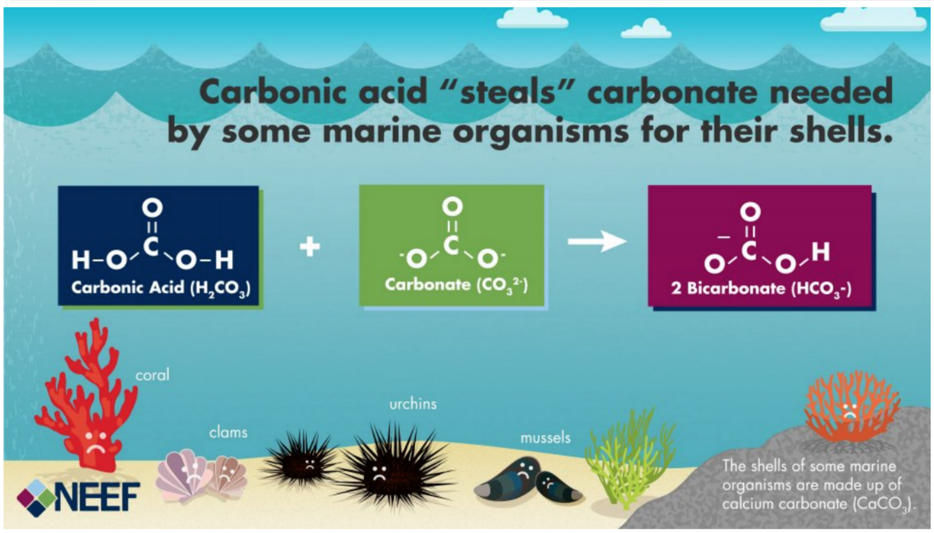
- Ask students to summarize what they learned in the last lesson. Remind students that when they breathed into the cups it changed the chemistry of the water.
- Ask students for ideas of different chemical tests that could be done to water.
- Explain to students that pH describes how acidic or basic a solution is. Ask students for ideas for what acidic, basic, and neutral means and if they can think of examples of which solutions might fall into each category. Explain to students that pH stands for power of hydrogen and show them this video on pH.
- Have students test household solutions to get a better understanding of pH. During this process, have the pH scale graphic up on the board. Have students start by using the worksheet to predict if each solution will be acidic, basic, or neutral, then within their lab group test each solution three times. Remind students not to touch the end of the litmus paper that they test the solution with since the oils from their skin may impact their results.
- Students can also test the before and after of the human smokestack experiment. In most cases litmus paper will not detect a difference. Explain that the red cabbage indicator is a more sensitive test than the litmus papers, which is why they may not be able to detect the change in pH. (if a pocket pH meter or something more sensitive than litmus paper is available, you can show this)
- As a class, talk about which solutions were in each category and how that compared to their hypotheses. (15 min)
- Wrap up
    - Discuss how living organisms thrive in a pH range close to neutral. Human blood has a pH of 7.4, whereas marine calcifiers prefer a pH close to 8. Why might this be?
    - Review different aspects of the carbon cycle where students' habits have impacts and review the Salish Sea Challenge with students to help them work on ways they can improve their habits.

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.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
Analyze & Interpreting data Scientific knowledge is based on empirical evidence.	PS1.B Chemical reactions	Cause and Effect

Graphics





Understanding the Science of Ocean and Coastal Acidification | US EPA

Vocabulary:

- Ocean acidification: The decrease in the pH of the Earth's oceans, caused by the absorption of carbon dioxide (CO2) from the atmosphere.
- pH: the power of hydrogen
- Base (Alkaline): Have a pH greater than 7 and a low concentration of hydrogen ions.
- Acid: Have a pH of less than 7 and a high concentration of hydrogen ions.
- Dissolution: the process where a solute in gaseous, liquid, or solid phase dissolves in a solvent to form a solution.

Worksheet

pH of Household Solutions

The **pH scale** is used to describe the acidity of a solution. The pH scale changes from **acidic** to **basic** (sometimes called alkaline). Pure water is **neutral**, in the middle. Most plants and animals like to grow in environments where the pH is close to the middle.

1. **Hypothesize** (predict) where on the pH scale each solution will fall (acidic, neutral, or basic). Look at items on the pH scale and find one you think is similar to your solution to help you guess.

2. **Test your hypothesis.** Dip a piece of litmus paper into each solution. Count "one, one thousand". Lay the litmus paper against the scale provided. Record your result with the number corresponding to the color you see.

3. **Repeat step 2** three times (each test is called a "trial") to make sure your results are consistent.

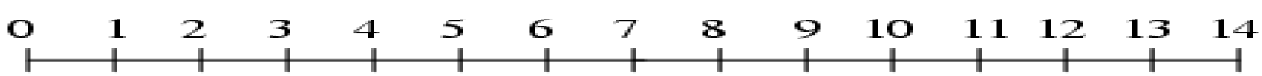
Solution	Hypothesis (A/B/N)	pH Trial 1	pH Trial 2	pH Trial 3	Mean*
Vinegar					
Lemon Juice					
Club Soda					
Pure Water					
Baking Soda					
Tums					
Seawater					

***Instructions for mean:** For each solution, add results from each trial. Divide this sum by the number of trials (3) to find the mean, or average.

Which solution is best suited for shellfish to live in? (circle one)

Highly Acidic Slightly Acidic Neutral Slightly Basic Highly Basic

Label the pH scale below with the solutions that you tested:



Lesson 3: Ocean Acidification and Oyster Life Cycle

Subject
Human impacts on the oyster life cycle

Objectives
Students will:
- Use a model to understand natural and human caused pressures that impact life cycle stages

Materials
- GSSC's life cycle box with display materials
- Ocean Acidification Slideshow (slides 23-28)

Size/Setting/Duration
Entire class/ Indoor (Optional Outdoor)/ 45 minutes

Background
Students will learn about oysters and other intertidal life cycles. They will obtain and combine information about multiple intertidal life cycles and seasonal growth patterns and use a model to understand natural and human caused pressures that impact life cycle stages. Students are introduced to the concept of ocean acidification as a chemical imbalance due to air and water pollution that can impact shell formation.

Procedure
Part 1: Introduction Powerpoint
- Slide 23: Ask students, "Do you have any ideas?"
- Slide 24: Ask students, "Thumbs up if you like oysters… shrimp… clam chowder?" Response: Students hold up thumb in response
- Slide 25: "What would happen if this seafood went away? If it did not exist anymore?" Responses may mostly be the impact to us. "Would their absence impact other organisms in the sea that eat these shellfish too?
- Slide 26: "What is SPAT?" Response: It is when the baby oyster transitions from its swimming stage to its attached stage. "What would happen if it did not attach?" Response: It would not be able to grow into an adult or reproduce to make more shellfish
- Slide 27: "This is what SPAT looks like when it is attached and starting to grow."
- Slide 28: Shellfish, crabs, and many other sea organisms are called calcifiers, because they take calcium from the water to make their shells under neutral pH conditions.

Part 2:

Have students play the other life cycle games included in the GSSC Games Kit which include:

- Oyster Life Cycle Game: This is a board game meant for four players. Players move through the board game and learn about the struggles oysters face as they grow into adults.
- Clam Life Cycle Game: Students try to assemble the clam life cycle cards in the correct order. This game can be done alone or in groups of up to 4 students. There are two sets included in this kit, so two groups could do this at once and try to see which group can assemble the clam life cycle correctly the fastest.
- Anemone Life Activity: Students learn about the two different ways sea anemones can reproduce through constructing the anemone life cycle stages with play dough. This activity can be done alone or in groups of up to 4-6 students.

For more details on the games please see the Games Kit Guide and the Games Worksheets.

Extension

- Rice
- "Spat Spots" (can be paper, rubber discs, or oyster shells)
- H+ T-shirts

Spat Tag (outdoor portion)

- Round 1: Predation
  - Students divide approximately into half. Team 1 is oyster larvae. Team 2 is predators. Arrange students so that the oyster larvae team is in a line on one end, the predator team is in another line in the middle of the field and the 'spat spots' are in a line on the opposite end of the field. Larvae attempt to reach the 'spat spots' before being tagged. If tagged, they must freeze. If they reach a spat spot, they may throw rice to 'reproduce'. Each larva must have his/her own spat spot.
- Round 2: Ocean Acidification
  - Divide students in thirds and give the third group t-shirts to signify that they are H+. H+ makes the ocean acidic, which makes it harder for oyster larvae to build their shells. Repeat the game.
- Round 3: Habitat Loss
  - Repeat the game again, but remove some of the 'Spat Spots". This represents what happens when there is less suitable habitat for larvae to attach and grow into adult oysters.

Part 3: Reflection (indoor)

- Ask students what some of the things they learned about oyster life cycles today. What were some of the pressures that they faced? What are some of the pressures that humans can impact?

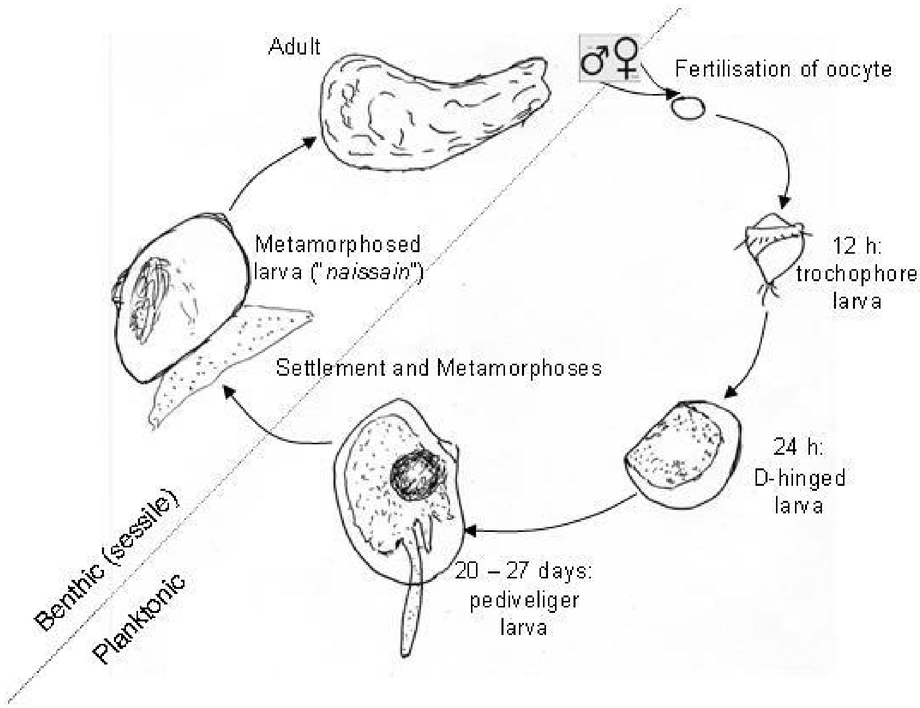
If you want more in depth lessons about life cycles please see GSSC's 5th grade curriculum which includes life cycle lessons or Maryland SeaGrant's The Life Cycle of an Oyster Lesson.

Students can also watch the video Acidifying Water Takes Toll on Northwest Shellfish.
Students can do a close read of It's called ocean acidification, and it's killed oysters by the billions.

Next Generation Science Standards

Performance Expectations		
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
Engaging in argument from evidence	LS2.C Ecosystem Dynamics, Functioning and resilience	Cause and Effect Stability & change

Graphics
Life cycle of the Japanese or Pacific Oyster (*crassostrea gigas*)



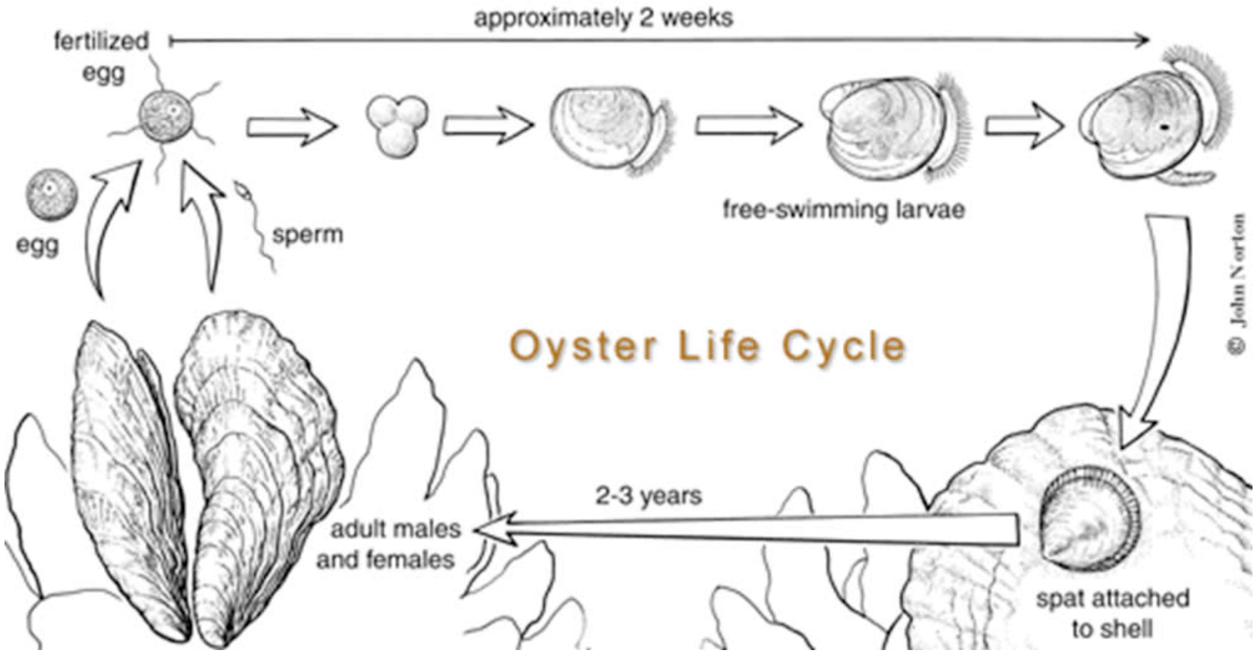
Vocabulary

- Mollusk – a phylum of invertebrate animals including snails, slugs, shellfish, and octopus
- Life cycle – a series of physical changes during the life of an organism
- Motile (free swimming) – capable of motion
- Larvae – an immature form of an organism, especially one which differs greatly from its adult form. There are several larval stages. (see life cycle diagrams and games)
- Spat - a juvenile oyster that has changed into an adult develops its shell and attaches to a substrate like a rock or shells. This is the life stage that is most vulnerable to ocean acidification. At this point, attachment and shell formation are interrupted.

Student Worksheet

Oyster Life Cycle and Ocean Acidification

Draw a circle around the life cycle stage that is most susceptible to ocean acidification.



In a short paragraph, explain why that stage is the most susceptible to ocean acidification.

Lesson 4: I'm Melting Demonstration

Subject
Ocean Acidification and Dissolution

Objectives
Students will:

- Identify the phenomenon (dissolution) and interpret that a chemical reaction occurred.

Materials
Each lab group will need a set of jars which includes:

- Three labeled plastic jars with at least 6 oyster shells (two per jar)
- Jar 1: filled with water
- Jar 2: filled with vinegar for two weeks
- Jar 3: filled with vinegar for two months

Shell Building Slideshow

Size/Setting/Duration
Entire class split into lab groups/Indoors/15 minutes

Background
Now that students have a better understanding of pH and the oyster life cycle we are going to look at how acidifying waters can impact calcifiers like oysters. Many organisms, including oysters, coral, sea urchins, and some species of plankton, use calcium carbonate to form their shells and skeletons. Increased acidity from the absorption of CO_2 reduces the calcium carbonate available for the marine organisms that need it. The acidity also makes the water more corrosive, which can dissolve shells in extreme situations.

Procedure

- Begin the lesson by reminding students of the pH of Household Solutions activity. Solutions we use everyday have a wide range of pH's from the most acidic (1), neutral (7), to basic (14). What were some examples of acidic solutions? How about basic? Neutral?
- Today we will be looking at some of the effects of ocean acidification. Let's look at these three jars. What do you notice about the three jars? Do you notice that two of the jars have vinegar in them? What did we learn in the pH of Household Solution experiment about vinegar? Is it an acid or a base? What do you notice about the shells that have been in vinegar the longest? Why might the water be murky?

Extension

Using GSSC's [Dissolving Shells Experiment](), students are able to track the rate of dissolution of shells using vinegar by weighing the shells over time. This can be done with the I'm Melting Demonstration or it can replace it. The Dissolving Shells Experiment requires two hour long classroom sessions.

For even further extensions look at NOAA's Marine Osteoporosis Lab.

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-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
Analyze & Interpreting data Scientific knowledge is based on empirical evidence. Engaging in argument from evidence	PS1.B Chemical reactions LS2.C Ecosystem Dynamics,Functioning and resilience	Patterns Stability & change

Student Worksheet

I'm Melting

Compare the shells that were soaked in vinegar to shells soaked in distilled water. Draw a picture of the jars below and use short sentences to answer the questions.

Shells in Vinegar	**Shells in Water**

1. What is happening to the shells in vinegar?

2. Why do you think this is happening?

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Career Explore: Ocean Acidification and Jobs

Subject

Careers related to OA, shellfish industry impacts.

Objectives

Students will understand the scope of ocean acidification, how it impacts industries such as shellfish and aquaculture, and explore what careers are tackling the issues of OA.

Materials

- OA Career Builder Slideshow
- Salish Sea Challenge
- Salish Sea Challenge Bingo

Size/Setting/Duration

Entire Class, Indoors, 25 minutes

Background

Now that students have a better understanding of how acidifying waters can impact calcifiers like oysters, we are going to take a look at careers that address this issue. Students will review OA, hear of local examples of industry facing the OA challenge, and learn about a national organization addressing OA.

Extension

Students can spend time sharing with their peers the progress of their Salish Sea Challenge, ways they have decided to mitigate their carbon footprint, and ideas they have for combatting ocean acidification. Students can also use the Salish Sea Challenge Bingo sheet.

Extension Lesson 5: Blaine Harbor Water Quality Station

Subject
Water Quality

Objectives
Students will:
- Measure water quality parameters to determine the health of a waterbody in their local watershed.

Materials
- Secchi disk
- Thermometers tied with rope
- GPS
- SPARK unit with weather attachment

Size/Setting/Duration
One third of class/Blaine Harbor dock/25 minutes

Background
This is a field inquiry activity that students will be able to access depending on their field site(s). These activities are designed to allow students to have hands-on experiences with their local environment. In this activity, students will be testing the water quality of Blaine Harbor and the Cain Creek watershed.

Procedure
- On the trip to the waterbody ask students to observe things that may impact the health of the water they will be testing (storm drains, trash, cars, etc).
- Once at the docks, each student will be given a lifejacket and clipboard with the Blaine Harbor Worksheet. Ensure that all students lay on their stomachs when looking in or sampling the water to prevent falling in. Have students start by writing down their observations of the weather.
- Using thermometers collect measurements for air and water temperature. Thermometers should be tied to string or rope so that water temperature can be collected under the surface.
- Turbidity
  - Turbidity is a measurement of how clear water is. To test turbidity we use a Secchi disk. Lower the Secchi disk until no longer visible. Slowly raise the disk until visible

and then count the feet of rope as you lift the rope to determine how deep the disk was when visible.
    - Ask students why turbidity might be important. Having water with high concentrations of sediment can impact fish's ability to breath.
- Using the SPARK unit with the weather attachment, students will collect data for wind speed, barometric pressure, and latitude and longitude.

Extension

- If possible, go to another waterbody and compare the water quality parameters to determine which is healthier. Ask students why this might be based on their observations of the watershed.
- Once back in the classroom, write the water parameters on the board. As a class, look at the EPA water quality standards (summary table included below). The freshwater standards are specific to the organisms that can live there and the actions that need better water quality (i.e. spawning). Compare your results to the table and determine how each parameter scores. Combine the results and decide how you would rank the water as a whole. Have students complete the post lab worksheet.

Next Generation Science Standards

Performance Expectations		
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
Analyze & Interpreting data Scientific knowledge is based on empirical evidence. Engaging in argument from evidence	PS1.B Chemical reactions LS2.C Ecosystem Dynamics,Functioning and resilience	Stability & change

Graphics

Aquatic Life Criteria in Marine Water				
Category	Temperature	Dissolved Oxygen	Turbidity	pH
Units	Highest 1-DMax	Lowest 1-Day Minimum	NTUs	pH Units
Extraordinary quality	13°C (55.4°F)	7.0 mg/L	Turbidity must not exceed: • 5 NTU over background when the background is 50 NTU or less; or • A 10 percent increase in turbidity when the background turbidity is more than 50 NTU.	pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.2 units.
Excellent quality	16°C (60.8°F)	6.0 mg/L	Turbidity must not exceed: • 5 NTU over background when the background is 50 NTU or less; or • A 10 percent increase in turbidity when the background turbidity is more than 50 NTU.	pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.5 units.
Good quality	19°C (66.2°F)	5.0 mg/L	must not exceed: • 10 NTU over background when the background is 50 NTU or less; or • A 20 percent increase in turbidity when the background turbidity is more than 50 NTU.	pH must be within the range of 7.0 to 8.5 with a human-caused variation within the above range of less than 0.5 units.
Fair quality	22°C (71.6°F)	4.0 mg/L	must not exceed: • 10 NTU over background when the background is 50 NTU or less; or • A 20 percent increase in turbidity when the background turbidity is more than 50 NTU.	pH must be within the range of 6.5 to 9.0 with a human-caused variation within the above range of less than 0.5 units.

Vocabulary

- Turbidity - cloudiness of water

Student Worksheet

<u>Blaine Harbor Data Sheet</u>

Name: ____

Station 1

Weather observations (clouds, rain, etc.)

____

____

____

	Air temp.	Water temp.	Turbidity	Wind speed	Barometric pressure	Latitude	Longitude
Field data							
Unit							

Station 2

	pH			Dissolved Oxygen	Salinity
	Litmus Paper	Pocket pH Meter	Color Indicator		
Field Data					
Unit					

We acknowledge and respect the treaty rights of the Coast Salish Peoples to the lands and waters of the SalishSea, and we recognize their stewardship since time immemorial.

Station 3

Organism inventory

Above the surface | Below the surface

Draw a diagram at least one organism. Include information such as location (above or below surface) and species.

Extension Lesson 6: Blaine Harbor Water Quality Lab Station

Subject
Water Quality

Objectives
Students will learn to measure pH using 3 methods, measure salinity (parts per thousand), and measure dissolved oxygen.

Materials
- Marine Water sample from Blaine Harbor
- Hach test kits (dissolved oxygen and pH)
- Pocket pH meter
- Litmus paper
- Hydrometer

Size/setting/duration
One third of class/Blaine Harbor Boating Center/25 minutes

Background
Students will activate prior knowledge about the pH scale and understand that optimal pH conditions for shellfish and other organisms are in the neutral pH range. They will understand why dissolved oxygen in water bodies is important and understand the salt content of marine water.

Procedure
- Have students use three methods (Hach pH kit, pocket pH meter, and litmus paper) to test pH and compare the results. Show students the laminated pH scale that shows household solutions, blood, pure water and sea-water.and ask what they know about the pH scale. Ask them the range of numbers represented in the pH scale? (0- 14) and what number is in the middle (7). Ask them what the 7 represents on the pH scale (neutral). Explain that most organisms exist in the neutral pH range (6.5-8.5). Ask them to point out where human blood is on the pH scale (7.4) and then point to where sea water is on the scale. Explain how the salinity and minerals contribute to a higher pH (8.2). Explain how these minerals like calcium carbonate are important for shellfish and other calcifiers to form their shells and survive to adulthood.
- Ask students why dissolved oxygen in water bodies is important. What needs oxygen? Explain that temperature and dissolved oxygen have an inverse relationship. As temperature increases, dissolved oxygen decreases. This is why fish need cold water. Explain that the

units used to express dissolved oxygen concentration are milligrams per liter or parts per thousand.

- Ask students whether Blaine Harbor is saltwater or freshwater, then ask them whether the Nooksack river is saltwater or freshwater. Show students the hydrometer with the Blaine Harbor sample water and pass it around for students to read the salinity in parts per thousand. Explain that salinity of freshwater is near zero. Ideally have a freshwater sample available to make the comparison. Explain that because saltwater has a higher density than freshwater when a stream flows into saltwater, the freshwater will tend to float.
- Show students the graphic (laminated) of fecal bacteria plates. Fecal bacteria get into streams and estuaries from the poop of warm blooded animals when it rains or from sewage leaks. Fecal bacteria indicate there may be bacteria in the water that can make us sick! It is safe to eat shellfish and swim in marine water where there are less than 14 fecal bacteria colonies (a single bacteria cell grows into a visible colony) in 100 ml of water. If possible, use the [Department of Ecology's website] to look up the fecal bacteria data for the location you tested to determine if it would be safe to eat shellfish there.

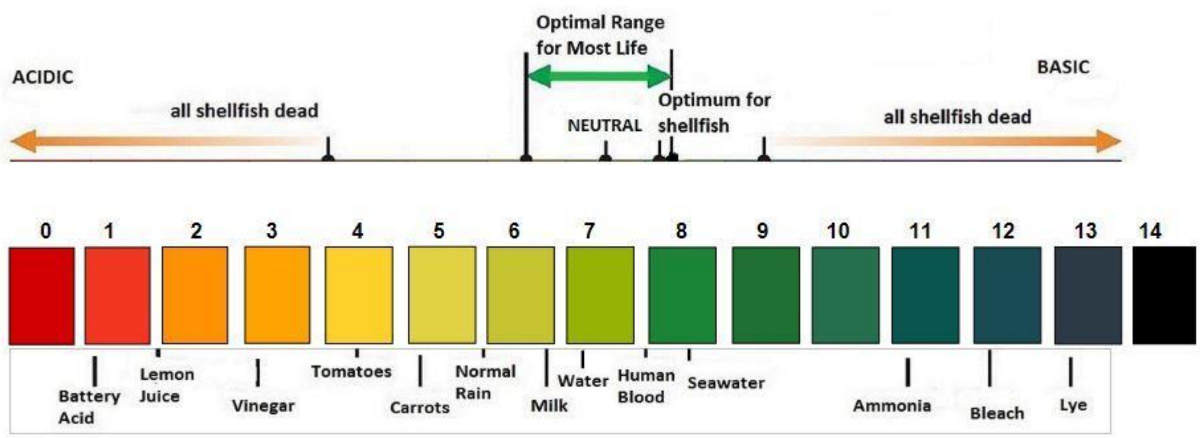
Extension

None

Next Generation Science Standards

Performance Expectations		
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.		
Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
Analyze & Interpreting data Scientific knowledge is based on empirical evidence. Engaging in argument from evidence	PS1.B Chemical reactions LS2.C Ecosystem Dynamics,Functioning and resilience	Stability & change

Graphics



Student Worksheet

Included in station 1 lesson.

Extension Lesson 7: Blaine Harbor Organism Inventory Station

Subject

Species identification

Materials/Teacher Preparation

- Clipboards
- Field notes pages (two copies printed front and back)
- Hand lenses
- Fish net
- Clear plastic cups (or other vessel to hold organisms)
- Life jackets
- Field identification guides (links provided in graphics)

Size/setting/duration

One third of class/Blaine Harbor dock/25 minutes

Background

After classroom lessons about the intertidal zone, students will be excited to get real life experience with some of these critters! The docks at Blaine Harbor are often home to anemones, sea stars, barnacles, mussels, and fish. Before this lesson, prepare students to be dressed for the outdoors.

Overview

Students will:

- Draw a diagram of an organism and identify the species based on physical features
- Inventory the biodiversity of an ecosystem

Procedure

- Each student will be given a lifejacket and clipboard with the organism inventory worksheet. Students will try to identify as many species as possible, both above and below the water, and diagram one organism. Once on the dock, students may gently collect organisms with fishnets and put them in plastic cups for diagramming. Ensure that all students lay on their stomachs when looking in the water to prevent falling in. Students should use the species guides to help identify the organisms that they find.
- Explain to students that one way to assess the health of an ecosystem is to look at biodiversity. This is why they will be trying to identify and inventory as many different species as possible at this station. Higher biodiversity enables the ecosystem to be more adaptable and resilient to changes.

NGSS

<table>
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</table>

Engaging in argument from evidence Scientific knowledge is based on empirical evidence	LS2.C Ecosystem dynamics, functioning, and resilience	Stability and change

Other Standards

Standard 1: Ecological, Social, and Economic Systems

Standard 2: The Natural and Built Environment

Graphics

To download free field guides visit:

NOAA Intertidal Zones Animals Field Guide

LiMPETS Field Guide

Vocabulary

- Species

Extension

- Students can pick one of the organisms that they identified to do a research project and presentation on. Students can present information such as:
  - What does your organism eat?
  - What are two things that eat your organism?
  - What habitat does your organism live in?

Worksheet

Included in station 1 lesson.

Extension: The ABC's of Ocean Acidification: Acids, Bases, and Calcification Races

Subject
Carbon Cycle and Ocean Acidification

Objectives
The students will:

- Identify the phenomenon (dissolution) and interpret that a chemical reaction occurred.
- Understand how changes in ocean pH affect calcifiers such as oysters.

Materials

- CO2 balls
- "Ocean" (sheet with a hole in it)
- Atom Cards (HHCOOOCa)
- Carbonic acid sign
- Orange sunglasses
- Star Stickers
- LEGO shell
- LEGO pieces

Size/setting/duration
Entire class/ Outdoor space/ 60 minutes

Background
Prior to this lesson, students should have done the pH of household solution experiment or another pH lesson.

Procedure
Acids, Bases, and Calcification Races Skit

- Let's begin this activity by having two students volunteer to act as roommates waking up on a cold day getting ready for work. Let's think of ways they might use - and possibly waste - energy getting ready for work! (Some examples to act out could be: taking long showers, turning up the thermostat instead of wearing a sweater, commuting long distances as a single occupant driver, etc.).
- Let's have them drive to work. What happens when they drive their cars? Here we have some CO2 molecules (balls), which go up into the air and then are absorbed by the ocean.

Have students throw balls of CO_2 molecules into the air and let them fall into the ocean (the sheet with a hole in it).

- Now we are going to look at what goes on a microscopic level and act out the molecular reactions that take place as the CO_2 meets H_2O. As the C-O-O molecule reacts with H-H-O, the molecule forms H_2CO_3, or carbonic acid.
- Arrange the students in this order – HHCOOO– and hold up a carbonic acid sign. The carbonic acid quickly dissociates into a free hydrogen (H^+) and bicarbonate molecule HCO_3 (HCOOO). Pull one of the hydrogens off. You can place orange sunglasses on the student to emphasize the reactive nature of the free hydrogen. The free H^+ is very reactive in solution.
- This is what leads to a decrease in the pH, or acidity, of seawater. In an acidifying ocean, researchers detect an increase in the amount of both free hydrogens and bicarbonate molecules. It is important to note that when people refer to ocean "acidification," the ocean is becoming more acidic, but still remains on the basic side of the pH scale.
- The bicarbonate molecule (HCOOO) can further dissociate into another free hydrogen (H^+) and remaining carbonate molecule (COOO). Carbonate molecules are very important. Many organisms in the ocean use calcium carbonate to build their shells. (Stick super stars on the shirts of the COOO molecule to emphasize their importance).
- Both calcium ions and carbonate molecules are typically found in the oceans in adequate quantities. Some originate from the weathering of parent rocks from river inputs and/or shifting tectonic plates. These substances may also be re-released into the ocean as organisms with calcium carbonate shells decompose.
- First we are going to see how oysters form their shells in a "normal"/healthy marine environment. We are going to have the 2 free hydrogens sit down or off to the side during this process. The carbonate molecule (COOO) will link up with the calcium molecule (Ca^+) to form calcium carbonate ($CaCO_3$).
- Now, the $CaCO_3$ molecule can place a Lego piece onto the oyster shell to illustrate how $CaCO_3$ molecules are the building blocks of shelled organisms. Oyster larvae begin their lives as free swimming organisms. It takes only 48 hours from the time an egg is fertilized until it becomes a shelled swimming veliger. Access to adequate amounts of calcium carbonate is critical for juvenile oysters during this time!
- Now, we are going to back up and start this process a second time demonstrating shell formation under more acidified ocean conditions. Have the 2 free hydrogens stand in a line separating/blocking the oyster and calcium molecule from the COOO molecule. The arrangement will look something like this.... Oyster shell Ca+ 2 free H+s COOO-
- The hydrogen ions are positively charged and the carbonate molecule is negatively charged. In chemical reactions, positive ions are attracted to negative ions. As the ocean becomes more acidic (more free floating hydrogens), the hydrogen ions tend to bind onto the carbonate molecules, shifting them back into bicarbonate (HCOOO). Ca^+ can only bind with carbonate (COOO), not bicarbonate (HCOOO), so the oyster has less CaCOOO to build its shell.

- You can demonstrate this by asking the COOO molecule to attempt to bond with the Ca+ molecule before the free H+ molecules bind onto it. This is the "shellfish races" portion of the play. This can get a little crazy/physical depending on the enthusiasm of your audience. You be the judge if this will work for your class. So, a H+ molecule will bind onto the carbonate molecule (COOO) creating HCOOO and the oyster will not get the CaCOOO that it needs.
- To review: HHO + COO forms H2CO3 (carbonic acid). This dissociates into.... H+ and HCOOO (bicarbonate). This dissociates into… H+ and COOO (bicarbonate).
- The COOO binds with Ca+ to form CaCOOO, the building block of shelled organisms. Under more acidified conditions, the H+ binds with COOO forming bicarbonate, decreasing the available COOO for shell building. Without enough CaCOOO, oyster larvae have a difficult time forming their shells.

Part 3: Wrap Up

- If there is time, watch one of these videos to wrap up what they just learned. ACE Science Short (Best for 6th grade) or NC Aquarium Fort Fisher Video (best for high school)
- So let's compare what we acted out today to the shells we saw. At current levels of ocean acidification, oysters are struggling to build their shells. If CO2 levels continue to increase we may have issues with the shells dissolving as the ocean becomes more acidic. They are a keystone species near the bottom of the food chain that are food for animals like otters, seagulls, seals. They also provide important three dimensional habitats that act as nurseries for many important species and protect our shorelines. A decrease in oyster population can cause the ecosystem to suffer. A healthy and diverse shellfish population supports a healthy ecosystem.
- What can we do to solve this problem? How can we slow the change in ocean pH so it supports healthy populations of calcifiers like shellfish, pteropods, crabs, starfish and many other organisms?

Extension

Have an article for students to read about local shellfish hatcheries issues with ocean acidification.

Students can also model the reaction by creating the molecules with marshmallows and toothpicks.

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

Scientific and Engineering Practices	Disciplinary Core Ideas	Cross-cutting Concepts
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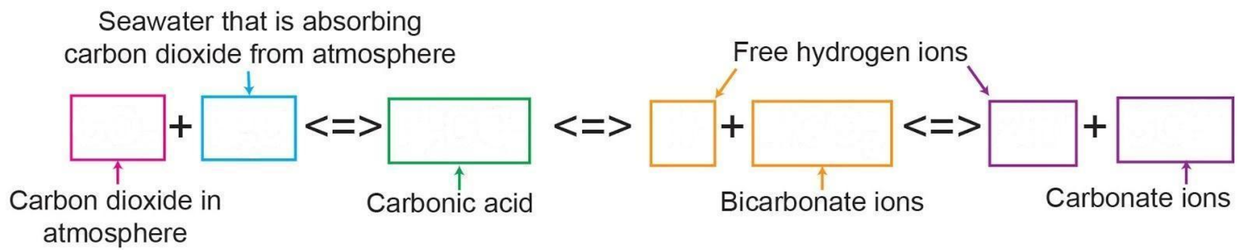
Student Worksheet

The ABC's of Ocean Acidification

Recall the human smokestack experiment. What was your original hypothesis for why the color in the cup changed?

Fill in the reaction of carbon dioxide and water:

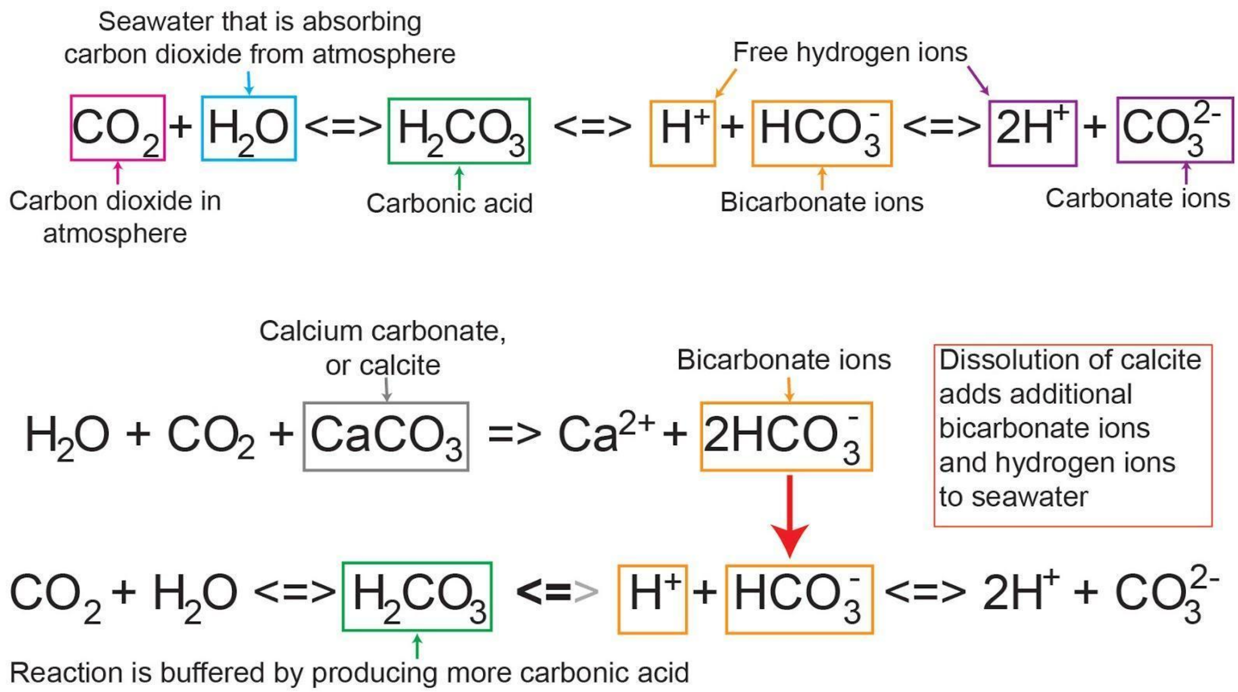


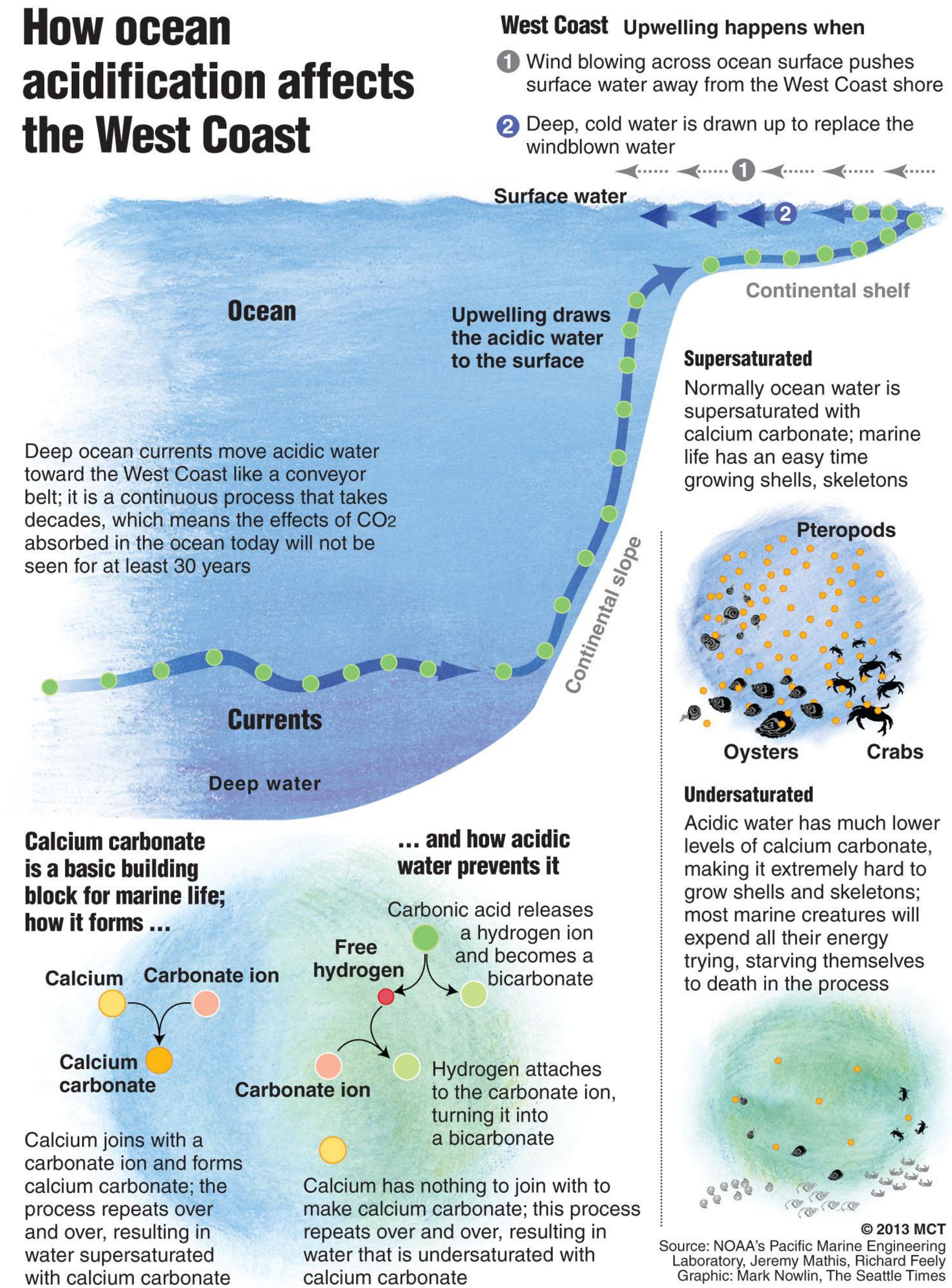
Was your hypothesis correct?

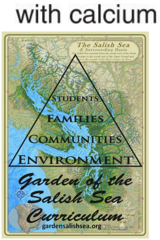
If not, why did the color change?

How does this impact shellfish?

Graphics/Teacher Guide







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Pacific Shellfish Institute

Lesson 8: A Tale of Two Cities & Unit Reflection

Subject
Unit Reflection

Objectives
Students will:

- Demonstrate understanding of the carbon cycle, ocean acidification, and human impacts

Materials

- GSSC's felt board set

Size/Setting/Duration
Entire class/Indoors/30 minutes

Background
None

Procedure

- Part 1: A Tale of Two Cities
  - Lead a discussion about how two cities with different amounts of CO2 in the atmosphere would look. Have students show their ideas by creating scenes on the storyboard.
  - Check for understanding:
    - CO2 is part of the natural balance of the Carbon Cycle.
    - CO2 is also created by cars and factories. This puts more CO2 into the atmosphere causing the Carbon cycle to be out of balance.
    - Ocean acidification is the result of too much CO2 in the atmosphere.
    - Ocean acidification is harmful to shellfish.
- Part 2: Reflection
  - Have students fill out the Reflection Worksheet
  - Collect/review results of the Salish Sea Challenge

Extension
Have students illustrate the two cities as an art project or use the included healthy watershed design worksheet.

Next Generation Science Standards

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LS2.C Ecosystem Dynamics,Functioning and resilience</td><td>Patterns
Cause and effect
Stability & change</td></tr>
</table>

Example of Felt Board

Student Worksheets

Ocean Acidification Reflection:

1) Describe the negative impacts shellfish experience as a result of ocean acidification. During which life stage is an oyster or clam most vulnerable to these effects?

2) Think about the felt board activity. Describe two things about the watershed that help keep the natural system in balance.

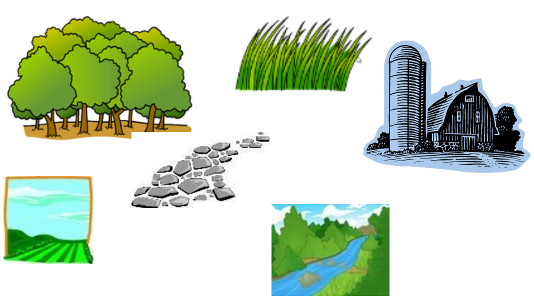
3) Carbon, just like water and many other nutrients in the environment, cycles through many states over time. Name some inputs to the carbon cycle and some items or places that act as carbon 'sinks.'

4) Describe 2 things you can do at home with your family to keep your watershed healthy.

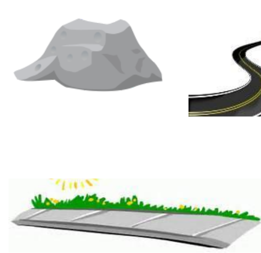
Watershed Healthy Design

Draw and label a map of a building lot with a house, or a farm next to a stream or the beach using the elements below. Label the surfaces **P** for **pervious** and **I** for **impervious** Use arrows to draw the path that run-off from rain will take on the site. Explain how your choices minimize impacts to the watershed and minimize carbon dioxide in the air.

Pervious



Impervious



Energy Choices

Explain how each of your watershed healthy design element choices will help to minimize water and air pollution. Also explain how people living on the property can use lifestyle habits from your Salish Sea Challenge to minimize their impact. Use the following vocabulary: **run-off**, **pervious and impervious.**

Salish Sea Challenge Assessment

In order to assess the impacts that your class had on the environment through the Salish Sea Challenge, we ask that you either have students return the Salish Sea Challenge with the table on the back filled out or hand out the following post survey so that we are able to quantify the impact of the program.

During this unit, how many times did you: (circle)

Ride your bike or walk instead of taking a car
0-5 times, 5-10 times, more than 10

Picked up your pet's waste
0-5 times, 5-10 times, more than 10

Recycled, reduced, or reused
0-5 times, 5-10 times, more than 10

Conserved energy by turning off power or other ways
0-5 times, 5-10 times, more than 10

Other (Please explain what you did and the number of times you did it)

____

____

During this unit, how many times did you: (circle)

Ride your bike or walk instead of taking a car
0-5 times, 5-10 times, more than 10

Picked up your pet's waste
0-5 times, 5-10 times, more than 10

Recycled, reduced, or reused
0-5 times, 5-10 times, more than 10

Conserved energy by turning off power or other ways
0-5 times, 5-10 times, more than 10

Other (Please explain what you did and the number of times you did it)

____

____