



Around the Americas

K-8 Teacher's Guide



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Around the Americas K–8 Teacher’s Guide

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AROUND THE AMERICAS

Many of the fundamental properties of the ocean are changing: seawater pH is decreasing, endangering coral reefs; warming waters are causing sea level to rise, imperiling low-lying areas; and Arctic sea ice is shrinking, threatening local wildlife. Changes in the marine environment affect not only inhabitants of the sea, but also have great ramifications for both coastal communities and inland populations. These changes are heavily influenced by human activity. Consequently, individuals can play an important role in protecting and improving the health of our oceans.

To build awareness about ocean health on an international scale, Seattle’s Pacific Science Center and Boston’s Sailors for the Sea have launched the *Around the Americas* project in collaboration with the University of Washington’s Applied Physics Laboratory, the Joint Institute for the Study of the Atmosphere and Ocean, MIT Sea Grant College Program, and NASA’s Student Cloud Observations On-Line.

Around the Americas is a clockwise circumnavigation of the North and South American continents as though they were one gigantic island. In May 2009, a 64 foot sailboat named “*Ocean Watch*” departed Seattle and is scheduled to visit 31 ports in 12 countries over the course of its 13 month voyage. On board are four crew members and one Science Center educator. Ocean and atmospheric scientists are joining the crew for certain legs of the expedition to conduct research. The goal of the *Around the Americas* project is to use this unusual adventure to engage and educate citizens in North and South America about ocean health issues using science-driven education materials and activities.

ABOUT THE GUIDE

Welcome aboard! The *Around the Americas* K-8 Teacher’s Guide features seven inquiry-based lessons to engage your students in learning about different aspects of ocean health. Each lesson in this guide is aligned to the ocean literacy principles (www.oceanliteracy.net) and U.S. and Canadian national science standards. Each lesson is designed for students in grades 6-8 and includes suggestions for adapting the lesson to younger students. Lesson topics include ocean acidification, coral reef ecology, changes in sea level, and sustainable fisheries. Exercises on atmospheric aerosols, underwater sound, and sea ice directly relate to research projects on board: updates of these projects will be posted to the *Around the Americas* website (www.aroundtheamericas.org) throughout the voyage. Each lesson has “extensions” to explore each topic in greater depth.

Thank you for your interest in these materials and in the *Around the Americas* project: we encourage you to dive in and follow the progress of “*Ocean Watch*” and her crew on-line at www.aroundtheamericas.org.

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CREDITS

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LESSON 1

Coral, Carbon Dioxide and Calcification

INTRODUCTION & BACKGROUND

What are corals?

Corals are marine animals found in all oceans, and are common in the tropics. Scientists classify them as **cnidarians** (“ni-DARE-ri-ans”). Types of coral vary but they all have a basic body form known as a **polyp**, which is a tubular body capped by a ring of stinging tentacles surrounding a mouth. This is the living part of a coral and resembles an anemone. Coral polyps are usually tiny, but many species have developed the ability to live in colonies. In the tropics, many coral colonies build spectacular, beautiful, and protective skeletons that form reefs. These skeletons are made of calcium carbonate, which is secreted by the polyps.

Even though the calcium carbonate skeletons of living corals is white, the brilliant colors of coral reefs result from varieties of single-celled microalgae, called **zooxanthellae** (“zo-uh-zan-THEL-ee”) which live in **symbiosis** within the coral polyps. A symbiotic relationship implies that each organism provides something to another organism such that living together is beneficial to the survival of the organisms. Here, corals provide zooxanthellae a safe, protected home. In return, zooxanthellae provide corals with energy by processing light and nutrients via photosynthesis.

Where do corals live?

Corals have very specific requirements for temperature, salinity, water depth and clarity. These conditions are met for tropical corals between the **latitudes** of 30° North and 30° South. The optimum temperature range for coral growth is between 73-84° F (23-29° C). While most corals can tolerate some variation from

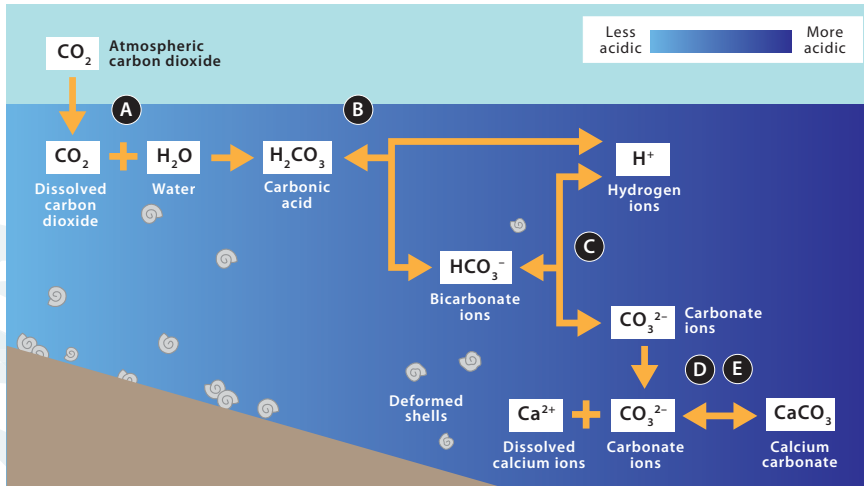
this optimal range, corals do not survive at temperatures below 64° F (18° C) or for extended periods at temperatures above 104° F (40° C). Corals require water with high salinity (32-34 ppt (parts per thousand)). Corals are found within 210' (70 m) of the ocean surface in clear waters, where they thrive in high amount of sunlight (NOAA: Corals, 2008).

How does the ocean process carbon dioxide?

The ocean has a complex way of processing carbon dioxide. This process is often referred to as the “ocean carbon cycle” or the “carbonate buffer system.” The major points are summarized below and a more detailed description adapted from The Royal Society is included online. These basic points are part of the activity procedure.

Starting from the atmosphere and working down:

- A. Carbon dioxide in the atmosphere mixes with seawater to produce carbonic acid.
- B. Carbonic acid easily splits apart into hydrogen ions (H^+) and bicarbonate (HCO_3^-) ions. (An increase in the concentration of hydrogen ions increases the acidity of the water, i.e. lowers the pH).
- C. Carbonate ions (CO_3^{2-}) combine with hydrogen ions to produce bicarbonate ions.
- D. Carbonate ions and calcium ions are used by marine animals (such as corals, crustaceans, and zooplankton) to create hard shells and skeletons of calcium carbonate. This is called “**calcification**,” or more generically, “biomineralization.”



Carbonate Buffer System. Source: University of Maryland

E. Calcium carbonate dissolves into calcium ions and carbonate ions. The rate of dissolution depends on pH, pressure and the amount of carbonate ions in seawater.

To summarize, the addition of carbon dioxide to seawater increases the amounts of hydrogen ions, carbonic acid and bicarbonate ions and lowers amounts of carbonate ions. (See *Online Supplementary Background Information for Lesson 1 for more information on changes in pH in seawater.*)

ACTIVITY MISSION

Time: 45 min.

Through a series of chemical reactions and physical changes, carbon dioxide (CO_2) from the air dissolves into seawater and is used by marine organisms, such as corals and invertebrates. Students will act out key stages in this process through motions, rearranging blocks and team tasks. Students will hypothesize the potential effects when variables are changed (e.g., the addition of massive amounts of CO_2 and increased water temperature).

CONCEPTS

- Carbon dioxide from the atmosphere is used by marine organisms through chemical reactions and physical changes.
- The ocean processes global carbon through complex systems involving **biotic** and **abiotic** factors.
- The health of coral is affected by changes in temperature, pH and the concentration of important chemical compounds.

LEARNING OBJECTIVES

- Students will be able to demonstrate their comprehension of carbon utilization by acting out each stage in the process.
- Students will be able to demonstrate their application of coral ecology processes by hypothesizing results to changes in the system.

STANDARDS & PRINCIPLES

U.S.: 6.2, 6.5; 11.3, 11.3

Canada: 306-3, 311-8, 111-6

Ocean Literacy Principles: 5f

PRE-DELIVERY PREP**Supplies Needing a Day or More to Prepare:** Purchase blocks**Hard-to-Obtain Materials:** None**Safety Procedures:** Monitor student use of small blocks.**SAFETY GUIDELINES****Hazardous Materials:** Small block pieces**Safety Concerns for Students:** Small block parts may pose choking hazards.**SUMMARY OF SUPPLIES****Durable Supplies**

ITEM	DESCRIPTION	QUANTITY
Interlocking blocks (e.g. LEGO® bricks)	Pieces that can represent different chemical ions and compounds involved in reactions, and can be assembled/disassembled in various arrangements and stacked to form a wall	1 set/class
Large opaque container	Container that gives the impression that it contains a VERY LARGE quantity of pieces representing CO ₂	1/class
Large quantity of "CO ₂ " pieces (optional)		As many as possible
Plastic storage boxes or tennis ball containers	One label per box: "Bicarbonate" "Carbonate" "Carbonic Acid" "Hydrogen Ions" "Calcium Ions" For <i>Ocean</i> only: "Water"	12 (one in reserve) One set each for <i>Ocean</i> and <i>Coral</i>
Table or Desks	One for <i>Ocean</i> and one for <i>Coral</i>	2
Heavy coat(s)	Clothing that will make the " <i>Coral</i> " warm and simulate rising water temperatures	1 or as many as needed
Tags/lanyards	Role Title and Job Summary	1/acting student

CONSUMABLE SUPPLIES

None

PROCESS & PROCEDURE

1. Select volunteers and have them line up side-to-side at the front of the class like an assembly line.
2. Assign roles:
 - *Coral*: 3 students — their “job” is to eat, grow, and build exoskeleton by producing calcium carbonate. Students recreate a coral: standing shoulder-to-shoulder, students on ends make “polyp” motions with one hand over their heads, the other hand can pass blocks to the middle person or build the exoskeleton. The student in the middle has use of both hands and can assemble/disassemble blocks; Add any other motions (jumping, twirling, etc.) to simulate an active, growing coral. However, *Coral* is fixed in one spot in the room — they cannot travel. *Coral*’s exoskeleton can be built on a table or desks so the rest of the class can monitor the progress of the skeleton.
 - *Ocean*: 3-5 students — their “job” is to transport components from place to place and facilitate chemical reactions. They can move about the room but can only hold one block component (carbon dioxide, carbonic acid, etc.) at a time. *Ocean* moves in fluid, wavy movements.
 - *Atmosphere*: 1 student or instructor — his/her “job” is to hold and distribute CO₂ blocks to *Ocean*.
 - *Dissolver*: 1-2 students — their job is to take apart the coral skeleton, simulating the effect of more acidic waters.

Note: each actor can handle only one block (compound) at a time.

The rest of the class observes.

Encourage them to join in “talking them through” the process and doing the motions of each step.

3. Any time there is a rearrangement of atoms (chemical reaction), everyone says “Reaction, Reaction” while shaking their hands.
4. *Ocean* begins with a supply of assembled water blocks and an amount of the other components as well. *Coral* may start with a partial wall of calcium carbonate or may build from scratch, depending on time.

The actions are listed below in the order of steps A-E shown on the Carbon Buffer System Diagram.

(A) Carbon dioxide in the atmosphere mixes with ocean water to produce carbonic acid.

1. *Atmosphere*: Gets carbon dioxide (CO₂) block and passes to *Ocean*.
2. *Ocean*: takes the (carbon dioxide) block and combines it with another block combination representing water (H₂O) to make a complex combination (carbonic acid). Puts in *Ocean*’s carbonic acid box.
3. Class: Says “Reaction, reaction.”

(B) Carbonic acid easily splits apart into hydrogen ions and bicarbonate ions. (An increase in the concentration of hydrogen ions increases the acidity of the water, i.e. lowers the pH).

4. *Ocean*: takes carbonic acid blocks and separates into hydrogen ion blocks and bicarbonate blocks. *Ocean* puts the hydrogen ion blocks into its hydrogen ion box and gives the bicarbonate block to *Coral*.
5. *Coral*: separates it into hydrogen and carbonate blocks, puts carbonate blocks into “Carbonate” box and passes the hydrogen ion block to *Ocean*.

(C) Carbonate ions combine with hydrogen ions to produce bicarbonate ions.

6. *Ocean*: combines hydrogen and carbonate blocks into bicarbonate blocks.
7. *Ocean*: places bicarbonate in “Bicarbonate” box.

(D) Carbonate ions and calcium ions are used by marine animals (such as corals, crustaceans, and zooplankton) to create hard shells and skeletons of calcium carbonate. This is called “calcification,” or more generically, “biomineralization.”

8. *Coral*: picks up a carbonate ion piece and combines it with a calcium ion piece and sets the calcium carbonate blocks in front of itself.
9. Building of pieces continues until there is a small “wall” or skeleton of calcium carbonate pieces.

Note: Arrange pieces and boxes so that Coral does as much physical activity as practical (jumping up, squatting down, turning around, clapping, etc.) during these biological processes.

(E) Calcium carbonate dissolves into calcium ions and carbonate ions.

10. *Dissolver*: takes one of the calcium carbonate blocks from the coral “wall.”
11. *Dissolver*: separates it into calcium and carbonate then puts the pieces into the “Calcium” and “Carbonate” containers

Note: designate the rate at which the dissolver does this, e.g. once out of every 5 blocks that Coral builds. Optimally, the rate that Coral assembles the wall will be a little faster than the rate at which the Dissolver removes pieces. Increased temperature and low concentration of CO₂ will increase the rate of the Dissolver.

K-5 ADAPTATION

Young children may enjoy the motions. Have students help brainstorm appropriate motions. Simplify reactions.

LESSON 2

Inquiry into Ocean Acidification

INTRODUCTION & BACKGROUND

What is ocean acidification?

Acidification is the process in which the pH of a liquid becomes more acidic than its original pH. Today, the world's oceans are becoming more and more acidic as a result of large amounts of carbon dioxide that human activity has added to the atmosphere. The situation has become so concerning that a 2005 report from The Royal Society of London explained “even the current level of ocean acidification is essentially irreversible during our lifetimes. It will take tens of thousands of years for ocean chemistry to return to a condition similar to that occurring at pre-industrial times.” Ocean acidification affects many marine organisms, such as corals and invertebrates, which play important roles in global chemical cycles and food webs.

Is seawater an acid?

Teachers and students typically discuss acids and bases in terms of the pH scale. A solution with a pH value from 0-7 is an acid. A solution with a pH value from 7-14 is a base. A solution with a pH value of 7 is neutral.

Although the ocean is becoming more acidic (through the process of acidification), its pH is still above 7. In order for seawater to fit the definition of being an acid, the pH needs to be below 7.

Normally, seawater in the Pacific and Atlantic around the Americas varies within the range of 7.9 – 8.2 (Royal Society, 2005). Within this pH range, living organisms thrive within the marine environment. Some species are able to adapt to pH values higher or lower than their “optimal” range. However, when the pH shifts too far beyond the range that can be tolerated – in either direction, acidic or basic – organisms die.

How does acidification affect calcareous (calcium carbonate-containing) species?

Acidification severely affects marine organisms that produce calcium carbonate (CaCO_3) structures and shells. These organisms include corals, zooplankton (such as coccolithophores, pteropods, and foraminifera), and invertebrates. Calcium carbonate dissolves in the presence of acids. **Calcareous** marine organisms continuously add calcium carbonate to their shells/exoskeletons. In a healthy system, the rate at which CaCO_3 dissolves and the rate at which calcareous organisms can replace CaCO_3 are balanced.

What are the sources of calcium carbonate in the ocean?

The calcium and carbonate ions found in the ocean originate from rocks and minerals on land. These ions are dissolved in rivers and transported to the ocean. Corals, marine invertebrates (such as crabs, mollusks and echinoderms) and zooplankton combine calcium and carbonate ions and secrete hard exoskeletons. Most of the calcium carbonate in ocean waters and sediments comes from the exoskeletons of zooplankton. Recently, researchers at the University of Exeter have begun studying the contribution of calcium carbonate from the excretions of bony fish. They have calculated that approximately 3-15% (and perhaps more) of the total carbonates produced in the ocean are contributed by bony fish (Wilson, 2009). “For a given total mass of fish, smaller fish produce more than bigger fish, and fish at higher temperatures produce more than fish at lower temperatures” (Brahic, 2009).

Depth (decibars)	0.00
Temperature (celsius)	9.632
Conductivity (mmhos)	4.770
Salinity (psu)	1.950
O2-% (O2 %)	83.6
O2-ppm (O2 ppm)	7.75
pH (pH)	7.855
Eh (mV)	55.4

Ocean Watch measures the pH of seawater. Above is an example of a lower-than-average pH measurement observed in the Gulf of Alaska.
© David Thoreson Images

**ACTIVITY MISSION****Time: 45 min.**

Ocean acidification involves seawater that is more acidic than the optimum range, yet it is still a base, with a pH greater than 7. Therefore, ocean acidification describes a *process*, not a state. Students will observe the effects of a weak acid on the dissolution of calcium carbonate. Students will make predictions about the effect of basic (alkaline) solutions on the calcium carbonate. Students will design an experiment to test their hypotheses with various solutions (pH \geq 7). This activity assumes students are familiar with basic concepts of acids and bases.

CONCEPTS

- The ocean is becoming more acidic, largely because of human activity.
- Acids dissolve calcium carbonate, which is found in corals and the shells of marine invertebrates.
- Acidification is a process, not a state.
- Changes in ocean pH can harm organisms when these changes exceed the functional range.

LEARNING OBJECTIVES

- Students will be able to demonstrate their knowledge of ocean acidification by defining terms.
- Students will be able to demonstrate their understanding of ocean acidification by making predictions.
- Students will be able to analyze ocean acidification and its impact on marine environments by designing an experiment and making inferences.

STANDARDS & PRICIPLES**U.S.:** 8.8, 8.9, 12.1, 12.3, 12.4-9**Canada:** 307-5, 208-5, 208-6, 208-7, 208-8, 209-1, 209-2, 209-3, 209-4, 209-6, 210-11**Ocean Literacy Principles:** 3e, 3f**PRE-DELIVERY PREP****Supplies Needing a Day or More to Prepare**

- Universal pH indicator, liquid or strips – Available from science education supply company or local aquarium supply store

Hard-to-Obtain Materials

- None

SAFETY GUIDELINES**Safety Procedures**

- Wipe up any spills immediately.
- Keep hands clean and away from eyes, nose and mouth.
- In case of eye contact, flush eyes with water for 15 min. Consult medical authorities.
- Clean-up: Contents of cups can be rinsed down the sink with large amounts of water. Plastic cups that are not cracked can be rinsed and re-used for other science activities (NOT FOR FOOD USE).

Hazardous Materials

- Universal indicator is flammable (alcohol base). Follow MSDS (Material Safety Data Sheet) for handling and storage.
- Eye irritants – ammonia and vinegar can be very irritating to eyes.

Safety Concerns for Students

- Monitor students for appropriate handling of chemicals and materials.

ACTIVITY MISSION

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
Cups	Clear, plastic	3/group
Safety goggles		1/student, teacher

Consumable Supplies

ITEM	DESCRIPTION	QUANTITY
Antacid tablets	Containing CaCO_3 (white, if possible)	50/class
Water		As needed
Ammonia, baking soda, or calcium carbonate	Household	As needed
Vinegar	Household	As needed
pH strips or universal indicator		1-2 strips/liquid sampled
Pipets or droppers for universal indicator		As needed
Paper and Pencil/Pen	To record data	1/student

PROCESS & PROCEDURE

This is a teacher demonstration or student activity. Recommended Group Size: four students per group.

Teaching about CaCO_3 and Acidic Solutions

1. Always wear safety goggles.
2. Add approximately 2 TBS (50 mL) vinegar to a clear plastic cup. (Amounts will vary with the supplies used - the solution should fill about 1 in. (2.5 cm) of the cup).
3. Measure the pH of the solution by dipping the edge of the pH strip into the vinegar or by adding 5 drops of universal indicator (enough to get a definite reading).

- What does the change in color tell you about the pH of vinegar? (The orange-red color shows that the vinegar is acidic.)
4. Add an antacid tablet to the solution and observe changes. (The CaCO_3 reacts with the acid, producing carbon dioxide (CO_2) bubbles. The tablet breaks apart as it dissolves.)

Making Predictions and Designing Protocol

- How will CaCO_3 react in bases (solutions with basic pH values, $\text{pH} > 7$)?
- Using the basic lab procedure (with or without modification) and the solutions available, what variables would you test? Why? (For example, test 3 different solutions $\text{pH} < 7$; test 3 different solutions $\text{pH} \geq 7$; test 3 solutions of same pH and vary time.)

Teaching about CaCO_3 and Basic Solutions

1. Always wear safety goggles.
2. Add approximately 50 mL (2 TBS) basic solution to a clear plastic cup.
3. Measure the pH of the solution by dipping the edge of a pH strip into the solution or by adding 5 drops of universal indicator (enough to get a definite reading). (*The pH should match product label. Otherwise, add drops of diluted ammonia, etc. to adjust pH.*)
4. Record the pH of this solution.
5. Add an antacid tablet to the solution and record observations. (*The tablet bubbles and starts to break apart as it dissolves.*)
6. Repeat procedure with the other two solutions.
7. Clean and put away materials according to teacher instructions.

Recipes for Basic Solutions with Ammonia and Vinegar

pH = 10 – undiluted ammonia (or ammonia:water 1:1)

pH = 9 – ammonia:vinegar 8 parts:2 parts

pH = 8 – ammonia:vinegar 6 parts:4 parts (OMSI, 1997)

- This will give approximate pH values. Test with pH strip or universal indicator.
- If pH needs adjustment, add more vinegar to make the solution more acidic or more ammonia to make it more basic.
- These solutions should be prepared the day of use. Without buffers, the pH of these solutions will not remain constant for long periods of time.

Notes: Universal indicator works best with clear liquids.

Misconception Alert: If colored calcium carbonate tablets are used, students may observe that the solution turns green (or pink, or orange...) as the tablet dissolves and the coloring mixes with the liquid. This is a physical change. Bubbles indicate chemical reactions.

K-5 ADAPTATIONS

Dissolve an Eggshell in Vinegar:

Put an egg in a clear container of vinegar. Make daily observations over 3-5 days. As the CaCO_3 shell dissolves, foam will form at the surface made from CO_2 bubbles and egg proteins. CaCO_3 structures dissolve slowly. Corals and marine invertebrates continuously form new shells.

Test the pH of Familiar Liquids:

Use pH strips to test the pH of liquids such as coffee, soda pop, orange or lemon juice, water, carbonated water, saltwater, milk, milk of magnesia, ammonia, bleach, etc. If the students are not familiar with acids and bases, show them a pH scale with the pH of these liquids. Have students test the pH of all liquids. Next, select four solutions – a very acidic/basic pair (such as vinegar/ammonia), and a slightly acidic/basic pair (coffee/saltwater). Have the students test the pH of all the solutions. Add an antacid tablet to the vinegar/ammonia pair of solutions and record observations. Make predictions about the intensity of the reaction (amount of bubbling) that the other two solutions will produce. Add antacid tablets and record observations.



LESSON 3

Sea Ice & Sea Temperature

INTRODUCTION & BACKGROUND

What is Sea Ice?

Sea ice is frozen seawater that is typically found in the Arctic and Antarctic regions. Sea ice is different from icebergs or glaciers, which form from freshwater sources (snow) on land (NSIDC, 2009).

How does sea ice form?

Saltwater, which contains water, salts and other particles, freezes at a lower temperature than freshwater: at average salinities (~35 parts per thousand), sea ice begins to form at about -1.8°C (28.7°F) (Garrison, 1996). As the water molecules in seawater form ice crystals, the salts are compartmentalized. Over time, these packets of salts are pulled through the ice by gravity. Eventually, salts are returned to the seawater under the ice and the overall salinity of the water increases.



A buoy used by the International Arctic Buoy Program for ice & weather forecasts. Ocean Watch deployed three of these in the Arctic. Photo courtesy of I. Rigor, UW-APL

Sea ice takes on different forms during the course of its development. In its early stages, it appears as a cloudy collection of ice crystals. As it continues to form, these crystals coalesce making round mats called “pancake ice.” As these pieces of ice consolidate, they ultimately form ice floes or sheet ice, which can be

thick enough to walk on (up to 10 – 13 feet or 3 – 4 m) (Garrison, 1996).

What are the connections between sea ice and ocean temperature?

Sea ice and seawater temperatures are connected in several ways. First, contact with sea ice cools the surrounding water. As the water cools, its density increases and the cooled water sinks. Second, sea ice affects the amount of energy that is absorbed from the sun. White sea ice reflects solar radiation back into space. Dark blue seawater, in contrast, absorbs solar radiation. Third, since seawater contains salt and other particles, it has to lose more heat energy (undergo greater cooling) to form ice crystals.

What is the concern about melting sea ice?

As amounts of sea ice decrease, the ocean loses its ability to moderate temperature changes. Heat energy is transferred from seawater to sea ice. If enough heat energy is present, the ice changes its phase from solid to liquid (melts). Scientists have recorded dramatic reductions in Northern Hemisphere sea ice over the past 30 years (IPCC, 2008). Without sea ice to absorb heat energy from the water, seawater temperatures rise with the addition of solar radiation. “The area of the [year-long Arctic] ice has been steadily decreasing since the satellite record began in 1979, at a rate of about 10% per decade. But the 2007 minimum, reached on September 14, is about 38% lower than the climatological average. Such a dramatic loss has implications for ecology, climate and industry” (NASA/ Goddard Space Flight Center Scientific Visualization Studio, 2009).

How does sea temperature affect ocean currents?

Sea ice helps drive the motion of deep ocean currents by changing both the temperature and salinity of the water. (See *Online Supplementary Background Information for Lesson 3* for more information on thermohaline circulation.)

Around the Americas and Sea Ice

The *Around the Americas* journey is possible because of recent decreases in Arctic sea ice. Now, it is possible for the boat *Ocean Watch* to sail from the Pacific to Atlantic Oceans through the Northwest Passage near northern Canada.

Educational Foundation

This activity is foundational to the advanced study of thermal properties in chemistry, biology and physics classes in later grades. Although your students may not be ready for the advanced concepts of heat of fusion, molecular bonding and specific heat, you may want to review the thermodynamics of phase changes for your personal background. The model in this activity illustrates the important role sea ice plays in moderating sea temperature – without it, the water heats quickly.

ACTIVITY MISSION

Time: 45 min.

Simulations of the thermal properties of water will illustrate the vital role that sea ice plays in moderating sea temperatures. Water, with floating ice, is heated on a hot plate. Students measure the temperature of the water at 15–30-second intervals, record their data and construct a line graph. Although heat is being added to the system, the temperature of the overall water will not change significantly until the ice melts.

CONCEPTS

- Water absorbs a large quantity of heat.
- Sea ice plays a large role in moderating global ocean temperatures.
- Models can represent complex systems.

LEARNING OBJECTIVES

- Students will be able to demonstrate their understanding of thermal properties of water by applying it to the role of sea ice in moderating ocean temperatures.
- Students will be able to demonstrate their understanding of changes in temperature data by constructing a graph.
- Students will be able to analyze global climate change by examining a model.

STANDARDS & PRINCIPLES

U.S.: 1.4, 9.3, 12.3-7

Canada: 311-12, 209-3, 209-6, 210-2, 210-4, 210-6, 210-12

Ocean Literacy Principles: 3f

PRE-DELIVERY PREP

Supplies Needing a Day or More to Prepare

- Ice cubes
- Hot plates:
Familiarize yourself with the unique qualities of your hot plates including:
Heat: At what setting (equivalent to “High”) does water boil?
Stirring: At what setting does the magnetic stir bar gently mix the water?
Location: Where will you locate the hot plates in the room? Outlets and/or power strips?

Hard-to-Obtain Materials

- Hot plates with stirring ability (Hot plates without magnetic stirring can be used. See Extensions for substitution notes.)

SAFETY GUIDELINES

Safety Procedures

- Allow hot glass to cool before handling, if possible. Otherwise, use leather gloves or hot pads while handling.
- Model: heat can be sensed by holding a hand near, but not touching, a potentially hot object. Pull away before actual contact.
- Seal broken glass in a cardboard box before disposal.

Hazardous Materials

- Hot plate

Safety Concerns for Students

The hot plate, glass container, water and steam above the container are hot. Students should avoid contact with these with bare skin.

SUMMARY OF SUPPLIES

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
Hot plate	Magnetic stirring capability preferable	1/group
Beaker or wide-mouth glass container (Pyrex)	2-C (500 mL) or greater capacity	1/group
Thermometer	Immersible, alcohol	1/group
Magnetic stir bar, or substitute manual stir rod (glass, metal, wood)		1/group
Leather gloves or Hot pads	Heat protection	As needed
Ring stand and clamp		1/group
Electrical power strips		As needed
Stopwatch or 1-min. timers		1/group
1-C (237 mL) measure		1/group

Consumable Supplies

ITEM	DESCRIPTION	QUANTITY
Water		As needed
Ice cubes, cooler		1 C (237 mL)
Paper and Pencil/Pen	To record data and graph results	2–3 sheets/student

PROCESS & PROCEDURE

This is an activity for student groups or a teacher demonstration.

Set-up:

1. Plug in the hot plates. (Arrange for enough room around each hot plate for groups of students to work.)
2. Fill the glass container approximately $\frac{1}{2}$ – $\frac{2}{3}$ full with water and place on the hot plate. (The exact amount of water does not matter, but all containers should have the same amount.)
3. Position the ring stand near the hot plate so the clamp can hold the thermometer in the water.
4. Gently add 1 magnetic stir bar to the water. Adjust the STIRRING control so the stir bar gently mixes the water, and note the power setting. Turn the STIRRING off, until you are ready to begin. (Stirring is preferred, but optional).



5. Position the thermometer so that it is immersed in the water (without touching the sides or bottom of the container) and the scale can be read clearly. Tighten the clamp around the thermometer to hold it in place.

Procedure:

1. Record the initial temperature of the water.
2. Add approximately 1 cup (237 mL)* ice to the water. (Approximately a water:ice ratio of 1:1.)
3. Record the temperature of the water and the appearance of the ice. Take readings and observations every 30–60 seconds.*
4. Turn on the STIRRING and HEAT controls. CAUTION: The hot plate and the water are hot. Do not touch.
5. Stop recording after 10 minutes or after the ice disappears.

* Results will vary depending on the amounts of water and ice and the heating capacity of the hot plate. Adjust amounts as necessary.

Data:

1. Plot your data of Temperature vs. Time and draw a line graph.

Interpretation:

- **What changes did you observe in the temperature of the water?** (didn't increase very much, then rose quickly after the ice melted)
- **What changes did you observe in the ice?** (no change, then got watery, and melted; gradual changes)
- **The same amount of heat was added to the water throughout**

the experiment — during the times when the temperature didn't increase very much and times when it increased dramatically. What was the heat energy used for while the temperature of the water remained somewhat steady?

(The heat energy was absorbed by the ice and used to break the bonds between water molecules as it transitioned from a solid to a liquid. A lot of energy is needed for water to change phase (solid-liquid, liquid-gas; gas-liquid, liquid-solid).

Application:

- **If this is a model of the Earth, what do the following parts of the model represent: water in the container, ice cubes, heat from the hot plate?** (seawater, sea ice, heat from the sun)
- **Based on this model, what do you predict will happen to global sea temperatures if polar sea ice melts?** (sea temperatures will increase a lot)
- **Why is it important for sea temperatures to be within a certain temperature range?** Biological and physical chemical reactions (such as cell metabolism and phase changes) are influenced by temperature. They do not occur or are stressed if the temperature is too high or too low.

Notes: The magnetic stir bar distributes the heat evenly throughout the beaker as the temperature increases. If hot plates with magnetic stirring are not available, manually stir the beaker with a stir rod (NOT with the thermometer). The stir rod can be glass, metal or wood (such as a craft stick), or other material suitable to your students. Stir the water (the same number of times) after each temperature measurement. Alternatively, you may choose to omit stirring, if uneven heating is not a factor you wish to control.



K-5 ADAPTIONS

Older Students:

Perform this activity as a demonstration.

- Have student “scribes” help keep time, record temperature, observations about ice.
- Student groups can record data, make graphs, and make predictions about the next reading based on data.

Younger Students:

Younger students may be familiar with how ice cools a cup of water and that the temperature quickly rises after the ice melts. Try the “low-tech” version: fill one cup with water. Fill a second cup with water and an equal amount of ice. Put the cups in a sunny window or under an incandescent lamp. Measure the temperature of the water in both cups. Record observations. While you are waiting for the ice to melt, look at books about ice, the water cycle or polar bears. Check the temperature every minute and record your observations. Discuss concepts in general terms and relate to water cycle.

Younger students may also enjoy reading stories by Inuit authors. See Extensions for more information.

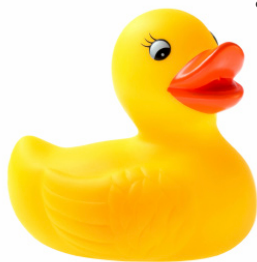
LESSON 4

Ocean Currents & Marine Debris

INTRODUCTION & BACKGROUND

How do scientists learn about ocean currents?

Scientists study Earth processes such as ocean currents by making observations and drawing conclusions. Typically, these observations involve carefully organized and often expensive experiments. However, sometimes accidental circumstances provide unusual opportunities for scientific observations. For example, if cargo transported on a container ship falls overboard and the contents float, wind and currents can carry the contents all over the world, providing new insights into ocean circulation.



Some popular items have been “lost at sea,” only to reappear mysteriously on ocean beaches months to years later. Some fun examples include Nike running shoes, rubber duckyies and a variety of other plastic bath toy animals (turtles, beavers and frogs). Scientists and beachcombers have been able to correlate reports of item sightings, shipping incidents, and knowledge about currents, which has resulted in predictions of where items may wash ashore and a deeper understanding of ocean currents. (See the Recommended Resources section for website references).

What effect does wind have on ocean currents?

Together, wind, temperature, and salinity are prime factors in circulating water around the globe. As the wind blows across the ocean, it moves the surface layer of water, primarily in the horizontal plane. (However, lower layers of ocean water are more resistant to movement, and the net effect is for lower waters to move in a direction perpendicular to

wind direction. This is called **Ekman transport**. (See *Online Supplementary Background Information for Lesson 4* for more information on Ekman transport).

What effect does temperature and salinity have on ocean currents?

Changes in temperature and salinity are the drivers of vertical ocean circulation. This process of mixing is called **thermohaline circulation**. (See *Online Supplementary Background Information for Lesson 3* for more information on thermohaline circulation).

What effect does the rotation of the Earth have on ocean currents?

The movement of seawater is also affected by the rotation of the Earth. Because the Earth rotates, moving air and water are deflected – to the right (clockwise, or toward the North) in the Northern Hemisphere, and to the left (counter-clockwise, or toward the South) in the Southern Hemisphere. There is no deflection at the **equator**. This is called the **Coriolis Effect**. (See Recommended Resources for animation references.)

What is marine debris?

Marine debris is any man-made material that is left in the ocean or on the coast. Marine debris is sometimes called “flotsam.” It is generally classified by its source: water-based or land-based. Marine debris takes many forms. Examples include fishing gear, nets, boats, cigarette butts, plastic bottles, human sewage, Nike shoes and rubber ducks (NOAA Marine Debris Fact Sheet, 2008). Marine debris not only pollutes seawater but also can entangle, poison, choke or starve marine animals.

Differences in seawater temperature and salinity drive ocean circulation. The pattern below is often called the ocean “conveyor belt.”

Source: Smithsonian Institute

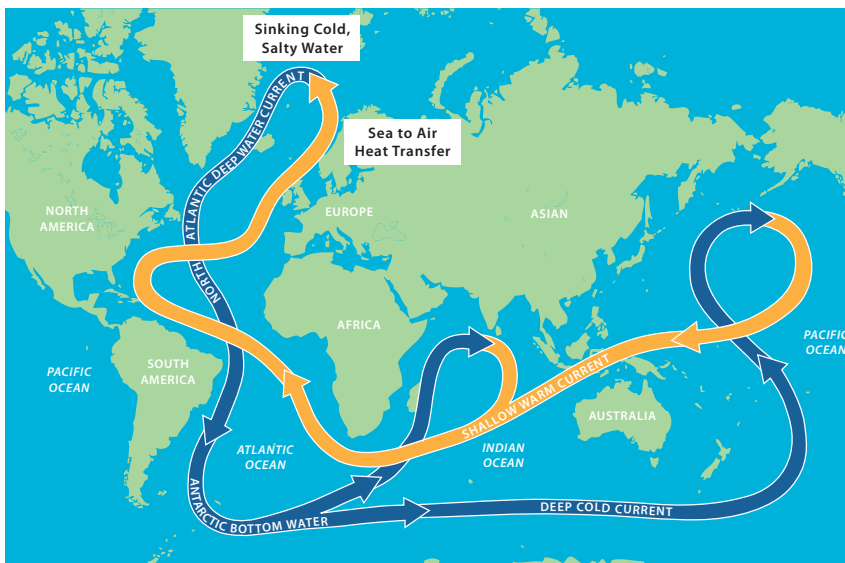
What effects do ocean currents have on marine debris?

Ocean currents transport marine debris. Most marine debris is made of plastic and floats near the surface. Marine debris can travel for many years and cover great distances. If marine debris does not get deposited on a beach, eaten by animals or transported to the ocean floor, ocean currents carry marine debris to places in the wide ocean where it gets “stuck” in **gyres** or circling currents. These masses of marine debris float around together.

Since plastics take a very long time to decompose, the “trash islands” continue to grow larger and larger.

What can students do to prevent marine debris?

Whether on land or sea, students can prevent marine debris by making efforts to reduce their use of materials and recycle those materials that can be recycled. Materials that are not-recyclable or are hard to recycle can be collected and disposed of properly so they will not end up in the ocean. Students can educate others in the community about how daily choices impact the accumulation of marine debris.



ACTIVITY MISSION

Time: 20-30 min. or several class sessions

This activity demonstrates key concepts of vertical and horizontal mixing, which are fundamental to ocean circulation and the transport of materials (e.g., nutrients or pollution) in the ocean. Specific exercises focus on the formation and movement of deep currents and how the Coriolis Effect impacts water circulation. This activity provides a starting point for students to research local measures for reducing, reusing and recycling, so waste does not work its way to the ocean.

CONCEPTS

- The motion of ocean currents is affected by wind (at the surface) and temperature (at greater depth).
- Large masses (“islands”) of marine debris have collected by the ocean’s currents.
- Scientists can learn about ocean currents by observing accidental marine debris.
- People can take actions to prevent the accumulation of marine debris.

LEARNING OBJECTIVES

- Students will be able to demonstrate their knowledge of physical processes by describing ocean currents.
- Students will be able to apply their understanding of physical properties by predicting the movement of ocean currents.

STANDARDS & PRICIPLES

U.S.: 1.1, 1.7, 9.3, 13.6

Canada: 311-9, 113-1, 113-9, 113-13

Ocean Literacy Principles: 1c, 6e, 6g

PRE-DELIVERY PREP

Supplies Needing a Day or More to Prepare

- Ice

Hard-to-Obtain Materials

- Immersible water heater

SAFETY GUIDELINES

Safety Procedures

- Keep water away from electricity.
- Keep hot water heater immersed in water while plugged in to electrical outlet. Do not touch.

Hazardous Materials

- None

Safety Concerns for Students

- Monitor use of immersible hot water heater. Do not touch.

SUMMARY OF SUPPLIES

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
Deep Currents:		
Pyrex glass loaf pan or small aquarium	clear, square, oblong, or round	1
Food coloring	red	1 bottle
Food coloring	blue	1 bottle
Pipets or droppers		2, one for each food color
Map of <i>Around the Americas</i> journey		1
Coriolis Effect:		
Glass pie plate (Pyrex)	clear	1
Overhead projector (optional)		1

Consumable Supplies

ITEM	DESCRIPTION	QUANTITY
Deep Currents:		
Cold water		Enough to fill clear glass container(s)
Hot water or immersible (tea) water heater		1
Ice cubes		Enough to fill the plastic bag and fit into one end of the clear pan
Plastic bag with zip-closure	1 quart-gallon (1–4 L) capacity, depending on size of glass container	1
Glitter or paper circles	Any small particles that float and sink when saturated can be used for marine debris	Amount determined by volume of pan
Coriolis Effect:		
Corn meal		½ tsp/demo
Transparency and Pen		1 each
Straws		1

PROCESS & PROCEDURES

Note: Use loaf pans for student groups or a small-medium size aquarium for a class demonstration.

1. Fill the loaf pan or aquarium with room temperature water.
2. Fill the quart/gallon plastic bag with ice. Seal the bag.
3. Immerse the bag in the water at one end of the pan/aquarium.
4. Add a small amount of blue food coloring to the water near the ice, just underneath the surface. Try to put the drop in one place, and not to mix it throughout the water.
5. Watch for movement of the blue food coloring, following the movement of the cold water.
 - What changes do you see? (Have students discuss an explanation, either to themselves or with partners.)
6. Immerse the hot water heater at the other end of the pan/aquarium.
7. Plug in the heater.

8. Add a small amount of red food coloring to the warm water at the other end of the pan/aquarium.
9. Watch for movement of the red food coloring, following the movement of the warm water.
 - What changes do you see? (Have students discuss an explanation, either to themselves or with partners.)
10. Add “marine debris” by sprinkling a small amount of glitter or paper circles (from a paper punch) to the water. (The density of the particles will affect where they float in the water column – on the surface, just below the surface or deeper.)
11. Debris “Islands” and Ekman transport: Use a straw to blow across the surface of the water in a direction perpendicular to the current. Observe the debris particles – do they clump together in islands? Observe the dye – as the surface direction changes – does the dye change direction?

Coriolis Effect (Littlefield, 2003):

1. Check focus of overhead projector.
2. Put transparencies on top of the overhead projector.
3. Place glass pie plate on top of transparencies on the overhead projector.
4. Fill glass pie plate with water, without spilling it on the projector.
5. Let the water settle, so it is still.
6. Gently sprinkle cornmeal particles on the surface of the water.
7. Turn on the overhead projector. The water and cornmeal pieces should be visible on the screen.
8. Pairs: Discuss, Make predictions, Support answers, Make a quick Sketch:
 - If a stream of air blows horizontally down the center of the plate (the equator), in what direction(s) will the particles move?
9. Blow across the surface of the water. (You may want to use a flexible straw, holding the short end parallel to the water surface.) Particles on the right side of the wind will rotate clockwise; particles on the left will rotate counter-clockwise.
 - What Earth process is this illustrating? Older students may recall the Coriolis Effect.
10. Use a transparency pen to identify North, South and Equator. Repeat demonstration so students can visualize air currents in the Northern and Southern Hemispheres.

K-5 ADAPTIONS

Read

Ducks in the Flow: Resources about Surface Ocean Currents for the Elementary Classroom (a story about rubber duckie debris in Book/Web Format)

"Ducks in the Flow: Resources about Surface Ocean Currents for the Upper Elementary Classroom." Windows to the Universe. 06 Mar. 2009
<http://www.windows.ucar.edu/tour/link=/teacher_resources/ocean_education/currents_main.html>.

Watch or read Paddle-to-the-Sea.

Paddle-to-the-Sea. Dir. Bill Mason. Perf. Stanley Jackson. DVD. Janus, 2008.
Holling, Holling Clancy. Paddle-to-the-Sea. Boston: Houghton Mifflin, 1969.

Creative writing prompts:

- If you were Paddle-to-the-Sea (or a Nike shoe, a rubber toy, etc.)... follow the waters in your watershed. Would you end up in the sea? What would you see and feel?
- Pretend you are a plastic bottle thrown overboard by a careless boater. Where did you enter the ocean? Where did the currents take you? What effect did the wind have? What animals did you see? Use the science concepts you know.

Kinesthetic Journey: (In the classroom or a large open space)

Recreate the concepts by describing different ocean and atmospheric conditions near your location while students act out the motions they would experience.

For example,

"Imagine you are a plastic bottle (or a Nike shoe, or a plastic toy, etc.) in the ocean. How would you move if you were...

- *Floating down a river?* (gently leaning side-to-side, up-and-down)
- *Bobbing about in the open ocean waves?* (more intense bobbing)
- *In the ocean and a fierce wind comes from (this direction)?* (students "blown" in that direction)
- *Now, the winds change to (this direction)?*
- *In the ocean and the sun shines brightly?*
- *In the ocean and the water feels warm?* (free, flowing motion)
- *In the ocean and the water starts to feel cool? Now, colder? The water turns to ice!? Starts to thaw... and suddenly you're free!* (motion slows, stops, and slowly begins again)
- *In the ocean and the current starts to flow in a circle?* (forming a large student "trash island")

LESSON 5

Aerosols & Clouds

INTRODUCTION & BACKGROUND

What are aerosols?

Aerosols – incredibly small particles suspended in air – are a vital ingredient in cloud formation. Aerosol particles range in size from about “10 nm (1 nanometer is a billionth of a meter) to around 100 micrometers (1 micrometer is a millionth of a meter)” (NASA, 2005). Aerosols provide substrates, or surfaces, upon which water molecules condense, grow into drops and eventually fall as rain. Students who are familiar with the water cycle may know that water vapor condenses into liquid water droplets, but the concept of aerosols may be new.

Aerosols can be classified either by source – industrial pollution, fires, desert storms, volcanic eruptions, sea spray or products from living things (pollen, spores, etc...) or by composition – carbon-based, sulfur-based, or mineral-based.

How do aerosols affect climate and clouds?

Aerosols affect climate. Aerosols can scatter incoming sunlight, resulting in cooling of the ground below. Conversely, aerosols can absorb energy from sunlight and warm layers of air. In addition, aerosols can prevent clouds from forming thick enough to cool the Earth below. Atmospheric systems are complex. It is difficult for scientists to predict the effects of aerosols on climate because aerosols are transitory – the particles do not remain suspended in the atmosphere for long periods of time. NASA scientists estimate that aerosol particles are in the atmosphere for only a few days before rain washes them away (2005).

Aerosols affect cloud formation. Without aerosols, rain clouds would not form. As water molecules condense on aerosol particles and form tiny droplets, they

join together and form larger and larger drops, until they are heavy enough to fall as rain. The concentration of aerosol particles affects the size of rain drops. The overall amount of water is the same; the size of rain drops and duration of clouds varies. For example, with a high concentration of aerosol particles, the water is spread out over a greater area and the rain drops that form are smaller than they would be if there were fewer aerosol particles. Smaller drops of water are not as heavy as large drops, so they are more likely to remain in the clouds. (See Figures 5a, 5b, p. 5, NASA Fact Sheet: *Aerosols: More Than Meets the Eye* for pictures of how aerosols affect rain drop size).

How do scientists study aerosols?

Scientists study aerosols using both satellites (such as NASA’s TERRA and CALIPSO satellites) and instruments called “sun photometers.” Data from sun photometers are typically more precise than satellite data. The researchers on board *Ocean Watch* will measure the amount of solar energy passing through the atmosphere using a sun photometer. The photometer on *Ocean Watch* measures sunlight in six different color bands from violet to red. The amount of sunlight that reaches the Earth is affected by the concentration of aerosols in the atmosphere. The higher the concentration of aerosols, the more light is scattered, resulting in less sunlight reaching the meter. Scientists will compare data from satellites and the photometer on *Ocean Watch* to evaluate the accuracy of the satellite data. This process is called “**ground-truthing**.” Ground-truthing is important when interpreting satellite data because some conditions, like snow on the ground, can look like cloud cover from a satellite image.



ACTIVITY MISSION**Time: 45 min.**

Students will gain a deeper understanding of the atmospheric observations being made during the *Around the Americas* expedition by the researchers on *Ocean Watch* as they experiment with creating clouds in plastic syringes and soda pop bottles. To determine the effect of aerosols on cloud formation, students will vary both aerosol concentration (particle amount) and composition (match smoke, chalk dust, ash, salt). Student groups will work together to compare results, with each group supervising the procedure of one bottle. (Or, if time permits, each group may test each variable). Students will investigate the following questions: How do clouds form? How does the amount of atmospheric aerosol effect cloud formation? (The question, “How do aerosols vary daily, among locations, globally?” can be addressed with a companion activity).

CONCEPTS

- Aerosols are very small particles suspended in air.
- Aerosols are essential for cloud formation.
- The concentration of aerosols in the air affects weather and climate.

LEARNING OBJECTIVES

- Students will be able to demonstrate their knowledge of aerosols and clouds by defining terms.
- Students will be able to demonstrate their comprehension of aerosols and clouds by interpreting experimental data.

STANDARDS & PRINCIPLES**U.S.:** 1.6, 12.1-8**Canada:** 311-9, 210-6, 211-1, 211-2, 211-3, 211-4, 211-5**Ocean Literacy Principles:** 3a-b

PRE-DELIVERY PREP**Supplies Needing a Day or More to Prepare**

- 2-L dry plastic soda pop bottles with caps – Empty, rinse and remove labels.
- Fireplace ash
- Paper funnels for chalk, ash, salt: Roll a piece of paper into a funnel and secure with tape. Trim edges as necessary, leaving enough of an edge to fold over if material is pre-filled and stored. Pre-fill with fireplace ash, chalk and/or salt and fold top and bottom to store. Or, have students spoon ash, chalk or salt into the funnel during class.

Hard-to-Obtain Materials

- None

SAFETY GUIDELINES

Safety Procedures

- Supervise matches at all times.
- Use these plastic syringes only for educational purposes.

Hazardous Materials

- Matches

Safety Concerns for Students

- Some steps of the procedure require the cooperation of all members in each group. Practicing the steps before adding chemicals may reduce chalk/ash/salt particles being blown into the air.
- Teachers may wish to light matches.

SUMMARY OF SUPPLIES

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
Part A:		
Syringe (no needle)	Plastic (60 mL or as large as possible)	1/group
Dropper bottle or container of water and dropper/pipet		1/group
Plastic pieces (ex: extra lids) (optional)	For sizing water drops	1/group
Part B:		
Plastic soda pop bottles	2-L	1 bottle/group of 2-3 students
Container of water		1/group of 2-3 students
Graduated cylinder/beaker or teaspoon (25 mL)		1/group of 2-3 students
Scoop	(Optional)	1 each for chalk, ash, salt/group
Clock in room or stopwatch	So students can measure seconds	1 clock/room or 1 stopwatch/group



Consumable Supplies

ITEM	DESCRIPTION	QUANTITY
Wooden matches		1 large box
Warm water		
Black construction paper	4.5" x 6" (11.4 cm x 15.2 cm) rectangles	1/group
Tape		Approx. 2 in. (5 cm)/bottle
Chalk dust	(optional)	At least 2 tsp (2 mL)
Ash from fireplace	(optional)	At least 2 tsp (2 mL)
Salt	(optional) table salt	At least 2 tsp (2 mL)
Paper funnel	Rolled together, secured with tape	1 each for chalk, ash, salt

PROCESS & PROCEDURE

Suggested order of activities:

Pre-instruction activity: Part A: Mini-clouds in a Syringe;

Post-instruction activity: Part B: Cloud in a Bottle, and Extensions

Part A: Mini-clouds in a Syringe – for small groups

1. Pull the plunger out of the syringe. (Keep it for Step 4.)
2. Add $\frac{1}{4}$ drop of water into the syringe. (If you're not sure how much this is, put one drop of water onto the desk or a small piece of plastic – squeeze the dropper bottle or pipette normally. Note the size of this drop and the amount of pressure you used on the dropper bottle or pipette. Now try to create a drop that is half of a half of the droplet you just made.)
3. Cover the tip of the syringe with your thumb.
4. Put the plunger into the syringe. Hold the syringe so the tip (and your thumb) points up.
5. Select a place on the table near its edge. Put the plunger down against the table. Use the weight of your body to press it down. (As the plunger moves toward the tip, it compresses the volume of air inside the syringe.)

6. While keeping the plunger compressed, quickly drag the syringe off the table.
(The high pressure inside the syringe will push the plunger back.)
7. Remove your thumb from the tip of the syringe and gently depress the plunger.
(A fine mist of cloud appears.)
8. Collect syringes and re-use for educational purposes.

Part B: Cloud in a Bottle General Experimental Procedure – for small groups

Each student group will test one variable, share data and form conclusions.
A description of the general experimental procedure and each variable condition:

1. Follow the instructions for your variable (see below).
2. For each trial...
 - a. Squeeze the bottle near the base. Hold for 5–10* seconds and then release.
(*All trials should use the same amount of time.)
 - b. Repeat Step a (above) five times.
 - c. Observe the inside of the bottle for clouds. (Students may find it useful to tape a piece of black paper behind the bottle to detect cloud formation)
 - Do you see a cloud inside the bottle?
 - How quickly did it form? How thick is it?(Use an appropriate rating method for your students – a 1–5 scale of cloudiness, percent or uniform descriptive words)
 - d. Record your results. Clean the bottle (removing as much water as possible) and repeat the procedure.
3. Run three trials and average your results.
4. Compare results of all variables with class.

Variables

No Water

1. The bottle should be empty and dry.
2. Do not add anything to the bottle.
3. Replace the cap on the bottle.
4. Complete Steps 2–3 of the Experimental Procedure.

Water Only

1. Use the plastic funnel to add 50 mL (10 tsp) water to the bottle, without getting water on the sides of the bottle.
2. Put on the cap and carefully swirl the bottle for 15 sec.
3. Complete Steps 2–3 of the Experimental Procedure.



Water and Smoke Particles

1. Use a plastic funnel to add 50 mL (10 tsp) water to the bottle, without getting water on the sides of the bottle.
2. Put on the cap and carefully swirl the bottle for 15 sec. Remove the cap.
3. Light a match and place it in the opening of the bottle. Do not drop it into the bottle.
4. Squeeze the bottle (blowing out the match), and let go of the bottle quickly to draw the smoke into the bottle.
5. Remove the match and replace the cap.
6. Complete Steps 2–3 of the Experimental Procedure.

Water and Chalk Particles

1. Use a plastic funnel to add 50 mL (10 tsp) water to the bottle, without getting water on the sides of the bottle.
2. Put on the cap and carefully swirl the bottle for 15 sec. Remove the cap.
3. Squeeze and hold the bottle, and place the paper funnel on the opening of the bottle.
4. Put a pinch/tiny scoop of chalk dust into the paper funnel and quickly let go of the bottle to draw the particles into the bottle.
5. Remove the paper funnel and replace the cap.
6. Complete Steps 2–3 of the Experimental Procedure.

Water and Ash Particles

Observe the ashes. Are the particles uniform in size? How do the particles compare to the chalk, salt or smoke particles? If more than one size is present, roughly estimate the quantity of each type of ash particle size in a scoop of ash.

1. Use a plastic funnel to add 50 mL (10 tsp) water to the bottle, without getting water on the sides of the bottle.
2. Put on the cap and carefully swirl the bottle for 15 sec. Remove the cap.
3. Squeeze and hold the bottle, and place the paper funnel on the opening of the bottle.
4. Put a pinch/tiny scoop of fireplace ash into the paper funnel and quickly let go of the bottle to draw the particles into the bottle.
5. Remove the paper funnel and replace the cap.
6. Complete Steps 2–3 of the Experimental Procedure.

Water and Salt Particles

1. Use a plastic funnel to add 50 mL (10 tsp) water to the bottle, without getting water on the sides of the bottle.
2. Put on the cap and carefully swirl the bottle for 15 sec.
3. Squeeze and hold the bottle, and place the paper funnel on the opening of the bottle.

4. Put a pinch/tiny scoop of salt into the paper funnel and quickly let go of the bottle to draw the particles into the bottle.
5. Remove the paper funnel and replace the cap.
6. Complete Steps 2–3 of the Experimental Procedure.

Clean Up

- Contents of bottles (except for ashes) can be rinsed down the sink with large amounts of water.
- Ash particles: pour liquid through a strainer. Collect ashes and add to compost or dispose in trash.
- Plastic bottles in good condition can be rinsed and re-used for other science activities (NOT FOR FOOD USE).

Notes:

Misconception Alert: Adults and students may associate the term “aerosols” with aerosol cans that use CFCs (chlorofluorocarbons) as a propellant. The use of CFCs as an aerosol propellant was banned in 1978 to prevent further accumulation in the upper atmosphere and protect the thinning upper ozone layer, which protects the Earth from harmful ultraviolet radiation. More information about non-CFC propellant products, including recycling methods, can be found at the Consumer Aerosol Products Council: “The Environment.” Home Page - Consumer Aerosol Products Council - CAPCO. 06 Mar. 2009 <<http://www.nocfcs.org/environment/home.htm>>.

K–5 ADAPTIONS

Perform Part B as a class demonstration. Use the variation (smoke, ash, chalk, salt) that is most appropriate for your region or current events.

Focus on cloud formation, identification and the role of clouds in the water cycle using additional exercises. There are some excellent activities developed by one of the collaborators of the *Around the Americas* program, the NASA Students’ Cloud Observations On-Line (S’COOL) program:

“S’COOL - For Teachers - Resources.” Education Resources from the Science Directorate at NASA Langley Research Center. 06 Mar. 2009
<<http://science-edu.larc.nasa.gov/SCOOL/ForTeachers-resources.html>>.

U.S.G.S. (United States Geological Survey). Water Science for Schools: The Water Cycle – Water cycle diagrams in English, French, Spanish, Portuguese, and other languages

“The Water Cycle, from USGS Water Science for Schools. Diagram available in 60 languages.” USGS Georgia Water Science Center. 06 Mar. 2009
<<http://ga.water.usgs.gov/edu/watercycle.html>>.

LESSON 6

Snapping Shrimp

INTRODUCTION & BACKGROUND

What are Snapping Shrimp?

Snapping shrimp are small shrimp with a big claw. These small shrimp are causing scientists to sit up and listen. For many years, scientists had noted a certain crackling noise in the ocean. The question facing them was “How is this sound being made?” Finally, scientists were able to capture snapping shrimp on video while recording underwater sounds. Using this information, the scientists discovered how the sounds are produced.

Snapping shrimp have one large claw that they use for defense and predation. When the claw snaps shut, a bubble forms between the sections of the claw and a jet of water shoots out. As the bubble travels, pressure changes cause the bubble to implode, producing a “snapping sound”. This noise is part of the “tropical biological background” noise. It can be heard by military SONAR sensors in submarines and even by snorklers swimming near tropical reefs.

Scientists who have studied snapping shrimp have noticed that these sounds vary. They are more pronounced in the evenings when the shrimp are more active. Snapping shrimp use their jets of water to stun prey and predators (other shrimp, crabs, invertebrates) up close. They also use the sound to warn other snapping shrimp to keep their distance.

Where do Snapping Shrimp Live?

Snapping shrimp are found in shallow, protected, warm waters. They do not live in polar regions. Snapping shrimp live in small niches among rocks and coral, digging out sand and lightweight material. Typically, they are solitary animals. However, they have been observed in mutualistic relationships with Goby fish – the shrimp digs a protected hiding spot they can share, and the fish (who has better eyesight than the shrimp) alerts the shrimp to the presence of predators.

The researchers aboard *Ocean Watch* will be using a **hydrophone** during the expedition to record different types of underwater sounds. It is likely that they will hear snapping shrimp when they are in protected, tropical waters and ports.

Scientists on Ocean Watch use a hydrophone (right) to listen to underwater sounds.

Image courtesy of J. R. Olson, Cetacean Research Technology



ACTIVITY MISSION**Time: 15-30 min.**

By taking on the role of a snapping shrimp or the sensors that detect them, students will explore the unique adaptations of snapping shrimp and how they are detected.

CONCEPTS

- Snapping shrimp are only one example of the variety of living organisms that the ocean supports.
- Snapping shrimp have unique adaptations.
- Scientists use technology (visual and auditory) to learn about snapping shrimp.

LEARNING OBJECTIVES

- Students will be able to demonstrate their comprehension of the human connections with the ocean and its unique inhabitants by describing their personal experience and observations with “shrimp static.”

STANDARDS & PRINCIPLES**U.S.:** 6, 9.7, 9.8, 12.1, 13.6**Canada:** 109-2, 111-2, 111-5, 422**Ocean Literacy Principles:** 5d

PRE-DELIVERY PREP**Supplies Needing a Day or More to Prepare**

- Signs

Hard-to-Obtain Materials

- None

SAFETY GUIDELINES**Safety Procedures****Hazardous Materials**

- None

Safety Concerns for Students

Tripping Hazard: Adequate space should be given for students to move around without contacting desks, chairs, or personal items.

SUMMARY OF SUPPLIES

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
None required; All are optional.		
Scenario cards: “Night”/“Day” “Boat”, “Whale”, “Predator”/“Prey” or other crustacean activity	Laminated (See Procedure for description)	1 each
Sound-maker	“Clickers” or household objects that can be used to make soft sounds	About 12

Consumable Supplies

None

PROCESS & PROCEDURE

Pre-simulation Preparation:

This simulation may be done in the classroom or a large open area. Adequate space should be given for “shrimp” to move around.

1. Assign students in the class to one of three different roles: “Detector,” “Emitter” or “Snapping Shrimp.” (More than one student may be “Detector” or “Emitter”, but the majority of the class should play Shrimp.)
 - **Detector:** Mimics a hydrophone by listening for signals. The Detector tries to locate/track the emitter and remember the sequence and location of sounds. The Detector produces a sound when it detects and records a signal. (You may wish to designate a specific sound the Detector is detecting, such as whale sounds.)
 - **Emitter:** Produces signals mimicking marine sounds, such as boats, submarines, whales or dolphins. Emitters should make soft sounds that can be made repetitively and heard by the Detector. They can be representative, rather than realistic, e.g. a spoken “ping”, soft bell, click of “clicker”, tap wooden sticks, etc.).
 - **Snapping Shrimp:** busy scurrying around the rocky, ocean shallows, will SNAP (using one hand, salad tongs, etc.) when other shrimp come too close to their territory (e.g., just beyond arms reach); more active at night than during the day.
2. Designate the “ocean” – the area that will be monitored by hydrophones. (You may decide if the Emitters and Shrimp must stay within this region of the ocean or if, boats or whales can “pass through.”)

3. The Detectors stand at a fixed location in the ocean (near the surface, at middle depths or on the ocean floor). They stand still. (You may decide which way the Detectors should face: toward the surface, the ocean floor, at an angle, etc.) They keep their eyes closed or are blindfolded so they cannot see the activity of the shrimp. (This sensor array has no optic sensors.)
4. The Shrimp and the Emitters are free to move about in the “ocean”, but cannot touch another shrimp or the sensors.)
5. The Emitter “pings”; the Detector responds with a sound.
6. The Shrimp mill about, SNAPPING when they meet other snapping shrimp.
7. As the “shrimp” acclimate to their role and environment, their activity (and SNAPPING) will increase. (You can silently cue the activity of shrimp and emitters by holding up various scenario cards –
 - a. “Day” – shrimp active in and around burrows, but not at great distances
 - b. “Night” – shrimp activity increases because it is difficult for predators to see them
 - c. “Boat” – travel near “ocean surface”
 - d. “Whale” – low tones, swim at all ocean levels
 - e. “Predator”, “Prey” or other crustacean activity.
8. After a few moments of “ping”-ing and SNAPPING, stop the simulation.
9. If possible, rotate roles so every student has a turn being a shrimp and either a Detector or Emitter.

(Note to Teachers: If students get carried away with snapping and it's difficult to be heard over the noise, the students have fulfilled the simulation in their own way – creating noise interference.)

Reflection

- What did you observe/experience as a shrimp/emitter/detector?
- How did this activity illustrate snapping shrimp and their habitat?

K-5 ADAPTATIONS

Write and illustrate a short story about your experience. Would you stay quiet or increase your snapping if a predator came near you? What happens to a snapping shrimp? How do researchers learn about them? What technologies do they use?

LESSON 7

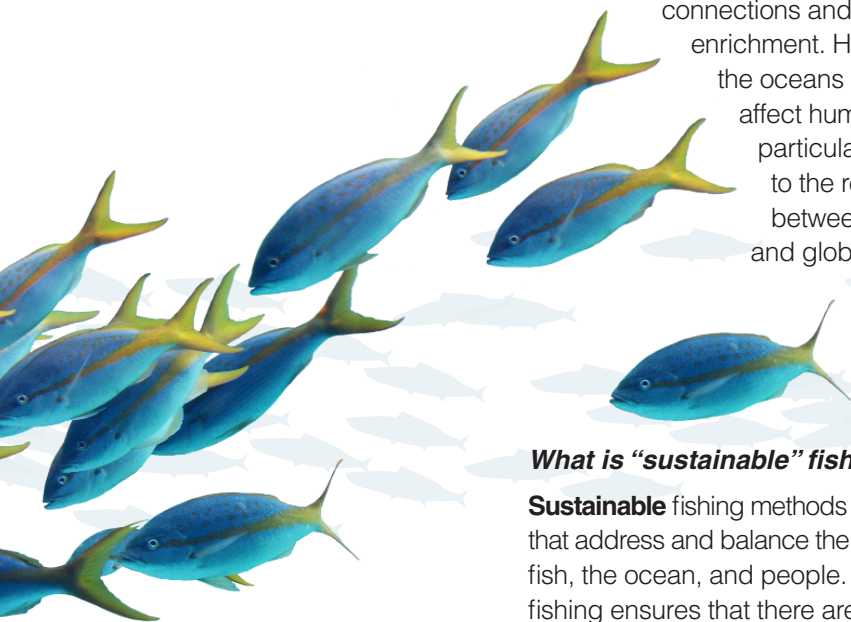
Sustainable Fisheries

INTRODUCTION & BACKGROUND

How are humans connected to the ocean?

Humans are inextricably connected to the ocean. The ocean is a source of food, medicine (from minerals, plants, invertebrates, fish and mammals), energy, and recreation. People use it for commerce (fishing, research, processing mineral and energy resources) and transportation (moving goods or people great distances). It is a rich source of human cultural

connections and personal enrichment. Humans affect the oceans and oceans affect humans: this is particularly relevant to the relationship between humans and global fish stocks.



What is “sustainable” fishing?

Sustainable fishing methods are strategies that address and balance the needs of the fish, the ocean, and people. Sustainable fishing ensures that there are enough fish left in the ocean to reproduce and enough fish to sustain human needs for food.

This type of practice maintains a healthy ocean ecosystem, by meeting the needs of all stakeholders in a way that provides for the future.

Special Focus: What are “catch share” programs?

Catch share programs are fish management practices in which the total quota of a certain type of fish is decided for the season, and divided into designated portions for each

participant. Catch share programs go by many names: Limited Access Privilege Programs (LAPPs), Individual Fishing Quotas (IFQs), or simply Catch Shares. In general, catch share programs encourage fishers to invest in the sustainability of fish stocks. All catch share programs are not identical. They vary with region, fish conditions, participants involved (both individuals and communities), and how catch shares are allocated (lottery, auction, direct sale) and maintained (returned or retained at end of season, purchased from other fishers).

What are the effects of catch share programs?

Scientists have recently discovered statistically significant benefits to catch share programs. Benefits of catch share programs include the use of more efficient fishing methods, improvement in the safety of fishers, and an increase in fish populations. In addition, since fishers in catch share programs know their fish quota, they tend to fish when weather conditions are favorable and there are good chances of catching fish. Fewer fishing trips use less fuel and fishers are less likely to fish during storms or other instances where physical risks increase. Fishers are also more likely to use methods that target their quota fish and reduce the amount of “**bycatch,**” or fish caught unintentionally and discarded.

Catch share programs are not perfect. Each region has its unique problems related to fish populations. However, researchers now have data that support the use of catch share programs as a way not only to slow the decline of fish loss, but also to increase fish populations (Costello, 2008).



Where are catch share programs used?

In the Americas, Catch Share programs are used on the West and East Coast of the United States (the Pacific Northwest, Alaska, New England, and North Carolina), British Columbia, Canada, the Gulf of Mexico, and Chile.

(See Online Supplementary Background Information for Lesson 7 more information on sustainable fishing).

ACTIVITY MISSION

Time: 30-45 min. (Procedure + Extension A)
20-45 min. (Extension B)

Students simulate fishers catching fish from the world's oceans. They explore different harvesting methods, using simple to complex technologies. In Extension A, students participate in a “catch share” program and examine the effect on fish populations and group dynamics. In Extension B, students identify local fish use and **overfished** populations.

CONCEPTS

- Humans are connected to the ocean.
- Human actions and technology have positive and negative impacts on the ocean.
- Ocean systems are very complex and involve many intertwined connections.
- Many of the ocean's fish populations have been over-fished.
- Sustainable practices can have ecological and economic benefits.
- Solving complex problems involves complex answers and cooperation.
- Individual choices have an impact on the environment.

LEARNING OBJECTIVES

- Students will be able to demonstrate their comprehension of sustainable practices by explaining “catch share” programs.
- Students will be able to demonstrate their analysis of sustainable practices by comparison and contrast.
- Students will be able to demonstrate their evaluation of sustainable practices by explaining their personal choices when eating fish.

STANDARDS & PRINCIPLES

U.S.: 6.2, 11.4, 13.6

Canada: 306, 113-1, 113-2, 113-9, 211-3, 211-4, 211-5, 430, 431, 432

Ocean Literacy Principles: 1b, 1e, 1g, 7c

PRE-DELIVERY PREP

Supplies Needing a Day or More to Prepare

- None

Hard-to-Obtain Materials

- None

SAFETY GUIDELINES

Safety Procedures

Monitor student use of materials.

Hazardous Materials

None

Safety Concerns for Students

Tokens are choking hazards.

SUMMARY OF SUPPLIES

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
“Fish” tokens (mixture)	Small and medium dried beans or pebbles	About 200
“Ocean” Basins	Bowl or coffee filter	1/group
“Boat”	Cup or folded paper boat	1/student
Spoons		1/student

Consumable Supplies

ITEM	DESCRIPTION	QUANTITY
Paper and Pencil/pen	For student use	1/student
straws		1/student

PROCESS & PROCEDURE

Adapted from Fishing for the Future, from Facing the Future ©2006. www.facingthefuture.org. Used by permission.



Pre-Activity Preparation (Optional)

1. Show students how to fold a boat from a sheet of paper. Students will use this boat to contain their “catch.” Only fish that land in the boat can be counted.

The Activity

1. Introduce and discuss the concept of sustainability using the following definition:
“Sustainability is meeting the needs of the present without limiting the ability of people, other species, and future generations to survive.”
 - Why might sustainability be an important goal for a society?
 - What might be difficult about realizing this goal?
2. **“Today you’re going to go fishing and explore some of these sustainability issues.”**
3. Explain the basic game rules:
 - a. Fishers - Each student will be a “fisher” whose livelihood depends on catching fish.
 - Each fisher must catch at least two fish (large or small) in each round to survive (i.e., get enough fish to either eat or sell).
 - b. Fish –
 - Medium beans (such as kidney beans) represent the largest and most valuable fish (tuna, swordfish, etc.).
 - Small beans (such as pinto beans) represent the next most-valuable fish (cod, salmon, etc.).
 - c. Methods – (listed here for quick teacher reference. Share with students before each season.)
 - Season 1: without hands, use straws to suck beans from bowl into boat
 - Season 2: hands on straws to catch fish
 - Season 3: spoon

General Rules for Playing the Game

1. Divide the class into groups of three or four students and have each group choose an ocean basin such as North Pacific, Arctic, North Atlantic, South Atlantic, Southern, South Pacific, etc.
2. Give each group one serving bowl and each student one boat and one straw. Have students create a data table similar to this Fishing Log: www.pbs.org/emptyoceans/educators/activities/fishing-for-the-Future.html

3. Put 20 small and 10 medium beans in each group's bowl. (You may wish to prepare these before class.)
4. Follow the directions for each fishing season.
5. Discuss impressions.
6. Repeat with Extensions and Discuss.

Season 1: (Method – Fishing rods)

1. In order to fish with their “fishing rods,” students must hold their hands behind their backs and use the “fishing rod” (straw) to suck “fish” beans from the “ocean” (bowl) and deposit them into their “boat” (cup).
2. Declare the fishing season “open” (Say “start fishing”) and give the students 20 seconds for the first “season” of fishing.
3. At the end of 20 seconds, declare the fishing season “closed” (“stop fishing”).
4. Have each fisher count his or her catch (beans in their boat) and record the data in their Fishing Log.
5. Fishers who did not catch the two-fish minimum must sit out for the following round.
6. The fish remaining in the ocean after each fishing season represent the breeding population. Add one new fish for every fish left in the ocean (bowl).

Variation for Season 1:

Have students close their eyes or put on blindfolds to simulate locating and catching fish without using technologies such as sonar.

Season 2:

(Method – Trawl nets or Long-line Fishing (See Recommended Resources))

1. In order to fish with their “newer technology,” fishers may use their hands on the straws.
2. Repeat Steps 2–6 in Season 1.

Season 3: (Method – the latest “fish finder” Sonar)

3. In order to fish with the “latest technology,” fishers may use a spoon.
4. Repeat Steps 2–6 in Season 1.

Variation for Season 3:

Give only one student per group the use of a spoon.
Sometimes there is a technological disparity among competitors.

Season 4 +: Expand Fishing Areas

“What happened when [ocean basin] ran out of fish? How are the fishers going to survive now?”

1. Have students brainstorm solutions. Allow students to “explore other fishing territories” (other ocean basins) when their ocean is depleted, but don’t tell them that they can do this beforehand. Fishers may either go as a group to another ocean or they may disperse to other oceans.
2. Repeat fishing, recording, and replenishing fish stocks until either sustainable fishing is achieved or until all (or most) groups fish out their ocean.

Reflection

- **As a fisher, how did you feel when you realized that you had depleted your fish stock?**
- **As a fisher, how did you feel when other fishers joined your ocean group?**
- **How does this activity relate to real ocean and fishery issues?**
- **What’s missing in this game?** (Impacts to other animals (e.g., birds and marine mammals) that rely on fish for their survival, population growth, etc.)
- **What happens to a resource when you have rapid human population growth, growing technology, and a finite resource?**

K-5 ADAPTATIONS

Substitute plastic marbles, small toy fish from a toy store or fish/oyster crackers for the “fish” tokens.

Write and illustrate a story. Creative writing prompts:

- What would it be like to be a fisher? What will the ocean be like if everyone tries to get the most fish? What should people do?
- What fish do the students and their families eat? Where does it come from? How does the fish get from the ocean to their plate?

Lesson Extensions

LESSON 1: CORAL, CARBON DIOXIDE AND CALCIFICATION

Extension A: Changes due to increased atmospheric carbon dioxide

Simulate a large amount of atmospheric carbon dioxide added to the system. You can introduce this as, “**we’ve simulated how part of this system might work... what would happen if we changed some of the inputs?**” Bring out a LARGE box of pieces (doesn’t have to be full, only look like it). Let the chain work (steps A-E) until they are overloaded and stop.

Extension B: Increased temperature

Coral and other biological systems are stressed by increases in temperature. It is possible to raise temperature to certain point and have the system function, but then productivity stops and eventually the organism dies.

Dress *Coral* in a heavy winter coat and hat. Turn on a bright light. Start the process again. Make sure that *Coral* does a lot of movement. Increased temperature increases rate of reaction, so have the assembly line work faster and faster until they are hot, overloaded and stop.

Extension C: Adjust the complexity to suit your students

- Use colored blocks to represent the different components (*See Supplementary Background Information for Lesson 1*) or design your own code. Use the code for labels and instructions.
- Use only key chemical names - carbon dioxide, water, carbonic acid, etc. – with or without formulas.
- Use tags/lanyards to designate roles – “Coral”, “Ocean”, “Atmosphere” and “Dissolver.” Include the Role Title and Job Summary.
- Brainstorm physical motions to represent the different parts/occurrences in the system (students can help with this). For example, the phrase “Reaction, reaction” – “jazz” hands; water – rippling wave motion with arms, *Coral* – back of wrist held to top of forehead, fingers opening and closing like a hydroid, one hand is free per student so they will need to work together to assemble blocks, etc.


LESSON 2: INQUIRY INTO OCEAN ACIDIFICATION

Extension A: Effects of acidification

Find online pictures of the effects of acidification on marine organisms and have students share these with the class

Extension B: Changes in pH over time

Humans have had a great impact on the world’s oceans. Ask students to think about the ocean during the distant past (over geologic timescales). What conditions (other



than humans) may have changed ocean pH? (*Answers will vary but may include volcanic eruptions increasing atmospheric carbon dioxide levels and the deposition of calcium-carbonate shells as a result of the Permian-Triassic extinction of many marine invertebrate species.*)

LESSON 3: SEA ICE AND SEA TEMPERATURE

Extension A: Examine current data

Examine websites from UW-Madison or NASA that show Sea Surface Temperatures (SST) or Sea Surface Anomalies (SSA) and make observations of changes in SST and SSA and discuss tools that are used to collect these data. (See Recommended Teacher Resources).

Extension B: Stories by Inuit authors

Younger students may enjoy reading these stories by Inuit authors:

- Kusugak, Michael, and Krykorka, Vladlyana ill. *My Arctic* 1, 2, 3. Toronto: Annick P, 1996. "This counting book introduces small children to the concept of numbers by using the Arctic wildlife as examples. With predator on one page facing prey on the other, readers learn about counting, animals and the richness of the northern environment." (Publisher's annotation) Ages: 4-7
- Munsch, Robert N., Kusugak, Michael, and Krykorka, Vladlyana ill. *A Promise is a Promise*. Toronto: Annick P, 1988. Allusha, ignoring her mother's warnings about fishing on the sea ice, encounters and then must outsmart the Quallupillugs, mythological creatures who are known to drag children under the ice to their frozen home. (www.nlc-bnc.ca/) Ages: 4-8
- Tookoome, Simon, and Oberman, Sheldon. *The Shaman's nephew: a life in the far North*. Toronto: Stoddart Kids, 1999. "...Oberman interviewed Tookoome, "-one of the last of the Inuit to live the traditional nomadic life in the Far North," over a 10-year period and translated his stories from his native Inuktitut." (School Library Journal; Copyright 2000 Reed Business Information) Ages: 9-12

LESSON 4: OCEAN CURRENTS AND MARINE DEBRIS

Extension A: Deep currents

Create thermohaline circulation (use an aquarium for class demonstration). Fill the aquarium 3:1 salt water: fresh water. Add at least 4 tsp. salt per gallon of water (35 g salt per liter). Dissolve thoroughly. (The salt water should look slightly "fuzzy" or "shimmery.") Method 1: Add the bag of ice at one end and the heater at the other end of the aquarium. Method 2: Reserve one part of the saltwater. Chill. Add the rest



of the saltwater to the tank. Carefully pour the freshwater down the side of the tank, to minimize mixing the water. Add the heater at the other end.

Finally, add drops of blue food color below the bag of ice (or area of chilled saltwater) and drops of red food color to the side of the heater.

Extension B: Watch and write about *Paddle-to-the-Sea* DVD

Creative writing prompts:

- If you were Paddle-to-the-Sea (or a Nike shoe, a rubber toy, etc.)... follow the waters in your watershed. Would you end up in the sea? What would you encounter?
- Pretend you are a plastic bottle thrown overboard by a careless boater. Where did you enter the ocean? Where did the currents take you? What did you encounter? What ultimately happened to you?

Encourage students to include scientific detail: where did the currents take you? Where in the water column did you travel: at the surface or in deep currents? What did you encounter (animals, plants, temperatures, light/dark, etc.)? What ultimately happened to you? (recycled, swallowed by a sea bird, joined the mass of trash islands, covered in algae, etc.)

Extension C: Discuss local connections

- What kind of non-trash marine debris items (Nike shoes, plastic bath toys, glass floats, etc.) have been found in your area? Interview adults or search the internet for information.
- What can people in your area do to prevent marine debris?

LESSON 5: AEROSOLS AND CLOUDS

Extension A: Vary the concentration of particles

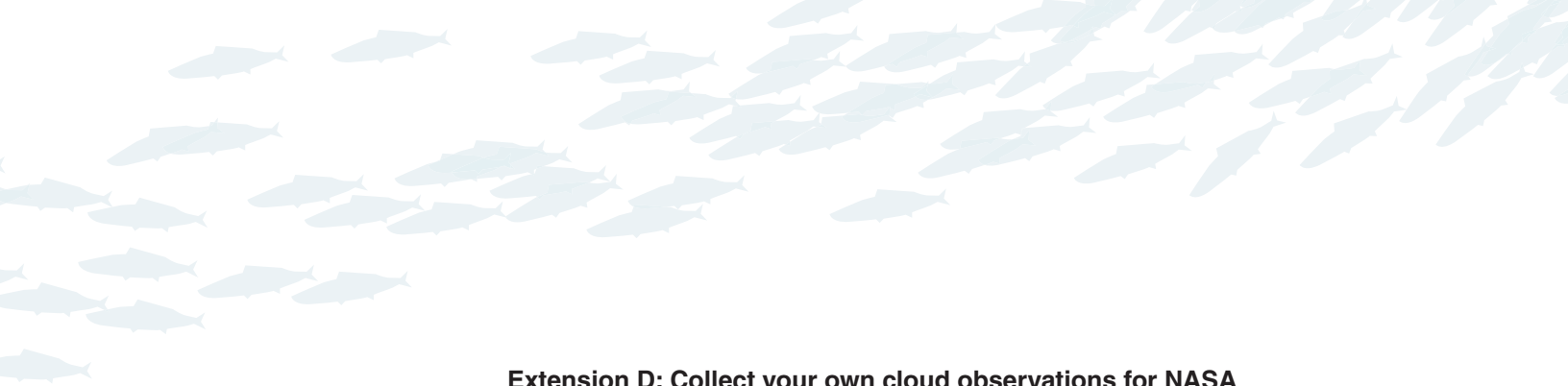
Use more than one match, a larger or smaller scoop of chalk, ash or salt. Have students help determine variables.

Extension B: Vary the temperature of the water

Use ice water to simulate clouds forming over polar oceans.

Extension C: How do aerosols vary daily, among locations, globally?

Use with “Aerosol Lab Activity” – (Trap and Count Local Aerosol Particles)
<http://asd-www.larc.nasa.gov/SOLAR/labactivity-index.html>



Extension D: Collect your own cloud observations for NASA

The crew of *Ocean Watch* collects cloud coverage data for NASA, and you can do the same from your school or backyard! Instructions and an online tutorial are here: <http://science-edu.larc.nasa.gov/SCOOL/index.php>

LESSON 6: SNAPPING SHRIMP

Extension A: Add additional roles

- *Detector/Researcher* (as many as desired) – sits with their back to the ocean. Has a checklist of possible sounds and records their identity/path. After scenario, checks data with Observers.
- *Observer* - Observes the scenario and records identity/path of sounds. Provides feedback to Detector/Researchers.
- *Goby* – pair some of the shrimp with a Goby friend. The shrimp should squint – enough to partially obscure vision, but not enough that shrimp without a Goby will get injured. The Goby watches and alerts the shrimp to predators and competitors. Who was more active – the solo shrimp or the Goby-shrimp pairs?

Extension B: Locations of snapping shrimp

Locate areas on a map or globe where you think researchers on *Ocean Watch* will find snapping shrimp.

LESSON 7: SUSTAINABLE FISHERIES

Extension A: Catch-share simulation

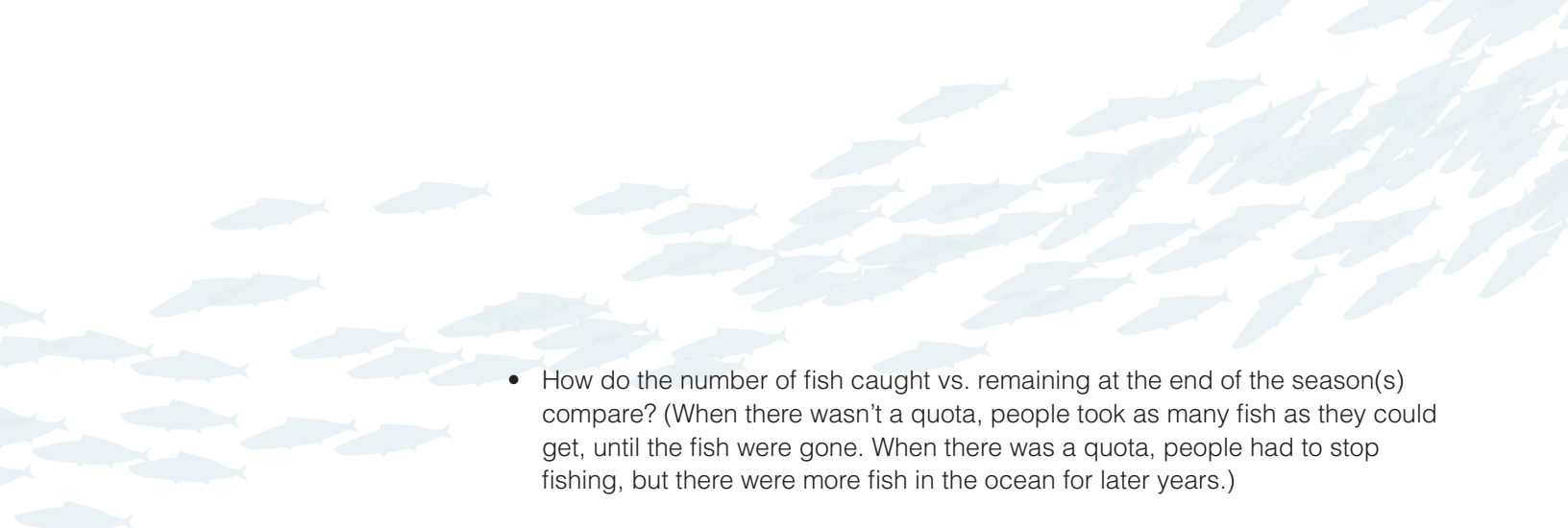
Each group designates one person as the Fish Regulator – the person setting the quotas. This person does not fish. The quota, or amount of fish that can be taken, is decided for the season. The Fish Regulator can take advice from others, but s/he determines the total of fish that can be taken, while leaving some fish in ocean so they will reproduce and replenish the fish stocks.

Every fisher in the group is allotted a share of the total quota.

Have fishers fish several seasons and reflect on process before you discuss the details of real catch share programs.

Reflection:

- What did you notice about the behavior of individuals in each season? (Individuals were not in as much of a hurry. There wasn't as much competitive behavior. There wasn't a rush. People took turns. People worked cooperatively.)
- How does these fishing seasons compare with the previous (non-quota) fishing seasons?

- 
- How do the number of fish caught vs. remaining at the end of the season(s) compare? (When there wasn't a quota, people took as many fish as they could get, until the fish were gone. When there was a quota, people had to stop fishing, but there were more fish in the ocean for later years.)

Variations to Extension A – Economic Effects

- A. Fish shares can be bid on and “bought” at auction and/or traded among fishers.
- How does this change the scenario?
- B. “Fish” tokens can be “sold” or traded in for “money.”

Students will need to “sell” their fish at the market (at a location away from their ocean, such as the front of the classroom). Fishers can bring their fish to market at any time. (A large crowd of students waiting to “sell” their fish will illustrate when the market is “flooded.”)

Vary the price (exchange rate) for the “fish” according to supply and demand – a large number of the same type of fish on the market will drive down the price-per-fish. Price ranges should suit the mathematical level(s) of your students.

Extension B: Do you know what fish you're eating?

Present the following Research/Reflection questions in class. Give students an opportunity to wonder and form their own questions on this topic. After they have completed their research, have them share their results, opinions and reasons.

Research Questions and Reflection:

- What type of fish do you eat?
- What types of fish are at the local stores and restaurants?
- Where do they come from? Oceans or rivers/lakes? Local or distant? Wild or Farmed?
- Are these fish available all year or only during certain times?
- What is the abundance of these fish? Are they over-fished?
- Based on your research, which fish would you choose to eat? How did your research influence your choice(s)?

Recommended Research Resources:

Blue Ocean Institute Seafood Guide:

“Blue Ocean Institute Seafood Guide.” Blue Ocean Institute. 06 Mar. 2009 <<http://www.blueocean.org/seafood/seafood/seafood-guide>>.

Seafood Watch Card:

Download a Regional Seafood Watch Card, Monterey Bay Aquarium, California. 06 Mar. 2009 <http://www.montereybayaquarium.org/cr/cr_seafoodwatch/download.aspx>.

FAO Fisheries Distribution Maps:

“FAO Fisheries & Aquaculture Compilation of Aquatic Species Distribution Maps of Interest to Fisheries, Overview.” Fishery Statistical Collections. Food and Agriculture Organization of the United Nations. 07 Mar. 2009 <http://www.fao.org/fishery/collection/fish_dist_map/en>.

Extension C: Local fishers

Explore the history, technology and cultural importance of fishing methods of various local commercial, recreational, subsistence and artisanal (traditional/tribal) fishing groups through guest speakers, fieldtrips, interviews and recordings (Marine Stewardship Council 2008).

- How does this fishing method work?
- If they could add a new or different fishing method/technology, what would it be?
- How did they start fishing? Are other family members fishers?
- What do they think would surprise most people about fishers or the fishing process?
- What do they enjoy the most/least about fishing?
- What is their favorite type of fish? Why?

Glossary

Abiotic: Non-living.

Acidification: The process of becoming more acidic from the original condition. Acidification does not require the final solution to be an acid ($\text{pH} < 7$).

Aerosol: Very small particles suspended in air. Aerosol particles provide a surface upon which water drops form.

Biotic: Living.

Bycatch: Fish caught unintentionally and discarded.

Calcareous: Containing calcium carbonate (CaCO_3).

Calcification: Biochemical reactions that deposit calcium carbonate forming a shell or exoskeleton for marine organisms.

Catch share program: An example of a fish management practice in which the total quota of a certain fish type is decided for the season, and divided into designated portions for each participant.

Cnidaria (ni-DARE-ri-a): A phylum of marine animals that are gelatinous and have stingers. The bell-shaped medusa forms are called “true jellyfish.”

Coriolis Effect: The deflection of air or water at the Earth’s surface caused by the rotation of the Earth. The deflection is northward (clockwise) in the Northern Hemisphere and Southward (counter-clockwise) in the Southern Hemisphere.

Ekman Transport: How layers of water are transported by wind. Ekman transport is 90° to the right of wind direction in the Northern Hemisphere, and 90° to the left of wind direction on the Southern Hemisphere.

Equator: An imaginary horizontal line drawn around the middle of the Earth that is geographically equidistant from the poles.

Ground-truthing: A method used to verify the accuracy of remote measurements. Measurements taken from the ground (often direct measurements) are compared to measurements taken from a satellite or other remote-sensing device (often indirect measurements based on calculations).

Gyre: A spiraling or circular current.

Hydrophone: An instrument that records underwater sound by using a transducer that only converts pressure into sound.

Latitude: Distance from the equator. On a map or globe, latitude lines run horizontally. Positive numbers indicate North; negative numbers indicate South.

Marine Debris: Any solid, man-made material left in the ocean or on the coast.

Overfishing: The practice of catching fish at a rate faster than the rate at which they can reproduce.

Polyp: The portion of a coral that is alive. Polyps have a simple, sac-like body shape with stinging tentacles surrounding the mouth opening.

Sea Ice: Ice formed from seawater. Sea ice forms in the ocean from saltwater. Icebergs and glaciers form on land from fresh water.

Snapping shrimp: A small shrimp (belonging to the genus *Alpheus*) that lives in tropical waters. Snapping shrimp use a large claw to create a jet of water to stun prey and communicate. Closing the claw creates a jet of water and bubbles that produce a crackling sound.

Sustainability: Meeting the needs of the present without limiting the ability of people, other species, and future generations to survive.

Symbiosis: Where two organisms live dependently on each other. Each organism provides something (e.g., food, shelter) to the other. The symbiotic relationship is beneficial to the survival of the organisms.

Thermohaline circulation: The movement of water currents around the globe due to changes in temperature and salinity, which impacts the density of water.

Zooxanthellae (zo-uh-zan-THEL-ee) : Various species of single-celled algae that live in a mutualistic symbiosis with coral (the symbiotic relationship is beneficial to both organisms). Zooxanthellae are photosynthetic and provide corals with nutrients and brilliant colors.



Recommended Teacher Resources

LESSON 1: CORAL, CARBON DIOXIDE AND CALCIFICATION

Web sites

NOAA animation of zooxanthellae (Click on purple image.):
http://oceanservice.noaa.gov/education/kits/corals/coral02_zooxanthellae.html

LESSON 2: INQUIRY INTO OCEAN ACIDIFICATION

Web sites

Pictures of the effects of ocean acidification on marine organisms:
<http://www.ocean-acidification.net/>

NOAA Research Council Report on Ocean Acidification:
http://www.nrc.noaa.gov/plans_docs/2008/Ocean_AcidificationFINAL.pdf

LESSON 3: SEA ICE AND SEA TEMPERATURE

Web sites

NASA/Goddard Space Flight Center's Climate Change Resource Reel:
http://www.nasa.gov/centers/goddard/earthandsun/climate_change.html

NASA Maps of Sea Surface Temperature:
<http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MYD28M#>

Near real-time global Sea Surface Temperature map at University of Wisconsin-Madison:
<http://www.ssec.wisc.edu/data/sst/>

Home Page of the Throps and the Squallhoots – Inuit stories, songs and games:
<http://www.athropolis.com/links/inuit.htm>

Arctic Voice - the Inuit website:
<http://www.arcticvoice.org/inuit.html>

Polar Bears and Climate Change:
<http://actionbioscience.org/environment/derocher.html>

Melting Under Pressure: The Real Scoop on Climate Warming and Polar Bears:
<http://pbsg.npolar.no/docs/StirlingDerocher-WildProf-2007.pdf>

LESSON 4: OCEAN CURRENTS AND MARINE DEBRIS

Web sites

Exploring Earth Visualizations website:

http://www.classzone.com/books/earth_science/terc/navigation/visualization.cfm

Curtis Ebbesmeyer's Beach Comers Alert website:

<http://beachcombersalert.org/NikeShoes.html>

NOAA Marine Debris Program's online resources:

http://marinedebris.noaa.gov/marinedebris101/resources_md101.html

Story of rubber ducks washing up in Britain:

<http://www.dailymail.co.uk/news/article-464768/Thousands-rubber-ducks-land-British-shores15-year-journey.html>

Books

Burns, Loree Griffin. *Tracking Trash Flotsam, Jetsam, and the Science of Ocean Motion (Scientists in the Field)*. Boston: Houghton Mifflin, 2007.

Ebbesmeyer, Curtis. *Flotsametrics And The Floating World: How One Man's Obsession with Runaway Sneakers and Rubber Ducks Revolutionized Ocean Science*. New York: Harper Collins Publishers, 2009.

LESSON 5: AEROSOLS AND CLOUDS

Web sites

NASA's Earth Observatory:

<http://earthobservatory.nasa.gov>

Global maps of aerosol optical depth:

http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MODAL2_M_AER_OD#

Calipso sun photometer simulator:

<http://calipsooutreach.hamptonu.edu/sunphoto.html>

LESSON 6: SNAPPING SHRIMP

Web sites

Listen to snapping shrimp at Discovery of Sound in the Sea's online audio gallery:

<http://www.dosits.org/gallery/inverts/2.htm>

LESSON 7: SUSTAINABLE FISHERIES

Web sites

Homepage of the National Marine Fisheries Service at the National Oceanic and Atmospheric Administration:

<http://www.nmfs.noaa.gov>

Article on Catch Shares:

<http://articles.latimes.com/2008/sep/19/nation/na-fish19>

Description of Commercial Fishing Methods:

http://www.fishonline.org/caught_at_sea/methods/

NOAA overview of Fishing gear and technology:

<http://www.nmfs.noaa.gov/fishwatch/fishinggears.htm>

Article on “How Fish are Caught or Farmed” from Monterey Bay Aquarium’s Seafood Watch Program:

http://www.montereybayaquarium.org/cr/cr_seafoodwatch/sfw_gear.aspx

An overview of the development of fishing technology, late 1800’s to 2000:

<http://features.csmonitor.com/environment/2008/06/10/nowhere-to-hide-the-on-slaught-offishing-technology/>

NOAA Fisheries Service information on Limited Access Privilege (LAP) Programs.

<http://sero.nmfs.noaa.gov/sf/LimitedAccessPrivilegeLAPPrograms.html>

PBS Article on “Marine Fisheries & Aquaculture Series: Empty Oceans, Empty Nets”

<http://www.pbs.org/emptyoceans/educators/activities.html>

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Desonie, Dana, Ph.D. Oceans How We Use the Seas (Our Fragile Planet).

New York: Chelsea House Publications, 2007.

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Odyssey Expeditions - Tropical Marine Biology Voyages! 1998. 05 Mar. 2009
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- "NOAA National Ocean Service Education: Corals."
NOAA's National Ocean Service. 25 Mar. 2008. 05 Mar. 2009
<http://oceanservice.noaa.gov/education/kits/corals/coral05_distribution.html>.

Journal Articles

- Glynn P.W. "Coral reef bleaching: facts, hypotheses and implications."
Biology 2 (1996): 495-509.
- Kleypas, J.A., R.A. Feely, V.J. Fabry, C. Langdon, C.L. Sabine, and L.L. Robbins,
Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide
for Future Research, report of a workshop held 18–20 April 2005, St. Petersburg, FL,
sponsored by NSF, NOAA, and the U.S. Geological Survey. 2006. 05 Mar. 2009
<http://www.ucar.edu/communications/Final_acidification.pdf>
- United Kingdom. The Royal Society. Ocean acidification due to increased
atmospheric carbon dioxide. June 2005. The Royal Society. 05 Mar. 2009
<<http://www.jncc.gov.uk/page-4003>>

LESSON 2: INQUIRY INTO OCEAN ACIDIFICATION

Books

- Pilson, Michael E. Q., 1998, An Introduction to the Chemistry of the Sea, Upper
Saddle River: Prentice Hall, Inc.

Journal Articles

- Brahic, Catherine. "Fish 'an ally' against climate change."
New Scientist 13. 16 Jan. 2009. 5 Apr. 2009
<<http://www.newscientist.com/article/dn16432-fish-an-ally-against-climate-change.html>>.
- R. W. Wilson, F. J. Millero, J. R. Taylor, P. J. Walsh, V. Christensen, S. Jennings,
and M. Grosell. "Contribution of Fish to the Marine Inorganic Carbon Cycle."
Science 16 January (2009): 359-62.
- United Kingdom. The Royal Society. Ocean acidification due to increased
atmospheric carbon dioxide. June 2005. The Royal Society. 05 Mar. 2009
<<http://www.jncc.gov.uk/page-4003>>.



Other Curriculum

Experiencing chemistry museum manual. Portland, OR: Oregon Museum of Science and Industry, 1997.

LESSON 3: SEA ICE AND SEA TEMPERATURE

Books

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“All About Sea Ice.” National Snow and Ice Data Center (NSIDC). 05 Mar. 2009 <<http://nsidc.org/seaiice/intro.html>>.

“September 2007 Arctic Sea Ice vs. 1979-2007 Average with Graph of 1979 to 2008 Ice Areas.” NASA/Goddard Space Flight Center Scientific Visualization Studio. 06 Mar. 2009. <<http://svs.gsfc.nasa.gov/goto?3573>>.

“Sea Change. NOW on PBS.” 09 Jan. 2009 <<http://www.pbs.org/now/shows/502/index.html>>.

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Intergovernmental Panel on Climate Change. IPCC Fourth Assessment Report: Working Group I Report “The Physical Science Basis” 03 Mar. 2008. 23 Feb. 2009 <<http://www.ipcc.ch/ipccreports/ar4-syr.htm>>.

LESSON 4: OCEAN CURRENTS AND MARINE DEBRIS

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Web sites

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NOAA. “Marine Debris.” Aug. 2008. 05 Mar. 2009 <www.noaa.gov/factsheets/new%20version/marine_debris.pdf>.

Plastic Debris Rivers to Sea Project. 06 Mar. 2009 <<http://www.plasticdebris.org/>>.



LESSON 5: AEROSOLS AND CLOUDS

Web sites

Aerosols: More Than Meets the Eye - FS-2005-9-072-GSFC. Sept. 2005. NASA. 05 Mar. 2009 <http://eosps0.gsfc.nasa.gov/ftp_docs/NASA-Facts-Aerosols.pdf>.

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“How Clouds Form: Understanding the Basic Principles of Precipitation.” Meteorology: An Educator’s Resource for Inquiry-Based Learning for Grades 5-9, Chapter 12. <<http://www.nasa.gov/centers/langley/science/met-guide.html>>.

LESSON 6: SNAPPING SHRIMP

Web sites

“A new goby-shrimp-association from the eastern Atlantic - by Peter Wirtz.” Explore Biodiversity: Tree of Life Science Media Project. 05 Mar. 2009 <<http://www.explorebiodiversity.com/Hawaii/Shrimp-goby/general/Grundel-Krebs.htm>>.

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Individuals

Peter Dahl, Ph.D., Applied Physics Laboratory, University of Washington, Seattle, WA, USA

LESSON 7: SUSTAINABLE FISHERIES

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Web sites

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